Bamboo: Structure and Culture

Utilizing bamboo in the industrial context with reference to its structural and cultural dimensions

Inaugural-Dissertation zur Erlangung des Grades
eines Doktors der Philosophie (Dr. Phil.)
im Fachbereich Kunst und Design
der Universität Duisburg-Essen

vorgelegt von

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Datum der Abgabe: 14.05.2007

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Eidesstattliche Erklärung

Hiermit versichere ich, dass ich die vorliegende Arbeit (Dissertation) ohne fremde Hilfe erstellt und alle Hilfsmittel und Quellen kenntlich gemacht habe.

Essen, 14.05.2007

Acknowledgment

For this dissertation I would first like to thank deeply my supervisor Prof. Dr.-Ing. Ralph Bruder. Without his kind acceptance of my research plan and his support and encouragement during the whole period of the research, this dissertation would not have been possible. My sincere thanks I would also like to give to Prof. Dr.-Ing. Bernd Baier, who has always given me his kind help during the PhD research and his supervision based on his know-how in the field of bamboo and construction. My best thanks also to Prof.Dr.Cordula Meier for her kind support and supervision. For general suggestions and motivations in the design research I would like to thank all the colleagues in the 'Institut für Ergonomie und Designforschung', especially Dr.Dietmar Gude for kindly reading my dissertation and his useful suggestions, and Stephan Trausch for his kind correction of my English. For the financial support I am very grateful to the Universität Duisburg-Essen for a two years' stipendium for my PhD research and thus Mrs Beate van Wasen for her kind help. Special thanks also to the 'Fördern durch Spielmittel e.V.' in Berlin and 'Happy Arts & Crafts' in Ningbo for their organization of the bamboo design workshop in Anji 2003 which offered me a good opportunity to gather experience on bamboo crafts and information about how designers from different countries think about bamboo. My heartfelt thanks I would also like to give to Mr. M.P.Ranjan for his warm support with his research on bamboo crafts in India.

Furthermore I am also very grateful to all my friends for their kind help in my study as well as daily life in Germany which will be kept in my heart wherever I might be later. My grateful thanks also go to my parents who always give me their tender carefulness from my hometown, and to my wife Jie and my son Fangsi, who give me motivation and encouragement deep in my heart.

Essen, 05/2007

Xiaobing Yu

Abstract

This dissertation is about the natural material bamboo in the industrial context. As a beautiful plant, bamboo has developed a survival strategy in nature with its efficient structure through million years of evolution. It has been used by man as a useful material worldwide since the beginning of human civilizations. In many countries bamboo has played an important role not only in everyday life culture but also in art, literature and philosophy due to its elegant shape, practical utilizations and symbolic meanings.

But in the industrial context this excellent natural material could not be utilized as in history because its irregular form, inhomogeneous structure and variation of the material properties are difficult to be processed by standardized machines and to be assembled with standardized industrial components. Because of its traditionally manual processing bamboo is regarded as imprecise, raw, undeveloped and as a "material for poor".

The industrialization of the material bamboo was supposed to solve the problem of utilizing bamboo in the industrial context, which has been considered an important strategy for local economic development in many developing countries where bamboo sources are abundant. Through industrialization bamboo is processed and fabricated into different standard industrial products which are mainly used as a cheap substitute for hardwood because bamboo grows much faster than timber and is a renewable source after 4-5 years. But in this process of industrialization bamboo loses its structural advantages and at the same time also loses the connection to its traditional bamboo culture.

Instead of industrialization, modernization should be the real solution for the problem of utilizing bamboo in the industrial context – the hypothesis of this dissertation. Modernization means the modernization of the relationship between the material bamboo and human needs, which was connected by craftsmen in the pre-industrial time, whereas this is achieved by a designer in an industrial context. Design with bamboo will be the first step of the modernization, where bamboo's structural and cultural dimension have to be taken into account as the main breakthrough for overriding the difficulties between the material bamboo and the designer. This step will then be regarded as the preparation for the second step – building the modern cultural identity of bamboo in the industrial context.

With more and more new bamboo objects having been designed with appropriate consideration of its structural and cultural dimensions getting into people's modern daily life, bamboo as material can build its new cultural identity in the industrial society – a cultural identity with multiple modern meanings which represent a harmony of its inner structural and cultural dimension and the outer industrial context. This will be the result of this dissertation. This study on bamboo also aims at giving an example of how design can contribute to a sustainable development in which not only technology and economics, but also environment, culture and tradition should all be considered thoroughly.

Contents

List of Figures vii

List of Tables x

1. Introduction 2

1.1. Introduction and theme 2
1.2. The research on bamboo 4
1.3. The aim and the hypothesis of this study 4
1.4. Methodology 5
1.5. The structure of the dissertation 5

2. Bamboo in structural and cultural dimensions 9

2.1. The structural dimension of bamboo 11
2.1.1. Bamboo as a plant: botanic characters 11
2.1.2. Bamboo as material: material properties 18
2.2. The cultural dimension of bamboo 23
2.2.1. Untreated bamboo as a plant 26
2.2.2. Treated bamboo as construction material 28
2.2.3. Bamboo as a symbol 39
2.3. Summary 43

3. The industrialization of bamboo: Bamboo in the industrial context 46

3.1. Missing links: Bamboo as a material in the industrial context 47
3.2. Industrialization of bamboo 49
3.2.1. The traditional bamboo working process as one basis for the industrialization of bamboo 51
3.2.2. The wood industry as second basis for the industrialization of bamboo 55
3.2.3. The industrial bamboo products and their working process 57
3.3. Between industrialization and tradition: lost in the transaction 69
3.3.1. Structural context 70
3.3.2. Cultural context 72
3.3.3. Summary: Materialgerechtigkeit for bamboo 73

4. The modernization of bamboo in the industrial context 76

4.1. Design with bamboo in the industrial context 77
4.1.1. Material bamboo and the designer in a system 78
4.1.2. The influence of the industrialization on the using of natural materials: wood material as an example 85
4.1.3. Bamboo utilization system in the industrial context 92
4.1.4. Design principle I: Industrial prefabricated bamboo material as a preparation for designer and architect 95
4.1.5. Design principle II: The natural structure of bamboo as a challenge for designers and architects 103
4.1.6. Design principle III: Natural bamboo as design element for designer 119
4.1.7. Design principle IV: Redefining the bamboo crafts in the industrial context 126
4.1.8. Summary 134

4.2. Building bamboo's modern cultural identity through design 135
4.2.1. Material and its cultural identity 135
4.2.2. Bamboo as material and its cultural identity 138
4.2.3. Building the modern cultural identity of bamboo in the industrial context through design 142
4.2.4. Summary 165
5. Summary and Outlook 167
5.1. Summary 167
5.2. Outlook 169
References 172

List of Figures

Figure 1- 1 Structure of the dissertation 6

Figure 2- 1 Bamboo in natural and human contexts 10
Figure 2- 2 Structure and functions of bamboo as a plant 11
Figure 2- 3 Some species of bamboo genus Phyllostachys (ref. M.F. Wetterwald) 12
Figure 2- 4 Geographical distribution of bamboo (ref. Bamboo Museum in Anji, China) 13
Figure 2- 5 Left: Laptomorphs (monopodial); Right: Pachymorphs (sympodial) (ref. McClure 1966) 15
Figure 2- 6 Diagrammatic longitudinal section of young bamboo culm (left) and the lower part and section of culm (right). (ref. McClure 1966) 16
Figure 2- 7 The diagrammatic picture of the bamboo culm cross section 17
Figure 2- 8 3D view of the bamboo culm (left) and the vascular bundles of bamboo culm (right). (ref. Liese 1985) 18
Figure 2- 9 Structure and functions of bamboo in different level 18
Figure 2- 10 Bamboo preservation methods 22
Figure 2- 11 Bamboo's structural and cultural dimensions 24
Figure 2- 12 Some Chinese characters with bamboo "竹" (Zhu) symbol and the explanation of bamboo symbol in the Chinese first dictionary „Shuo Wen Jie Zi"(Han Dynasty 100-121 AC) 25
Figure 2- 13 The connection between the structure and culture of bamboo 26
Figure 2- 14 Bamboo structure and its uses as untreated plant 26
Figure 2- 15 Village house with bamboo (left) and in the painting by Wu Guanzhong (right) 27
Figure 2- 16 The treated bamboo as material: from bamboo structure to bamboo culture 28
Figure 2- 17 Bamboo Architecture "GanLan" style in South China 30
Figure 2- 18 Bamboo suspension bridge "An-Lan" in Sichuan Province in Southwest China (ref. Needham 1958) 31
Figure 2- 19 Traditional bamboo chairs and bamboo chair in open tee house in Southwest China 31
Figure 2- 20 Typical daily life scene in summer in Wuhan in South China has been used as the motive for the street sculpture - bamboo bed serves as important furniture there. 32
Figure 2- 21 Left: brick drawing "dinner" (Donghan Dynasty 25-220 AC), in which the man on the left has chopsticks in his bowel. Right: the use of chopsticks 33
Figure 2- 22 Bamboo basket from Northwest India (ref. Ranjan 1986) 34
Figure 2- 23 Bamboo umbrella from Japan and craftsman making a bamboo umbrella 34
Figure 2- 24 Bamboo fish trap and fish basket in Northwest India (ref. Ranjan 1986) 35
Figure 2- 25 Bamboo book from Zhou Dynasty in China (475 – 221 BC) 36
Figure 2- 26 JiaXuan paper (left) and Chinese ink painting on JianXuan (right) 37
Figure 2- 27 Bamboo brushes for Chinese painting and calligraphy 37
Figure 2- 28 Bamboo flute "Xiao"(left) and "Dizi"(right) 38
Figure 2- 29 Bamboo engravings 38
Figure 2- 30 Bamboo painting and calligraphy by Zheng Banqiao (1693-1765) 41

Figure 3- 1 Relationship of bamboo's working process and its utilization 48
Figure 3- 2 The synthesis of the industrialization of bamboo 50
Figure 3- 3 The traditional working process of bamboo 51
Figure 3- 4 Bamboo splitting and the tool for it (ref. Mark Meckes) 52
Figure 3- 5 Simple machetes for splitting bamboo (ref. Dunkelberg 1978) 53
Figure 3- 6 Bamboo woven basket "Thumok" from Manipur in Northwest India (ref. Ranjan 1986) 54
Figure 3- 7 Wood-based products: from raw wood to products 56
Figure 3- 8 Processing of Plywood 57
Figure 3- 9 Industrial Bamboo products 58
Figure 3- 10 Working process of Plybamboo (ref. Zhang 2001) 59
Figure 3- 11 Left: splitting machine for bamboo split (ref. the catalogue of Weizhou International Co., Ltd); right: the pressed and flattened bamboo (ref. Zhang 2001) 60

Figure 3- 12 Mat woven plybamboo, left: before the gluing and pressing; right: end product (ref. Zhang 2001) 60
Figure 3- 13 Laminate bamboo with diverse cross section structures 61
Figure 3- 14 Bamboo chips (left, ref. Zhang 2001) and chipboard (right) 62
Figure 3- 15 Bamboo Veneer (ref. Hangzhou Zen Bamboo & Hardwood Products Co., Ltd) 62
Figure 3- 16 Bamboo residual fiber can be glued together into bamboo adobe by natural glue 63
Figure 3- 17 Bamboo reinforcing being used in concrete block construction by the US Navy for a radar site at Tarlue Naval Station in the Philippines 64
Figure 3- 18 Left: test on the bamboo reinforced concrete run by Bernd Baier in Aachen, Germany (ref. Baier); Right: house made of bamboo reinforced concrete wall and bamboo sheet roof under test at Earthquake Engineering and Vibration Research Centre in Bangalore 65
Figure 3- 19 Bamboo fiber line for Chitianhu Bamboo Pulp Co, China by Kvaerner Pulping AB (ref. Kvaerner Pulping AB) 66
Figure 3- 20 Bamboo textile and fiber (ref. the catalogue of China Bambro Textile Co., Ltd, Beijing) 66
Figure 3- 21 Working process of bamboo charcoal 67
Figure 3- 22 Working process of canned bamboo shoot cans 69
Figure 3- 23 Left: Stem section of a yew wood; right: Culm section of bamboo Phyllostachys Pubescens 70
Figure 3- 24 The utilization rates of wood and bamboo 72
Figure 3- 25 Doors made of plybamboo (left) and plybamboo floor (right), in which bamboo as a substitute for hard wood. 73

Figure 4- 1 Two levels of Modernization of bamboo *96*
Figure 4- 2 The triangle of the material utilization system *79*
Figure 4- 3 Crystal Palace by Joseph Paxton, 1851, London *81*
Figure 4- 4 Bauhaus in Dessau by Walter Gropius, 1925-1926 ..... *83*
Figure 4- 5 Left: C4 Stool and Table Set by Marcel Breuer, 1926; Right: Tubular steel chair MR 10, by Mies van der Rohe in 1927 ..... *83*
Figure 4- 6 Planter, cocktail shaker and vase made of spun aluminum by Russel Wright, 1932 ..... *84*
Figure 4- 7 Chairs made of aluminum in different times: No.313 by Marcel Breuer in 1932-34 (left); W.W stool by Philip Starck in 1999 (middle) and Orgone Chair from Marc Newson in 2000 (right) *85*
Figure 4- 8 The industrialization of wood and wood design *86*
Figure 4- 9 Chair No. 14 made by Michael Thonet in 1859 (left); the mould for bending wood in Thonet (right) (ref. Thonet) *88*
Figure 4- 10 Armchair 41"Paimio" (1931-32) by Alvar Aalto (ref. Reed 1998) *88*
Figure 4- 11 Plywood chair WCL(left) and form experiment (right) by Charles Eames. *89*
Figure 4- 12 Wood house constructions in North America *90*
Figure 4- 13 Finnish Pavilion in Seville, Spain, 1992 by Juha Jääskeläinen, Juha Kaakko, Petri Rouhiainen, Matti Sanaksenaho, Jari Tirkkonen *91*
Figure 4- 14 Bamboo's utilization in different time contexts *92*
Figure 4- 15 Two different ways for finding the solutions with different references on structural and cultural aspects from different sides of material bamboo and designer *94*
Figure 4- 16 Industrially prefabricated bamboo products *95*
Figure 4- 17 Bogner Ski by Schwabe & Baer Entwicklungs GmbH, 2005 (ref. Schwabe & Baer Entwicklungs GmbH) *96*
Figure 4- 18 Bogner Snowsports Helmet by Schwabe & Baer Entwicklungs GmbH , 2005 (ref. Schwabe & Baer Entwicklungs GmbH) *97*
Figure 4- 19 Laminated Bamboo Furniture designed by Michael McDonough in 1998 (ref. Roy Wright) *98*
Figure 4- 20 Bamboo Furniture "Spring Chair" and "Becca Stool" by Adapt Design, 2004 (ref. Adapt Design) *98*
Figure 4- 21 Divan bed "spring" by Krista Kosonen (left) and bamboo trivet "Kantava" by Mikko Paakkanen (right) *99*
Figure 4- 22 Bamboo Roof at Rice University in Houston, USA, 2002/03, Shigeru Ban Architects (ref. Shigeru Ban Architects) *100*
Figure 4- 23 Bamboo Roofs in the Madrid Barajas Airport by Richard Rogers Partnership and Estudio Lamela, 2006 (ref. Amparo Garrido and Richard Bryant/arcaid.co.uk) *101*
Figure 4- 24 Bamboo Furniture House, Great Wall at Shui Guan, China, 2002, Shigeru Ban Architects (ref. Soho China) *102*
Figure 4- 25 The evolution process of natural material and the developing process of industrial product *104*
Figure 4- 26 Some bamboo connections *105*
Figure 4- 27 Principle model I of bamboo construction system *106*
Figure 4- 28 Principle model II of bamboo construction system *106*
Figure 4- 29 Bamboo grid shell structure by Baier in Aachen *107*
Figure 4- 30 Bamboo construction with concrete and steel bolt by Simón Vélez, 2000 (ref. Simón Vélez) *109*
Figure 4- 31 Zeri Bamboo Pavilion in Expo2000 Hanover designed by Simón Vélez *109*

Figure 4- 32 Bamboo bridge in Perira with 52 meters span designed by Jörg Stamm, 2001 (ref. Jörg Stamm) *110*
Figure 4- 33 Bamboo connection designed by RWTH-Aachen (ref. Christoph Tönges) *111*
Figure 4- 34 Bamboo pavilion and its connection by Koolbamboo *112*
Figure 4- 35 The bamboo connection and the roof construction designed by Bambu-Tech (ref. Bambu-Tech) *113*
Figure 4- 36 Bamboo connections by Shoei Yoh (left) and Renzo Piano (right) (ref. Shoei Yoh + Architects; Renzo Piano Building Workshop) *114*
Figure 4- 37 Bamboo bus station: concept design for bamboo connection *115*
Figure 4- 38 Bamboo cane (Phyllostachys Pubescens) and section for possible connections *118*
Figure 4- 39 Bamboo Ply Composite structure by Tropicasean (ref. Tropicasean) *118*
Figure 4- 40 Bamboo in Japanese garden (ref. Bess 2001) *119*
Figure 4- 41 Great Bamboo Wall by Kengo Kuma 2002, Bejing (ref. Soho China, 2002) *121*
Figure 4- 42 Bamboo pavilion in Berlin by Rocco Yim 2000 (ref. Rocco Design Limited, 2000) *121*
Figure 4- 43 Park house Zoo in Leipzig, designed by HPP Hentrich-Petschnigg & Partner Architects Leipzig, 2004 ..... *123*
Figure 4- 44 Bamboo furniture "bamboo acrylic" by Fernando + Humberto Campana *123*
Figure 4- 45 Bamboo project "BarCode" by Bruno Winter (ref. designreport, 2005) *124*
Figure 4- 46 Bamboo bench and stool „Dr. Bamboozle" designed by Sylvain Willenz in Belgium 2002 ..... *125*
Figure 4- 47 Bamboo Möbius by Belgium designer Marc De Jonghe (left) and "cheeseburg adventure" by the author (middle and right) during the international design workshop "Toys from Bamboo and other Materials" for disabled children, China, 2003 ..... *126*
Figure 4- 48 Traditional bamboo baskets from Japan (ref. Hans Spörry 1890) *127*
Figure 4- 49 Bamboo utensils for the Japanese tea ceremony. From left to right: Hishaku; Chasen; Chashaku; Natzume (a piece ofbamboo cane); Natzume (bamboo basket). (ref. Hans Spörry 1890) *130*
Figure 4- 50 The working process of making bamboo Chasen (ref. Austin and Ueda 1972) *131*
Figure 4- 51 Bamboo fan "SENSU" in Japanese traditional culture: in NOH play and with a Geisha. *131*
Figure 4- 52 Left: Modern bamboo crafts with traditional styles "Fragrant Wind" by Nakatomi Hajime, 2005; Right: Modern bamboo artwork "Born" by Monden Yuichi, 2005 (ref. TAI Gallery) *133*
Figure 4- 53 The material and its cultural identity *143*
Figure 4- 54 Food container "Stuffables" by Tupperware and the Tupperware Party "A Taste of Tupperware" (ref. the Tupperware catalogue "Foundraiser 2006") *145*
Figure 4- 55 AUTHENTICS products: pedal bin TIP designed by Konstantin Grcic; eggcup EIKO designed by Chritina Shäfer (ref. AUTHENTICS, 2006) *146*
Figure 4- 56 Zech Zollverein Shaft XII designed by architect Fritz Schupp and Martin Kremmer *147*
Figure 4- 58 Baker House in MIT by Alvar Aalto *148*
Figure 4- 58 Paper log house for refugee in Kobe, Japan 1994 (left) and in Kaynasli, Turkey 2000 (right) by Shigeru Ban (ref. Shigeru Ban Architects) *150*
Figure 4- 59 Japanese Pavilion in EXPO2000 Hanover designed by Shigeru Ban 2000 ..... *150*
Figure 4- 60 Bamboo's cultural identity in the industrial context *152*
Figure 4- 61 Baharegue for the wall construction (left. ref. Jörg Stamm)and a residential estate constructed from bamboo in Manizales, Columbia (right. Ref. ZERI Foundation) *161*
Figure 4- 62 Architecture concept for 228 National Memorial Park in Taiwan 2006 (ref. 228 National Memorial Park) *162*
Figure 4- 63 Industrial and natural aesthetic characters *164*
Figure 4- 64 Modern designs with inspirations from natural structure (left: Olympic Station 2008 in Beijing, ref. Herzog & de Meuron; right: Blow Up - Citrus basket designed by Fratelli Campana for Alessi) *164*
Figure 4- 65 Bamboo used in one interior design in Passagen 2007, Cologne *165*

List of Tables

Table 2- 1 Chemical compositions of bamboo and softwood. (ref. Janssen, 1981) 19
Table 2- 2 Mechanical properties of bamboo species Phyllostachys pubescens and Guadua angustifolia. (ref. Steffans 2000 & Zhang 2001) 20
Table 2- 3 Material mechanical properties and strain energy stored. (ref. Janssen, 1981) 20
Table 2- 4 Material efficiency for strength and stiffness. (ref. Janssen, 1981) 21

Table 3- 1 Traditional working processes and their tools 53

Table 4- 1 The summary of a questionnaire on the question why the designer (architect) has (not) used bamboo as design material. 93
Table 4- 2 Different bamboo connection concepts in summary 116

Chapter 1

Introduction

The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful, it would not be worth knowing, and if nature were not worth knowing, life would not be worth living. Of course I do not here speak of that beauty which strikes the senses, the beauty of qualities and of appearance; not that I undervalue such beauty, far from it, but it has nothing to do with science; I mean that profounder beauty which comes from the harmonious order of the parts and which a pure intelligence can grasp - Jules Henri Poincaré (1854-1912)

1. Introduction

1.1. Introduction and theme

Bamboo is widely used as a material in Asia, South America and Africa, where abundant different species of bamboo grow. Nowadays, over 2.5 billion people worldwide use or trade in bamboo worth 4.5 billion US Dollar every year [1](INBAR 1999). For Europeans, bamboo is an exotic plant, as a material it was even stranger before the sixteenth century when it was first introduced in Europe. But in other continents like Asia, Africa and South America people have used bamboo in their daily life for more than thousand years, from bamboo buildings to bamboo furniture, from bamboo bridges to bamboo foods. There are sculptures as well as music instruments made of bamboo (Farrelly 1984). In countries like China, Japan and Korea, bamboo also is a frequently used popular motive for poets and painters. Philosophers and literateurs took bamboo as a symbol for a good personality: making progress; modest; straight (Wang 2000) – there, bamboo is not only a useful material for their everyday life, but also has

[1] Information from The International Network for Bamboo and Rattan (INBAR), the most official international organization on bamboo and rattan in the world, which is dedicated to improving the social, economic, and environmental benefits of bamboo and rattan by supporting and organizing numerous activities like researches, workshops, training programs in a global network of partners from the government, private, and non-profit sectors in over 50 countries. It was established by a treaty in November 1997 and now has its headquarter in Beijing, China. For more information about INBAR and information on research of bamboo: http://www.inbar.int

already been developed into a so called "bamboo culture"[2] through the long time of cohabitation with people.

Since the Industrial Revolution more and more new industrial materials have been invented and developed to meet the ever growing needs of people in the industrial world. As a symbol of the industrialization cast iron and later steel have been developed and widely used in mass production since the middle of the 19th century. Now people can find them everywhere: from building construction in the industry to the kitchen knife in the household. Another industrial material – aluminum – has been mass produced and used in industry no more than one hundred years, but now has taken over the place of steel in many fields because it is as strong as steel, but lighter. The plastics, for their versatility, formability and low price, have become one of the largest material groups used in modern society. Sooner or later the industrialization has spread from Europe and American to the rest of the world. Diverse industrial materials like steel, aluminum, plastics and cements come into people's daily life there. More and more buildings, furniture and other objects of utilities, which previously have been made of bamboo, are made of these industrial materials now. At the same time bamboo has lost its traditional place in people's everyday life.

Compared to steel, cements and plastics bamboo has many advantages like strength, elasticity and lightness, but also disadvantages in processing and connection: its tube structure is very good for tensile and press loadings, but its irregular dimensions and inhomogeneous material structure are not easy to be processed by machines and incompatible to the standardized industrial connecting components. Moreover, bamboo's easily split canes are difficult to be treated with nails and screws which are normally used for wood. Such shortages restrict the use of bamboo in the industrial context.

Considering the special properties of bamboo, especially its fast growth, easy to cultivate and excellent mechanical properties, researchers have begun trying to get the natural material bamboo industrialized so that it can be used in the industry. Among the numerous industrial utilizations of bamboo, plybamboo is nowadays one of the most typical and often found industrial products of bamboo. Like many other industrial bamboo board-like products, plybamboo is processed more or less according to the process of engineered wood products, namely here plywood. In the processing, bamboo canes will be split into strips at first and then cut into square sections so they can be glued and pressed together into a multi-level-board. This way bamboo turns into an industrial standard product which has similar or somehow better qualities than relevant industrial wood products. After this kind of industrial processing, plybamboo is often used as a substitute for wood products like floorboards, or bottom boards, for vehicles and forming boards for concrete (Zhang 2001). Compared to normal wood floorboards, plybamboo has a slightly harder surface and an interesting texture.

The industrialization gives bamboo a new chance to be used as a material in the industry. But in this way of industrializing bamboo also loses its structural advantages: through the industrial processing, the original tube structure of bamboo is destroyed and pressed into solid material. This process, borrowed from the wood industry, has proven efficient for wood processing because wood has a relatively more homogenous solid structure, but bamboo possesses a more differentiated hollow structure, therefore in the processing the loss of material is remarkable. On the other hand, the industrialization of bamboo has its orientation mostly in the industrial production in which bamboo is transformed into only semi-finished-products. These industrial bamboo products nowadays are used more often as a substitute for wood products, like floorboard or door-board, which neither have inherited its historical context in traditional culture nor built its own new cultural identity in modern society.

For those countries which have a long tradition of utilization of bamboo in people's daily life, the bamboo is not only a material for making different kinds of goods for their daily needs, it has become

[2] Bamboo even has a big influence on the regional cultures in many countries and places where bamboo resources are abundant, "Bamboo Culture" as a concept is only acknowledged in some countries in East Asia, like China, Japan and Korea. (Wang 2000)

something which carries the people's local culture there. Through the industrialization the people's life changes a lot and local traditional culture has already lost its place in modern society. Nowadays, in traditional "bamboo countries" like China, India or Thailand which still belong to the developing countries and are now booming with their industrializations, people have to face the facts that on the one side they are abundant of bamboo and have a long handcraft tradition of using it, yet on the other side they have to open the place of bamboo to some other industrial materials in their industrialization process. The one thing they can do is to keep the traditional bamboo culture in the museum. This problematic contradiction of bamboo in modern society is the starting point of this research.

1.2. The research on bamboo

Bamboo is not a new field for researchers: in China, in Jin Dynasty (265-420 A.C) there has been monograph which observed and recorded the botanic properties of diverse bamboo species (Wang 2000). In modern times, researchers have studied bamboo from different perspectives: McClure (1966) could belong to the first generation of bamboo researchers who have holistically studied the biological properties of bamboo. Liese (1961, 1985 & 2003) dedicated his research on the micro structure of bamboo and has made notable progress in the research on the species of bamboo. Research on material properties, especially the mechanical properties and the typical bamboo constructions has been done by Janssen (1981) in his dissertation and research activities. The utilization of bamboo in building structure, especially in traditional house construction in Southeast Asia, has been studied by Dunkelberg (1978) in his dissertation. The research in this category can be summarized as to answer the question "What is bamboo?"

There are also numerous architects and civil engineers who have tried to study the possibilities of using this natural material in their architectural design and building constructions. The research by Frei Otto and his staff at the Institute for Lightweight Structure (Institut für Leichte Flächentragwerke, IL) had its emphasis on bamboo for both sides: as a natural building material and as material for lightweight structure. Their study on bamboo has evoked a wide interest in bamboo as building material among the academic society in Germany (Gaß et al 1985). Experimental constructions with bamboo in IL and by other researchers like Baier (1985 & 1996) and Minke (1985) has demonstrated the use of bamboo in modern curved grid shell construction. The situation is somehow different in the developing countries where bamboo has been used mostly to solve their practical problem: house building. Lopez (1985), Lozada (1985), Vélez (Kries 2000) and Stamm (2005) represent this group in Latin America; they use bamboo for solving the social problem of house shortage there. The researchers from India like Ranjan (1986) have concentrated more on the actuality of traditional bamboo handcrafts and their new developments in India, whereas Bess (2001) from USA did her study on the traditional bamboo crafts and culture in Japan. In China, researchers like Zhang (2001) and institutions like Nanjin Forest University and Chinese Academy of Forestry concentrate more on the economic value of bamboo as a fast growing natural material in the industrialization. Based on the industrial bamboo prefabricated products like plybamboo and laminated bamboo, there are more and more designers and architects such as Ban (McQuaid 2005) and Richard Rogers (Richard Rogers Partnership 2005) doing experiments on using bamboo-based industrial materials in their works. This category of bamboo research can also be outlined as "What can be done with bamboo, both in academic and practical sense?"

1.3. The aim and the hypothesis of this study

This dissertation will study bamboo from the perspective of design research, study the bamboo's utilization in the industrial context as a system in which the natural structure and the cultural aspects of the material bamboo determine the inner character of the system. These two factors will be regarded as the key points for properly understanding and utilizing the material bamboo in the modern industrial society. The utilization of bamboo in the industrial context is defined here as the process of dealing with these two inner factors in the outer industrial technological and cultural context. This principle will be used to analyze the industrialization of bamboo in some developing countries like China in which the uses of bamboo are mostly based on technical and economic reasons, whereas the structural and cultural

aspects have been ignored. How is bamboo to be used in the industrial context, in which the inner structural and cultural factors can be harmonized with the outer industrial context? This will be the main question for this research.

As hypothesis, the modernization of bamboo instead of industrialization will be put forward as the answer of the question. The modernization of bamboo is not just the new processing of bamboo material with industrial equipments, but a new definition of the relationship between the bamboo's natural structure and the "life-form" [3] of the material bamboo in the industrial context. The modernization will be discussed from two perspectives: at first the relationship between the bamboo structure and the designer. The second is bamboo and its cultural identity. By a new definition of bamboo in industrial contexts, namely with designers (instead of craftsmen) and the industrial culture (instead of a traditional pre-industrial culture) a new vision of the modern utilizations of bamboo will be opened and a new cultural identity of bamboo will be built in the industrial society. A harmony of the relationship between bamboo, designer and cultural identity will be the symbol of the modernization of the bamboo.

1.4. Methodology

This dissertation shall not be another bamboo encyclopedia or run a project on a special field of bamboo, it wants to choose bamboo as an issue from the perspective of design research, therefore some other factors like economic and politic aspects, which are also very influential in deciding bamboo's utilization and cultural identity in the modern society, are not included in this research. Although the author has done some experiments on bamboo's construction and design, this serves only as a collection of experience for the better understanding of bamboo. This research uses the existing research on bamboo as main information resource for studying the characters of bamboo. This includes a number of the literature about bamboo researches in biology, architecture, design and cultural history. To redefine bamboo in the industrial contexts, the research has references to different fields of research like building construction, architecture, ecology and bionics. Material culture as a special research area has received more and more attention in design research nowadays, which also offers very important principal suggestions in studying the relationships between bamboo and its cultural meanings in the industrial society. All this existing knowledge will serve as material to prove the hypothesis of this dissertation from structural and cultural perspectives. The aim of this research method is to put the bamboo into a wide scientific context so that the understanding and utilizing of bamboo can be more comprehensive and systematic.

1.5. The structure of the dissertation

The structure of the dissertation can be seen in Figure1-1:

[3] The word "life-form" is used in biology or ecology to describe all life structure such as a plant, animal, fungus or bacterium, capable of growth and reproduction (Chambers 21st Century Dictionary 2001, under the lemma "Organism"). Here it is used as a metaphor for form of a material in people's social life.

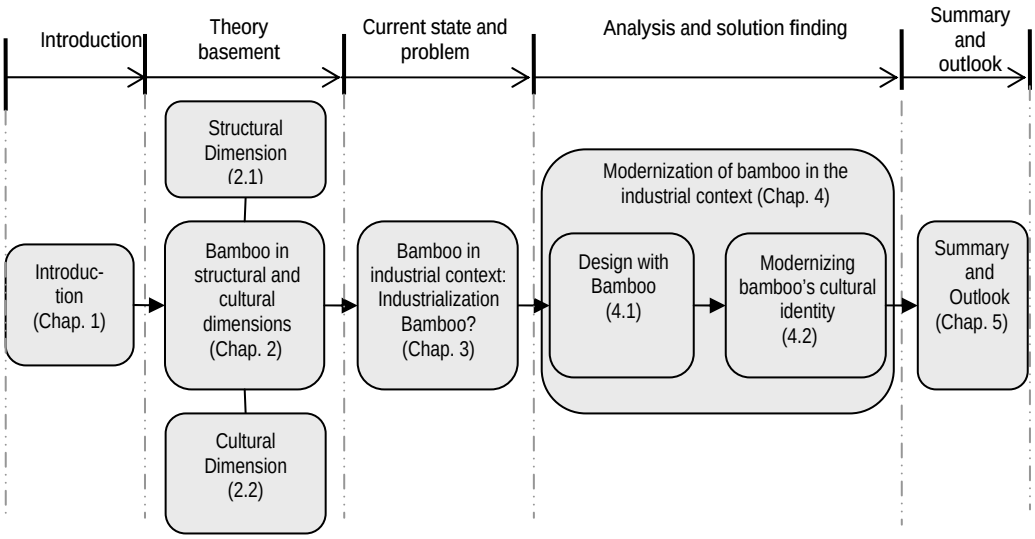


Figure 1- 1 Structure of the dissertation

The first chapter is an introduction of the whole dissertation, about the choice of the theme, the methodology and the research structure. The second chapter is the theory and knowledge basis about bamboo: understanding bamboo before doing research in bamboo. This is based on the existent research in bamboo in different fields like biology, civil engineering, material science, culture and history, but this is done from two perspectives: from the structural dimension and the cultural dimension. These are used to define the inner characters of bamboo material and to better understand bamboo in a utilization system, which will be the basis for the following discussion on bamboo's utilizations in the industrial context.

Chapter 3 observes bamboo in the industrial context. This will begin with the problem that bamboo has been facing in the industrial society: the natural material bamboo because of its natural structure is not suitable for the industrial standardized working process. The result is that bamboo lost its place in people's daily life. Its cultural meanings which have been appreciated by people in history have no influence anymore in the industrial society. How to find the ways to help bamboo re-enter into the modern industrial society will be the most important question in this part. Different kinds of industrializing the material bamboo which are mostly learned from the industrialization of wood have been conducted in many traditional bamboo countries so that bamboo can be processed into standard industrial products there by machines and sold worldwide. In order to give an outline of this trend of using bamboo which has also been promoted as an economic developing strategy there, different industrial pre-fabricated bamboo panel products and some typical industrial bamboo utilizations will be investigated; their working processes and material (product) properties will be also studied in this chapter. The following discussion will focus on the question: How far have the structural and cultural factors been influenced by the industrialization of bamboo? How far is the industrialization of bamboo reasonable, in the sense of adequately understanding the structural and cultural dimensions of the material bamboo? The criticism of the industrialization leads to the further search for the correct answer to the question which will be discussed in Chapter 4.

Instead of industrialization the modernization of bamboo will be the answer to the question. This will be also the main topic of Chapter 4. The modernization of bamboo has two levels of meanings: firstly the modernization of the utilization of bamboo, which means the design with bamboo (section 4.1), and secondly the modernization of bamboo's cultural identity in the industrial context (section 4.2). For the first, design with bamboo will be defined as the modernization of the relationship between the material bamboo, the designer and the human needs, all of which constitute the utilization system of the material bamboo. To build a new relationship between the material bamboo and its user – designer is the key point for the design with bamboo. The designer in the industrial time should take the responsibility

which was accepted by the craftsman in the pre-industrial time. From the structural and cultural perspective four principles will be put forward to help building this relation: on the one side the material becomes easier to use by designers, on the other side the designer gets closer to using bamboo:

- Industrialized bamboo structure as a preparation for the designer
- Natural bamboo structure as a challenge for the designer
- Natural bamboo as design element for the designer
- Redefining the traditional bamboo crafts in the industrial context

The modernization of bamboo's cultural identity in the industrial context will be discussed in section 4.2 as the consequence of designing with bamboo. In this chapter the general relationship between the material and its cultural identity will be discussed, whereas in the industrial era the design works as the connection between the material and the social culture. Examples of some typical industrial materials will demonstrate how design can determine the cultural identity of the material in industrial society. Subsequently the bamboo's cultural identity in the industrial society will be discussed to show that only through appropriate[4] design with bamboo it can change its negative image and establish its new cultural identity in the industrial society.

Chapter 5 is the summary and outlook of the dissertation. The conclusion of the dissertation's hypothesis will be summarized here. Design which has harmonized the inner structural and cultural dimensions of bamboo and the outer industrial technical and cultural context will be the solution for the new utilization of bamboo in the industrial society. Furthermore, the author hopes that through this study on the natural material bamboo it will evoke more concerns among designers about the sustainable development for our society.

[4] A more precise description of this is the German word "materialgerecht", to which it is difficult to find an equivalent word in English. "Materialgerecht" refers to the principle that the form of the design or artwork should reflect the material's own properties and characters, and shall not just be an imitation of the others. More discussion of this aspect can be found in Chapter 3.3.3

Chapter 2

Bamboo in structural and cultural dimensions

"A good cook changes his knife once a year-because he cuts. A mediocre cook changes his knife once a month-because he hacks. I've had this knife of mine for nineteen years and I've cut up thousands of oxen with it, and yet the blade is as good as though it had just come from the grindstone. There are spaces between the joints, and the blade of the knife has really no thickness into such spaces, then there's plenty of room - more than enough for the blade to play about in. That's why after nineteen years the blade of my knife is still as good as when it first came from the grindstone." – understanding the ox by a cook

- Chuang Tze[5]

2. Bamboo in structural and cultural dimensions

Before bamboos are used by human beings they are at first a plant with a special kind of structure that makes bamboo different to any other plant in nature. Its special structure is the result of million years of natural evolution and proved a very effective and efficient organism on the one hand; on the other hand it also makes bamboo a very useful material for humans. Its natural structure explains why bamboo is used by so many people and has such a long history in people's life – not only as a material, but also as a cultural being in the human society. From a plant to material, man has to re-structure the bamboo's own natural structure into numerous objects to meet his needs in everyday life. This kind of re-structuring has changed the structure of bamboo, but from another point of view it has changed the people's own daily life to an even deeper degree: bamboo becomes one of the most important things in their history, their tradition and their culture. Bamboo has developed into a cultural being. The different roles which bamboo plays in the relationships to nature and human beings represent on the one hand how bamboo's inner structure adapts itself to the outer environments and on the other hand how humans form bamboo's inner structure for their own needs. This is shown in Figure 2-1.

[5] From the book "Chuang Tze: Nourishing the Lord of Life", translated into English by James Legge. Chuang Tze (庄子) was one of the most famous philosophers of the Taoism (along with Laozi) in ancient China who lived around the 4th century BCE during the Warring States Period. More about Chuang Tze and his philosophy on the internet: http://en.wikipedia.org/wiki/Zhuangzi

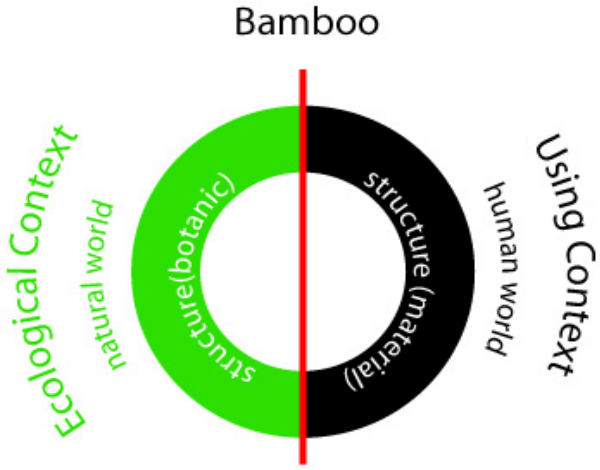


Figure 2- 1 Bamboo in natural and human contexts

In this chapter bamboo will be studied at first from the structural perspectives, namely how bamboo's structure developed to fit its environment and how it is restructured by human beings for different utilizations. From this perspective bamboo is a plant and a material. Its structure serves at first its function as a plant on the one side, on the other side it contributes to the material properties when it is used by human beings as a material. Therefore the study on material bamboo will begin with its biological properties, which is the basis for the bamboo's material properties. The study on the structural properties will rely mostly on the literature of biology and will be divided into two parts: the structural features and their relevant functions. The material properties will be discussed as a result of the biological structure of bamboo. The material characters will be divided into three parts: the chemical properties; the physical properties; the mechanical properties. Finally the pre-processing of the bamboo is discussed, which serves like a connecting phase between the bamboo plant and bamboo material.

The second part of this chapter is to understand bamboo from the historical perspective. This is another dimension of bamboo which refers to the bamboos after they come into the human world and are used as a material in people's daily life. Bamboo in nature is an highly developed and efficient structure which could be taken as a coded system; on the other side it is also a material for human beings and for this purpose its naturally coded structure will be de-coded by people (commonly by the craftsmen) into numerous forms of functional objects: they are planted in the garden, cut and connected into house construction, split into strips and woven into baskets, or carved into art works or music instruments. All of these utilizations of bamboo in people's everyday life have turned into a kind of material (bamboo) culture. Furthermore, the elegant structure and form of the bamboo has become a symbol, a metaphor in art, literature and philosophy – the so called "high culture". Both of these two dimensions, namely the structural and cultural dimensions and their interlaced relations, are decisive in defining bamboo as a material so different to any other materials like for example wood, stone, marble or industrial materials like plastics, steel and concrete etc.

2.1. The structural dimension of bamboo

2.1.1. Bamboo as a plant: botanic characters

Botany is the scientific study of plant life (Botanical Society of America 2006)[6]. In this part the botanical features of bamboo will be discussed, which help bamboo as plant to live and flourish on earth through millions years of natural evolution. The study will concentrate on the relationship between the structure of bamboo and its function. The structure will be examined from two points of views: from the outer form of bamboo (morphology) and from inside (anatomy). The function of its structure will be divided into outside environmental function (ecology) and inner function (physiology).

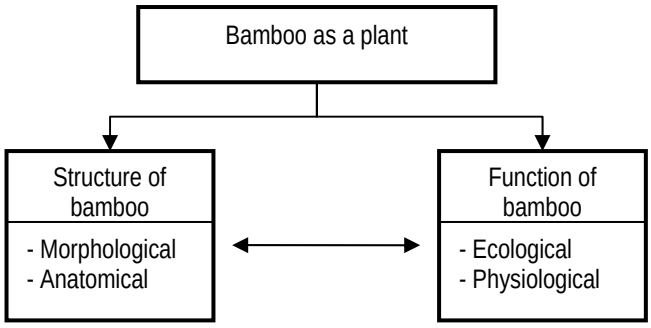


Figure 2- 2 Structure and functions of bamboo as a plant

From many points of view the bamboo could be a perfect example for the natural evolution. Of all the plants it is one of the most elegant in form and structure. It has all the gifts from nature that the other plants may only share: lightness, strength, vitality and beauty. One of bamboo's striking features is that bamboos have immense vitality, grow very fast, and almost have the fastest growth among all the plants on earth. It can adapt itself to the environment very well. Given all kinds of hardship of nature bamboos always manage to survive, grow and flourish. They have a very efficient way in their construction; with the limited nutrient they get from the surroundings they build their culms with internodes and nodes, which is very strong but also very light.

Before doing further studies on bamboo, some general knowledge about it should be gathered. Bamboo can be defined in several ways, depending on what it is to be used for and from which point of view it is to be observed. The architect would like to define bamboo as a building material with a special structure, and the anthropologist would like to take bamboo as a cultural being. But from the point of view of botany bamboo is at first a plant. Before one examines the different kinds of relationship with humankind and the society it is better to look at the bamboo as a life-form itself: the biological classification, ecological and physiological properties as well as the morphological and anatomical characters.

2.1.1.1. Classification

Bamboos are a group of woody perennial evergreen plants in the true grass family *Poaceae*, subfamily *Bambusoideae*, tribe *Bambuseae*. According to Cronquist (1988) bamboo is classified botanically as followed:

Kingdom: *Plantae*

[6] Botany is a branch of biology, sometimes referred to as plant science(s) or plant biology. Botany covers a wide range of scientific disciplines that study the structure, growth, reproduction, metabolism, development, diseases, ecology, and evolution of plants. See http://en.wikipedia.org/wiki/Botany

Phylum (Division):	*Magnoliophyta*
Class:	*Liliopsida*
Subclass:	*Commelinidae*
Order:	*Cyperales*
Family:	*Gramineae (Poaceae)*
Subfamily:	*Bambusoideae*
Tribe:	*Bambuseae*
Subtribe:	
Genus:	
Species:	

Under the bamboos (tribe *Bambuseae*) there are 9 subtribes with 30 to 90 genera and from 500 to 1000 species. Two of the most commonly used bamboo species, *Phyllostachys pubescens* and *Guadua angustifolia,* respectively belong to the genus *Phyllostachys* of the subtribe *Shibataeinae* and the genus *Guadua* of the subtribe *Guaduinae*. The species of bamboos holds difficulties in classification: because bamboo flowers only at long intervals (about 25-35 years) and dies after the flowering, it is difficult to identify bamboo by flowers and fruits which are usual for plants. There are many different opinions on the identification of bamboo; Ueda classified bamboos into 47 genera and 1250 species (Ueda 1960). According to McClure there are 63 genera and about 700 species of bamboos in the world (McClure 1966). The difference of the classifications of bamboos comes from the different criteria for classification. Besides the floral characters, which are the most identification keys for plants, there are still other criteria, for example vegetative structures, anatomical characters like epidermal features, arrangement of the vascular bundles, structures of bud sheaths and leaves and the morphology of the culms.

Two points are remarkable here for the definition of bamboo: firstly it belongs to the family *Gramineae* which is one of the largest and most important plant families to human beings: some species like rice, maize, wheat and barley belong to this family. Secondly bamboos are different to trees as the latter grow yearly in length and diameter. This is because the vascular bundles of bamboos are not arranged in the ring-form along annulus like as the tree but irregularly in the cross-section. Although it is classified to the grasses, all bamboos have the material characters of wood in their stems (culms): they are very hard on the surface, grow straight and tall (can reach 35 m with *Phyllostachys pubescens*) and its diameter can reach over 30cm with *Dendrocalamus giganteus*.

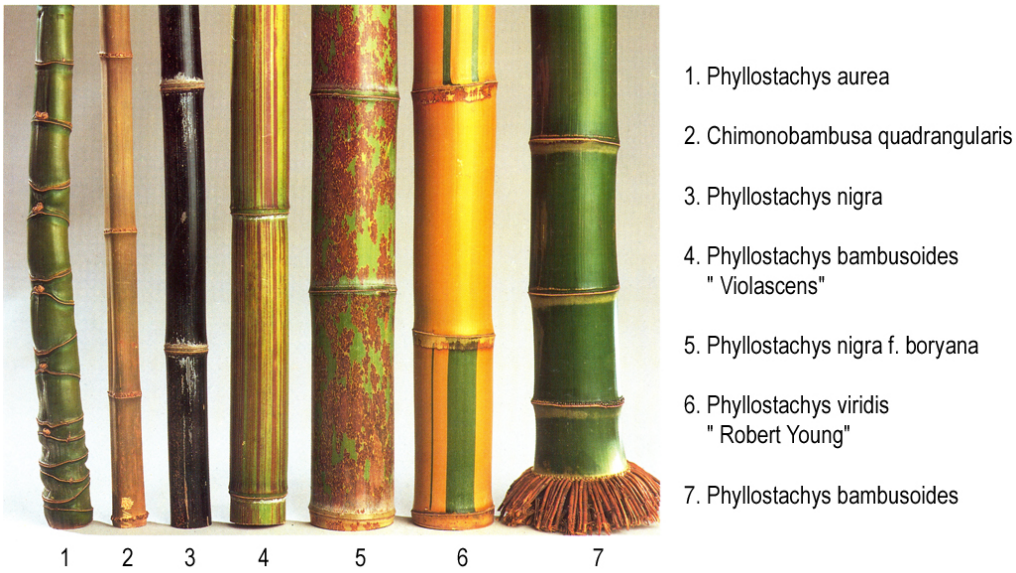


Figure 2- 3 Some species of bamboo genus Phyllostachys (ref. M.F. Wetterwald)

2.1.1.2. Ecological requirements

'Oekologie' (Ecology) as a scientific term was firstly coined by the German biologist Ernst Haeckel in 1866 who used it to encompass the study of an animal in relation to both the physical environment and other plants and animals with which it interacted. According to one of the most comprehensive definitions Ecology is the study of animals and plants in their relations to each other and to their environment (Kendeigh 1961: 468). More detailed definition from Wikipedia: Ecology, or ecological science, is the scientific study of the distribution and abundance of living organisms and how the distribution and abundance are affected by interactions between the organisms and their environment. The environment of an organism includes both physical properties, which can be described as the sum of local abiotic factors such as solar insolation, climate and geology, and biotic factors, which are other organisms that share its habitat[7].

- **Geological distribution**

The bamboos grow naturally in all the continents except Europe. They can be found from a latitude of 32° south to 46° north. Generally bamboos prefer the tropical or sub-tropical climates with an average annual temperature between 20°C and 30°C, but some kinds of bamboos can live in the fields with temperature as warm as up to 40-50 °C (like *Oxythenanthera abyssinica* in central Africa) and other kinds of them can withstand the cold weather with temperatures under 0°C (*Phyllostachys mitis* in China). Bamboos grow mainly at altitudes between 100 and 800 meters, but can also be found at sea level and in the mountains above 3000 meters (McClure 1966) (Liese 1985).

Figure 2- 4 Geographical distribution of bamboo (ref. Bamboo Museum in Anji, China)

- **Interaction with natural surroundings**

Bamboos have no special requirement of soil types, with the only exception of saline soils. Reports in Japan have shown that bamboo could even survive after the nuclear bomb. Bamboo was one of the first plants that grew from the ruins of the bomb crater in Hiroshima (Lucas 1976).

Bamboo is a plant with an utmost extremely high vitality and has developed excellent strategies in the competition with other plants for getting limited essential sources in nature. Bamboos often grow in the medium and lower stories of moist tropical forests and dry deciduous forests with trees and shade-loving plants. They can rapidly invade into any area through spreading their subterranean rhizome and raising their sprouts out to where a bit of sunshine comes. Some species like *Phyllostachys pubescens* can build an almost pure bamboo forest where other trees can hardly compete with them. It is reported that some

[7] See the definition at http://en.wikipedia.org/wiki/Ecology

bamboos like *Sinocalamus latiflorus* can retard the other low plants around them by releasing allopathic substances from their leaves (Liese 1985).

2.1.1.3. Physiological features

In botany, the plant physiology is the study of the function of the plant. Here it refers to the functions of bamboo as a living organism. The bamboo as a plant grows like a combination of the grass, leaf-bearing tree and palm. Like grasses bamboos have tubular blades, lancet-shape cover leaves and panicles flowers, and especially the "bamboo trees", namely the culms, grow out of the subterranean rhizomes. Their growth also has some characteristics of trees: the longevity of their canes, their branches and the lignifications. But bamboo's trunk growth is somewhat like that of the palm: they transport energy that the rhizomes get from the soil for bamboos´ growth without increasing their diameter (Dunkelberg 1985).

The different growing rhythms of the different parts of bamboo also demonstrate a strategy of surviving: the rhizomes grow subterraneanly in autumn and winter to store the nutrients and produce enough buds for the shoots - and at the same time also build an optimal network in the whole forest or the field under the earth. All these works are finished by bamboo rhizomes in the seasons in which the climate and atmosphere on the ground are hard for the plants and other creatures to grow and so most of them chose to slow down their life activities or even sleep. In spring and summer time bamboos have already prepared well and show their huge vitality by the fast growth of the shoots and culms in the shortest time. In this growing phase the task of the bamboo culm is to reach the maximal height of the plant in the shortest time so that the leaves can have their maximal space to get enough sunshine and rainfalls for the photosynthesis. Compared to trees, bamboos grow very fast. They can grow a daily average of 20 cm, up to one meter in one day during spring time by *Phyllostachys pubescens*. Within a period of 2 to 4 months bamboos can reach their full height of 15-30 meters, to a diameter of 5-15 cm and a wall thickness of 10mm. Before the culms reach their highest points they will not grow their branches. During this time all the new growing culms only get nutrients from the rhizomes and other older culms. This also demonstrates the special surviving strategy of bamboo: the leaves always have a relatively high position so that they can get better insolation. On the other side the culms also build a straight and clear form to support the leaves and transport the nutrients.

Bamboos flower only once in their life and the same species of bamboo often flower simultaneously, independent from their location and age. Different bamboo species have different intervals of flowering periods, from 20 to 80 years. Bamboo normally flowers in December/ January and consequently seeds will get mature in February/April. After that bamboo will die. The explanation for this strange phenomenon is that the flowering and the fruiting consume all the energy and nutrients which have been stored in the rhizomes and culms and thereafter cause their death. This is also different to the growth of the trees which use flowering as the way for propagation. The main method for bamboo's propagation is the vegetative reproduction by the new buds grown from rhizomes and seeds only as the last choice which will end the life of the whole plant (with some genera like *Phyllostachys* and *Arundinaria* only the flowering culms will die but the rhizome will keep (Liese 1985)).

From the point of view of the biomass productivity bamboo has similar or even lower numbers than those of trees. The study of Hunter and Wu (2002) on the bamboo biomass showed different records from different literatures according to the different bamboo species and environmental conditions. The annual productivity biomass of bamboos ranges from 10 to 20 ton/ha/year, whereas wood, for example in Canada, has an average annual biomass production between 21 and 25 ton/ha/year (Heilman et al 1993). The similar biomass productivity but the different growth speeds also show that bamboo and tree have a different strategy in their life-forms. This point will be discussed later in Chapter 3 dealing with the processing methods of bamboos and woods.

2.1.1.4. Morphological explanation

Morphology is the study of the structure and the form of the organisms, which determine the classification, the evolution of the organisms. One segment of the morphology study is the functional morphology, where the relationships between the structure of organisms and their functions are the main topic. From the morphological perspective, bamboo has two important features which make bamboo very successful in surviving through millions of years of the evolution process: the rhizome system and the culm.

- **Rhizomes**

The rhizome system was labeled by McClure (1966) as one of the four most important botanic characters of bamboo and constitutes the structural foundation of the growth of the plant. Since it is subterranean and not easy to access the importance of the rhizomes system is generally neglected by taxonomists and anatomists. But it is exactly the rhizomes system that makes bamboos grow so fast and resistant to hard environmental conditions. This is that bamboos are different to the trees regarding growth. With trees the growth is mainly the growth of the trunks, whereas with bamboos it is the growth of the rhizomes. Rhizomes prepare all the things needed for the growth of culms: they grow and produce two things: rhizome necks and buds. From rhizome necks other rhizomes grow and culms grow out of buds. Not stopping the production of these two elements, rhizomes spread and build a huge subterranean network from which the bamboo culms can grow. This kind of life strategy explains why bamboo has more ecological advantages for being used as a material: the rhizomes build a huge subterranean network which can fix the soils in the bamboo growing areas very well. The felling of some of the bamboo culms from one rhizome system after 3-5 years will not destroy the whole growth of bamboos, whereas with trees this means the end of the tree's life.

The bamboo rhizomes can basically be divided into two main groups:

- Laptomorphs or also called monopodial bamboos that have long and thin rhizomes from which the buds produce single and regular shoots. The bamboo species *Phyllostachys pubescens* belongs to this group.
- Pachymorphs or also called sympodial bamboos that have short and thick rootstocks from which the canes grow up. The bamboo species *Guadua angustifolia* belongs to this group.

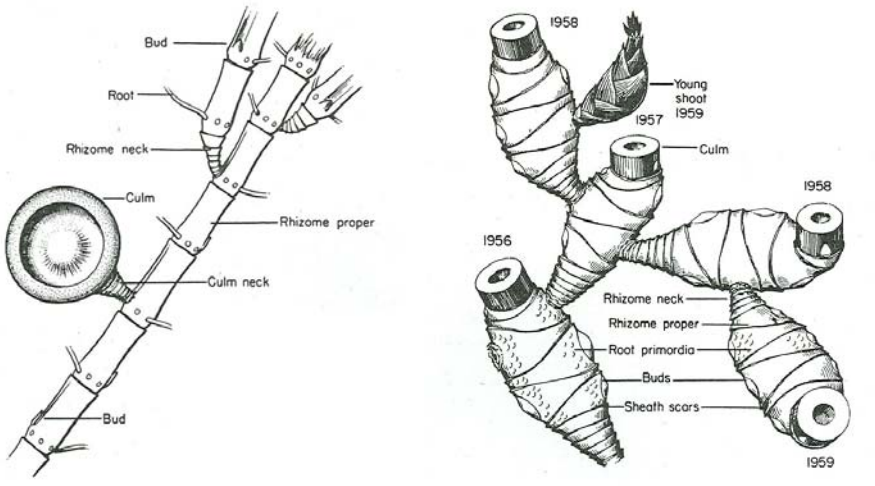


Figure 2- 5 Left: Laptomorphs (monopodial); Right: Pachymorphs (sympodial) (ref. McClure 1966)

The monopodial rhizomes grow horizontally over long distances, a rhizome stolon grows to a length of about 1-6 meters each year, the new stalks can grow from the side buds at the nodes and turn to into

sprouts on the ground and then to culms. So the culms have a long distance from each other. The sympodial rhizomes have on the other hand a short, shrubby arched form with long offshoots. The upper part of the rhizome has the buds, one of which develops into another short rhizome. The rhizome grows upwards to emerge from the ground to be a sprout and then a culm. So the culms are grouped closely together. The bamboos with monopodial rhizomes grow mostly in subtropical areas where the temperature is modest, whereas those with sympodial rhizomes grow mostly in tropic areas.

- **Culm**

The culm consists of internodes and nodes. It is the visible part of bamboo which makes bamboo so unique as a material and a plant. It is also where bamboo differs from grass and tree. The growth of the culm begins from the buds on the rhizomes: the buds grow at this position for several years before they become bamboo shoots and emerge out of the soils. The later structure of culms (the internodes and nodes) has already been totally defined during this phase. The overground growth of bamboo is like the shift of telescope tubes from bottom to top. The culm diameter tapers also from bottom to top, like the wall thickness. Similar to the tree the bamboo culm has a wooden character which makes it different to those of grasses. But different to trees is that bamboos lack a vascular cambium layer and meristem cells at the top of the culm. The vascular cambium is the perpetually growing layer of a tree's trunk beneath the bark that makes it increase in diameter each year. The meristems make the tree grow taller. The structure of culms is more like the one of grass: from the longitudinal section, it is hollow like a tube but divided into segments (internodes) by nodes. The length of internodes which influence the uses of the material differs from species to species; it can be up to 60 cm with *bambusa textiles*. It also changes along the length of bamboo culm. Its values increase from the bottom to the middle of the culm and then decrease to the top. The tissues (cells) are axially arranged in the internodes and through the nodes they are interconnected in bundles (Liese 2003).

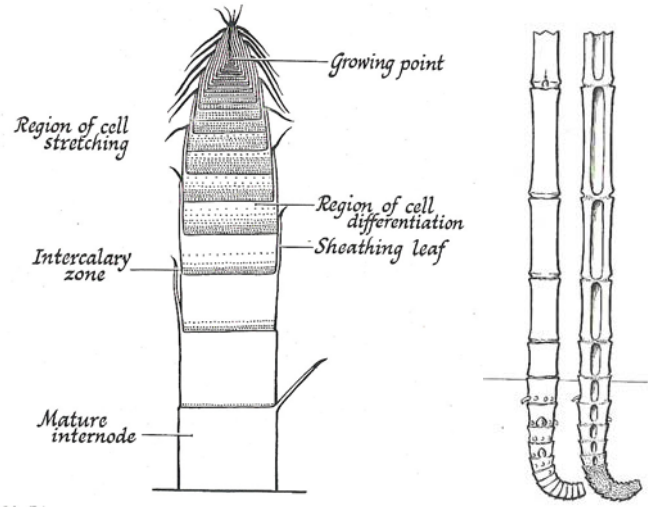


Figure 2- 6 Diagrammatic longitudinal section of young bamboo culm (left) and the lower part and section of culm (right). (ref. McClure 1966)

2.1.1.5. Anatomical explanation

Under the microscope the cross section of a culm shows a very special arrangement of the cells and demonstrates a harmony of the function and construction in nature. Kratzsch (1933) has divided the bamboo culm cross section from outer to inner into four sectors to demonstrate the gradual anatomical changes. For a better understanding of the processing of the bamboo culm, here the division created by Zhang (2001) will be used, in which the bamboo culm cross section is divided into three sections.

- The skin: the cortex of the bamboo culm cross section. Watertight layer which protects bamboo against moisture lost from inside and invasion from outside. No vascular bundles fund in this section.
- The bamboo timber: between the skin and the pith, with vascular bundles and parenchyma tissues. It is the main structural and functional part of the culm.
- The pith is the inner surface of the bamboo cavity. It is a parenchyma tissue, without vascular bundles

The culm compromises about 50% parenchyma, 40% fibers and 10% conducting tissue (vessels and sieve tubes) (Liese 1985).

- The parenchyma: the parenchyma forms the basic tissue in which the vascular bundles are embedded (biological function). It is like the filler and binder for the fibers which together build the construction (structural function)
- The fibers: The fibers are like the skeleton. The fibers together with the parenchyma build the basic construction of the culm.
- The conducting tissues: the biological functional part works for transporting nutrients and water in the culm. They are embraced and therefore protected by dense fibers and together form the vascular bundles.

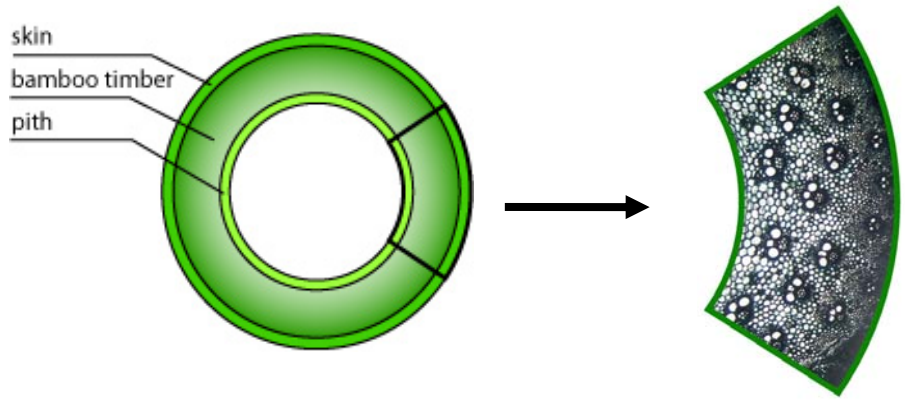
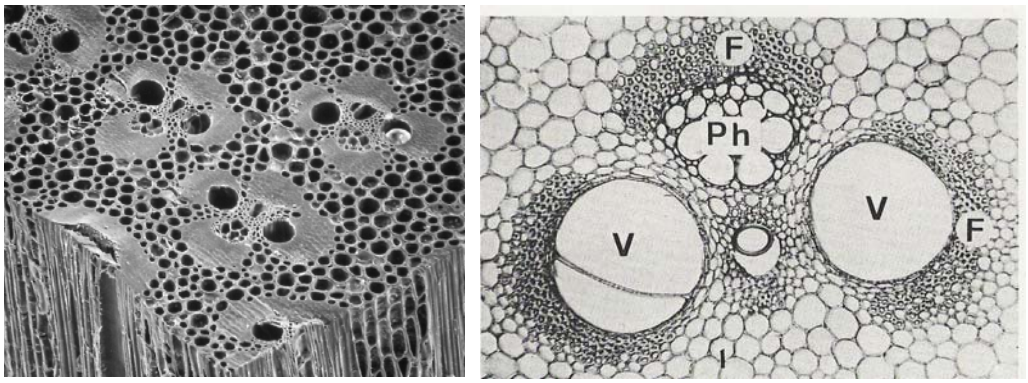


Figure 2- 7 The diagrammatic picture of the bamboo culm cross section

The functional division of these three tissues and the structural combination are similar to that of the animal body – the skeleton, muscle and the blood vessel. This principle has in a way also been used by human beings in the industrial world, like in reinforced concrete. But the bamboo culm has a much more elegant and finer structure: the outer third of the culm has a much higher percentage of fibers than the inside and at the peripheral zones the vascular bundles are also smaller and more intensive than those of the inner parts. Two functions account for that: firstly the tube structure always has its largest tensile and compression at the peripheral zones when it is bended, so the distribution and arrangement of the cells guaranty the highest strength at this part. The second is, the harder and denser the peripheral parts, the better the culms are protected from outer invasions. Also bamboos have in their upper part of culm much more fibers so that the bamboo has more elasticity on its upper part; this property prevents that bamboo is destroyed in strong wind or heavy rain and snow.



V: Vessel of xylem. Ph: Phloem. F: Fiber cap

Figure 2- 8 3D view of the bamboo culm (left) and the vascular bundles of bamboo culm (right). (ref. Liese 1985)

2.1.2. Bamboo as material: material properties

The botanical properties of bamboo explain why bamboo is such a highly developed plant in nature. Material bamboo is the bamboo plant after its "death" in which the substance and the structure of the bamboo plant do not serve the growth of the plant, but the use of human beings. So the material properties of bamboo are the sum of the substances plus the structure of the substances. As material bamboo means mostly the culm, when the material properties of bamboos are discussed it mostly means the properties of the culm. The material properties will explain how the bamboo plant changes to bamboo material. This study will provide different perspectives, namely chemical, physical, mechanical and processing.

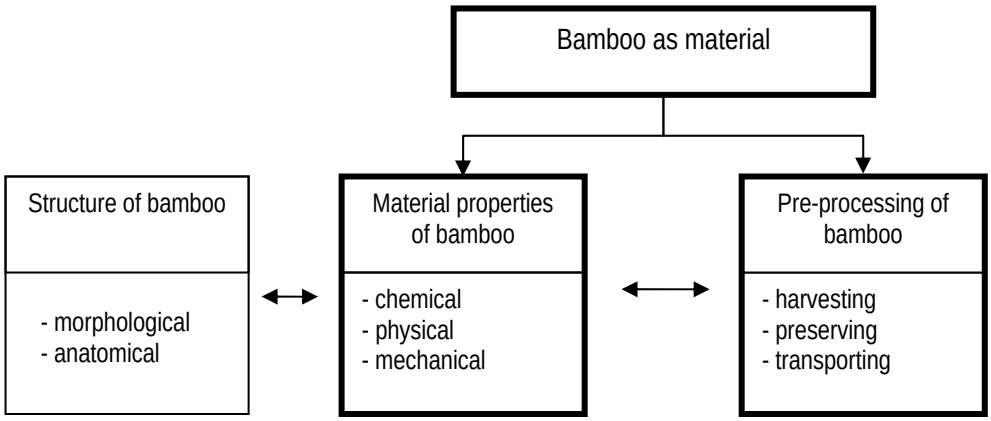


Figure 2- 9 Structure and functions of bamboo in different level

2.1.2.1. Chemical properties

The chemical properties influence the growth and the mechanical properties of bamboos. Through the chemical analysis more information on the taxonomical identification and propagation can be obtained. The chemical composition of bamboos also has an influence on deciding what kinds of bamboos with which kind of material in combination is suitable for the utilizations.

Bamboo consists mainly of cellulose, lignin and hemicellulose which are not different to that of trees. The difference lies in the percentages of each component and their micro structures. Some minor

chemical components are resins, tannins, waxes and inorganic salts. This chemical composition changes according to the species, the age and the parts of bamboo. The variation of bamboo's chemical composition has a big influence on the physical and mechanical properties of bamboos and therefore the treatment and utilization of bamboos (Liese 1985).

- **Cellulose**: Cellulose $(C_6H_{10}O_5)_n$ is a carbohydrate. It forms the primary structural component of green plants. For the plants the primary cell wall is made of cellulose and the second cell wall is made of cellulose with a varying amount of lignin. Cellulose is also the most abundant form of living terrestrial biomass in the world, which in combination with lignin and hemicellulose can be found in all the plants (Crawford 1981). It is also the major constituent of paper and for the synthesis of the plastics celluloid.

- **Lignin**: Lignin is an integral part of the cell walls of plants, especially in tracheids, xylem fibers and sclereids. It is the second most abundant organic compound on earth after cellulose. Lignin makes up about one-quarter to one-third of the dry mass of wood. The lignin fills the cell wall of the plant in the space among the cellulose, hemicellulose and pectin components. It confers mechanical strength to the cell walls and thus the whole plant. It is important in conducting water in culms. Because it is difficult to degrade it helps to build a barrier to defend the plant against the invasion of pathogens and enhances the durability of the plant. The high lignified wood is durable and yields more energies than cellulose. But it is a detrimental for paper making and therefore should be removed by pulping.

- **Hemicellulose**: Hemicellulose is similar to cellulose but is less complex. Hemicelluloses bind with pectin to cellulose to form a network of cross-linked fibers in plants. The hemicellulose in bamboo has its main component xylan between that of the hardwood and softwood.

The percentages of these three main components compared with wood can be seen in Table 2-1:

	Cellulose (%)	Lignin (%)	Hemicellulose (%)
bamboo	55	25	20
softwood	50	25	25

Table 2- 1 Chemical compositions of bamboo and softwood. (ref. Janssen, 1981)

2.1.2.2. Physical properties

- Specific gravity

The specific gravity of bamboo ranges between 0.5 and 0.8 g/cm^3 (oven-dry weight). This value increases from the central parts to the peripheral parts of the culm and from the bottom to the top (Liese 1985).

- Moisture content

Moisture content influences the utilization of bamboo in a similar way like that of wood. The moisture content of bamboo depends on: 1. Bamboo species: the different species have a different amount of parenchyma cells which correlate to the water holding capacity (Liese & Grover 1961). 2. Culm zones: the base has a higher value than the top. The inner part of the culm cross section has a higher value than the outer part. 3. Nodes or internodes: the nodes have a lower value than internodes (up to 25%). 4. Seasons: at the end of the rainy season it is much higher than at the end of the dry season; 5. Age of the cane: the young culm has a higher and more uniform moisture content than the mature one (Dunkelberg 1985). After the harvesting the moisture of bamboos can be influenced by the humidity and dryness of the environment.

- **Dry shrinkage**

Unlike wood bamboo begins to shrink from the beginning of drying (Liese & Grover 1961). The process is not regularly and will stop at about 40% moisture content. After the bamboo is cut, its moisture content decreases and the dry shrinkage begins. The dry shrinkage varies in different directions. Zhang reported about the dry shrinkage of *phyllostachys pubescens*, when the moisture lost is 1%, the average shrinkage rate is: lengthwise 0.024%, tangential 0.1822%, radial 0.1890% (on node parts 0.2726%, on inter node part 0.1521%) (Zhang et al 2001). The dry shrinkage also increases from inner to outer parts. The dry shrinkage of the outer part of bamboo in length direction can be neglected, but the crosswise shrinkage is large.

- **Resistance against natural pests**

Bamboo has organic nutrients which are favorable to insects and microbes compared to wood. These organic substances are protein (1.5 – 6.0%), carbohydrate (2%), starch (2.0 – 6.0%), fat and wax (2.0 – 4.0%). (Zhang et al 2001). Under proper temperature and humility bamboo is apt to be attacked by insects and fungi. There are traditional as well as modern methods to deal with this.

2.1.2.3. Mechanical properties

The studies on bamboo mechanical properties are commonly based on laboratory tests of the strength of bamboo (tensile strength, bending strength, compression strength, shear strength and modulus of elasticity) (Atrops 1969, Janssen 1981, Dunkelberg 1985). These tests show remarkable differing values when changing species, ages, moisture content, locations, soil and climatic conditions. The variation of mechanical properties is similar to wood, but even more remarkable. This is one of the reasons why bamboo is difficult to be used in the industry. To show the material mechanical properties two bamboo species, *phyllostachys pubescens* and *Guadua angustifolia,* which are most commonly used in building constructions, are selected in Table 2-2:

Species	Compression strength σ (N/mm²)	Bending strength (N/mm²)	E Modulus (N/mm²)	Shearing strength (N/mm²)	Tensile strength σ (N/mm²)
Phyllostachys pubescens	56	129.1	10500	13.9	196.0
Guadua angustifolia	56	74	19000	9	140

Table 2- 2 Mechanical properties of bamboo species Phyllostachys pubescens and Guadua angustifolia. (ref. Steffans 2000 & Zhang 2001)

Compared to other building materials like wood, cement, steel and glass, bamboo has excellent mechanical properties, with which it can be a very good building material. The comparison of bamboo to some other typical building materials in mechanical properties can be found in different references (Janssen 1981, Dunkelberg 1985).

Material	Working stress σ (N/mm²)	E (N/mm²) Modulus of elasticity	Working strain $\varepsilon(10^{-6})$	Strain energy stored	
				J/m³	J/kg
concrete	8	25 000	300	1200	0.5
steel	160	210 000	800	64000	8.2
wood	7.5	11 000	700	2600	4.3
bamboo	10.7	20 000	500	2500	4.2

Table 2- 3 Material mechanical properties and strain energy stored. (ref. Janssen, 1981)

The research by Janssen (1981) shows that compared to concrete, steel and wood bamboo has excellent mechanical properties with reference to material efficiency for strength (working stress per volume unit) and stiffness (E modulus per volume unit) as in Table 2-4.

material	$\frac{\text{Working stress}}{\text{Weight by volume}}$	$\frac{E}{\text{Weight by volume}}$
concrete	8/2400 = 0.003	25000/2400 = 10
steel	160/7800 = 0.02	210000/7800 = 27
wood	7.5/600 = 0.013	11000/600 = 18
bamboo	10/600 = 0.017	20000/600 = 33

Table 2- 4 Material efficiency for strength and stiffness. (ref. Janssen, 1981)

Some researchers try to analyze and calculate bamboo's mechanical properties by studying its molecule structure. Janssen developed a mathematic model of cells of bamboo culm to calculate the mechanical properties, whose principle has been used in the research on mechanical properties of cell walls in wood (Janssen 1981). Ye (1995) studied the different mechanical properties in the outer, middle and inner parts of the bamboo culm by studying the distributions of vascular bundles in these fields. These studies reveal the relationship between the micro structure of bamboo and its properties and help to form a better understanding of the mechanical properties of bamboo.

2.1.2.4. Pre-processing of bamboo

Here the pre-processing of bamboo means the preparation of bamboo for its further utilizations as a material. It is the phase between the bamboo plant and the bamboo material. The difference of the utilizations of bamboos determines the processing of bamboo and also changes from one to another. For example the bamboo sprouts are very popular foods in Asia and will be cut in the beginning of the sprout growth in the spring; whereas the bamboo culms for building normally come from the 4-5 years old bamboo and should be cut in fall and winter. But generally there are three phases which most of the utilizations have to take: the harvest; the transport and the preservation.

- **Harvest**

The harvest is different from one to another according to which part of bamboo will be harvested and for what purpose the bamboo is used. The proper harvest time and methods will provide bamboo material with the best quality and at the same time prevent damaging the growth of the bamboo plant.

As delicious food bamboo sprouts are one of the most important traditional utilizations of bamboos in Asia. For the sprout, the best time of harvest is the early spring when the bamboo shoots just grow out of the earth. But for the building materials or for tools, the 4-5 years old is generally regarded as the best age for bamboo culms harvest, because these bamboo culms are mature enough and have reached their highest value in strength. After this time the strength of culms decreases. Research has reported that there are species that can increase their highest bending strength up to an age of 8 years and compression and tensile strength up to an age of 6 years (Zhou 1981). This shows the difference among the species. The principles about the age of bamboo to harvest are that cutting young bamboo culms with only 1-2 years will damage the growth of the rest of the bamboo plants, whereas the harvest of matured bamboo culms will encourage the growth of the new bamboo culm and stimulate the metabolism of the bamboo plant. Bamboo culms which are more than 10 years old have low quality both in the sense of material and plant. The time for harvest should be in the dry season in order to keep the moisture content in the

bamboo culm low. Otherwise the culms will easily attacked by fungi and rot, and also increase the transport costs (Janssen 1988). The cut of bamboo culms in one season should be no more than 25% of the total culms in order to keep a stable productivity of the whole bamboo forest. The cutting position should be about 30 cm above the ground in order to not destroy the rhizome and it should be just above a node so that the water will not be collected there and cause the plant to rot (Austin 1972).

- **Transportation**

Transportation happens normally between the place of harvest and the processing place. The factories or workshops are often placed near the bamboo forest in order to save transport costs. Because of the tube structure of the bamboo culms a long distant transport of raw bamboo culms is not profitable. In some places people traditionally have used river as the natural transport channel which is cheap and efficient. The river transportation has another advantage: it prevents bamboo from attacks by insects.

- **Preservation**

The preservation of bamboo after the harvest is so important that it decides the quality of bamboo material in later utilizations. Similar to wood the bamboo is easily attacked by insects, fungi. According to Janssen (1988) the untreated bamboo culms can have a maximum of 10-15 years of lifetime if they are kept under cover and in a not very humid climate. In direct contact with atmosphere they can only last 1-3 years.

Because of bamboo's anatomical structure the treatment is also difficult to carry out: there are no radial oriented vessels, all of them are arranged mostly axial and isolated by parenchyma in the internodes and only connected at the nodes. The outer and inner walls are covered with dense wax which prevents a loss of water. Therefore preservatives can only get through the culms in axial direction at both ends of the culm (Liese 1985).

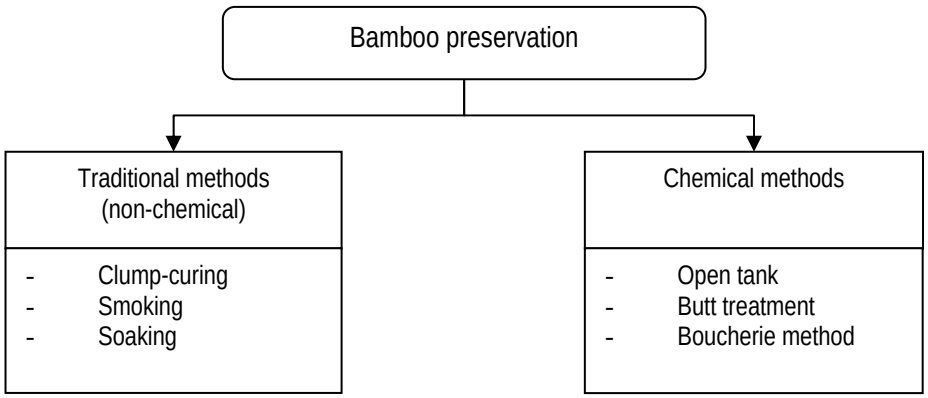


Figure 2- 10 Bamboo preservation methods

There are two groups of preservation methods: the traditional methods and the chemical methods. Janssen (1988) described three traditional methods of bamboo treatment:

- Clump-curing: In the clump-curing method the branches and leaves on the bamboo culms are kept after they are cut down, which will evaporate after some time. This will reduce the starch content of the culms and therefore increase resistance to insects, but not against termites and fungi.

- Smoking: bamboo culms are put into the smoke with a temperature of about 120°C for some time so the insects are killed. It is believed that this way will increase the durability of culms. But

during the process the bamboo culms can be broken and the color will get black. This method is popular in Japan.

- Soaking: after cutting the bamboo the culms are soaked with water or mud for several weeks and then dried for one week in the shade. During the soaking the starch and sugar of the parenchyma cells are leached or deduced, so the resistance against insects will be increased, but not against termites and fungi.

In the chemical methods chemical preservatives like CCA (copper-chrome-arsenic composition) or cheaper ones like boric acid and borax are used to keep bamboo culms from being attacked by insects. There are three kinds of processing methods (Janssen 1988):

- Open tank: bamboo culms will be soaked in a tank filled with chemical preservatives for about one week. Then the culms are left to dry for one week in a vertical position, protected from sunshine.

- Butt treatment: the bottom of freshly cut bamboo culms with branches and leaves is soaked in the drum of preservatives. The branches and leaves serve as a pump because of the evaporation. This will enable the preservatives to get through the tissues of the bamboo culms from bottom to top. After one or two weeks, when the color of the leaves changes, the culms are put into empty drums to collect the surplus of the preservatives of the culms.

- Butchery method: one side of the bamboo culms is enclosed with tubes which are connected to a drum with preservatives that is put on an about 10 meters high tower. Then the preservatives are pressed into the bamboo culms by the height pressure of the preservatives.

These are the advantages of the traditional ways of treatment: they cost little and are easy to process. For the small scale like village families these methods have been used for a long time. The disadvantage lies in the low efficiency. In comparison the chemical methods are much more efficient than the traditional ones, but are also more expensive and need more equipment for processing. Both traditional and chemical ways of preservations are the pre-processing for increasing the durability of bamboo culms in the later utilizations, which can be extend by the careful use of bamboo in the structures, for example not using them directly in contact with rain, sunshine or earth.

2.2. The cultural dimension of bamboo

Bamboo is a material with structure and culture. The material bamboo, since its long history of versatile utilizations in people's daily life, has become a kind of "bamboo culture" in countries like China, Japan and many other countries. This kind of "bamboo culture" can be read from three perspectives: firstly bamboo is the medium by which the local cultures have been represented, transferred and developed. An example for this is the Japanese tea ceremony, for which bamboo utensils have been used exclusively. Secondly bamboo becomes a certain "material culture" itself through the numerous utilizations of bamboo goods in people's everyday life. Thirdly bamboo is taken as a motive in the people's high cultural life (in comparison to the everyday culture in the second category), such as bamboo poems, bamboo paintings and bamboo philosophy.

These structural and cultural dimensions of bamboo and their relation can be related to the history of bamboo. The history of the natural material bamboo has two meanings: firstly the natural history of bamboo as a plant, and secondly the material history after it is used as material by human beings. The natural history has its result: the natural structure of the material. It possesses the current structure because of millions of years of the evolution process in nature. This is one of the differences between

the natural material and an artificial one. The French socialist and philosopher Jean Baudrillard has described the material wood in a way that it is not just as a functional substance but a

> *"Soulful nostalgia: because it comes from the earth, it lives, breathes and 'works'. It possesses hidden warmth, it does not shine like glass, it burns from inner out. There is the time saved in its texture, which is ideal container and content at the same time… the wood has its own smell and even parasites. In short, this material is a being"* (*Baudrillard 1968: 50*)

As a natural material, bamboo has similar characteristics like wood: the material bamboo inherits the natural history of its growth in nature, and this makes it so special that it differs from all man-made materials, also from the other natural material wood in reference to structure.

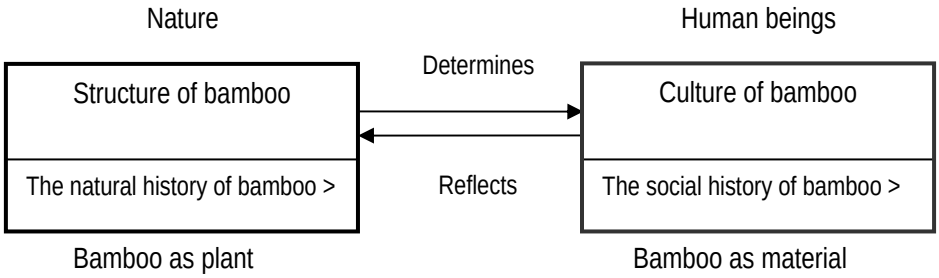


Figure 2- 11 Bamboo's structural and cultural dimensions

The second part of the history of material bamboo is the "social" history: Bamboo is a "material" which as a term itself reveals the social attribute of bamboo. It is a "material" because it is useful. For such a natural material used by people for thousands years, the history of the utilizations has been already "accumulated" in the material bamboo and belongs to a part of the material itself. This historical character is different to those newly invented artificial materials. It is the culture of the material bamboo (see Figure 2-11).

Because of their special natural features, bamboos have been used as a universal material by human beings already in the onset of human evolution. In China the use of bamboos goes back to 5000 years ago in the Stone Age and Bronze Age. It is also not surprising that during the long time of being with human beings the bamboo is not only a plant but becomes more and more like the horse, the cow, wheat and cotton, which are responsible for man's own evolution (Farrely 1984). They take bamboos as their friends in their lives; bamboos have often been taken as favourite themes in the painting arts, calligraphy, and in poems (Wang 2001). The widely uses of bamboo have been recorded in historical literature. In the Jing dynasty (265 - 316 A.C) Kaizi Dai wrote the book "Bamboo Encyclopedia" which is regarded the first book on bamboo research in the world. The evidence of widely using bamboo in the human society can be found in the Chinese characters. In Chinese the character "竹" (Zhu) is not only a character, it is also a part of a character or letter, through which the meaning of the words has more or less relations with bamboo. In the Chinese official dictionary "XinHuaZiDian" there are 209 characters with "竹" symbol, for example: "简" (Jian) means the first book that was made of bamboos before paper was invented. "筷" (Kuai) means chopsticks, which can be made of bamboo, wood, or animal bones, but were originally made of bamboos. "筝" (Zheng) means "kite" because originally kite frames were made of bamboo strips. Each of the 209 Chinese characters with the "竹"bamboo symbol can tell a story about bamboo from a special perspective.

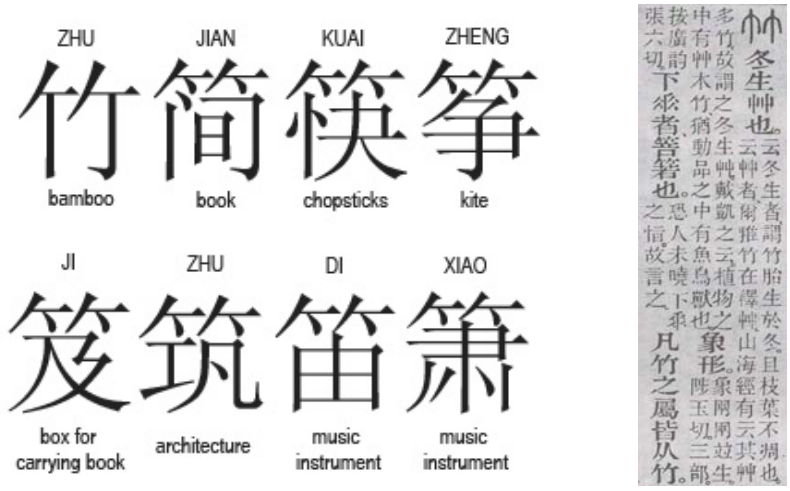


Figure 2- 12 Some Chinese characters with bamboo "竹" (Zhu) symbol and the explanation of bamboo symbol in the Chinese first dictionary „Shuo Wen Jie Zi "(Han Dynasty 100-121 AC)

Furthermore, bamboo has played an important role in cultural development; bamboo can be found everywhere in daily life culture (Wang 2001). The specialty of bamboo as a plant and as material has also fascinated researchers from all over the world and many of them have done research on the role of bamboo in the social culture. Spörry has collected hundreds of things made of bamboo from Japan at the beginning of 20 century and made an exhibition in Switzerland, giving the Europeans a general insight into bamboo culture in East Asia (Brauen 2004). Farrelly (1984) has collected one thousand things made of bamboo in his book which range from house building to chopsticks. Dunkelberg (1985) did a detailed study in his dissertation on bamboo as a building material in Southeast Asia, where he did a detailed research on traditional bamboo building construction and style. Ranjan (1986) has written books about the beautiful Indian handcrafts made of bamboo which are nowadays still used in the north of India. All this research shows the versatility of bamboo as a useful material.

In this chapter the study on the conventional bamboo's utilizations will be based on literature studies. For a better understanding the relationship between bamboo's natural structure and its utilizations will be categorized into three parts: bamboo as an untreated plant; bamboo as a treated material; bamboo as a symbol (see Figure 2-13). Relevant examples in each category do not wish to cover all the uses of bamboo, but rather serve as a selection of typical ones to represent a close relationship between bamboo and the human culture and how bamboo's natural structure influences its cultural meanings. The location of the examples does not play any role in the research – the presentation of these examples shall show how bamboo does play important roles in human culture, regardless if the culture is Chinese, or Columbian or African.

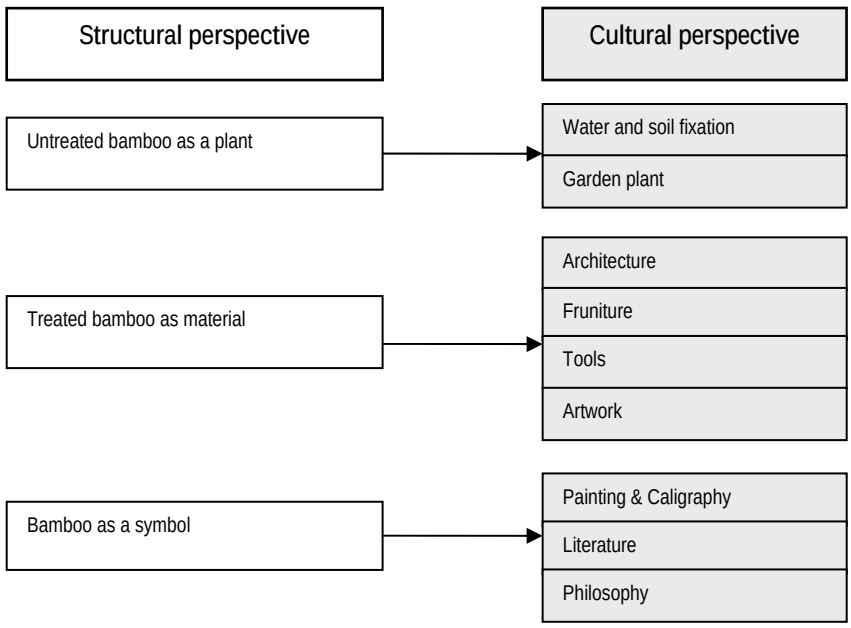


Figure 2- 13 The connection between the structure and culture of bamboo

2.2.1. Untreated bamboo as a plant

Because of their fast growth, high resistance to hard weather, straightness, lightness, elasticity and most important their beautiful colors and forms of the leaves and stems, bamboos have been planted in Asia, Latin America and Africa from the beginning of their civilization. They are planted around the houses or in the gardens for their practical purpose as well as their beauty.

Figure 2- 14 Bamboo structure and its uses as untreated plant

2.2.1.1. Water and soil fixation

Because bamboo has its subterranean rhizome which has much more vital growth than the root of timber, planting bamboo has been a very good way to keep the water and soil. The history of *Guadua* in Columbia could be a good example: the most common bamboo genus in Latin American is *Guadua*, it could be seen everywhere in the time of the Western settler coming to Columbia. It helped resisting the destruction and decay of the land. But during the cultivation of corn and other crops like grasses for livestock, the *Guadua* groves were cut and burned, as the stumps of *Guadua* groves are good fertile soils for corn and grasses. As a result the corn fields became wider and bigger but *Guadua* groves shrunk, but the flow of water in the streams became intermittent, the rains led to more flooding. Thus the people

realized that *Guadua* is the natural guardian for the water supply. So they began to re-plant the *Guadua* groves to help keeping water and soils (Farrely 1984).

2.2.1.2. Garden plant

Planting bamboo in private gardens has been a trend among the intellectuals in China for thousands of years. Bamboos in garden became as a special kind of art, the plants were chosen as friends of the garden's owner, also personified to reflect the owner's personality. Intellectuals, who were the main contributors to the Chinese culture, saw the garden as the space of their soul and took plants in the garden as the sign of their spirit – high-hearted; free from vulgarity. Shu-Shi, a famous poet, painter and calligrapher in Song Dynasty, China, wrote in his poem: "Man can live without meat, but how can man live without this friend (bamboo)? Without meat man could only get thinner, but without bamboo man become vulgar".

Figure 2- 15 Village house with bamboo (left) and in the painting by Wu Guanzhong (right)

For the village houses in South China there has been a long tradition that every family has a cluster of bamboos aside their houses. The clusters of bamboos can be found in front of the house, in the backyard, wherever there is a small free place of ground. For these village houses the bamboo gives them at first the green shades in a hot sunny summer, guards the houses from heavy rains washing out the ground basement, but also a lovely playground for children and a feeding place for poultry and livestock. Bamboo and house together build a beautiful picture of the village life in south China, even here bamboos are planted more for practical reasons than aesthetic values.

2.2.1.3. Food and medicine

Bamboo is not only eaten by panda bears, human beings have used it for food for thousands of years. Bamboo sprouts are considered one of the most delicious and healthy foods in China, Japan and other Asian counties. In 1979 150,000 tons of bamboo sprout have been produced only in Japan. In Taiwan alone there are bamboo sprouts worth 50 million US Dollars exported every year (INBAR 2004). In traditional Chinese medicine bamboo sprouts also provide a good medicine for keeping the inner balance of the human body[8]. In the summer time people have often too much "Yang" or "Fire" element in the body, so eating bamboo sprout soup especially from the bitter bamboo (*Pleioblastus amarus*) can help to reduce too much "fire" element in the body. Other parts like leaves and the middle parts of culms from the fresh bamboos have been used as well for tea or other popular drinks in summer.

[8] A simple introduction to the traditional Chinese medicine can be found on the internet: http://en.wikipedia.org/wiki/Chinese_medicine. The relevant references are also listed there for further reading.

2.2.2. Treated bamboo as construction material

Because of its special structure bamboos become more than a plant in the garden but a useful material for construction in different fields. They have been treated in different ways to make numerous products, buildings, furniture, tools and other things for practical uses (Figure 2-16).

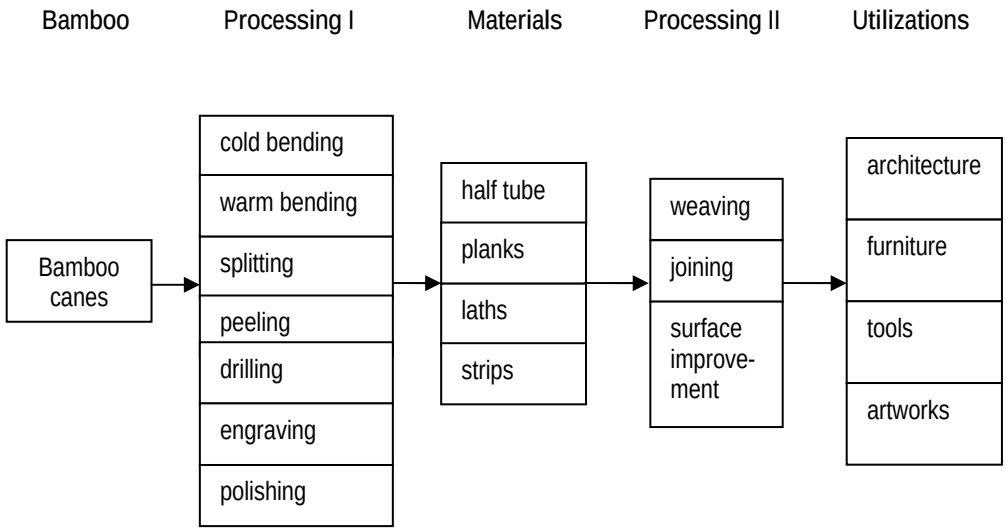


Figure 2- 16 The treated bamboo as material: from bamboo structure to bamboo culture

People in Asia, Africa and Latin America have used bamboo as a material for their daily life for thousands of years. In Wu Xin, a small town in Southeast China, more than 200 bamboo objects have been recovered that were made about 4700 years ago. These objects range from bamboo woven basket, matting, and fishing net and already show a high level of handicraft. Now some similar bamboo objects are still used there, but some of them can only be found in the museum or in literature. In China the literature on traditional uses of bamboo often range into the bamboo culture. In Song Dynasty (960 A.C. – 1279 A.C.) bamboo utilizations in building have been categorized in the "Ying Zhao Fa Shi" (approx. 1102.A.C), one of the oldest building lexicons in China. And thousands uses of bamboo have been recorded in various literature (Wang 2001). Another important branch of bamboo utilizations in construction is the bamboo woven crafts, in which bamboo works not only as the functional structural elements, but also represents a high aesthetic value. There are several researchers who have recorded this in different countries. R.J.Ranjan (1988) has studied the traditional bamboo woven baskets in Northeast India where nowadays these bamboo crafts are still kept in a traditional way. Hans Sprörry's collection of traditional bamboo crafts from Japan has shown to Europe for the first time how wonderful this material could be treated in numerous bamboo objects (Brauen 2003). Nancy Moore Bess could be a modern craftsman and artist from the West who describes the traditional bamboo crafts in modern Japan (Bess 2001).

The traditional methods for treating of bamboo represent on the one hand the structural advantages of bamboo material compared to other natural materials like wood or stone, on the other hand the intelligence of the handicraftsmen: they respect the natural structure of bamboo and use it in a way that all the advantages of bamboo have been used to full capacity. The traditional bamboo crafts show a high level of harmony of both sides: the natural structure and the human initiative in the bamboo handicrafts. In this part the examples will be assorted from the perspectives of the utilizations, in which the processing of bamboo will be concerned relevantly.

2.2.2.1. Architecture

Bamboos as a material for building came from the same time that human beings tried to use wood for their buildings. For the easiness of its treatment bamboos could be often used in building. In China in the Qing Dynasty (221 B.C. – 206 B.C.), there have already been recordings about bamboo palaces showing that all the buildings in a palace in southwest China were made of bamboos.

The uses of bamboo in the house construction can be from the roof, wall, support to the floor. Bamboos can be untreated tube, split planks, or woven planks in the buildings. Dunkelberg did his study in detail on the traditional bamboo buildings in Southeast Asia (Dunkelberg 1985). Ranjan has also described the bamboo architectures in Northeast India in his book about the bamboo crafts in that territory (Ranjan 1986). In Latin American countries like Columbia and Ecuador there are also many records on bamboo architectures with different styles compared to those of Asia and Africa (Farrelly 1984, Revelli 1997). In areas like North China, Japan and Korea, where the climate is much colder and with drier air, the bamboo buildings are not so practical in the winter, but the bamboos are still to be seen everywhere in the house and are used as one of the important constructive or decorative elements for the interior.

The bamboo used in the buildings can be sorted into three categories: for bearing; for space partition and for joint. The different usages decide how it would be treated. For the first task the following two kinds of bamboo species are mostly used: *Guadua angustifolia* and *Phyllostachys Pubescens*. The *Guadua angustifolia* is a sympodial bamboo whereas *Phyllostachys Pubescens* belongs to monopodial bamboo. But both of them have a big stem, in average both bamboo species can be up to 20 cm in diameter and 30 m in length. For the compression stress the tube form of bamboo stems could be directly used for the construction, here bamboo cane shows its wonderful features like: strong, light, and easy to process. For the tensile stress it can also be split into strips and woven together as bamboo rope. For the second task the bamboo cane will normally be split into bamboo half tube, planks, laths and further to strips, then bamboo planks, laths and strips can be woven together to be constructional elements. Small bamboo tube, laths and strips and rattan can be used for the joints.

- **"GanLan" bamboo house**

Bamboo cane could be used directly for building constructions. In many places in Southeast Asia, Latin America and Africa there are still houses which are built with traditional bamboo construction (Dunkelberg 1985). "GanLan" bamboo house could be typical for one of them.

In South China the bamboo building is seen as one of the typical style, special in Yunnan province called "Gan Lan" style, most of which are made of *Phyllostachys Pubescens*. This kind of architecture has already appeared in Song Dynasty (960-1279 A.C) in China. In this area the climate is similar to that in Thailand, Malaysia and India: it has a high temperature and air humidity in summer, it also rains very often, so the flood often washes out all the things on the ground. The bamboo building and its special two-level-construction has special advantages against humidity, high temperature, the flood, insects and other small animals. The most important reason for bamboo building is that the bamboo as a building material is easy to get, easy to work with and easy to build.

Figure 2- 17 Bamboo Architecture "GanLan" style in South China

Similar to China countries like the Philippines, Thailand, Malaysia from Southeast Asia and Columbia in Middle America also have abundant examples of traditional bamboos buildings. There are hundreds of millions of people in the whole world - South and East Asia, Middle America, and Africa – who live in houses made of bamboo. The report of the INBAR shows that in Bangladesh, 73% of the whole population live in bamboo houses.

- **Bamboo bridge**

Bamboo has been used for bridges in several ways. Bamboo bridges can just use bamboo canes as the main construction elements, big bamboo canes like the *Phyllostachys Pubescens* in Asia, or the *Guadua angustifolia* in Latin America. The bamboo canes will be joined by rattans or bamboo strips, the road on the bridge can be paved with bamboo planks or just untreated tube of bamboo canes. Another way of using bamboo in building bridges is the rope construction. The Western researcher Needham recorded in his work "Science and Civilisation in China" the most famous suspension bridge made of bamboo ropes - the An-Lan Bridge over Ming River in Sichuan province in Southwest China (Needham 1971: 192). For making the bridge suspension ropes, bamboo canes are split into slips and twisted into ropes. Thanks to its high tensile strength, bamboo ropes can be very strong and durable. The bridge was originally built in Qing Dynasty (about 256 BC) by the governor of the province Li Bing and rebuilt several times in history. In the year 1177 the 3.6 m wide bamboo bridge had 5 spans and each span had 36.5 m as recorded by the Chinese scholar Cheng Ta. In 1958 the bridge was changed to 8 spans with different lengths, the longest of which has 61 m. The 320 m long bridge has its 2.75 m wide deck carried by 10 bamboo ropes with 16.5 cm diameter, whereas each of the 2 rails had been carried by 5 such bamboo ropes (Figure 2-18). This bamboo bridge has been regarded as great engineering work in ancient China (Needham 1971).

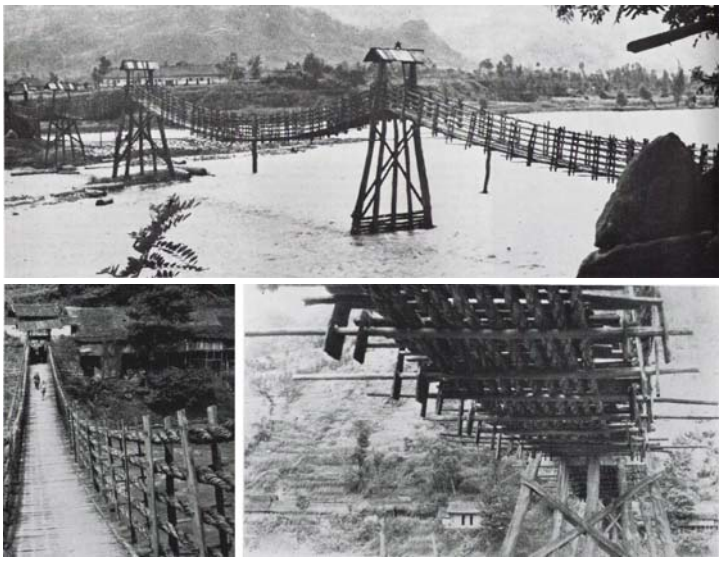


Figure 2- 18 Bamboo suspension bridge "An-Lan" in Sichuan Province in Southwest China (ref. Needham 1958)

2.2.2.2. Furniture

Bamboo has been used for making furniture in different ways: bamboo stem can be used directly as the main structure of the furniture; it can also be split into strips and slices, and then can be woven together into different surfaces of the furniture. Bamboo tube in furniture shows the lightness and strength of the material, and bamboo strip and slice shows the versatile usage of bamboo. Through different combinations bamboo can be used for almost all kinds of furniture: desks, chairs, beds, folding screens.

- **Bamboo chair**

The bamboo chair is one of the most popular furniture made of bamboo in South China. The making of the bamboo chair has been kept from generation to generation without changing the style for more than hundreds years. The bamboo chair shows a traditional handicraft treatment with bamboo material, which also presents a simple, beautiful and functional solution to the problem between the natural structure and the human's needs in the daily life before the industrialization.

Figure 2- 19 Traditional bamboo chairs and bamboo chair in open tee house in Southwest China

In China the bamboo used for making chairs is *Phyllostachys pubescens*, also called Moso in China, one of the most widely distributed and utilized bamboo species in China. In South America the *Guadua angustifolia* is the most common species for making bamboo chairs. The bamboo canes with a 5-7 cm diameter are used for the basic frame of the chair, whereas the small bamboo canes and splits are attached to the frame to form the surface for supporting the human's body. Besides fulfilling the basic function as a seat, the different patterns have been developed to give different impressions.

The strength, stability and lightness of the bamboo chair made them a kind of favorite furniture not only for the households of different classes, but also a kind of standard public furniture for tea houses. Especially in Southwest China such as Sichuan province, the tea house could be the most popular public place for people meeting with friends, discussing business, playing Mahjong[9], watching Chuan Ju (Sihuan Oper)[10] and listening to Ping Shu (Chinese Crosstalk)[11].

- **Bamboo bed**

In South China and Thailand the weather in summer is extremely warm and moist. In such places bamboo has been used for summer furniture for a long time. Bamboo cane is a good heat conductor. This allows bamboo to be a material for the hot summer to calm down people there, like in a bamboo bed. In many places in South China such as the city Wuhan, the bamboo bed is taken as standard equipment in every family for the hot summer night. Numerous bamboo beds are set up outside of the house or just on the street sides when the evening comes, people – man and woman, adults and children, gathered together around their bamboo beds, either playing Chinese chess, or telling stories, to spend their sleepless night time until to the early morning as the air cools down. This phenomenon has been well kept till the air condition was applied in normal households in this city (see Figure 2-20).

Figure 2- 20 Typical daily life scene in summer in Wuhan in South China has been used as the motive for the street sculpture - bamboo bed serves as important furniture there.

There are many ways to use bamboo cane for the bed. The bamboo bed used in the city Wuhan has a construction especially suitable for the mobility and for hot weather: Bamboo canes are used for the bed frame and the bamboo strips are arranged together to form the inner sleeping panel. The legs which are standard elements for interior beds are left aside. This kind of panel bed is very practical for transportation in the summer. Because the hot weather commonly stays until late at night, the temperature in the house is much higher than that outside at night. With this bamboo bed people can

[9] Mahjong is game for four players; it originally comes from Chinese and is popular in many Asia countries as a form of gambling. There are different variations on how to play the game. One popular rule is that the first of four players who has finished building complete suits of 14 or 17 tiles is the winner of the game. More about Mahjong see http://en.wikipedia.org/wiki/Mahjong.
[10] Chuan Ju is one of the traditional Chinese Operas from Sichuan province, often played in tee houses.
[11] Ping Shu is a traditional Chinese story talking performance, originally it often took place in tea houses.

easily take it to go outside and put it on the ground and sleep there; after the sleep they can easily bring it back into the house. Other uses of bamboo for making beds: the thin strips from outer parts of bamboo canes can be woven together to make a bamboo matting. This bamboo matting also has a long history and nowadays is still employed in such places. People there don't have air condition, but they get the most comfortable and cheapest cooling from the natural bamboo. This bamboo matting has not only the practical functions, but also aesthetical functions: the surface of the matting is also the show place of the craftsman for their art talents: the different patterns represent their art talent. Such kind of bamboo matting can be also made of bamboo blocks which are stringed together by strings. It serves the similar function but is much heavier.

2.2.2.3. Household tools

Tools made out of bamboo can be found almost everywhere in kitchens, in living rooms and sleeping rooms, from small things like chopsticks to big things like baskets for keeping domestic animals. The collected examples here show its typical uses, and the relation between the uses and its working methods.

- **Chopsticks**

Chopsticks are the tool for eating in China, Japan and other East Asia countries. Using chopsticks for eating, compared with knife and fork in Western, has been described by Roland Barthes as one of most important representations of the Asian culture (Barthes 1981). Originally chopsticks were made of bamboos, and most of them nowadays are still made of bamboos. As the main tool for Asian food culture chopsticks are the summation of knife and fork in the West. Even though bamboo is not the only material for the making of chopsticks, it is the most common and the cheapest material for making them. Bamboo chopsticks have their beauty not only for the color, the surface, the lightness and the strength, but also in the simple treatment of the material and the elegant gesture in the using of the chopsticks in catching, holding and transporting the food while eating.

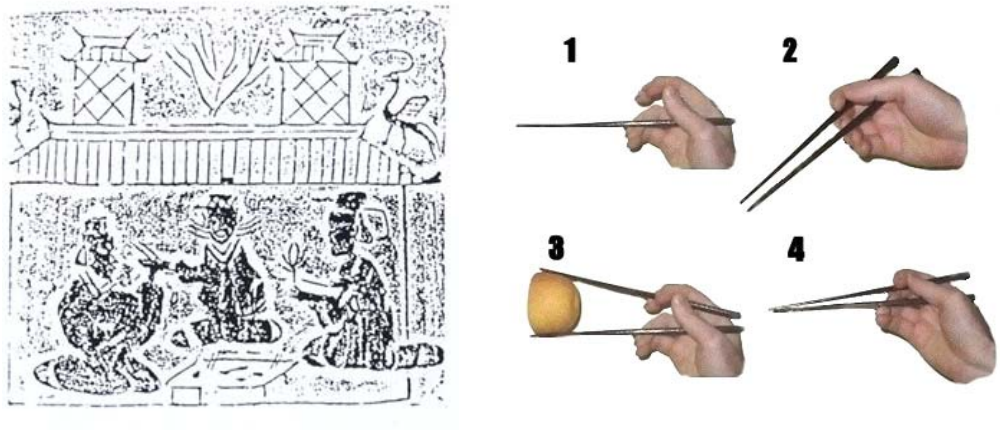


Figure 2- 21 Left: brick drawing "dinner" (Donghan Dynasty 25-220 AC), in which the man on the left has chopsticks in his bowel. Right: the use of chopsticks

- **Baskets**

Here the name bamboo basket is a very broad concept. It means all the objects that are made of woven bamboo strips. These woven bamboo strips can be very closely-knit with little holes, can also be loosely woven together with big holes, depending on what kind of object it will be used with. Baskets made of bamboo can be used almost everywhere in the house. R.J.Ranjan has written a book about the fine handicrafts in Northeast India, where bamboo woven baskets are still kept well as a tradition (Ranjan 1986). In her book "Bamboo in Japan" Nancy Moore Bess has also written about how bamboo baskets crafts represent an important segment of Japanese traditional crafts and culture which in the modern

time are still kept as a kind of fine arts (Bess 2001). Different kinds of baskets made of bamboo not only show the versatility of bamboo material, but also count as an evidence for the fine techniques of the handicraftsmen.

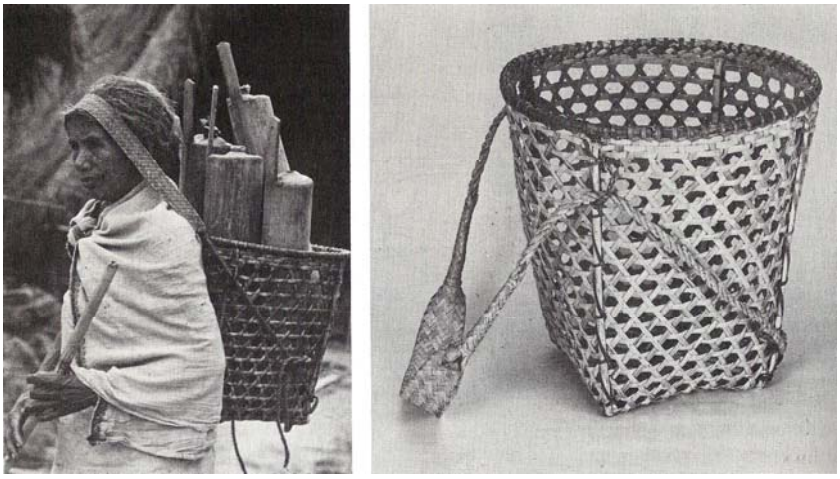


Figure 2- 22 Bamboo basket from Northwest India (ref. Ranjan 1986)

- **Umbrella and rain shields**

The bamboo umbrella could be a masterpiece of bamboo utilization. The bamboo cane would be used as the support for the whole construction. Two types of bamboo strips would then be joined to form a lever, and many of these levers would be connected together by paper to form a circumferential surface – to protect people from the rain! Through the lever mechanism the bamboo umbrella can be easily put together to save space and is easy to transport – an elegant solution with beautiful architecture. This has been invented for hundreds years and nowadays the modern umbrella has almost the same principle but different materials.

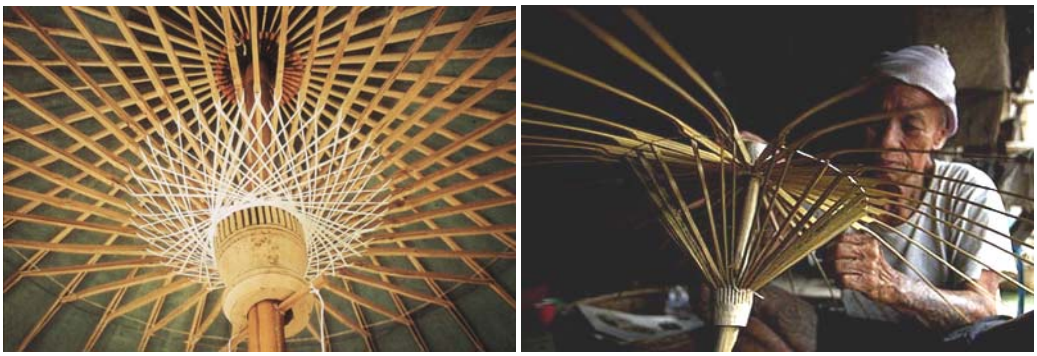


Figure 2- 23 Bamboo umbrella from Japan and craftsman making a bamboo umbrella

Another kind of rain shield, which has same function as the umbrella, is the rain hat. For workers it is more practical because people can use their hands while they are wearing it. So it is more commonly seen in the villages where things are judged at first on their practical functions. The bamboo hat has a sandwich structure, in which the bamboo strips are woven to form two layers to fix a layer between them, which is commonly made of palm leaves. This kind of sandwich structure keeps the hat water-resistant.

2.2.2.4. Working tools

- **Water pipe and brine conduit**

Bamboo canes are excellent natural pipes and have been used as pipes for water transportation for hundreds of years before industrial materials like iron or plastic were used. Similar to the *Guadua angustifolia* in Latin America the bamboo *Phyllostachys pubescens,* also called Moso bamboo in Asia is very widely used as a construction material. It has an average diameter of 6-18 cm and can be up to 30 cm at the midculm. The big hollow internodes with the nodes can serve well as a container for transporting fluids. A good example is the bamboo brine conduit in the salt fields in Sichuan Province in Southwest China. Using bamboo as a conduit for water has a history of more than one thousand years in China. In the time of Song Dynasty (960-1127 AC) the bamboo brine conduit techniques had already been very well developed: bamboo canes with larger diameters are put into the salt field one after another till the brine position could be tens meters. Then the bamboo canes with smaller diameters will be fed into the large bamboo conduit to transport out the brine. Here the larger bamboo canes serve as the well wall to keep the freshwater and earth out, whereas the small bamboo pipes lead out the salt water (Farrelly 1984).

- **Fishing tools**

There are three kinds of fishing tools mostly used with bamboo: fish poles, fish traps for catching and fish baskets for carriage. Fish poles can be just a simple bamboo culm. With the elasticity of the bamboo cane the fish pole can change the shape under the stress of the escaping fish without getting broken. This is the same as bamboo under wind and rain. The fish poles can also be divided into 3 or 4 pieces, so the upper part can be put into the lower part, and all together can be convenient for transporting.

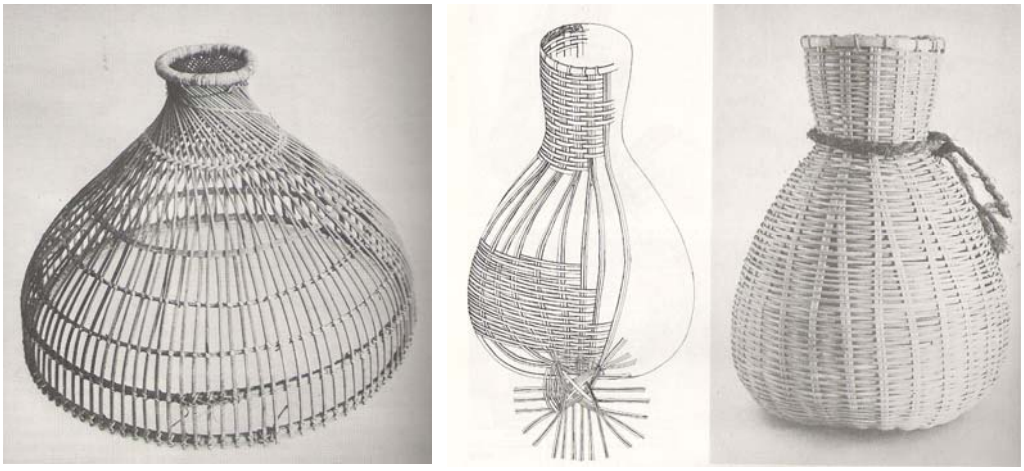


Figure 2- 24 Bamboo fish trap and fish basket in Northwest India (ref. Ranjan 1986)

The bamboo fish net is actually a big bamboo basket. In South China, India or Thailand, bamboo nets are the main tools for fishing. The constructions and forms of fishing nets vary from place to place. In Northwest India like Assam, Tripura and Manipur the people already use several kinds of fishing traps to catch fish (Ranjan 1986). All of them show the similar uses of bamboo material: two openings on the straps: the big opening lets fish in, the small one is for fishermen catching fish which are captured in the net. The two openings are made from bamboo splits frame which serve as a basic structure, then the bamboo strips are woven together onto the frames to form a space net for catching fish.

In China the fishing straps have similar structures and functions. There are also other kinds of fishing nets where bamboo canes build a structure for spreading the net which is made from materials like texture strings, and as a lever to draw up the net from the water and lay down the net into the water.

This kind of fishing net can be made much bigger than the bamboo strips woven net, and is also used for fishing in big rivers or on the sea shore.

The fish baskets for carriage show the advantages of the bamboo material and the fine weaving techniques: the lightness, the elasticity and the durability in water. 'Simple and practical' are important characters of the fish baskets. If there were no bamboo, how could man make such kind of fish baskets (also the fish traps and poles) out of other materials so well as the bamboo?

2.2.2.5. Writing tools

- **Bamboo "book"**

The first "book" was made of bamboo! "竹简" (Zhu Jian) is the name of the first bamboo book which was invented around the Sang Dynasty (about 1500 B.C). A "bamboo" book was made of hundreds of bamboo strips and joined by threads to build a volume or book. The Chinese civilization began to be recorded with this simple kind of bamboo tool. No one knows who the ancestors and how he got this idea to use bamboo to design the recording medium, but we can imagine how important a role bamboo played in the early days of human beings.

In China archaeologists have found several archaeological places where abundant old bamboo books were buried. These bamboo books recorded every aspect of social life, from religious activities to laws, from philosophy to art. Bamboo books had been used for a long time until paper was invented. Because of this important usage of bamboo it has also been said that Chinese civilization is a bamboo civilization (Wang 2000).

Figure 2- 25 Bamboo book from Zhou Dynasty in China (475 – 221 BC)

- **Bamboo paper**

Whereas in ancient China the tortoise shells and bamboo was the first material for writing, in other places the ancient people used other things to write. About 3000 BC in Egypt for example papyrus was used for writing. The word "paper" comes from the ancient Egyptian writing material papyrus which was woven from papyrus plants. But paper in its modern sense was first invented about 105 A.C in Han Dynasty by Chai Lun, who had developed a totally new paper-making method from wood pulp and other textiles. This invention caused a significant progress in the history of human civilization because after that paper became a mass medium for writing which everybody could afford.

Figure 2- 26 JiaXuan paper (left) and Chinese ink painting on JianXuan (right)

Wood was firstly used as the material for paper making, but later in the Jing Dynasty (256-420 AC) people in South China began to use bamboo for paper making because bamboo is abundant there. In Song Dynasty (960-1125 AC) Su Yijian has recorded the bamboo papers and their making process in his book <paper book>. Some cities in South China are famous already for their special bamboo papers. In the city Jiajiang of Sichuan Province in Southwest China people had developed a bamboo paper called JiaXuan which has such a high quality that they were cherished by famous calligraphers and painters (Figure 2- 26). The city thereafter became a famous bamboo paper city (Wang 2000).

- **Bamboo brush**

Bamboo can be split axially to get slices and strips with different thickness, or just be cut section-wise to get a bamboo tube with a different length. The small bamboo canes can be used as brush holders. According to the size of the letters to write, the diameter of the bamboo canes for making brush holders can be 5mm to 20 mm. One side of the cane is open for holding the brush hairs. The other side is naturally closed with the nodes with a small hole for a string ring to hang the brush. For pen making bamboo cane is beautiful, stable, light and easy to get and to work. Bamboo already belongs to the pen. This is also why the "pen "(or brush) in Chinese "笔" (Bi) has also a symbol of bamboo "竹".

Figure 2- 27 Bamboo brushes for Chinese painting and calligraphy

2.2.2.6. Music and dancing instrument

For its special node tube structure and excellent sound characters, bamboo has been used as a music instrument for a long time. "Bamboo" is one of the eight basic Chinese traditional music sounds: Silk, Bamboo, Wood, Stone, Metal, Clay, Gourd and Hide. "Xiao" (箫) and "Di" (笛) are two typical music instruments made of bamboo stem. The hollow space inside the bamboo cane is an ideal sound box. The making of these instruments is simple and the material is also easy to get. So the instruments have been widely accepted as folk music instruments and nowadays they are still very popular among common people. Both of "Xiao" and "Di" use only one bamboo pipe. There are five or six holes in the wall of the pipe. By controlling the opening or closing the different holes on the wall, music could be made. The

difference between "Xiao" and "Di" is the way of playing and also the characters of the sound. The "Xiao" is an end-blown flute and is crosswise to the mouth when played, whereas the "Di" is a middle blown flute and is played laterally to the mouth.

Other countries in South America and Africa have similar folks music instruments made from bamboo canes.

Figure 2- 28 Bamboo flute "Xiao"(left) and "Dizi"(right)

2.2.2.7. Artwork

Bamboo engravings are often made on bamboo objects like bamboo brush cups (holders). The bamboo brush cup is one of the most common objects on the desktop in the old times. Besides its practical function, the bamboo tube serves also as the medium for art – the engravings whose diverse motives and fine techniques can show artistic interests of the owner.

Figure 2- 29 Bamboo engravings

Bamboo engravings can also in themselves count as art forms without any practical functions. The thick bamboo canes from bamboo species *Phyllostachys Pubescens* can be cut into pieces of different forms on which diverse motives like landscapes, plants, or birds can be engraved. Together with the calligraphy this piece of bamboo root can be a beautiful artwork. Bamboo root is also one of the favorite materials for sculptures. The special forms of the bamboo roots inspire the artists to cut them into different figures (Figure 2-29).

2.2.3. Bamboo as a symbol

Alongside its long-time practical utilizations in people's everyday life, bamboo itself has also become something more than a material for practical uses but a symbol in human's cultural life. Because of its special natural structural characters bamboo becomes one of the most favorite plants in many countries. In East Asia like in China and Japan, it became a symbol for good characters of persons which have been widely represented in different cultural forms like painting, calligraphy, poetry, music and philosophy.

2.2.3.1. Between bamboo plant and its cultural meanings

Bamboo belongs to grass in reference to its growth, but also has the material characters of trees. As a plant bamboo is a masterpiece of nature from many sides of view, which has also been cherished in those traditional bamboo countries like East Asia and has already become one part of their cultural life.

- **The growth pattern**

Bamboo as a plant, compared to other plants, has its special growth pattern and botanic characters which play a key role to the people's love to this plant. The rhizome underground builds the whole reproducing and nutrient supply system. This helps bamboo growing very fast in the spring time, as known from the literature the maximum is 1 meter per day. And the subterranean rhizome develops into a network which helps bamboo to get enough nutrients from the earth even under hard conditions. At the same time it fixes the whole bamboo plant – its rhizome and its culms in the earth.

Bamboo's culms have already finished its node and internodes structure before it grows out of the earth, like a telescope shift from the earth into the air. This special growing method also helps bamboo to finish the growth of culms in a short time in spring when all the conditions are best – in 3 months a bamboo culm can get its full height, then for almost all the rest of its life-span the culm matures.

This whole growth pattern demonstrates a highly developed strategy of bamboo in nature. From the point of view of biology bamboo is one of the best examples for the evolution of nature. This is also why in the ancient times in countries like China the people loved bamboo as a plant and used bamboo as a metaphor for the personality of good mankind: making progress; maximal output with minimal demands; good preparation for life.

- **The form**

The form of bamboo is another prominent factor that lets bamboo be a lovely plant to mankind. Its culm is straight and slim: more than thousand bamboo species show the diversity in form but most of them have their culms straight and slim. But if only straight and slim the bamboo culms would be boring. This would never be found in nature – at the top of the culms there is a natural curve because of the gravity and the tenderness of the new growing top of the culms. But this does not reduce the charm of bamboos but adds a special elegance to them and makes them more interesting in form.

Different to the tree trunk the bamboo culm has nodes dividing the whole culm into many internodes. This has its biological function: by the nodes the vessels and fibers of bamboo have intensive branches and transverse conduction and bend radically inwards so the bamboo culms are interwoven together at the nodes: the whole culms will then be strengthened there (Liese 1985). These functional elements have their visual sense: the whole culm is divided by the nodes with diminishing distances from bottom to top. This gives the whole culm a changing rhythm, or precisely saying, a rhythm of growth.

The colors of the bamboo culms are mostly green, with some exceptions like *Phyllostachys nigra* with a black color or *Phyllostachys bambusoides Castilloni'* with a yellow. Because bamboos are woody perennial evergreen plants which belong to the true grass family Poaceae, bamboo has its green culms like most of the other grasses. Different to most of the grasses which change their color from green to yellow and

lose their gloriousness in the cold winter, bamboos keep their green even in cold and always give mankind a optical pleasure when all the grass and trees shrivel at this moment.

The leaves of bamboos are also an important part of the whole beauty of the plant, showing their elegance with their shuttle form, interacted composition and their liveliness as the wind comes.

- **The structure**

Bamboo's structure is an excellent example for the long process of evolution in nature. Its hollow culm proves to be one of the strongest but lightest structures in the world. The inner hollow space is divided into many small, closed spaces by the nodes which strengthen the whole culm. Its outer part, the culm wall, has a much higher percentage of fibers, whereas the inner part has a higher percentage of parenchyma and conducting cells. In the outer part the vascular bundles also have a smaller diameter than that of the inner part. All these features make bamboo outer part of culm wall denser and harder than the inner, which also fits to the functions of both parts: the outer part protects the bamboo plant, while the inner part transports the nutrient. Compared to solid wood, the hollow structure makes bamboo much more efficient in the use of its substances.

This structural property makes bamboo a metaphoric example for the modest personality in China. All these natural features of bamboo can find a metaphoric meaning in cultural forms like paintings, poems or literature. Artists use bamboo in these diverse cultural fields as a metaphor for the ideal characters and morals of a person who often is the artist himself or who he wishes to be. These are commonplace topics in the traditional arts like calligraphy or traditional brush paintings in East Asia like China or Japan. Several painting methods or styles have been developed for painting bamboo, especially with the brush.

2.2.3.2. Bamboo as a symbol in the cultural forms

- **Chinese painting and calligraphy**

Calligraphy in China is an art with a long tradition, together with Chinese brush painting and seal cutting it forms the three main visual arts in China.

Since the Tang Dynasty (618-907 AC) the theme of the Chinese painting has been enriched from simple human figures to landscapes and plants. The landscapes and plants in the paintings were often not a realistic representation of the objects, but more and more an ideal reflection of the human world. The landscapes in the paintings show the Shangri-La, whereas the plants painted are a symbol of the good characters of the people. That is why the landscape and plant painting are so popular and appreciated among intellectuals and officers who are often good painters themselves. They collect the paintings which represent their personalities or their ideals.

Four of the plants are mostly painted by the artist in Chinese painting: plum blossom, bamboo, chrysanthemum and orchid, the so called "Four Gentlemen" in Chinese painting. These plants represent elegance, lordliness, loyalty, modesty and enterprising. Bamboo as one of the four plants stands for modesty, enterprising and independence which are ideal characteristics for an intellectual. Many paintings have shown bamboo in different styles. There are some painters like Zheng Banqiao in Qing Dynasty (1644-1911 AC) who are especially famous for their bamboo paintings. These are often highly appreciated, not only because of the high aesthetic value, but rather for their personality which is represented by their bamboo paintings.

Similar to Chinese painting is Chinese calligraphy. Chinese calligraphy seen pragmatically is the handwriting of characters, whereas artistically it is a kind of abstract art. This abstract art form is based mainly on the fact that Chinese is a symbol language, where the meaning is expressed by two-dimensional constructions or by combining the simple symbols which also have basic meanings. The different styles of writing the characters can express different aesthetic meanings. Chinese calligraphy is closely related to Chinese painting and Chinese poetry. This is also why the calligrapher often is a painter

and a poet. Different art forms combined in one artist – he is often called not an artist, but an intellectual. It is therefore that all of these art forms have the similar theme to represent – the only difference is the way of interpretation.

Figure 2- 30 Bamboo painting and calligraphy by Zheng Banqiao (1693-1765)

Bamboo, due to its well-spread usage in people's daily life, has also been reflected in Chinese language. Like discussed before, there are more than 400 characters containing the bamboo letter in Chinese dictionaries. As an abstract art form Chinese calligraphy has more and more interest in the bamboo's natural form: its culms, its leaves and the bamboo plant as a whole. This beautiful plant is considered as the good metaphor for personality. Zheng Banqiao, one of the most famous Chinese calligraphers in Qing Dynasty, had developed a style of painting and calligraphy which came from the inspiration of bamboos.

- **Literature**

Bamboo can be found in different literature like tales or poems. In China there is a famous tale about one species of mottled bamboo called "Xiangfei" bamboo. Princess Xiangfei, who was the daughter of King Yao - famous for his water control on Yellow River, was waiting for her father coming home, who had gone to the Yellow River to control the flow. But instead of seeing her father back she heard the bad news that her father had died working on the river. She could not believe the news and still kept to go to the bamboo forest everyday where she waited for the return of her father. She could not help crying in the bamboo forest day after day. Her tears fell onto the bamboo culms. After a long time the color of the bamboo culms changed into the mottled pattern. Since that time this kind of bamboo has been called "Xiangfei Bamboo" as a reminiscence to Xiangfei's loyalty to her father.

In Japan, a famous tale is told about an old childless bamboo cutter Taketori-no Okina. One day when he was walking through the bamboo forest he found a mysterious, shining stalk of bamboo and cutting it open, he found a little girl in it. He and his wife took this little girl as a gift from God, named her Kaguya Hime and raised her as their own child. Thereafter this old bamboo cutter found that whenever he cut open a stalk of bamboo, there was a small nugget of gold in it. He became richer and richer. On the other side his daughter Kaguya Hime turned out to become a beautiful woman and attracted many rich

young princes to court her. She refused all princes, even one of them called Tennō whom she really loved, because of her destiny: she was not of this world but a princess from the moon. She had to return back to the moon when she had grown up. As she loved her foster parents so much, her eyes always filled with tears when she saw the full moon in summer nights. The emperor Tennō asked all his soldiers to keep Kaguya Hime from going back to the moon but failed. He dispatches his soldiers to climb up the tallest mountain in Japan to burn his letter to Kaguya Hime. This is why the St. Fuji in Japanese is called "Fuji-San" which means "Mountain Abounding with Warriors" (Shikibu 2002).

As discussed before, poetry, calligraphy and painting, these three art forms are mostly regarded as in harmony together in China. After Tang Dynasty (618-907 A.C.) the Chinese painting was often accompanied with poetry and calligraphy as a whole art work. The poem is the explanation of the painting and the painting on the other side as an illustration of the poem; calligraphy here is also a graphical element in the painting. So the bamboo poems began to be popular among the circle of intellectuals like the bamboo painting. The poems about bamboo can be found long ago in Zhou Dynasty (770-221 B.C.) in China. But before the Tang Dynasty (618-907 A.C.) the poems written about bamboo are mainly about the natural beauty of the bamboo plant and the diverse uses of bamboo in people's daily life, whereas the poems after Tang Dynasty are more abstract and metaphorical about the characteristics of bamboo with in relation to that of the people, such as its straightness, its elegance, its lightness as well as its modesty. This trend stayed for hundreds of years until the end of last dynasty Qing Dynasty (1644-1911 A.C.) in China.

There even was a very famous kind of poems called "Zhu Zhi Ci" which can be translated into English as "bamboo knot poem", it originally came from the folklore in southwest China before Tang Dynasty (618-907 A.C.). The farmers there sang this kind of folklore with music and dance accompanied with bamboo canes for the rhythm. This folklore was widely spread in that field and then was borrowed by some of the famous poets in that time and turned to be one famous type of poetry in the history of Chinese literature, even though its content actually has no direct relation to bamboo.

- **Philosophy**

Bamboo has the connection to philosophy in China since the Tang Dynasty (618-907 A.C.) when bamboo began to be popular among the intellectuals and Buddhist monks. Before that time bamboo had already been widely used in people's daily life. But it is mostly connected to the practical usages, its metaphysical meanings have not yet been spread out.

Taoism believes the human's behavior should be in harmony with nature, and the harmony between Yin(-) and Yan(+). Johannes Itten has recited sentences from "DaoDeJin" which show the spirit of the Yin and Yan:

Thirty spokes meet at a nave;
Because of the hole we may use the wheel.
Clay is moulded into a vessel;
Because of the hollow we may use the cup.
Walls are built around a hearth;
Because of the doors we may use the house.
Thus tools come from what exists,
But use from what does not.
(Laozi, "Taodejing" capital 11)[12]

[12] Laozi (老子), one of the most famous Chinese philosophers, lived in the 4th century BC and founded Taoism - one of the most important Chinese philosophical schools in the history of Chinese culture. More about Laozi and his philosophy as well as his works on the internet: http://en.wikipedia.org/wiki/Laozi

Bamboo is the ideal object to represent Taoism: it is a natural plant but has been so widely used everywhere in human's life. It is strong but light, the substance in bamboo can be perfectly used for the function in accordance with the principle of Taoism: What is useful is what does not exist.

Other than Taoism, Confucius concentrates more on the peoples' relationships in society, asks people to behave under a strict regulation to keep society stable. His principle of man's conduct in society can be found different parts of the works of Confucius:

"When called to office, to undertake its duties; when not so called, to be retired;-it is only I and you who have attained to this."
(Confucius, Analects, Chapter 13, Shu Er)[13]

Mencius (4th century B.C), one of the most important theorists of Confucius, has developed this principle and defined the ideal, great man according to the idea of Confucius:

"To dwell in the wide house of the world, to stand in the correct seat of the world, and to walk in the great path of the world; when he obtains his desire for office, to practise his principles for the good of the people; and when that desire is disappointed, to practise them alone; to be above the power of riches and honors to make dissipated, of poverty and mean condition to make swerve from principle, and of power and force to make bend:-- these characteristics constitute the great man."
(Mencius, T'ang Wan Kung, part II)

Even though Confucius has many totally different ideas to those of Taoism, bamboo still finds an admirable place with him. Different than in Taoism, Confucius takes bamboo as a good example to show the idea of how people should continue going ahead to develop themselves alone under severe conditions. In this meaning bamboo in nature is a perfect metaphor for the ideal people in society.

After the introduction of Buddhism from India into China, it grew together with the local Taoism and became a special philosophy: Zen, which also spread to Japan and Korea. The bamboo can be found in every Buddhist cloister. It is considered one of the most important elements of meditation. The growth of bamboo is also a good example for the exercise of the Buddhist monk.

2.3. Summary

First of all bamboos are plants – it is the result of million years of evolution process in the world. It represents an excellent survival strategy in nature: from the subterranean growth of the rhizome to the elastic and resistant culms; from the micro structure of the cells and tissues of the culm to the vivid growth pattern. The natural environments are the outer ecological context of the bamboo structure. The environments influence the evolution of bamboo; on the other side bamboos have also developed a strategy to meet the environmental demands. In the natural world the life strategy is the adaptation of the organisms to the environment in the sense of physiology, morphology and anatomy which have been fixated in the genes of the organisms and help the organisms to conquer the living site for surviving by using the limited resources as efficiently as possible.

The struggle for survival makes bamboo not only an excellent plant but consequently a useful material for human beings. Either the plant as a life-form or just parts of it – the culms, the leaves or the sprouts, serve people in their daily life. The use of bamboo as a material for human beings put it into another environmental context: the human world. Compared to the ecological context of bamboo in the natural

[13] Confucius (孔子, 551 – 479 BC) was one of the greatest Chinese thinker, philosopher and educator, whose teachings and philosophy have deeply influenced Chinese, Korean, Vietnamese, and Japanese life and thought. His philosophy known as "Confucianism" emphasized that the life of a person should correspond to governmental morality, correctness of social relationships, justice and sincerity. Confucianism has won in prominence since the Han Dynasty in Chinese society. More about Confucius and his philosophy at http://en.wikipedia.org/wiki/Confucius

world which "checks" the bamboo with ecological measurement, the human world as the environmental context "reads" (measures) the bamboo with material properties: chemical, physical and mechanical properties, some of which have also logical relationships with the bamboo's botanical properties, especially with the morphological and anatomical structures of bamboo.

Bamboo is structure when it is observed from the botanic and material perspectives. Bamboo is also culture when it is seen from the perspective of the relationship to human beings.

The bamboo in the using context of the human world has also a history of thousands years. Different to bamboo as a plant in the natural world, the process of using bamboo in people's life represents another adaptive strategy developed by people, especially the craftsmen who make bamboo such a useful material in their daily life. The cultural dimension of bamboo is at first determined by its structure, which is different to any artificial and natural material like steel, glass or wood. The relationship between bamboo and mankind represents how people (the craftsmen) respect the natural structure of bamboo and how they have developed in a way to use the material bamboo in its maximal potential. This is also why the utilization of bamboo has reached such a level that a special bamboo culture has been developed.

Chapter 3

The industrialization of bamboo: Bamboo in the industrial context

The best standardization committee in the world is nature herself, but in nature standardization occurs mainly in connection with the smallest possible units, cells. The result is millions of flexible combinations in which one never encounters the stereotyped.

- Alvar Aalto

3. The industrialization of bamboo: Bamboo in the industrial context

Industrialization, or industrial revolution, is a process of economic and social changes, whereby a human society is transferred from a pre-industrial to an industrial state (Wikipedia 2006). In the process the economic and social changes are closely intertwined with the technological innovations, in which the new materials and the industrial production process play an important role. On the other side, the traditional handcrafts have to give up their place to the industry. Bamboo and bamboo goods – one of those traditional handcrafts, also lose their traditional place in the modern industrial world.

In such countries and areas where industries are still not developed well or even non-existent, the traditional bamboo crafts still have their places. There the conventional bamboo utilizations are kept as they were, or change slowly and gradually but still stay in a handcraft way. For example the traditional bamboo house as well as bamboo tools and furniture are still used in many countries in Southwest Asia and Latin America; but in places where the industrialization has already taken place and diverse industries have been developed well, the traditional bamboo utilizations are hard to find in the modern everyday life as they were in history. There bamboo is regarded as the "material for poor", which is associated with underdeveloped, out of time and raw etc.

While, as a prejudice, the industry represents the modernity and power of the human beings on earth, things which are not produced by the industry are likewise labeled "out of date" or "undeveloped". Bamboo which has been used and processed not in the industry but in a crafted way of course belongs to this group. But is it really true that bamboo can only be a primitive material used by poor people? This problem of bamboo is not caused by the material bamboo itself, but how the bamboo as a material is used, and how it is processed. From many aspects bamboo can be proud of being a highly developed plant and material as discussed in the last chapter. The principle of its natural structure, from the rhizome to culms has surpassed many of the industrial works. The problem bamboo faces in the industrial world only exists because the industrial world simply has a different "code-system", where all

things have to adapt to. This is totally different in the pre-industrial era where people (craftsmen) tried to process the material in a way that the natural properties of the materials were highly respected. During the industrialization, the automatic machines and the mass production have replaced the traditional handwork and craft production for its higher rate of production and consequently the lower production costs. Besides, the standardized production allows manufacturing such goods like automobiles for which highly interchangeable components are required. Traditional bamboo utilizations were accompanied with handcraft working processes like any other traditional craft, do not meet such requirements of industrial production. They ceased slowly from the mainstream of society.

Given that bamboo possesses such excellent material properties and a long history of usage in people's everyday life, how to use bamboo in the industrial context is the question challenging not only the craftsmen who have worked with bamboo for a long time, but also the engineers, scientists from different disciplines who are all fascinated by the excellent properties of bamboo. Research and experiments have been done at first in the working process of bamboo treatments. Bamboo has to be industrialized in order to be integrated into the whole industrial production: machines have been developed and used in the bamboo working process formerly carried out by craftsman. Various industrial pre-fabricated bamboo products have been produced in industrial mass-production. Through the industrialization bamboo is able to enter the whole industrial production process, but also loses its structural and cultural background. The industrialization is still not the ideal answer to the question of how to use bamboo in the industrial context.

This chapter will first study the situation of bamboo in the industrial world in which bamboo material and its handwork processing have to face the competition of the new industrial materials and their production system. This will then be followed by research on the industrial bamboo products and their relevant working process. The discussion of the question whether the industrialization of bamboo material is the proper way to utilize bamboo in the industrial context will be the third part of the chapter which will lead to the next chapter: design with bamboo.

3.1. Missing links: Bamboo as a material in the industrial context

Industrialization took place in the second half of the 18th century, at first in the Western European countries like England, France and Germany, where a high level of handcraft had developed. The diverse handcrafts in different branches like metal, wood, ceramic and etc. suffered from the birth of a new way of making goods – the industrial production. The traditional hand- made working process was replaced by the machine- made, and thus conventional materials were also replaced by industrial ones. Iron and steel took the place of wood and stone in many fields. Nikolaus Pevsner describes in his book "Pioneers of Modern Design" how iron entered the industrial world using architecture as an example:

> *"The history of iron as a material of more than auxiliary usefulness in architecture begins when the inventiveness of the Industrial Revolution has found out how iron could be produced industrially, that is after 1750. Attempts were soon made to replace timber or stone by iron." (Pevsner 1975:118)*

He then gives architectural examples from as early 1752, when cast-iron columns supported a chimney in Alcobaca in Portugal, and the flax-spinning mill at Ditherington in 1796, in where was fully replaced by cast-iron for supports, not only in the columns but also for beams. He cites the words of a London architect George Aitchison (1864) that "*one rarely sees a large building being erected without iron columns and iron girders*" (Pevsner 1975:122). These changes did not happen to bamboo at that time because in those countries no species of bamboo grows, nor can traditional bamboo utilization be found there. Yet many years later, after the industrial revolution, the rest of the world got industrialized sooner or later. The countries or places where bamboo utilizations have their long history also faced the changes accompanying industrialization.

The traditional bamboo utilizations lost their flourish in countries like Japan, later also Korea and China where the industrial civilization from the West began to inhabit the place of the local traditions quickly.

Traditional bamboo products, which mostly are accompanied with the handwork process, can hardly play against the modern machine-made products in the market economy. In countries or places where the industry has still not shown its full power, like India, Thailand, Columbia and some countries in Africa, the traditional bamboo products keep their place in daily life. But even in these areas the people are ready to buy industrial products from outside instead of the traditional bamboo product, not because the industrial products are better but simply because they are modern.

As a result of the industrialization the materials and the productions are highly standardized. To meet the ever-growing requirements of the products there are always new materials invented and developed. Since the globalization of the world economy makes the whole world easily share the newest technology at the same time, the designer needs not limit himself to a certain material which he can get in his surroundings to design and produce new products, whereas in history this was the most important reason for the craftsman to choose the materials. The decision of a designer to chose one kind of material will mostly be based on the material's properties and its relevant working process so that the goods can be produced with machines and the whole production cost could be kept low.

In the industrial working process bamboo has its disadvantages in two dimensions compared to industrially standardized materials: from the material perspective, its irregular and tube-shape structure changes its diameter from one culm to another and its strong longitudinally arranged fiber is difficult to be joined with other materials by common means like nail or screw. From the designer perspective, the designers have been educated to use standard materials, which are easy to integrate into the industrial production process. Even if they find that bamboo is an excellent material they would have to give up working with this material because of the difficulty of handling it. The mass production system is one of the most important links in the whole chain of the industrial world. Without fitting into this production system, bamboo as a material can also hardly get into the industrial world. Bamboo loses the connection to people's everyday life in modern industrial society.

The loss of bamboo in the industrial world can be seen in two sides: the first is the handcraft working process of bamboo which is not suitable to the industrial mass production; and the second is that the traditional bamboo goods do not match the modern people's everyday life – they face the competition of similar products from modern industry. The relation of bamboo's working process to its utilization can be identified as a dialectic pair: On the one hand the progress of working methods helps people to explore the potential of new bamboo utilizations, on the other hand the changes of people's lifestyle and the new contents of life challenge the craftsmen to find new working methods to keep bamboo's utilization up to the current lifestyle (Figure 3-1).

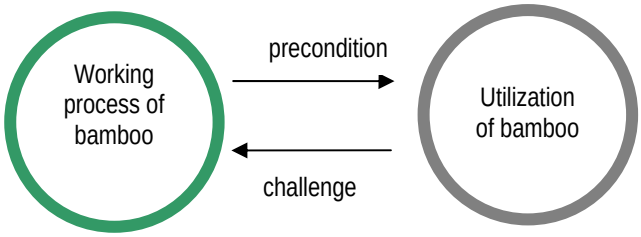


Figure 3- 1 Relationship of bamboo's working process and its utilization

The traditional working process is based mostly on bamboo's natural structure and the life needs of human beings. It has developed along with the long history of bamboo's uses in human society and harmonized with human society like an evolution process before industrialization totally changed the world. The conflict between handcraft and industry is no longer a new topic nowadays, but was once a

lively social discussion in the beginning of industrialization. At that time the newly emerging industry had a strong impact on the traditional handcrafts from different perspectives, and the economic, aesthetic and social changes brought by the machines evoked resistance at a large scale. The Arts and Crafts Movement in Britain was one of the most influential movements in which people tried to protect the traditional crafts against the industry. The movement originally was set up to fight against the industrial working process because of its inhumanity and the ugliness of the industrial products and their productions It did not save the traditional crafts in terms of its working process, but on the contrary helped the industry to develop itself from its first naïve form to a better designed generation. At the end the industrialization proceeded and machines were established as a means of labor-saving in the working process, and thereafter as a way of freeing the creativity from the restriction of materials and their working process, as Walter Gropius commentated:

> *"So long… as machine-economy remains an end in itself rather than a means of freeing the intellect from the burden of mechanical labor, the individual will remain enslaved and society disordered". (1934: 682)*

Conventional materials like wood and metal became industrialized during the industrial evolution along with traditional handcraft working methods. Their working process was mechanized and automated. This kind of industrialization did not happen so early to bamboo because of structural and geographical reasons: firstly its structure, as discussed in the second chapter, is much less homogenous than other materials for example wood, which is easy to be treated by hand but more difficult by machine; secondly the places where it grows and is utilized are those places where the industrialization took place very late. So in the end bamboo stands as a foreigner in industrial society even if it has been used for people's everyday life for thousands of years.

To get to be used in the whole industrial process is the aim of the industrialization of bamboo as a material in the industrial time. This process can be seen in two ways: at first, the mechanization, in which the powered machines are used to replace manual power in the bamboo working process. Secondly, the standardization, which here in its narrow sense means to turn the bamboo canes into certain standard forms to fit the whole industrial utilizing environments. Mechanization saves manpower in the production and also makes more and wider ranges of products possible; The standardization is generally defined as the development and implementation of concepts, doctrines, procedures and designs to achieve and maintain the required levels of compatibility, interchangeability or commonality in the operational, procedural, material, technical and administrative fields to attain interoperability. Both ways are the challenge for bamboo as a natural material to get back into the people's daily life in the industrial age.

3.2. Industrialization of bamboo

The traditional working process of bamboo can keep its way along the industrial manufacture, but only be restricted in the category of handcraft. In the industrial world this category handcraft has its place without doubt, but only on a very restricted scale which does not match the productivity of bamboo in nature as well as its booming time in history. Bamboo stands facing industrialization.

The traditional working process and tools of bamboo are handcraft and are both based on the special structure of the bamboo plant and the techniques of the craftsmen. In the long history of bamboo utilizations the craftsmen have got to know the material characteristics of bamboo and used simple tools to finish the working process in a professional way. This way of a traditional working process is not based on the industrial standards and machines but on the material properties, not on the market economy principle but on the life needs of the local people. It did work well for thousands of years of human evolution, but is not suitable to the industrial society. In the whole industrial production system any component serves as one part of the whole system. For its function as a material bamboo should be standardized like all the other industrial material, so that it can be worked by machines. And the components made of bamboo can be assembled with other components made of other materials to become an end product. The standardization in the sense of material means it should be produced or

processed into standard shape (dimensions) so that it can be measured and treated with machines, and further it can be joined together with other industrial materials or pre-made elements. In the end industrial products should also be standard products which can be used in the standard industrial environments (i.e. electronic devices always have a voltage of 230 V, 50 Hz in Europe, which has been defined by the European Union). The whole industry demands that all the material should be standardized and then used in the industrial production under different industrial standards. This is also valid for bamboo if bamboo wants to be one of them.

As an excellent plant in nature and an excellent material in history, bamboo should not be neglected and be much more useful than it is now. Working on bamboo in an industrial process, this could be the first idea to help bamboo to become used more in the industrial world. The industrialization of bamboo can be divided into two parts: the industrial working process and the industrial bamboo products. The former means the mechanization of the bamboo production and the latter refers to the standardization of the bamboo products. These two parts have a close relationship to each other. The new industrial bamboo products determine how the working process should be industrialized. On the other side the industrial working process makes possible the bamboo products in the sense of "industrial".

The industrialization of bamboo is not like a totally new thing from the outer world, but more like one step of a continued process. It is still largely based on the traditional bamboo crafts. The traditional bamboo crafts offer a rich material knowledge and experience on bamboo which is important for the industrialization of bamboo. Actually, craftsmen who keep their work in craft methods in the industrial time always have to improve their tools to make their works more efficient and with a better quality. Nancy More Bess, a famous artist and craftswoman with bamboo who lives in the USA and Japan, reported in the 7th World Bamboo Congress in New Delhi 2004:

> *"Each craft has developed and perfected tools and techniques specific to the demands of that craft and are modified to accommodate individual versus commercial use. For example, in commercial basketry workshops now occasionally use molds to guarantee production of identical, equal value baskets." (Bess 2004: 1).*

The industrialization of bamboo can be seen as one extra rapid step of a continuous progress of bamboo. This extra rapidness was caused by the new technology from industry, especially from wood industry because wood has the closest properties to bamboo and therefore the industrialization process of wood can give bamboo the best example of how to accomplish it.

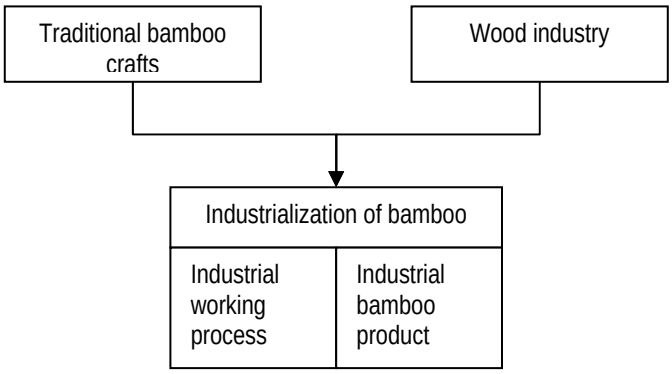


Figure 3- 2 The synthesis of the industrialization of bamboo

The process of the industrialization of bamboo in the sense of mechanized production has its difference in different countries and places according to the degree of their industrialization. In China for example, the country began the industrialization at the end of the 19th century, whereas the industrial bamboo products and production started in the 1950s, as the people in the places abundant of bamboo began a new orientation of the bamboo products to the industrial world. Firstly by producing the traditional

bamboo goods like weaving baskets, some simple industrial machines and tools have been designed for cutting, splitting and sanding. Consequently people started to learn the techniques and utilizations from other industries especially the wood industry, trying to produce new industrial bamboo products in an industrial working process.

So before the start of the industrialization of bamboo, the traditional bamboo handcraft, especially its working process will be studied. Subsequently the industrial wood products and their working process will be studied then. Both of these two parts will serve as the theoretical preparation of the research on the industrialization of bamboo.

3.2.1. The traditional bamboo working process as one basis for the industrialization of bamboo

Traditional bamboo utilizations are based on the material features of bamboo and the methods how the people work on it. After the pre-processing of bamboo, as discussed in chapter 2, bamboo material will be further processed into different raw materials according to what kind of objects it is used for. For large constructions like buildings or some furniture bamboo culms will keep their tube form. What people do is to make cuts for the connection together with other parts, or to bend it into a certain form. For baskets and some surfaces of furniture bamboo will be cut into splits and maybe further into thin strips. Other than the research on the botanic and materiel properties of bamboo, the traditional working processes and tools more or less lie in the experience and the technique of the craftsmen, and are often transferred from one generation to the next without any systematic study. In his dissertation Dunkelberg (1978) sorted the typical working methods and the tools for bamboo buildings in Southeast Asia. More working methods and techniques for traditional bamboo woven furniture and tools were studied by Ranjan (1986).

The mainstream of the traditional working process from the raw material (bamboo canes) into useful bamboo objects can be divided into two steps: first is the material treatment, which means de-structuring the original bamboo into splits (or strips). Then the second, re-constructing the bamboo splits or strips with or without other materials into the end bamboo objects.

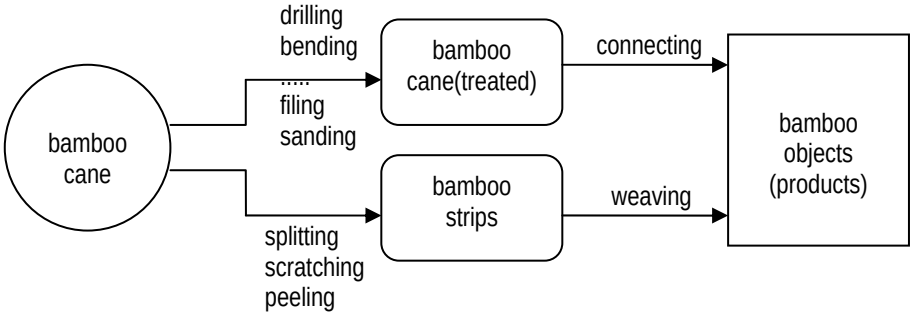


Figure 3- 3 The traditional working process of bamboo

3.2.1.1. Material treatment – de-structuring the bamboo canes

- **Splitting**

Cutting the bamboo culm with one longitudinal cut and then breaking the whole culm longitudinally, the bamboo can be worked from a tube into a plank.

- **Cutting: Strips Laths**

To get bamboo strips or laths the bamboo needs to be cut longitudinally several times. There is a special knife for cutting a cane into 8 pieces of small strips. With this kind of knife the cut can be more efficient and precise (Figure 3-4).

Figure 3- 4 Bamboo splitting and the tool for it (ref. Mark Meckes)

- **Scratching**

After cutting the bamboo into strips it often needs scratching the surface to get rid of the sharp edges and to get a glazed surface.

- **Drilling and scorch drilling**

The way of getting a hole in the bamboo cane is drilling. Different from drilling holes in wood, drilling holes in bamboo cane is much more difficult. Due to bamboo's strong axial structure, it is easy to split the bamboo cane by drilling. Scorch drilling is a more useful way to make a hole. The hot blade of the drill helps making holes easier and will not split the cane.

- **Filing**

Using a file can bring the edges and holes into a precise shape. Owing to their hard surface finishing files are mostly used in the work, whereas rasps are seldom used.

- **Sanding**

Sanding can make smooth edges and surfaces. It is a useful finishing process for fine objects such as furniture, artwork and music instruments. It is an important preparation for painting the surface because the silicified outer layer of the cane is difficult to paint with colors.

- **Peeling**

Even though the silicified outer layer is the hardest part of the of bamboo cane and very good against any outside invasion, it has also the disadvantage when the bamboo cane or slips need to be attached to or by other materials. So it is often necessary to peel this layer for further treatment such as painting.

- **Cold bending**

The fresh small and freshly cut bamboo cane or split laths can be easily bended with some simple form molds. This process is often used in furniture making.

- **Warm bending**

Warm bending is used for more complicated form making. For building bamboo furniture this is often used. The bamboo will be heated over fire to get an equal temperature and then can be formed into different shapes as desired. This process can shape a more precise form with the help of a mold.

- **Shavings**

Bamboo laths can be further worked into small and thin shavings and then can be sewed together to make very fine artwork like fans. This control of weaving shavings can create different patterns. This is similar to silk sewing.

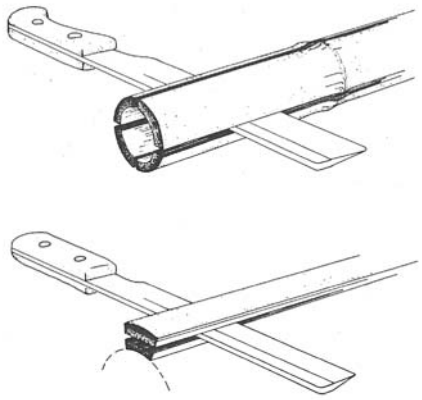


Figure 3- 5 Simple machetes for splitting bamboo (ref. Dunkelberg 1978)

3.2.1.2. The tools for working on bamboos

For the aforementioned working process there are relevant working tools. The common tools for the traditional working process on bamboo are knife, scraper, saw, file, gouging tool and drill. Because of bamboo's special structure it is very easy to cut bamboo culms longitudinally but difficult to cut cross-sectionally. A machete-type knife is the most useful tool for cutting bamboo into strips with different widths and thicknesses. It can cut bamboo culms into strips, laths and other shapes for different uses. But for a good quality the handicraftsmen need a good technique. The saw, driller and other special tools can be used for some special objects to work more precisely and efficiently. The tools for cutting bamboo get blunt more quickly than that for cutting woods, because bamboo cane has a very hard coat. The different working processes and their relevant tools can be seen in the Table 3-1.

Working process	Tools	Function
splitting	splitter; chisel; knife	splitting bamboo culms into strips with required width.
cutting	knife	cutting strips into laths
scratching	scraper	making surface smooth
drilling and scorch drilling	drills	making holes
filing	files	making surface smooth
sanding	sands	making surface smooth
peeling	knife	getting rid of the outer silicified layer
cold bending	mould from wood or other materials	changing the shape of bamboo canes or splits
warm bending	mould from wood or other materials; fire or warm water	changing the shape of bamboo canes or splits
shavings	knife and scraper	getting rid of the outer silicified layer
carving	knife; gouger	carving and gouging the cane to get the required form

Table 3- 1 Traditional working processes and their tools

3.2.1.3. Bamboo Jointing

Through different working processes the bamboo cane can be worked into different constructing elements for different uses. The elements will be joined together by different techniques. They can be joined together without any other materials, or can be also joined with other materials to make different objects.

- **Bamboo joints without other materials**

The handicraftsman developed many methods of jointing bamboo without other additional materials. The simplest one is just to lay the half cut bamboo cane over another. This method is often used for the bamboo roof construction. There are some examples which show that bamboo canes can be connected just by drilling a hole in the big cane and sticking the small cane into it, or by drilling holes into both canes and inserting a bamboo nail as a fixation for both canes. This has often been used for furniture.

The most useful way of joining bamboo without any additional other materials is **weaving**. Bamboo's vascular bundles are strongly axially arranged; after bamboo cane has been cut into strips and laths, its elasticity and tensile strength makes it easy to bend and difficult to break. Bamboo strips can be woven together to build a construction surface. This method makes it possible to use bamboo in the most versatile ways - for a wall in building, for some other kinds of space partition in the house or for many useful tools and facilities in the household. The weaving constructions of bamboo not only provide the practical function, but also the aesthetic one. As discussed in the second chapter, bamboo woven patterns have developed into artworks in China. Weaving is not only a method of joining, but a special process of bamboo handcraft which represents not only the special material properties but also the highly developed techniques of craftsmen.

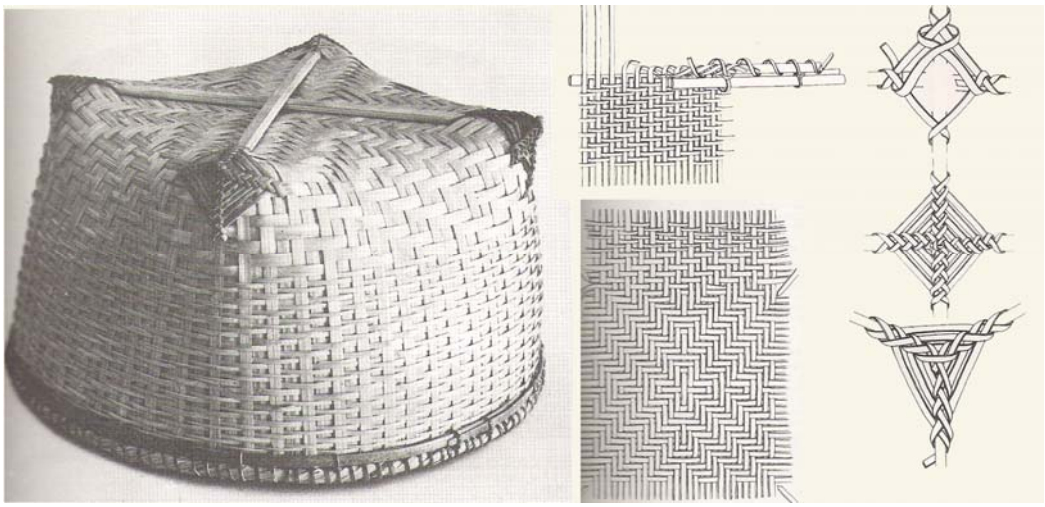


Figure 3- 6 Bamboo woven basket "Thumok" from Manipur in Northwest India (ref. Ranjan 1986)

A large part of the traditional bamboo utilizations are woven goods. Dunkelberg (1978) has recorded some woven bamboo panels in house building in South Asia. The woven bamboo wall panels are often made of bamboo splits in large dimensions and with a simple structure in order to achieve a higher resistance. For furniture, baskets and household tools much thinner and finer bamboo strips are used for a more complicated structure. Examples are the bamboo handcrafts in Northwest India which Ranjan (1986) has recorded and sorted. These examples also show how the material bamboo differs from other natural materials like wood. As described in Chapter 2 bamboo has very long fibers parallel to the culm, so the longitudinal cutting of bamboo is very easy and can be split into very thin and small strips without breaking it. The bamboo canes should first be split into strips with a different thickness and width and then the bamboo strips can be woven together to form different useful things like wall panels, furniture,

baskets or other tools. The weaving techniques represent on the one hand the high flexibility and multi-facility of the material bamboo and on the other the highly developed techniques of the craftsman.

Generally, bamboo strips are as flexible as strings but stronger and more elastic so that objects woven of bamboo strips have strong form stability. The forms and the weaving methods also vary from one product to another depending on what they are used for. The tools for weaving bamboo are mostly the two hands of the craftsman, but the techniques for that demonstrate a very high level.

- **Bamboo joints with other materials**

Bamboo constructions are often joined by other materials. In combination with other materials the bamboo canes serve mainly as bearing elements and the other materials as joining element. Conventionally rattans are mostly used as the joining material for bamboo constructions. Rattans are spiny climbing palms growing in the tropical forest. Because of their strength and flexibility rattans are used for weaving furniture alone but also very often used together with bamboo for making furniture, in which bamboo canes are used as the main strain element and need not be split whereas rattan canes are used like strings.

In the last fifty years some modern methods have been developed for joining bamboo with other materials which led to a much wider utilization of bamboo. These new methods will be discussed in the next chapter.

3.2.2. The wood industry as second basis for the industrialization of bamboo

Among all the materials nowadays widely used in the industrial society, wood has its properties and history of utilization most similar to bamboo. Wood could be one of the oldest materials used by human beings and for thousands of years before the industrialization wood has already been used for building and making furniture all over the world.

Despite of the difference in structure, the history of wood as a utilized material can be compared to that of bamboo. Both flourished in the pre-industrial time. The things made out of them can be found everywhere in human's everyday life. But the difference lies in the situation after the industrial revolution. With more and more industrial material emerging, bamboo lost its place while wood has not only kept its place but even broadened it. Through the industrialization not only the working process of wood has been mechanized and standardized, but also a wide range of engineered wood products have been developed, which are totally new and have better material properties visible from many sides. Most of all, wood can be used better and wider in the industrial world than before. What happened with wood will certainly be a good role model for bamboo.

3.2.2.1. Industrial wood products in the wood industry

The most important change in wood utilization in the industrial time is the industrialization of wood in the sense of both production and product: the mechanization of the processing and the new industrial wood-based products.

During the time of industrial revolution more and more machines were used in wood processing which were traditionally done with natural power resources like water, animals or human beings. This makes the whole wood processing from the beginning (cutting the trees) to the end products efficient and precise, and turns the process into a mass manufacture. But more important for the broad utilization of wood as an industrial material are the new wood-based products. Despite having been used for thousands of years by men, wood has its disadvantages in the industrial environment: it is irregular and limited in form and unstable in quality. The industrial wood-based products are designed to overcome such shortages of natural timber:

- To overcome the dimensional limitations of sawn timber
- To improve quality; remove the uneven and irregular parts of the natural wood; enhance performance, structural properties and stability
- To transform the natural orthotropic product into one with more homogenous properties
- To optimize the use of a valuable resource and to minimize waste.

The results of the developments in the timber industry are different kinds of industrial wood-based products with the following forms:

- Board materials such as plywood, Oriented Strand Board (OSB), Medium Density Fiberboard (MDF) etc. are available for a wide range of structural, decorative and utility uses.
- Structural timber composites produced in large sections for use as beams, columns and other structural components. Products include glued laminated timber (glulam), Parallel Strand Lumber (PSL) and Laminated Veneered Lumber (LVL).
- Timber I-joists comprise a timber flange, typically solid timber or LVL (Laminated Veneer Lumber) and a panel product web, usually OSB (Oriented Strand Board). They offer a number of benefits over traditional sawn joists, including low weight, no moisture movement and a greatly reduced risk of squeaks.
- Engineered wood flooring provides a durable and stable decorative floor that is less prone to moisture movement than traditional solid timber flooring. It comprises a solid timber walking surface bonded to an engineered timber substrate for strength and stability.

3.2.2.2. The working process of industrial wood-based products

All the industrial wood-based products compensate each other in the production. On the one side the different wood-based products are based on the structure of raw wood, on the other side they are produced in this way because of the later uses of the consumer or for other industrial goods.

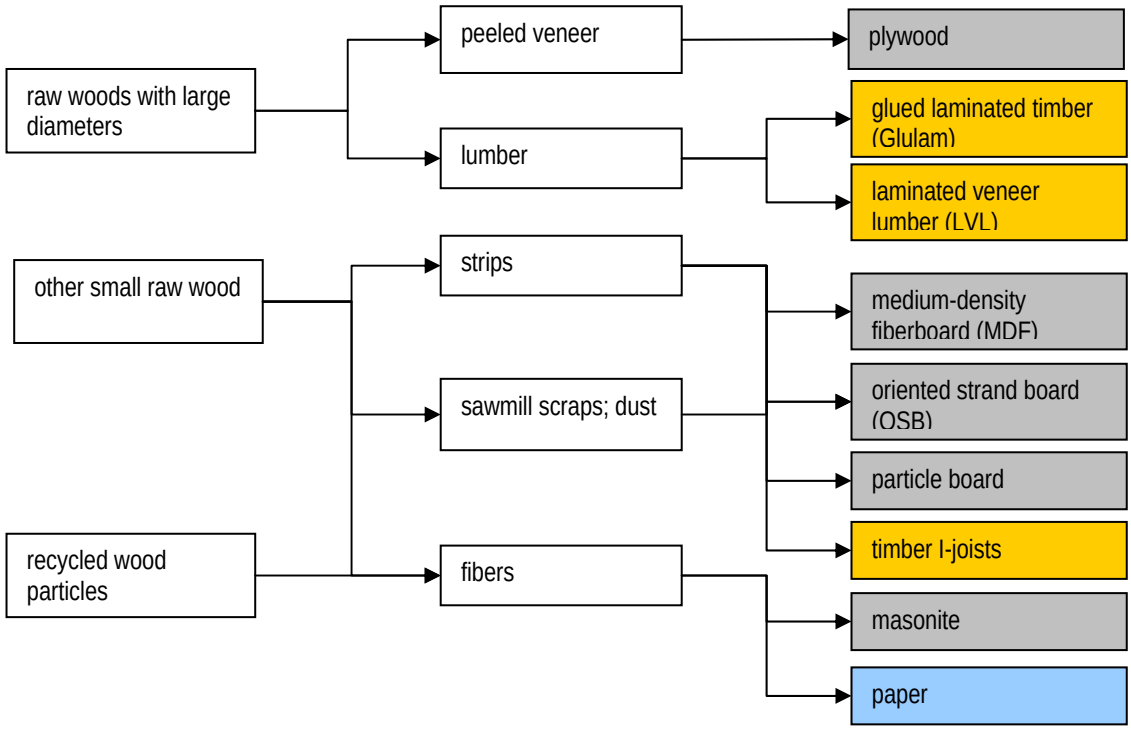


Figure 3- 7 Wood-based products: from raw wood to products

Plywood was the first type of engineered wood invented. It is one of the most commonly used wood-based products in the world; the USA alone need 1.5 milliard m² per year. It is made from thin sheets of wood veneer, called plies or veneers, which are stacked together with the direction of each ply's grain differing from its neighbors by 90° (cross-banding).The plies are bonded under heat and pressure with strong adhesives, usually phenol formaldehyde resin, making plywood a type of composite material. A common reason for using plywood instead of plain wood is because plywood is more stable and because it is less prone to change (shrink, twist or warp) (Wikipedia 2006).

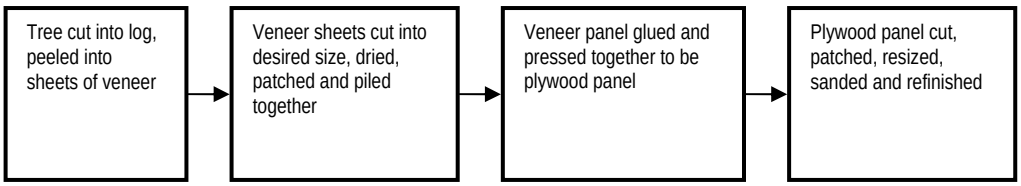


Figure 3- 8 Processing of Plywood

The processing method of plywood reflects that the industrialization of wood improves the properties of natural wood on the one side in reference to the industrial utilization; on the other side it also enhances the ratio of utilization of raw wood. The process can be shown in the following scheme:

In plywood production there is almost no waste of material: the residual from the sawing and sanding is used for paper making or for MDF and particleboard.

3.2.3. The industrial bamboo products and their working process

Before the industrial revolution the West had little influence on the countries where bamboo had been used for a long time. The working process of bamboo was still kept a handcraft. The handicraftsmen used simple tools to build, make furniture and other household things with bamboo. The working methods, the tools and the objects of bamboo, which they made for their daily lives, were all based on the material features of bamboo, and they all together constitute the cultural dimension of bamboo.

In such places where bamboo was the only material people can get from the surroundings, they had no choice but to use any other material. Even if other materials were available they were much more expensive to get or to process. But things changed after the industrialization and industrial products were introduced into these traditional bamboo countries: now people there had more choices of products and materials for their live. The producers, who emerged those handicraftsmen, have also learned to work with new industrial materials other than traditional bamboos. Compared with bamboo industrial materials like steel, glass or aluminum offer more freedom to the designer and engineer in designing and producing products, more precision at a lower cost.

Interesting is that all these industrial countries are not those which are abundant with bamboo resources. The original industrial revolution, seen from the perspective of materials, has much to do with iron (steel). Nikolaus Pevsner (1975: 118) has described how the material iron has contributed to the modern engineering architecture: "*Engineering architecture in the nineteenth century was largely based on the development of iron, first as cast iron, then as wrought iron, later as steel. Towards the end of the century reinforced concrete appears as an alternative.*" The iron industry and the steam power had changed the whole world. This trend expanded widely and brought industries based on materials like steel, aluminum and plastic. Wood, which is a traditional material as old as bamboo in the history of men, also became industrialized through the introduction of the new working process and new wood products like plywood, MDF. The bamboo, on the other hand, was kept away from industrialization for a long time.

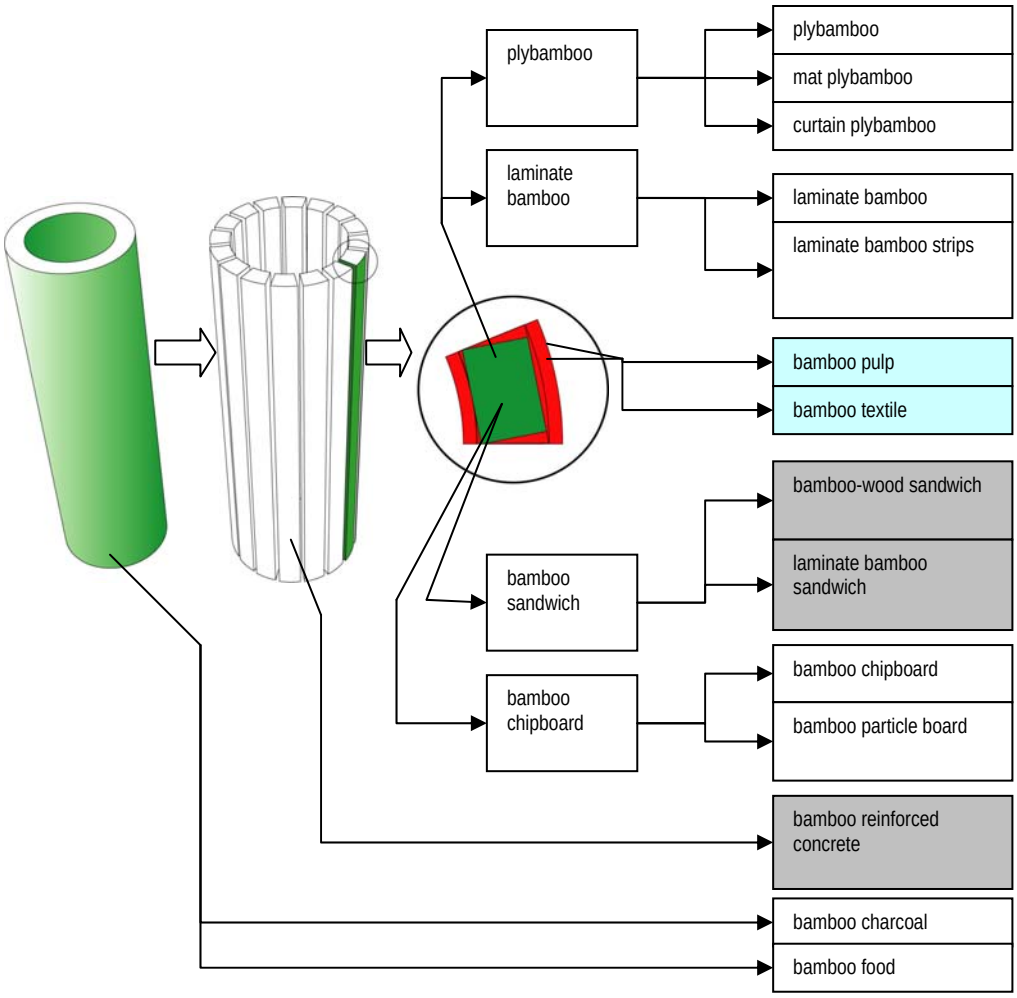


Figure 3- 9 Industrial Bamboo products

Inspired by the processing in the timber industry, engineers and researchers in developing countries like China and India, for economic reasons, began to look for ways to process bamboo with industrial methods.

As a natural organic material, bamboo is similar to wood. They are both heterogeneous and anisotropic. But the difference in morphology, structure and chemical composition of these two materials leads to different mechanical features that make it impossible to use highly efficient processes and processing machines from the wood industry directly for bamboo processing.

According to the present technology there are following products which are produced under industrial working processes (Zhang et al 2001). Some of them come from traditional handwork products, but are now produced with machines in an industrial process (see Figure 3-9). The working processes for most of the industrialized bamboo products (materials) are similar to those for wood such as plywood or MDF. The bamboo skin will peeled off because it is too hard and also too difficult to be glued with adhesives. Then bamboo tube will be split into small slips and then put together with other materials or slips into a patchwork as one layer. Several layers are glued together to form a multi layer board. The following bamboo industrial products are common examples which demonstrate how the industry has changed the structure of bamboo in the industrialization.

3.2.3.1. Plybamboo products

The name "Plybamboo" comes from the similar industrial wood product "Plywood". According to the INBAR technical report (Zhang et al 2001), it is also one of the typical industrially pre-fabricated bamboo panel products. Together with laminate bamboo they are the main stream of industrialized bamboo material. Its product properties are comparable to its wooden counterpart. Its working process and the machines also represent the typical industrial bamboo panel products: at the beginning of the process the bamboo cane will be cut into plain fragments with a certain thickness, then be pressed and flattened into strips with a thickness of 60 mm – 120 mm under high temperature. The strips will be assembled in a lengthwise and crosswise direction alternately, and are then hot-pressed together with phenol formaldehyde resin.

The detailed working process can be seen in Figure 3-10 as described by Zhang (2001). Tree stems for making plywood often have a large diameter; in addition, the year ring structure of trees makes it easy to peel a tree into wood veneers which are piled as well, glued and pressed together into plywood. The hollow structure and small diameter of a bamboo culm makes it difficult to process as done for plywood. So bamboo canes will be split, warm pressed into a flattened panel and then be stripped of the green and yellow skins, where cracks can not be avoided. In the processing of another industrial bamboo panel product, laminate bamboo, the strips will be shaved into a square format so that they can be piled together to a panel. This process reduces the cracking of the product but is accompanied with a high amount of material loss.

For cutting the simple cutting machine is used to cut the bamboo cane into strips with certain formats. The hot pressing machine is used for making the strips soft and flat. Basin is often glued on the strips by hand. Then the pressing machine can press the different layers of strips together into plybamboo. The technology of pressing-flattening under high temperature is simple, and the utilization ratio is relatively high; the disadvantage is that there cracks on the surface may occur.

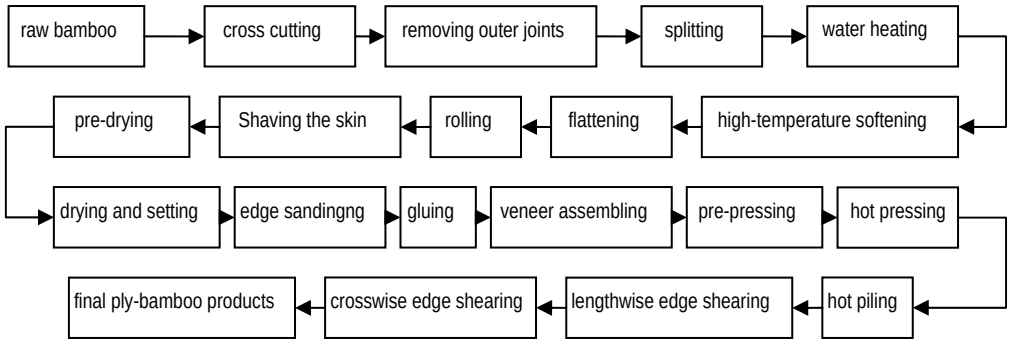


Figure 3- 10 Working process of Plybamboo (ref. Zhang 2001)

Plybamboo offers a big dimension board with excellent mechanical features like high strength, small deformation and a stable form. The bamboo veneer is 4 – 9 mm. Most plybamboos have 3 – 5 layers. The density is 0.8 – 0.85 g/cm^3. The lengthwise MOR// ≥ 90 Mpa, the crosswise MOR$^{\perp}$≥40 Mpa. (MOR: Modulus Of Rupture, the capacity of material bearing bending stress). Because of the cracks caused by the press-flattening process, the optical surface quality is not so high. This is also why plybamboo is mainly used for engineering structures like bottom boards of trucks and busses or panels for making concrete.

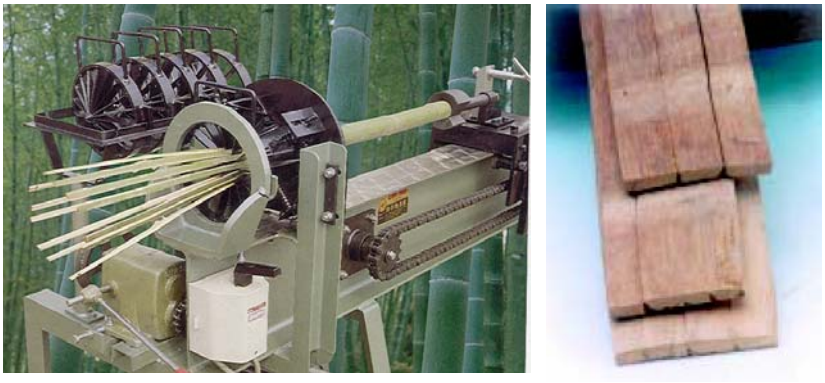


Figure 3- 11 Left: splitting machine for bamboo split (ref. the catalogue of Weizhou International Co., Ltd); right: the pressed and flattened bamboo (ref. Zhang 2001)

Plybamboo can be processed further into mat plybamboo and curtain plybamboo. The difference between mat plybamboo and curtain plybamboo is the weaving method and the patterns. For the mat plybamboo people use slivers with 0.8 – 1.2 mm thickness, then weave them into mats and then glue and dry them, finally assembling and pressing them together.

The splitting and weaving operations can be done by traditional handcraft tools, so it can be produced in rural households with simple equipment. The production also requires little raw material, so bamboos with different cane diameters can be used. It is also easy to build a factory to manufacture the products in less industrialized areas with bamboo resources of a smaller diameter.

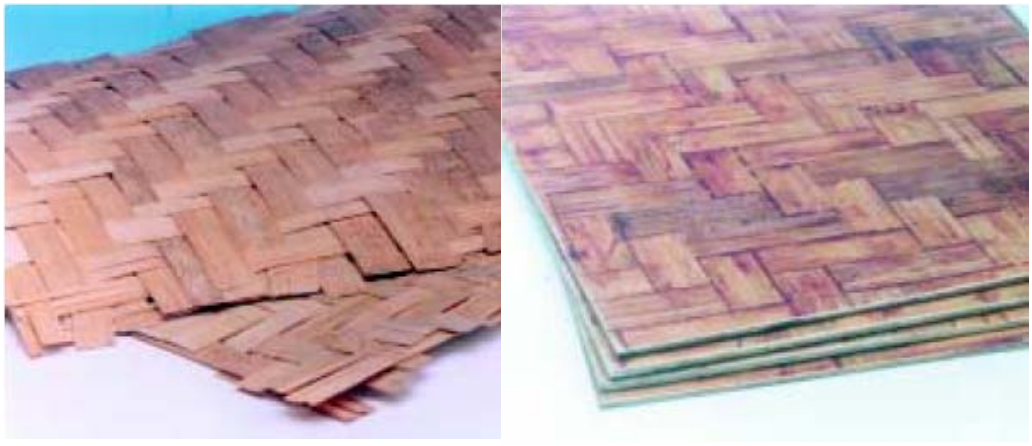


Figure 3- 12 Mat woven plybamboo, left: before the gluing and pressing; right: end product (ref. Zhang 2001)

The product is commonly made of two to five layers. The thin mat plybamboo can be used for packaging and covering of railway wagons whereas the thick mat plybamboo is often used as concrete forms and bottom boards of trucks.

Similar to mat plybamboo, in making curtain plybamboo the bamboo stems are split into strips and woven together. The difference lies only in the weaving method: when making curtain plybamboo the bamboo strips are arranged parallelly, strings are used in between. The splitting tool is similar to those for making mat plybamboo, it can be handcrafted or machine-made. But for weaving the special weaving machine is often used to make the weaving precise and efficient. Compared to mat plybamboo curtain plybamboo is more often used for interior decorations and furniture design.

3.2.3.2. Laminate bamboo

Another widespread industrial pre-fabricated bamboo panel product is laminate bamboo. The difference between plybamboo and laminate bamboo is the diverse working process and thus the different product properties. When producing laminate bamboo, the bamboo canes are cut into square edged strips with 0.5 – 30 mm thickness and 10 – 20 mm width. Then these strips are glued and dried and several layers of strips are then assembled and laminated into laminated bamboo strips. The inner layers can also be made of other materials such as wood. The strips are soaked in phenol formaldehyde resin and arranged in a parallel order. Using high pressure the strips soaked with resin are pressed together and then a sawing machine is used to get even sides of thickness and width. Before the pressing the bamboo strips should be bleached or carbonized. The products are multilayered.

Figure 3- 13 Laminate bamboo with diverse cross section structures

The working efficiency and utilization ratio is low, but the surface of laminated bamboo board is fine-grained, so it has a decorative function and can be widely used for furniture or other interior objects.

The first and second steps of the manufacture process can be done in handwork or industrially. For splitting bamboo canes the conventional knife or modern cutting machine can be used, different in efficiency and cost. The glued and soaked bamboo strips are often hand worked but can also be made by some simple machines with a low automatization degree.

For pressing a machine is needed to guarantee high pressure and temperature. The density of the laminated bamboo strips is high (more than 1.0). Because the strips are arranged in a parallel way, the lengthwise intension can reach MOR//≥100, much higher than that of a crosswise arrangement. The end products are also mainly used for bottom boards of trucks, busses and railway wagons.

3.2.3.3. Bamboo chipboard (particle board)

The aim of the bamboo chipboard is to use bamboo in a high utilization ratio. Bamboo with a small diameter and those parts of the bamboo stem that can not be used for plybamboo can be cut into small pieces and processed into bamboo chipboard.

The working process of bamboo chipboard is similar to that of the wood particleboard: rolling, cutting, chipping, re-drying, gluing, spreading and hot pressing. The machines for producing bamboo chipboard are also similar to that of wood particleboard. The cutting machine cuts bamboo into small pieces (chips). The gluing machine glues all the small chips together and the pressing machine takes over the last step of pressing the chips into a panel and giving it a standardized shape.

Compared to other bamboo panel products, the utilization ratio of raw material for bamboo chipboards is high. 1.3 tons of raw materials can be processed into 1 m^3 of bamboo chipboard. And the supply of raw material is abundant (Zhang et al 2001).

Figure 3- 14 Bamboo chips (left, ref. Zhang 2001) and chipboard (right)

Bamboo chipboards can be used in construction such as ceilings, roof-boards and light partitions, door shutters, paneling and decorating boards. They can also be used as filling material - bamboo curtains or bamboo mats can be bonded onto chipboard to get a different surface and can be used in different fields.

3.2.3.4. Bamboo Veneer

Bamboo veneer is sliced from the bamboo laminated panel. Even though it has a very hard surface it can still be bonded with other material like chipboard, MDF and multiplex.

According to the manufacture process from Hangzhou Zen Bamboo & Hardwood Products Co., Ltd, the bamboo stems are cut into strips at first, then pressed together horizontally (plain pressed) or sideways (side press) and glued under pressure into panels or planks with the characteristic bamboo knots. The bamboo plank is laminated into a block, then conditioned and soaked in water. Bamboo veneer is sliced from blocks. The bamboo veneer is dried and selected. All sheets with defects are separated out and are cut into smaller sizes; the smaller sizes are then joined to a regular size by a longitudinal splicing machine. Splitting machines and saw machines are used to process bamboo into strips. The gluing machine and pressing machine are used to turn bamboo strips into planks. The high quality slicing machine slices the laminated bamboo block to get the bamboo veneer (Hangzhou Zen Bamboo & Hardwood Products Co.,Ltd 2004).

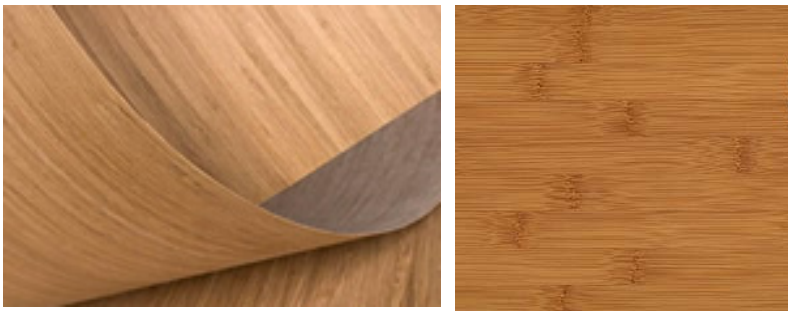


Figure 3- 15 Bamboo Veneer (ref. Hangzhou Zen Bamboo & Hardwood Products Co., Ltd)

The bamboo veneer possesses the natural beauty of the bamboo structure and the hardness of its surface; the hardness can reach 4.0N/mm^2. At the same time it is flexible. It can be bonded onto different structural materials to obtain a wide usage. Adhered with different under-layers bamboo veneers can be used in interior decoration and furniture.

3.2.3.5. Bamboo composite with other material

- **Bamboo-wood sandwich composite**

Bamboo-wood sandwich composite uses bamboo mat and bamboo curtains for the layers outside, the wood strips are used for inner layers. Between the different layers a paper layer soaked with phenol formaldehyde resin is used. Then all layers are assembled and pressed into a bamboo-wood sandwich composite with 28 mm thickness. The bamboo-wood sandwich has a similar production process like plywood. The product is light, but strong: it has an excellent wear ability, high strength and rigidity. The density is less than 0.85, MOR ≥ 80 Mpa; MOE ≥ 10000 Mpa (MOR: Modulus Of Rupture; MOE: Modulus Of Elasticity).

- **Laminated bamboo-wood sandwich composite**

The laminated bamboo-wood sandwich is made of curtain plybamboo for the surface and several sawn boards with 10-12 mm thickness for the inner layers. The combination of bamboo surface and wood on the inside makes laminated bamboo-wood sandwich possess a high strength and wear ability like bamboo and a high nail holding power like timber. In comparison to the bamboo chipboard the sandwich construction with the wood inner layers also saves in production costs.

- **Overlaid bamboo chipboard and plybamboo**

Different to the bamboo-wood sandwich, the overlaid bamboo chipboard and plybamboo are made of bamboo chipboard and plybamboo as the inner layer, with wood veneer and one or two layers of paper soaked in phenol formaldehyde resin or melamine resin as the surface. This provides the products with high mechanical features and at the same time they can be bonded with other materials such as concrete. These products are used as construction elements in producing concrete.

- **Bamboo adobe**

Bamboo adobe uses bamboo chips in the production in a way similar to that of bamboo chipboards and bamboo wood sandwich boards. But here bamboo chips are used as filling; together with the natural gluing material the product is suitable for tensile loading and compression load. This is a good side-product in the bamboo board production, where a large percentage (up to 30%) of bamboo cane is cut out as residual material and normally used for fire. Furthermore, this bio-product can use other natural residual materials, field crops fiber like cotton, rice and jute phloem tissue and seed padding, depending on what kind residual material can be gotten easily and cheaply. A German company called WBT Biothek GmbH has developed a natural glue or bond lubricant which can glue together bamboo chips. The end product has a stable form and high stability against compression load. This could be an ecological material with huge design potential.

Figure 3- 16 Bamboo residual fiber can be glued together into bamboo adobe by natural glue

3.2.3.6. Bamboo reinforced concrete

Bamboo was first used for making reinforced concrete in China in 1918. Other countries like Germany in1935 and USA in1943 also reported their research on bamboo reinforced concrete. This use of bamboo primarily came out of military intention, for replacing steel in railroad bridges and other military constructions. But the technology soon found its place in the domestic economy.

Glenn and associates (1950) at the Clemson College of Engineering in South Carolina made the most comprehensive experiments on this field in the USA. In these experiments bamboo was used in different concrete forms such as beams, girders, columns, ground supported slabs and walls.

Brink and Rush carried out a project in February 1966 for the U.S. Naval Civil Engineering Laboratory, Port Hueneme, California for studying the properties of bamboo reinforced concrete. In the project they also made suggestions on the design and construction with bamboo reinforced concrete. The selection and preparation of bamboo for the making of reinforced concrete have been introduced. They also gave the field personnel the construction principles and examples for bamboo reinforced concrete.

Figure 3- 17 Bamboo reinforcing being used in concrete block construction by the US Navy for a radar site at Tarlue Naval Station in the Philippines

In Aachen, Germany, Bernd Baier and his research team have experimented with a reinforced bamboo concrete and did a mechanical test in the laboratory. After the test they built an archetype bamboo house constructed with bamboo splits and clay. Newly reports about tests carried out by UK and Indian researchers in 2004 tried to use bamboo reinforced concrete to erect low-cost buildings in India and other places in South Asia, where earthquakes erupt frequently. The prototype house was built with a roof made of water-proof bamboo sheets and bamboo reinforced concrete walls. It had been shocked by the earthquake simulator in the Earthquake Engineering and Vibration Research Centre in Bangalore with five consecutive 30-second pulses, equivalent to 7.8 on the Richter scale. The simulation was more than 10 times as violent as the Bam earthquake in Iran 2004, yet the house emerged unscathed.

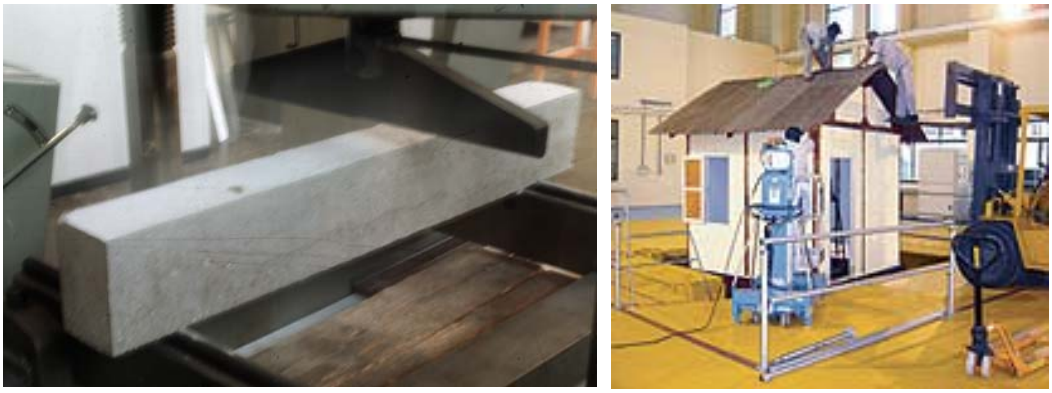


Figure 3- 18 Left: test on the bamboo reinforced concrete run by Bernd Baier in Aachen, Germany (ref. Baier); Right: house made of bamboo reinforced concrete wall and bamboo sheet roof under test at Earthquake Engineering and Vibration Research Centre in Bangalore

Not only because of its cheapness, but also due to the lightness and strength of bamboo it can be as a good alternative to steel in reinforced concrete.

3.2.3.7. Bamboo pulp

Because of its high percentage of fibers (about 40 - 60%) which are long and strong (1.5 - 4 mm), bamboo is very suitable for pulp making (Liese 1985). Bamboo has been used in China for papermaking already for more than 1000 years. Nowadays only a small part of bamboos are used for the traditional handmade bamboo paper, most of them are used in industrial bamboo pulp. Compared to timber bamboo has a more rapid growth and renewal: 4 years after the planting it can be used for production and annually 25% of the whole plantation can be pruned in the 70 years of its whole life span without destroying its biomass, whereas timber normally needs 25-60 years to be fit for commercial use. Now bamboo pulp is regarded as the alternative to wood pulp, especially in countries like China, India and Thailand, which suffer from a shortage of wood pulp. In India it is reported that more than 2.2 million tons of annual 3.2 bamboo output are used for pulp making (INBAR 2004).

It is reported that in Southwest China, the world largest bamboo pulp factory will start up in 2007 with a production capacity of 750 tons of bleached pulp. The pulp machine supplier Kvaerner Pulping AB Sweden designed the fibreline with a totally modern industrial process and equipments based both on the industrial timber pulp production process and bamboo's special properties.

Because bamboo has similar paper properties (fiber length and strength) like softwood and since the cooking and bleaching conditions are similar to those of hard wood it is suitable for mixed cooking with hardwood. Another important point is that bamboo can be cut into proper chips, which allows continued cooking. The Compact Cooking process by Kvaerner Pulping AB is based on this property of bamboo.

One disadvantage in bamboo pulping is that bamboo has a rather high silica content (about 2%) leading to scaling problems in the cooking plant, as well as in black liquor evaporation and in lime (about 65%) reburning. The company uses the Compact Cooking Process to minimize the scaling problem, to purge the lime mud and to keep an equilibrium SiO_2 (SiO_2: The chemical compound silicon dioxide, also known as silica, is the oxide of silicon) content of 650 mg/l in the white liquor. (Andtbacka 2004)

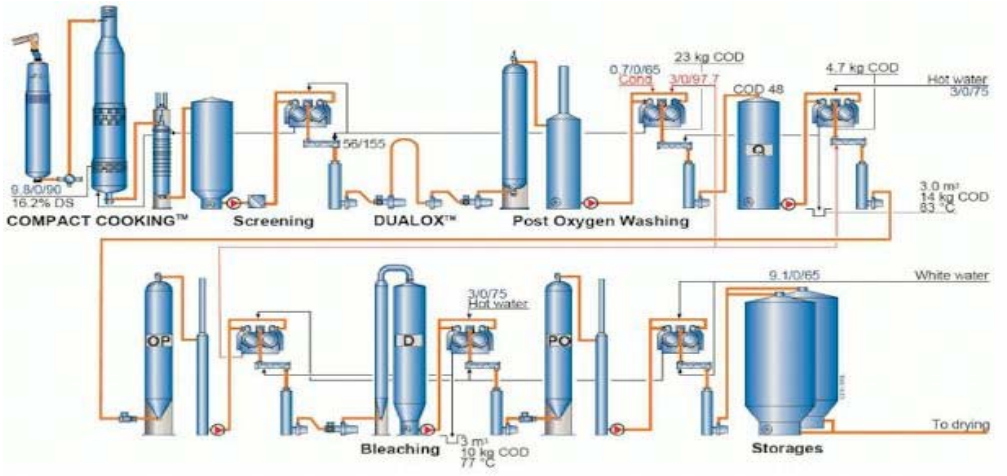


Figure 3- 19 Bamboo fiber line for Chitianhu Bamboo Pulp Co, China by Kvaerner Pulping AB (ref. Kvaerner Pulping AB)

3.2.3.8. Bamboo textile

Bamboo pulp can be further processed into bamboo fiber, yarn and filament for industrial usages and garment producing. In China there are several factories which use similar technology and processes to produce bamboo fiber, yarn and filament.

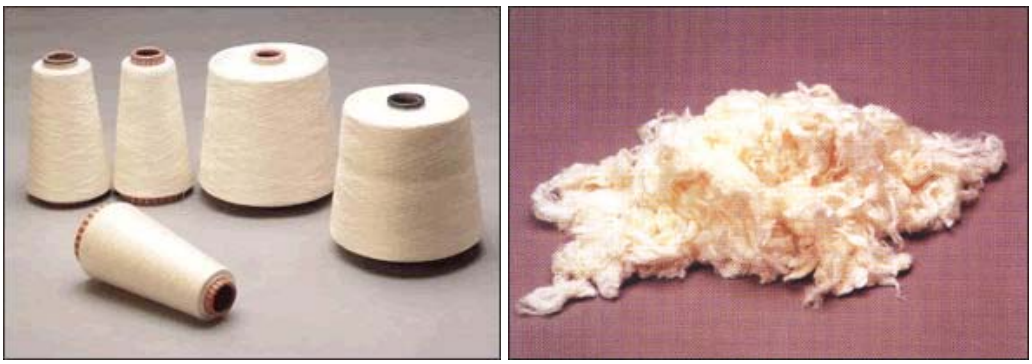


Figure 3- 20 Bamboo textile and fiber (ref. the catalogue of China Bambro Textile Co., Ltd, Beijing)

As a natural fiber the bamboo fiber has the following advantages:

- *Natural anti-bacteria*
  Because bamboo has a unique anti-bacteria and bacteriostasis bio-agent named "bamboo Kun", this substance, in close combination with bamboo cellulose molecular during the production, make bamboo fiber have the function of anti-bacteria, bacteriostasis and deodorization. The test by the Japan Textile Inspection Association has shown that even after 50 times of washing, bamboo fiber fabric still possesses the excellent function of anti-bacteria: it showed a 70% death rate after bacteria being incubated on bamboo fibre fabric. (China Bambro Textile 2004)

- *Breathable and cool*
  Due to various micro-gaps and micro-holes in the cross-section of the bamboo fiber, it has a very good ability to absorb and ventilate moisture. Apparels made of bamboo fiber can absorb and ventilate the human's sweat very fast, as if the apparels could breathe. And these bamboo fiber clothes keep the human body cool in summer.

- *Green product and biodegradable*
  The bamboo fiber and yarn products are, like many other bamboo products, biodegradable, so it is also eco-friendly.

Bamboo fiber can be widely used for producing apparels such as sweaters, shirts, bathing-suits, mats, blankets, towels etc.; or for sanitary materials like bandages, surgical clothes, nurse's wears and so on. It can also be woven into other materials like wool or cotton to get an ideal material combination for different situations.

3.2.3.9. Bamboo charcoal and bamboo vinegar

Bamboo charcoal is a solid product made from bamboo culms by pyrolyzing. Accordingly, the shape of the bamboo charcoals can be round, sliced, broken, particle and powder charcoals. Bamboo vinegar is the by-product of bamboo carbonization, which is gotten by condensing the smoke of the kiln.

- The processing

The production process can be summarized as follows:

Figure 3- 21 Working process of bamboo charcoal

Any species of bamboo can be used in making charcoal, but different species have a different yield of charcoal; this ranges from 10% to 25% (Kosokawa 2002). Moso bamboo (*Phyllostachys pubescens*), because it is easy to get, is the commonly used bamboo for charcoal making. The kiln can be made of mud, brick, iron or steel. The iron and steel kiln make the carbonizing process more stable and thus result in a high yield, but are also more expensive. Different kilns have similar working processes and only differ in time control. As an example a kiln made of brick has a 14 m^3 chamber volume and a capacity of 2.5-3.5 tons. The production process takes 5-7 days (Bhawan et al 2005).

To ignite the bamboo, the air valve of the kiln must be opened and burning bamboo culms thrown into the chamber through the fire holes. After 1.5 to 2 hours the temperature of the chamber will reach to 100 °C, which means the bamboo has dried and ignited. At the same time the kiln starts to produce bamboo vinegar through the chimney. In carbonization, through controlling the openings of the kiln; the fire causes a lot of heat in the kiln, and the temperature rises to 280-450 °C, which is higher than the auto-ignition point of bamboo. Then the thermolysis process starts in the kiln - the bamboos get carbonized. After the carbonization process, the kiln is kept closed for one day and the charcoal is left to cool.

- Properties and uses

Compared to wood charcoal, bamboo charcoal has advantages in easy carbonization, low tar content, level of hardness and filterability. Besides, bamboo charcoal has a high level of porosity and a large surface. The adsorption capacity of bamboo charcoal which is carbonized at a high temperature of 1000 °C is approximately ten times that of Bincho charcoal (Kosokawa 2002). It is used as fuel, absorbent for purifying water, meliorating the soil and promoting the root system of plants, preserving the freshness of vegetables and deodorization.

Bamboo vinegar, also called pyroligneous liquor, contains more than 200 chemical components, mainly organic acid, alcohol, neutral materials, aldehyde, poly-phenol and alkaline. It can be used as a soil fungicide for promoting plant growth, as deodorizer in cosmetics and medicines.

3.2.3.10. Bamboo food

Bamboo as food mostly means to use the bamboo shoots as vegetables; this has a long tradition and was kept and developed even further in the industrial time. Bamboo shoots exported from China in 1999 alone summed 200 million US Dollars, which was about 40% of the whole bamboo product export. In recent years, Australia consumes between 4, 000 and 12, 000 tons of imported canned bamboo shoots each year.

In order to provide for this large consume of bamboo food, the production process also has developed. Industrial processing methods and machines have been introduced for planting, processing and preserving bamboo shoots. This helps the more wide and efficient uses of bamboo for foods.

Like the traditional bamboo food processing, the modern bamboo shoot production also includes three phases: planting, processing and preserving. According to the technology report of INBAR, the processing can be summarized as following (Xiao et al 2004):

- **Planting and harvesting**

Bamboo plantations special for bamboo shoots are different to those for producing bamboo culms as building material. Species selected for bamboo shoots can be monopodial bamboos as well as sympodial bamboos, with the sole difference in the plantation. The monopodial bamboos prefer sites with a warm, moist climate and annual precipitation over 1,200 mm, whereas the sympodial bamboos have higher demands for temperature and humidity. The plantation should be located on foothills and river banks under 200-300 meters above sea level. A relatively level site is required with deep, loose, fertile sandy loam. During the bamboo growth weeding must be done to ensure that the bamboos have enough nutrients and moisture. Soil loosening can improve the water conservation in the soil and is helpful for growth of bamboo's shoot and roots.

Sympodial bamboos yield bamboo shoots from May to October and the most productive times are from June to July. Edible shoots should be harvested before they become tough, the delay of the harvest will cause the loss of quantity and quality of the bamboo shoot. Most of the shoots produced in summer will be harvested; when cutting shoots, at first the soil is removed around the shoot, cutting it off from the rhizome and finally returning soil to the harvesting hole. The basal part of the shoot can be retained intact and shoot buds on it may develop as shoots in the present or coming year.

- **Processing and preservation**

Bamboo shoots can be used for three kinds of food products: dried bamboo shoots; canned bamboo shoots; soft packed bamboo shoots. The processing for dried bamboo shoots is not new, it has been known for hundreds of years. Nowadays most of the bamboo shoots are processed into canned products. This is one of the most commonly used techniques in the food industry for food and fruit treatment. Since 1950, people also use this method for bamboo shoot processing, to keep bamboo for a long time and for worldwide transport. The soft packed bamboo shoots use PET/PP folios as package material and are kept in a vacuum. The technology was at first studied in 1950 in America and was approved for use in food production by the Food and Drug Administration in 1977. Now it is also widely used in Japan and China for bamboo shoots packaging.

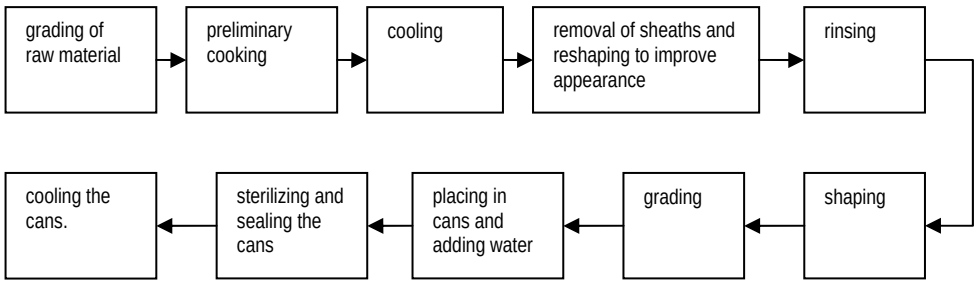


Figure 3- 22 Working process of canned bamboo shoot cans

For the canned bamboo shoot the processing is generally done as in Figure 3-17. The mechanization degrees range from place to place depending on how large the investment is. Because of the high investment costs of the machines, human labors are still intensively used in the production lines. Machines are used at the important positions.

3.3. Between industrialization and tradition: lost in the transaction

Through the industrialization some of traditional bamboo's utilizations turn to be more efficient by the processing with industrial machines, and also overcome the geographic restriction. But some of the industrial uses have also brought problems, because large percentages of the industrial bamboo utilizations are based on the technology of wood industry: how the woods have been used and processed is transferred onto the processing of bamboos. In many features bamboo has similar properties like wood: both of them are heterogeneous, hygroscopic, cellular and anisotropic material. The chemical composition of both materials consists of cellulose, hemicelluloses and lignin (see chapter 2). But from the structural point of view, bamboo and wood are very different: bamboo is hollow and timbers are solid. This difference makes the utilization of bamboos inefficient if it is handled in the same way like timber. Because timber has its inner parts as the main useful part, after the processing the timber lost its surface which is only a small portion of the material and leaves the inner parts which provides the biggest portion of the material (the substance wood). Then the material can be rebuilt (re-organised) into products like furniture, building structure or paper etc. But for the bamboos, if treated like timber, after getting rid of the outer and inner surface of the culms like it is done in most ways of bamboo production, the rest of the culms used in the bamboo products counts only as a small portion of the whole. These are for example bamboo board products like plybamboo, chipboards and bamboo pulp. Bamboos as materials are still used here in an inefficient way (Figure 3-23).

Another point is that bamboo's industrialization takes bamboos as one link of the industrial processing chain. For the industrial production process, bamboo's own structure has to be destructed and even the botanical or physical features are be changed. At the end the industrial bamboo products have not so many features to let it be recognized as bamboo products like with the traditional bamboo products. These new bamboo products neither have anything to do with their old cultural context nor do they keep their new cultural context at the same time.

Figure 3- 23 Left: Stem section of a yew wood; right: Culm section of bamboo Phyllostachys Pubescens

But in many countries or places such kinds of industrial bamboo products are just booming and can be seen as a good example for the new development of bamboo's utilization. This is just because the material bamboo is cheap and the working cost is still very low there. The industrialization of bamboos takes place purely out of economical reasons. It is a new way to help alleviating poverty in these places, but is little concerned with the utilization of bamboos as a whole system. The result is that bamboo is utilized in a way which deprives it of its structural and cultural context.

3.3.1. Structural context

Compared to wood, bamboo has a much faster growth rate, not really because bamboo produces more substance than trees do, but mostly because its growth is more efficient. As discussed in Chapter 2, bamboo only needs 3-4 years to be mature enough for normal utilizations, whereas timbers need 50 years to be suitable for harvesting. The fast growth of bamboos has its reasons: not only because it has an underground rhizome system, but also due to its special structure of the culms, which is the main part of bamboo for most utilizations: the bamboo has hollow culms, whose outer parts are much harder and denser than the inner parts. The substances that bamboo gets and produces during the growth contribute mostly to the outer hard part of culms, which carries most of the burden in the whole construction; the inner part of the culm, which is soft and protected by the outer parts, has a large channel system to transport the nutrients everywhere from the rhizome. And the center part of the culm is hollow, which on one side does not affect the strength of the whole structure, yet on the other side helps reducing the substance consumption of bamboo. This means bamboo has its growth arranged efficiently: discarding all the unimportant things and concentrating on the most significant ones.

This can also be explained by using the concept of *MIPS,* which has been developed by the Wuppertal Institute for Climate Environment Energy for the examination of the efficiency of material utilization. The abbreviation *MIPS* stands for Material Input per Service Unit. The *MIPS* concept and its practical application in the form of the Material Intensity Analysis (MAIA) can be applied in a variety of ways to organizations and whole economic systems. *MIPS* is an elementary measure to estimate the environmental impacts caused by a product. Therefore, *MIPS* can be applied in all cases where the environmental implications of products, processes and services need to be assessed and compared. For example, for the service carpet cleaning there are two types of products: the carpet sweeper and the normal carpet cleaner. From the *MIPS* perspective, a carpet sweeper has a much lesser *MIPS* value than the carpet cleaner and therefore the former is much more efficient and ecological than the latter (Ritthoff et al 2002). Even though the *MIPS* concept is developed by the Wuppertal Institut for the application in the human world, we can still transfer the concept onto nature: for the same function in a plant, the bamboo culm has a much lower *MIPS* than the tree trunk and therefore is more efficient and developed.

Another concept to examine how efficient a construction can be is the *BIC*, which was developed by the Institute for Lightweight Structures (Institut für Leichte Flächentragwerke abbr. IL) at the University of Stuttgart (Otto 1982). *BIC* describes the relationship between the mass of an object and its maximal capacity to transfer the strength under a certain load. For measuring the *BIC*, another term, *TRA*, is defined as the capacity to transfer the strength under a certain load. The *TRA* is the breaking load, F multiplies the power transfer distance s. and then the *BIC* can be calculated according to the following formula:

$$BIC = \frac{m}{TRA} = \frac{m}{F \times s} \text{ (g/Nm)}$$

The power transfer distance is the shortest way between the point of load incidence and the point, the surface of the body whereto the strength is transferred. The *BIC* is dependent on the mass, the form and the material of the object, the kind of the load and the arrangement of the load.

Another term λ, called Relative Slenderness, is used to describe the minimal distance which a loaded object has to transfer.

$$\lambda = \frac{s}{\sqrt{F}} [m / \sqrt{N}]$$

The higher the value λ of an object is, the more the material expense it has, and also the bigger the *BIC* it has. The *BIC* measures the material expense of an object, by which the object can furnish with a certain form and certain capacity to transfer the load. The *BIC* describes the efficiency of the object construction. The most efficient object is the one with lowest material expense, but the largest capacity of load transfer – the lowest *BIC*. The IL used the *BIC* and λ method to compare many different objects – natural objects like wood, bamboo and human made objects like steel and aluminum. In the tension test bamboo has the lowest *BIC* value: it is reached about 67% of aluminum's value, 50% of steel's and 25% of wood's. Bamboo cane is regarded as one of the most efficient constructions in nature and human made materials. (IL 1985)

Here, bamboo as a natural product means a structure which is not just the simple summation of the substances, but a logical organization of the materials.

The traditional utilizations of bamboos are mostly based on the combination of both sides: one side is bamboo's own structure and the other side is the live needs of the people. Without industrial machines and high technology the human beings don't have so many possibilities to work with nature as in the industrial time. They stay in nature and try to build their own world – a human made world for their lives. They have to obey to or respect the rules of nature – even if they try to overcome the limits given to them. The bamboo's structure is what they have to accept as a precondition for their using. Straight, light, strong, with a fast growth as well as a hollow structure and difficult to join with other materials are both advantages and disadvantages of the structure they have to accept. They have to use bamboos in a way that the utmost advantages of this plant can be used avoiding the disadvantages. As the result, more than thousand years of traditional utilization of bamboos and numerous objects made of bamboos have proven the successful relationship between bamboo's structure and human utilizations. Bamboos as material fulfill almost all human needs in their daily life. This is not an accident but an evolution of human beings.

The existing relations changed after the industrial revolution. The industrial revolution is not only the turning point in human society but also in the relation between the human beings and nature. With the help of the new technology, human beings can always exceed the boundary of the power, nothing seems impossible for mankind to do – to destroy or to produce. With the machines and tools it is now possible to process bamboos in ways that were impossible in the pre-industrial time.

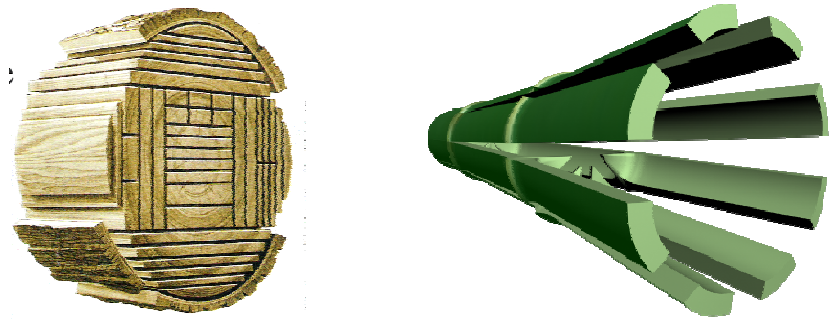


Figure 3- 24 The utilization rates of wood and bamboo

In many industrialized utilizations discussed in this chapter bamboos are treated as pure materials which are similar to wood – the difference is only that bamboos have a harder surface and a faster growth. Actually, the industrialization of bamboos is mostly based on experience gathered in the timber industry. It also isn't odd that people immediately use the technology from timber industry to treat bamboo, because bamboo, its uses for human beings as mentioned, has classified itself more or less as wood. As timber got its utilization industrialized more than hundred years ago and nowadays has a quite developed status, the easiest way to help bamboo get industrialized is to follow the way of timber industry.

Then the special hollow structure of bamboos is not an advantage but a disadvantage for the industrial processing: Because of its hollow structure the bamboo has to be split into strips and the outer and inner surface of the culms are cut off, then only the middle part which has been cut into a square shape can be glued together to produce the wide format plybamboo board (see 3.2.1). Through this industrial process bamboo's important structural advantages like strength, lightness and elasticity are not taken into account, only its hardness and mass have been taken into consideration, which are exactly not the most advantageous sides of bamboo. This could be the loss of bamboo's structure as it gets industrialized (Figure 3-24).

3.3.2. Cultural context

Through a long history with human beings bamboo has developed into diverse forms of culture based on its numerous practical or symbolic utilizations in people's daily life. This is not only bamboo itself as the plant which has its own botanic life cycle before it is used as material by human beings, but refers more to the use of bamboo in the daily life of human beings and the bamboo as a symbol in art, music and literature. This phenomenon of bamboo culture has been defined in countries like China, Japan or Korea as the "Bamboo Culture". In China, bamboo culture was defined as "all the objects, patterns and symbols in daily life, arts, literature and philosophy in which bamboo is used as the main object of representation" (Wang 2000). In other countries in South America and Africa the cultural context of bamboo relates mostly to the bamboo objects in their daily life. Bamboo building, bamboo tools and bamboo plants around the houses can be found everywhere in those countries and places. This could be described as the "Alltagskultur", one of the German word that describes "*the customs, habits, objects of everyday life, which in sense of culture is not included into the classic high culture like arts, music and literature which are defined by the elite*" (Wikipedia 2005).

The traditional uses of bamboo are based on the bamboo's structure and the daily life of human beings. The special structure of bamboos has its advantages like lightness, strength, elasticity, beauty, fast growth and easiness in processing. These structural factors help bamboo to be one of the most important and popular materials in the pre-industrial time in countries and places where bamboos are abundant. Even if different countries have different ways of using bambo, the utilizations in these countries still have their common sense through the long time of development, like the evolution process in nature. A bamboo

basket in India looks similar to that of Africa and America. In all the bamboo objects there is the representation of the bamboo's special structure as well as the intelligence of human beings. For example, the bamboo bridge in South Asia, in which bamboo culms serve as the supportive element of the building, shows the strength and lightness of bamboo culms. Whereas the elasticity of bamboo culms can be seen in the bamboo basket, where bamboo culms are split into strips and woven together. With these traditional bamboo objects the advantages of bamboo as a material can not be replaced by other natural materials like wood or metal. Here the use of bamboo as a material has not destroyed but enhanced the natural beauty of the structure. This is also why bamboo as a material is not only just a substance, but has been defined as a cultural being in the "Alltagskultur" (everyday life culture), as well as a symbol in art and literature in those countries like China and Japan.

But the industrialization of bamboo is based on other factors of the industry: the industrial production and economic principle. Even the structure of the material will also be taken into account, but only secondary. In the industrial process bamboo has to be de-constructed and then reconstructed into such kinds of industrial products like plybamboo. As a cultural factor bamboo has lost its character in this process. Finally it would be difficult to feel BAMBOO in the end product.

The cultural factor of traditional bamboo's utilizations has a strong connection between bamboo's physical properties and the bamboo's end objects. This is difficult to see in the industrial product. The appearance of industrial prefabricated bamboo products has little in common with the original bamboo plant, even though the texture of bamboo culms can somewhat be found in them. As the industrialization of bamboo has learned a lot from the timber industry, the end products of industrialized bamboo have also been adapted to those of industrial wood products. One of the examples is the bamboo door made of plybamboo in which nothing more than the surface texture is different to the wood doors. Another example, the plybamboo floor, which could be one of the most popular industrial bamboo products in the market, has its most important sales points firstly in the special surface texture. Secondly it is regarded as a good replacement of wood because bamboo grows faster than trees do. These products could neither be seen as successors of the former bamboo culture, nor a representative of the new bamboo culture.

Figure 3- 25 Doors made of plybamboo (left) and plybamboo floor (right), in which bamboo as a substitute for hard wood.

3.3.3. Summary: Materialgerechtigkeit for bamboo

"Materialgerecht" is a German word which can be translated literally as "appropriate for the material involved". "Materialgerechtigkeit" as a term originally from writings of Lange (1907), had once been a central discussion in the second half of the 19th century which was against the abuse of decorations and ornaments on materials without considering their properties. Later this has been developed more generally to a term that refers to the use of material not only according to the functional and aesthetic

requirement, but also to the material's own properties like its structure, its strength, its hardness and so on, so that the material will also contribute to the character of the products.

Even if the industry shows its power in including bamboo into a process which changes bamboo's natural structure into a standardized form and thereafter makes it possible to use bamboo in the industrial world, bamboo in such product forms has not been used to its full capacity and lost many of its characters. Its special natural structure and long history of culture disappeared during the new industrial processing and utilization. Bamboo is nothing more than a cheap alternative for the expensive hard woods.

Industrialization of bamboo in the sense of production process could be the first step for the bamboo to re-enter the industrial society. The industrialized re-construction of the bamboo's own natural structure is a compromise between the material and the utilization at the cost of losing the bamboo's own important structural and cultural characters. From the structural and cultural perspectives the industrialization is still not the right answer for the question of how to correctly utilize bamboo in the industrial context. The utilization of bamboo should be more profound and wider than just the industrialization of the material and the processing. To utilize bamboo in a way that bamboo's own structure can be fully taken advantage of (materialgerecht) and to build a new culture of bamboo based on the appropriate material utilizations are the aim, which will be the main topic for the next chapter.

Chapter 4

The modernization of bamboo in the industrial context

Solving a problem simply means representing it so as to make the solution transparent – Saul Amarel

4. The modernization of bamboo in the industrial context

One of the most important features of industrialization is the mechanization of the working process with machines. Standardization is the requirement to the materials and working elements in the working process. This is also the reason why bamboo is difficult to be used as a material in the industrial world. Through the industrialization bamboo can be processed into different kinds of prefabricated industrial products. On the one hand this helps bamboo to be standardized for further use in the product design but on the other hand it destroys bamboo's natural and advantageous structure. Furthermore, because of the industrialization of the material bamboo it concentrates not on the end use of bamboo in people's daily life but just brings bamboo into the industrial working process. Bamboo could not form its own identity in human's cultural life like that in history – a "bamboo culture" in the industrial context could not be realized through industrialization. On the contrary, through industrialization the difficulty in treating bamboo's natural structure is no longer a problem, which leads to a kind of carelessness in using it: due to its fast growth and hard surface it is "ideal" to use bamboo as a cheap substitute for hard wood. In these cases its special structural advantages have turned into a disadvantage and are not fully used, whereas its cultural meanings have also been lost in industrial bamboo products. Even though bamboo can get into the whole industrial manufacturing process through this kind of industrialization, for the material it is still not the appropriate ("materialgerecht" in German) utilization of bamboo, and therefore can not have its own identity as a material in the industrial society.

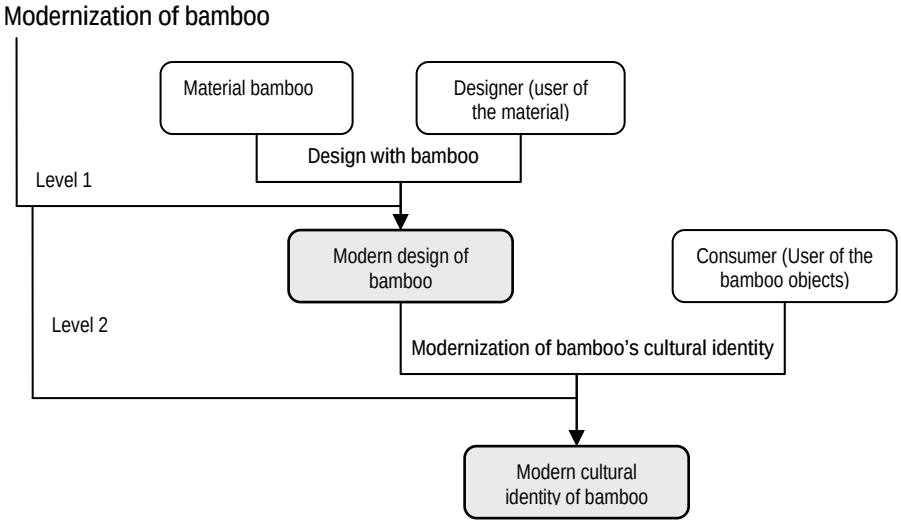


Figure 4- 1 Two levels of Modernization of bamboo[14]

Instead of industrializing, the "modernization" of bamboo should be the solution for the problem of utilizing bamboo in the industrial context. Modernization here means building a new relation between the material bamboo and human's life needs in the industrial context and there are two meanings closely related to each other: the first is the modernization of bamboo's utilization, namely the design with bamboo in the industrial context, which is firstly based on bamboo's inner structural and cultural dimensions and secondly on the new processing conditions and human needs of the outer industrial context. The latter is the modernization of bamboo's cultural identity. Through an appropriate design with bamboo, the material can be used in products in a way that its special characters can be represented properly and bamboo itself can be used and experienced by people in their everyday life. As a result, a new cultural identity of bamboo in the modern industrial culture can thus be attained (see Figure 4-1).

4.1. Design with bamboo in the industrial context

Through industrialization the context of bamboo utilization has been changed. To analyze the reason for the comedown of uses of bamboo in the industrial context it is important to analyze the relationship between bamboo and the human life which shows the difference between the traditional way and that of the industrial time. Whereas in history craftsman connected the human's life needs, the designer (industrial) is the one who plays this role in the industrial world.

The traditional bamboo utilizations were not wrong in the pre-industrial time. They offered practical, good solutions for the problems between what humans needed and what they could get in people's daily life. The tasks were passed on to the handicraftsmen in these times without industrial conditions like machines and automatic processing. They had the techniques for dealing with bamboo with their hands and with their tools too, they faced the quests of the things they should produce from the customers and also from their own life. This turned into a tradition which was passed on from one generation to the next and was also enriched and developed. With such simple working tools and the wonderful skills

[14] The modernization of bamboo in the industrial context will be divided into two levels: firstly the modern design with bamboo in the industrial context. This will be the precondition for the second level, namely the modern cultural identity of bamboo. The modern design of bamboo is the result of the modernization of the relation between the material bamboo and the designer (the user of bamboo) which will be the topic of the first part of Chapter 4(4.1). The modern cultural identity is consequently the result of the modernization of the relationship between bamboo objects and consumers (as the end user of the bamboo objects) in the industrial context which will be the issue in the second part of Chapter 4 (4.2)

bamboo has been made into numerous goods everywhere in people's everyday life and has further developed from being only a material into a cultural being.

The traditional ways of utilizing bamboo are basically still right in their industrial context in sense of the relationship between material structure and its treatment (processing). The task in general sense is the same: to find solutions between what humans need and what they can get. What changed are the preconditions of bamboo utilizations: From the only material people can get to a material among many other alternative competitors and from the handicraftsmen to the industrial designer. The changes in the relationship among material, people and the task also ask for a new structure of the system.

The industrialization of bamboo is a movement from the material side. It is correct so far because it has tried to find the way to put bamboo into the industrial working process, to help bamboo to be worked by machines. But since they are just minor from the point of view that bamboo products could and should be produced by machines, regardless bamboo's own structure, this would not be an utilization adequate to the material and will also not last long. On the other side, even if the industrialization of the working process has treated its natural structure appropriately, bamboo has just been processed into some kind of half-products and is still not presented in the end products and therefore still not joined with people's everyday life which is determinative for a material to obtain its identity in the industrial society. Compared to the glorious culture of bamboo crafts in history, the industrial utilizations of bamboo in the modern world are still not enough.

To help bamboo to a better use in the industrial context, the industrialization of bamboo as a material in the processing is just one attempt which is undertaken from the point of view of production. This is mostly based on the industrial working process like the mechanization of the production and standardization of the product components. But since the task is to help bamboo to be properly and widely utilized in the industrial world, it is not enough to just industrialize bamboo in the working process - especially because it is a material with a natural structure that is difficult to standardize. Like discussed in Chapter 3, even though bamboo is industrialized in many ways which give it many new potentials, the price is also high: bamboo has lost its structural advantages and its cultural meanings. To solve the problem it is required to think the whole task in a new way: to think about the bamboo's utilization in a system in which the important factors related are involved and to solve the problem by building a new harmonic relationship within the system.

The bamboo utilization system in the industrial context will be studied at first by a general discussion of the relationship between the designer and the materials. This will be done by the view back into the history from the industrial revolution to the modern times, followed by the discussion on the industrialization of wood and the design with wood which serves as a case study for the utilization of bamboo in the industrial world. All the studies in other fields from the historical perspective are supposed to give a theoretical basement for the design with bamboo, to show how both sides – the material and the designer – can change to form a better material utilization system.

The modernization of bamboo will be discussed from both sides of the relationship between the designer and the material: namely from the material's side, how the material can be "changed" to fulfill the designer's tasks. And from the designer's side, how the designer can innovatively use the material in his design work. Four design principles are then put forward to present how design can work with bamboo in the industrial context – to show how a modern relationship between designer and the material bamboo can be developed and therefore how bamboo can be appropriately utilized and how it can find its new identity in the industrial world.

4.1.1. Material bamboo and the designer in a system

To analyze the factors that determine the utilization of bamboo, Figure 4-2 displays the process generalization of the material utilization in a system. The designer in his general sense means a craftsman in the pre-industrial time, whereas in the industrial time it means an industrial designer (here the

industrial designer is also used in a general sense, to whom the application 'engineer' also applies). The use of the material originally comes from the life needs of human beings. Through the designing and processing of the material a product (house, furniture, tools etc) and its function come into being which can fulfill the needs of human's life. Here the designer plays a key role in the process of connecting the material to the human needs. Through the product design of the designer the human needs get fulfilled by the designer in a form of a product with certain functions, whereas the materials get used – in other words organized and processed logically and economically in a form of product. In this whole design system map there are three small process cycles: 1. the design process cycle including designer, material and product; 2. the design purpose cycle of designer, product and human needs; 3. the material cycle of material, product and human needs. Each cycle represents an emphasis on the special relations. But in a whole system each of these three cycles will not work alone but interact with each other. So to solve problem of bamboo (*material*) the other two elements *designer* and *human needs* and their relationships should be taken into account as a whole.

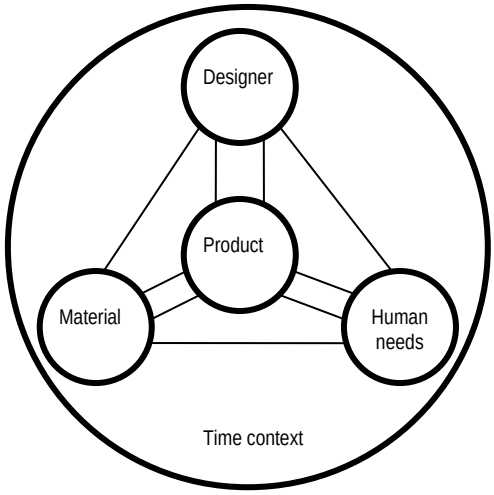


Figure 4- 2 The triangle of the material utilization system[15]

The process of the system can either be started from *human needs* or *material*. In general the process of the system begins with the side of *human needs*, that means the human beings have their needs for daily life, for example to sit in the house; he (the *designer*) tries to find a way to solve the problem – designing a chair for sitting. For the chair he needs the *material* and tools to produce it. In the surroundings the most common material he can find is bamboo, other materials like wood he has also considered but it is not so easy to work with, so he made the *product* chair with bamboo. This could be a typical scenario of the bamboo's uses in the pre-industrial time in the countries where bamboos were abundant. And the people who were responsible for the design were mostly the handicraftsman and the processing methods were also handwork. From the *material's* side this could be seen in the way that the *designer* (craftsman) has the experience and knowledge of the *material* bamboo, he can find new product ideas and *human needs* and design products especially out of the *material* bamboo.

Things changed in the industrial time. The role which was formerly played by craftsmen is now taken over by the designer (and engineer). Both of them play the key role in connecting the material to the human needs. The difference can only be found in the ways the tools are used for their works. The industrial working process has changed the world so dramatically that everything in our daily life has

[15] The product is regarded as the result of both relations. For example, in the relation between designer and human needs the product with a certain function serves as the result of the designer's design which represents the human needs. Here the concept of this system map is to explain that the relationships among these three elements – material, designer and human needs are important to solve the problem of the material in the industrial context.

been stamped with "Made by Industry". The material bamboo which was so popular with the craftsmen is now not the only material that the designer can get, but on the contrary could only be the last alternative for the designer because there are so many industrial materials being processed easily by machines and the industrial process, whereas bamboo's non-standard form and structure is too difficult to work with.

On the one side the material is a very important factor for designers in the design process: the properties of materials, like mechanical properties as strength, hardness and elastic modulus etc. or the aesthetic features such as color possibilities or surface finish possibilities are important aspects for designers to decide which material they should choose for their product design. All these factors also determine how successful the end product could be under the functional and aesthetic requirements (Cornish 1987). Ashby and Johnson have also argued that the developments of materials play an increasingly important role in the design process. The changing of the material in product design reflects not only the development of the material technology itself, but also represents the ever changing requirement from the environment, the investment climate and industrial design, all of which "*result in an evolution in the use of materials for a given product or product class*" (Ashby & Johson 2002: 20). On the other side the designers decide how a material could be appropriately utilized in the product design. Through the adequate choice of materials and their relevant processing methods in innovative product designs the designers can always find new utilizations of materials and therefore a new "definition" of the material in its new "life form". The successful history of the product "POST IT" from 3M could be a very good example of how the innovative use of the material (technology) in a product can "change" the technology in society.

The changes of the general relation between material and designer since the industrial revolution will be discussed in the following part, to see how the development of materials and their working methods can influence the designer in his designs and on the other side also how designers can change the development of the materials through their innovative designs.

4.1.1.1. Material and designer in the industrial time

If the relationship to industrial material is concerned especially, design can be defined here in its narrow sense as the construction and styling (more precise is the German word "Gestaltung") with materials, to use them in industrial products which have not only a direct (use) function but also an aesthetic function. Here the materials mean the materials which are produced by the industrial mass production whereas the industrial design means the logical and aesthetic organization of the industrial material to fulfill a certain task. The development of the relationship between material and designer can been seen in the history that began with the industrial revolution.

At the end of the 18th and the beginning of the 19th century when the industrial revolution began, the relationship between industrial processing and the products it produced was at first dramatic change in society. Beginning in England, the traditional economy which was based on manual labor was replaced by that of industrial manufacturing. The steam power powered machines and metal machine tools made manufacturing possible in a much larger dimension. The scientific revolution and technical innovation in that time made it possible for the industry to produce new materials that fulfill the industrial production and to process material in an efficient way. The steam power invented by James Watt in 1776 helped the growth of mining and of the metallurgical industries in England. The application of steam power had a great impact, especially in spinning mills where previously the machinery worked by water power. This freed the factory from geographic restriction and allowed the mass manufacturing.

But mechanization does not mean good product design, quite the contrary was the case at the beginning of the industrial revolution in Europe, especially in England, where the traditional handcraft had a long history and strong influence on people's everyday life. The industrial products produced from a standardized mass production by the new machines had a bad reputation at first: low quality, no taste, boring. "*There was a continual sense also in England that mechanization had led to the loss of aesthetic standards in objects aimed at the mass market*" (Sparke 1987). William Morris criticized that the production process of the

industrial products at that time has separated themselves from the natural life of people. The conflict between industrial production and traditional craft and art was the main topic in that time in Europe. There were different attitudes to this argument. People like William Morris, A.W.Pugin and John Ruskin in England kept supporting traditional crafts and were against mass manufacture products. Other people in England, like Henry Cole, were relatively compromising, they accepted mechanization and industrial materials but emphasized ornament had the highest importance in design. Therefore they published books about ornaments to guide the people to the "right" taste of design. The architecture and products of this time represented the beginning of the modern industrial design[16] – the first attempt to find a harmonic relationship between the technical developments and the presentation of these new developments. On the one hand the new industrial materials and their processing made it possible to do a totally new construction and design: architects and designers were looking for new ways to make design (in the sense of engineering design) based on the new materials and processing. On the other hand they still had only the old handcraft way to represent these new technologies. This could be seen in the Great Exhibition of 1851 in London. The Crystal Palace, designed by Joseph Paxton, was totally constructed with iron and glass and was made of prefabricated standardized units. But the interior design of this architecture kept to the old Victorian style with overloaded ornaments. Here the designer and architects still tried to unify industrial technology and old taste.

Figure 4- 3 Crystal Palace by Joseph Paxton, 1851, London

On the other hand in Germany, Austria and France, the Art Nouveau movement had its big influence all over Europe between the second half of the 18th and the beginning of the 19th century. This was a movement in architecture and decorative arts which tried to achieve unification through different visual arts like painting, sculpturing, furniture making and architecture. The structure and decoration were united in cure lines which were inspired from nature or the human body. In different countries it had different names: 'Jugendstil' in Germany, 'Stile Liberty' in Italy, 'Sezessionstil' in Austria and 'Modern Style' in France. Art Nouveau did not negate the machine, as other movements such as the Arts and Crafts Movement, but used it to an advantage. For sculpturing the principle materials employed were glass and wrought iron, leading to a sculpturesque quality even in architecture (Wikipedia 2005). The natural form and style of Art Nouveau often led to a modification of its actual structure for example in architecture. This was actually against the principle of mechanical mass manufacture. But the search for a harmony between structure and decoration has a reference to the modern movement of later times. In addition, its influence on the society served as a social preparation for the later modern movement.

The proto-modernism was a transitional phase out of the Art Nouveau. Designers and architects like Henry van de Velde, Peter Behrens, C.R. Mackintosh, Josef Hoffmann, Otto Wagner and Adolf Loos in

[16] Industrial design at that time had not the same meaning as this concept has today. It meant more or less the artwork or decoration for the industrial product and inherited strongly from the handcrafts.

Europe and Louis Sullivan in the USA had led the movement to a further step. They accepted the mechanization, the industrial mass production, as the precondition for the design and architecture. Yet from the details of their designs and architectures there were still very strongly influence by Art Nouveau, but the whole structure and the materials had already shown the new style of geometric simplicity, engineering rationality and material purity. Otto Wagner wrote in his "Die Baukunst unserer Zeit":

> *"Jeder neue Stil ist allmählich aus dem früheren dadurch entstanden, dass neue Konstruktionen, neues Materiale, neue menschliche Aufgaben und Anschauungen eine Änderung oder Neubildung der bestehenden Formen erforderten. […] Alles modern Geschaffene muss dem neuen Materiale und den Anforderungen der Gegenwart entsprechen, wenn es zur modernen Menschheit passen soll, es muss unser eigenes besseres, demokratisches, selbstbewusstes, unser scharf denkendes Wesen veranschaulichen und den kolossalen technischen und wissenschaftlichen Errungenschaften sowie dem durchgehenden praktischen Zuge der Menschheit Rechnung tragen – Das ist doch selbstverständlich*[17] *(Wagner 1914: 30-39).*

Different architects had different interpretations on the idea that the form of design (architecture) should represent the modern context of time (the industrial context). Wagner's townsman Adolf Loos went much further in regard to the ornament of architecture. His idea that all ornaments without useful purpose are like a crime was expressed in his famous essay "Ornament and Crime":

> *"The path of culture is the path away from ornamentation towards the elimination of ornament. The evolution of culture is synonymous with the separation of the ornamental from the functional. The Papuan covers everything within his reach with decoration, from his face and body down to his bow and rowing boat. But today tattooing is a sign of degeneration and is only used by criminals or degenerate aristocrats. And the culture man finds, in contrast to Papuan negro, that an untattooed face is more attractive than a tattooed one, even if the tattooing were the work of Michelangelo or Kolo Moser himself, and man in nineteenth century wants to feel that not only his face, but also his suitcase, his dress, his household and his house are safe from the artistically trained latter-day Papuans. The Renaissance? We have reached further. Our temples are no longer painted blue, red, green and white, like Parthenon. No. we have learned to discover the beauty of bare stone."(Loos 1908: 120)*

Bauhaus School, a new architecture and design school founded by Walter Gropius in Weimer and later in Dessau, belongs to those institutions which tried to build the new relation between industry, technology and design. They took mechanization, mass production and standardization as the irresistible movement of civilization. The product design should take them as the precondition, and build a new aesthetic of industrial time.

> *"The aesthetic satisfaction of human soul is just as important as the material. Both find their counterpart in that unity which is life itself" (Gropius 1965: 24).*

Through the efforts of the pioneers of those times the industrial design had reached a new industrial aesthetics which was based on the function of the product and the industrial processing.

Through the Art Nouveau and proto-modernism the design movement to modernism got clearer and clearer. On the one side the mechanization and mass production went deeper and wider. New technology came forward faster and faster. On the other hand the traditional art and craft could not keep up with the technical development. The design had tried to find a way that technology and aesthetic were united in the products or architectures. The architects and designers like Peter Behrens, Walter Gropius, Mies van der Rohe began to look for the new form and design based on the industrial mass manufacture. The architecture by Walter Gropius also constructed with cast iron and glass, with a totally new form

[17] My English translation: "Every new style comes from the combination of the following important factors: the new constructions, new materials, new human needs and the new outlook of the existing forms. […] all the modern designs must adapt to the new materials and the new demands, if they are designed for the modern people, they should contribute to our new democratic, self-confident and sharp thinking, to our amazing achievements of technology and science as well as to our continuous practical movement of humanity – this is obvious!"

language: functional, rational and without any unnecessary ornament. This gave the world a new definition of industrial aesthetics (Figure 4-4).

Figure 4- 4 Bauhaus in Dessau by Walter Gropius, 1925-1926

> *"Those architectural works of today's pioneers show clearly, how the sense of form has developed hand by hand with the invention of new materials and new constructions, by which the engineer and the architect stand in the background along with the spirit of their time, which leads to the new technology consciously or unconsciously." (Gropius 1926: 159)*

New materials like steel and glass played an important role in the whole industry. The development of new materials in the USA occurred at first as the consequence of the expansion of the mass-manufacture-industry in the inter-war time. Many large companies had invested in the research for new materials. For example, Toledo Scale Company set up a special research apartment in a university in the late 1920s to develop the new plastic scale body. Ford Motor Company made its own steel and set up research on the pressing of steel and other pressing materials in the time between the 1920s and 1930s. The development of the pressing materials led to a new body-shell construction in product design.

Figure 4- 5 Left: C4 Stool and Table Set by Marcel Breuer, 1926; Right: Tubular steel chair MR 10, by Mies van der Rohe in 1927

New materials and new technology in material development also give designers new inspirations and possibilities for new product design. For example, the seamless tubular steel was a total new material in the 1930s, whose technique was at first developed by an inventor called Mannesman. It had the advantages of being light, strong and modern. But at that time as the tubular steel was produced in large

quantities by the industry, the use of this new material was mostly for the industrial construction. It was not well integrated as an important element in interior design. The furniture made of tubular steel is restricted to some kitchen sets or standard furniture in public spaces like in hospitals and churches. Inspired by this new material and its processing, many German and Dutch designers and architects at that time began to design furniture with a totally new form language. Famous examples are Marcel Breuer and Mies van der Rohe; both designed new chairs and desks with this material and created a new aesthetics for furniture design: light, elegant and modern (Sparke 1987).

While this modernism gradually got an important place in society, developing new modern materials was not only the task of scientists and engineers, but always also the inspiration and desire of designers and architects. On the one hand the new materials and technology tried to find the way to get used in the product and to get further acceptance in society. On the other hand the new materials and technology also gave designers and engineers new chances to solve the problem in product design, to help the designer with finding new design aesthetics. Used by designers and architects in the new products and architecture, the new industrial materials and technology also received their acceptance in society and played an important role in social culture. For example, plastic as new material came into the industry in the second half of the 20th century, strongly influencing the product design, especially in home electric appliances. The material plastic and its processing helped designers to get more freedom in the form making during the product development. Freeform and curves can be more easily constructed by molding. Earlier, the outer shape of the electric appliance was mostly decided by the inner structure. For example the first generation of household appliances was more or less functional equipment. Through the new processing the designer got more freedom in the design and style. And this helps the materials to be more and more used in products and therefore in the people's everyday life.

The property of the new materials and their processing are one side, the desire of the human's social life are the other side, both of which the designer has to face. Based on the existing materials and techniques the designer has to find the way to design products which can fulfill the human's life needs. To get out of the technical limits the designer has to know a material's properties and its processing methods quite well, and he has to cooperate with the engineer to help to finishing his product design from the very early concept to the end product by using the suitable material and processing methods.

Figure 4- 6 Planter, cocktail shaker and vase made of spun aluminum by Russel Wright, 1932

New materials have been developed from the industry as the technology progressed. With the new and better properties they can cut down the production costs, therefore the industry can produce cheaper and better consumer goods. For example aluminum was found by Sir Humphry Davy in 1808 as a metal similar to silver but very light, but it was only after the Frenchman Paul Héroult invented the Hall-Héroult electrolytic process in 1886 that extracting aluminum from minerals was economically acceptable.

Aluminum has properties like lightness, high resistance to corrosion, high thermal and electrical conductivity and a highly malleable form. These material properties give aluminum a large potential in utilization in comparison to steel or copper. From its most early usage as a conductive material in electronics, aluminum alloy has developed into a material family which can be found almost everywhere in the industry: construction material for aircraft and rockets; body-shell for the automobile; construction material and surface for furniture. This is not only the success of the material's scientists, but also of the effort of designers and engineers who bring aluminum into people's everyday life by using it in consumer and industrial products. It was said that the aluminum helped the new streamline style to be a most popular design in that time. Designers and architects who led the popular design trends on the other side likewise explored the utilization potential of aluminum. Russel Wright, one of the most famous industrial designers in the USA who worked with aluminum, extensively tried his design with spun aluminum. His commodity designs with aluminum are characterized by the elegance of the material aluminum and its special finishing techniques (Figure 4-6). In the modern time the progress in the research and production of the material aluminum has always been accompanied with new designs which have used this new technology development in different products. In transport design this developing line can be seen from the popular streamline-form in the time of 1930s and 40s in which material properties like cleanness, sleekness, novelty and its processing technology represented the spirit of the time: aerodynamics, speed, lightness, to the Audi A2 in 1999 – the first all aluminum passenger car. The same can be found in furniture design: from the beginning of Marcel Breuer's experiments on aluminum seating in 1930s to the most recent W.W stool from Philip Stark for Vitra in 1999 and Marc Newson's aluminum furniture series Orgone for Pod in 2000 (Figure 4-7).

Figure 4- 7 Chairs made of aluminum in different times: No.313 by Marcel Breuer in 1932-34 (left); W.W stool by Philip Starck in 1999 (middle) and Orgone Chair from Marc Newson in 2000 (right)

After years of efforts in the utilization of aluminum in product design and architecture, aluminum is nowadays one of the most useful metals in the world. If measured by quantity or value, the use of aluminum exceeds that of any other metal except iron. The annual primary production in 1999 was about 24 million tons and secondary - recycled - production reached some 7 million tons. The total of some 31 million tons can be compared to 14.1 million tons of copper, 6.0 million tons of lead and 0.2 million tons of tin (The International Aluminum Institute 2000).

The development of the relationship between designer and material after the industrial revolution represents first of all how technology in materials has influenced the designer in his design works and then also how designers respond to the new developments in material and find the new possibility in using them in their design, therefore also contributing to the development of the material technology[18]. A more relevant example for the material bamboo will be the following part which is concentrated on the history of the industrialization of wood and its relationship to the designer.

4.1.2. The influence of the industrialization on the using of natural materials: wood

[18] A deeper study on the relationship between technology and design in history can be found in literature like Spark (2004) with a general discussion on this topic, Meikle (1995) and Nichols (2000) which focus on how the plastics and aluminium have changed the design and the social culture in history.

material as an example

Similar to bamboo wood could be one of the oldest material human beings have ever used in history. During the industrialization wood has also undergone revolutionary changes – from a natural material to an industrial material. Actually the industrialization process of bamboo has learned a lot from the wood industry because of the similarity in the material properties of wood and bamboo. But the structural difference of bamboo and wood, as discussed in 3.3.1, reveals that copying from the industrial processing of wood to that of bamboo is not a appropriate way for using material ("materialgerecht" in German) and therefore can not really help bamboo to enter the industrial world. Furthermore, the most common uses of industrialized bamboo material are just as a substitute of wood material because bamboo grows faster and cheaper. This situation of bamboo in the modern society is far away that of the pre-industrial era in which bamboo has developed into a cultural being found everywhere in people's daily life.

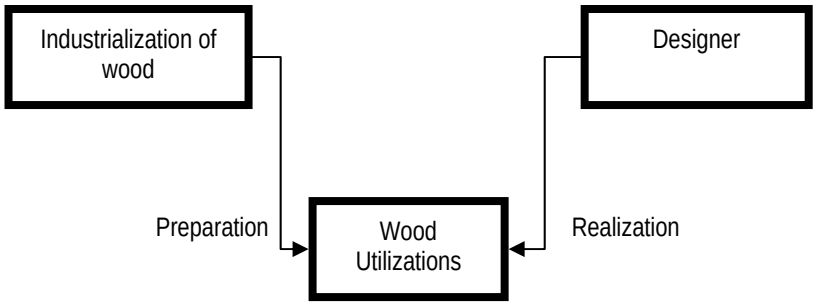


Figure 4- 8 The industrialization of wood and wood design

But on the other side, the history of the industrialization of wood could work as an example of how successful a natural material could be in the industrial world. For bamboo, wood can teach a lesson not only on the industrialization methods, but more on the whole process from a material to a useful end product in the people's life and then in the end build its own identity in everyday culture in the industrial society. This process could also be divided into two phases: the industrialization of wood material and the use of the industrialized wood materials (products) in the design (Figure 4-8).

4.1.2.1. The Industrialization of wood as the preparation for the design with wood

As discussed in 3.2.2 the industrialization of wood could be found in two fields: the one is the mechanization of the working process, namely the use of machines in the processing of wood, to reach a high efficiency of the work and to give the wood products a more stable quality and a low price. The second is the diverse kinds of engineered wood products, which compared to the natural wood material, are improved in the material properties through the new structural arrangements. Some of the industrial wood products and their processing methods have been invented and developed by carpenters long before industrialization. What the industrialization has done is to automate and mechanize the working process, which allows a large production dimension. For example the oldest plywood had been found in ancient Egypt in about 2000 BC. In the pre-industrial time expensive woods veneer had already been used by carpenters for the decorative furniture surface making. Through the industrialization this technique could be combined with the mass production and was used to produce industrial veneer wood products. For example the veneer was at first sawn by hand before the special circle saw had been invented. But the whole wood industry had not changed too much until the invention of the veneer husking machine in 1818 and the cutter machine in 1834 and their patenting.

The industrialization of wood as a material on the other side is the standardization of the wood. The standards like ASTM (American Society for Testing Materials) and DIN (Deutsches Institut für

Normung) define the wood materials according to their mechanical, physical and chemical properties. With such standards wood can be used like other industrial materials such as steel, aluminum or plastics in the industrial products. The industrial wood materials (products) determine how the working process and the relevant machines have to be, and its improved material properties provide a new potential for the designers to use them in their design, which will in return enhance the "natural" material wood to build its new identity along with the numerous artificial materials like steel, plastics or glass etc. in the modern industrial society, by the innovative use of the material in product design.

4.1.2.2. Design with industrial wood material

In the industrial time the different kinds of wood still keep their traditional uses in different fields after the industrialization; for example hard wood like white oak, because it is tough, strong and durable, is always highly regarded as the ideal material for shipbuilding, bridge, cooperage, barn timber, farm implement, railroad crosstie and flooring. Black Walnut is highly prized for its dark-colored true heartwood, has been used for gunstocks, furniture, flooring and a variety of other woodworking products. The soft wood-like Spruce is used for general construction work, crates and musical instruments. The industrialization makes it possible to use wood in a much wider manner in the industrial world. It changed the natural wood from its original form and properties into a standardized material which can be produced in mass production and therefore with low costs. Its standardized form and stable quality also makes designers use it in industrial product design, which demands that all the components should be standard and exchangeable in production.

Through the innovative utilizations of new industrial wood materials in design and architecture the designer could explore the new potentials of the materials and find the new "life form" of the materials in people's daily life. On the contrary this makes the material wood be more popular in modern society. Because wood as a natural material has its special material properties which differ to those of the artificial ones and also because it has had a long history in the people's life before the industrial revolution, it is important in the utilizations of industrial wood materials to keep the special material properties and its cultural aspects in the product design. This can be seen in different areas of wood utilizations.

Building houses and furniture could be the oldest use of wood. Based on the industrial wood processing and products, the utilizations of wood have been enormously wide-spread in the industrial time. Wood has its advantages like availability in many species, sizes, shapes and conditions to suit almost any demand, long durability and high performance in construction, good insulating properties against heat, sound and electricity, ability of absorbing and dissipating vibration (wood handbook 1999). The industrial wood-based products compensate natural woods with more features which are suitable for industrial utilizations. For the designers and architects the industrial wood-based products have almost all the properties for the modern industrial design and architecture: mass manufacture; standard format; stable mechanical properties; easy to shape by machines and to fasten with adhesives, nails, screws, bolts and dowels. Besides, compared to human-made industrial materials like steel, glass or concrete, wood always has the advantage of all natural products – a natural feeling. For these two advantages wood, one of the oldest materials in human history, always will be a modern material in the industrial society.

New product design and architecture are based on the new features of the industrial wood-based products have consistently crossed the limits of the utilization of wood. From the large wood structured engineer buildings to small wooden decorations. Through these design and architecture works the versatility of the wood material reaches an acceptance in the human's life. Only because the industrial wood-based materials have been used in the human's everyday life in forms of products or architecture, the industrialization of the traditional material wood has achieved its goal. Examples can be found in the history of the industrial wood furniture design, starting with the German entrepreneur Michael Thonet when he founded his furniture workshop in 1819 in Boppard and began to experiment with laminated and solid wood for producing innovative chairs. The result of these experiments was the chair No.14, one of the most successful industrially designed pieces of furniture ever. It consists of only 6 deformed

solid wooden parts, 10 bolts and 2 screw nuts – a simplified form which could be achieved by its mass-production: before the 2nd World War this chair had already been sold worldwide with more than 50 million pieces (Figure 4-9).

Figure 4- 9 Chair No. 14 made by Michael Thonet in 1859 (left); the mould for bending wood in Thonet (right) (ref. Thonet)

In Finland the designer and architect Alvar Aalto has worked with wood material all his life. After more than five years of experiments to master the technique of gluing the veneer and deforming the plywood, he began making his wood furniture out of plywood in the thirties. The innovative form and structure of chairs and stools made of plywood turned him into one of the most famous modern Scandinavian designers in the 20th century on the one side, on the other side made plywood a popular modern material for furniture design.

Figure 4- 10 Armchair 41"Paimio" (1931-32) by Alvar Aalto (ref. Reed 1998)

Another famous designer enthused in the industrial wood material is Charles Eames. Charles Eames became famous for his first chair design with plywood in the design competition "Organic Design in Home Furnishings", organized by the Museum of Modern Art in New York in 1940. He, together with Eero Saarinen and Ray Kaiser (later married to Charles Eames), won the prize with their revolutionary chair design with the new plywood technology. He developed and used the wood molding technology originally developed by Alvar Aalto to make the complex free curve of the chair. In 1942 Charles Eames and his wife Ray Eames signed a contract with the US Navy to develop splints and stretchers from

plywood because of the strength, lightness and ease of the deformation of the material. Subsequently Ray and Charles Eames had designed and produced their famous plywood chairs series in the time from 1942 to 1946, some of which has been exhibited in the Museum of Modern Art in New York. With the material plywood Charles and Ray Eames had explored the widest possibility of its utilizations in the sense of furniture design. About him Aicher has written:

> *"Not the material makes out the design. Just Charles Eames is an example for that: he uses not only the steel and plastics, but wood, many woods. A technical object is an organized object. It should be deformed….Charles Eames followed another principle than that of Rerrit Rietveld. Material was there for him to deform, not for sawing off, and the central topic of his technique is the joint…" (Aicher 1991: 64-65)*

Plywood in the eyes of Charles Eames is not only a material, but an unlimited possibility of form-changing, which in the pre-industrial time can commonly be reached through the knife of the craftsman, but now through industrial molding.

Figure 4- 11 Plywood chair WCL(left) and form experiment (right) by Charles Eames.

Through the efforts of many such designers, famous or not famous, plywood and other industrial wood products become one of the standard materials in modern furniture design. Despite the industrialization of the natural wood material made it possible for wood to be used much more in the industrial world due to its improved properties, still without the innovative use of the material by designers in their works, these technical improvements of the material could not really have made wood so widespread in people's daily life.

Figure 4- 12 Wood house constructions in North America

Wood used in architecture is even a larger field than furniture design. While in tropical places the wood tents or yurt count as the ancient forms of wood buildings, in North and Eastern Europe people had already used wood block construction to build houses at about 700 BC. This has been developed into the half-timbered building which can still be seen in many places in Northern Europe and North America. In the modern time the use of wood in architecture has also changed in many ways because of its industrialization. Building with wood is no longer just the job of the carpenter, but more often the work of architects. Industrial wood products have been widely used in architecture which leads to a standardization in the building industry and thereafter to a progress of the quality of the wood house and a descent of the costs. This could be between the end of the 18th century and the 19th century in the USA, where the architects and engineers had developed wood constructions and architecture into a highly modern and at the same time low-cost house style. Wood is one of most abundant resources in America and has a history of utilizations of more than 400 years when the first colonists came from Europe and brought the wood building techniques from England and other European countries. *Through the industrialization, the steam power began driving saws, planers, and sanders, wood became a purchased commodity. Carpenters lost their previous close connection to the forest, but they gained a cheaper and vaster supply of wood, much of it available ready-cut into the shapes, sizes, and components they needed* (National Building Museum 2001: 1)[19]. The old heavy timber construction methods which came from Europe then were transferred into the lighter and stronger 19th-century balloon frame and, ultimately, today's more refined platform frame. Steam-age machine processes also enabled a freer space in the stylistic diversity and various decorations of Victorian architecture. With the innovative, steam-powered woodworking machinery refined wood products and wood decorations became relatively cheap and available to more people. Industrial wood products like plywoods; particle boards and wood-simulating plastics, laminates, and other synthetics replace much of the solid wood pieces of previous centuries. During this period, Americans began to regard wood as an indicator of authenticity, quality, and refined character.

[19] Cited from the introduction of the exhibition "Wood: An American Tradition" organised by The National Building Museum from September 2000 to April 2001 in Washington. It showed how the technology has changed the utilization of wood in building in America.

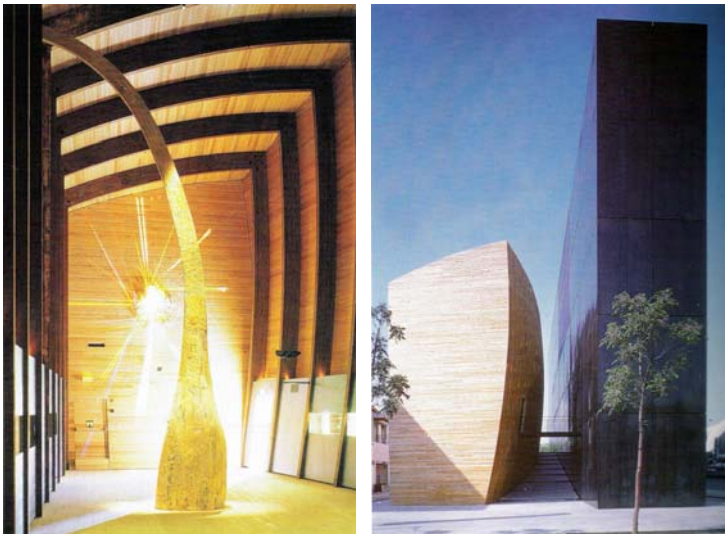


Figure 4- 13 Finnish Pavilion in Seville, Spain, 1992 by Juha Jääskeläinen, Juha Kaakko, Petri Rouhiainen, Matti Sanaksenaho, Jari Tirkkonen

Another example comes from Europe – the modern Scandinavian wood architecture. Buildings in Scandinavia have their tradition of using wood in construction. This began there in very early times because they had a very long winter time and huge forests full of pine trees and other trees. Warm and comfortable are still the most important factors wood material has , which the other industrial materials steel, glass and concrete are not supposed to have. Before the industrialization the log cabin construction was the most common method for building walls, whereas the roof was often constructed with reed grass. Although this kind of tradition has its evidence in Sweden and Denmark, it is only a very small part of all buildings nowadays. This is so for two reasons: one is the shortage of the natural wood sources and the other is the safety against fire. The modern industrial produced wood materials like plywood and wood veneer are used more and more in the buildings for construction because of their efficiency and versatility in construction. The new modern architecture has continued the wood tradition in a context of industrial production.

This has different reasons: traditional, economical as well as ecological and aesthetic ones. To reach the level of a special phenomenon in the world's modern architecture scene, this owed a lot to the pioneers of the modern architects and designers who tried to experiment on new industrial wood-based products in their architecture and constructions - from the first generation of modern architects like Alvar Alto in Finland to the new generation like Inger & Johannes Exner in Denmark and Biong&Biong and Niels Torp AS Arkitektre MNAL in Norway (Affentranger 1997). The architecture ranges from libraries like the Viipuri City Library by Alvar Aalto in 1930s (Reed 1998) to churches like the Lyng Church and Parish Center in Erritsø by Inger&Johannes Exner in 1990s. The material wood has been used as a dominant element in the form language and construction. One of the most influencing examples can be the Finnish Pavilion of the EXPO 1992 in Seville with the theme "Light, Tradition and Technology" (Figure 4-13). The pavilion consisted of two buildings, the "keel" and the "machine", and the narrow space between them. The "machine" is a 48-meter-long, 20-meter-high and 4.5-meter-wide steel constructed and steel plate covered box, representing "Technology", whereas the "Keel" is a 35-meter-long and 15-meter-high wooden building with a shape and construction similar to a boat. The huge supporting ribs made of plywood are like that of the typical rib structure of a wooden boat, and the wood plates covering the whole building also represent the cover techniques of boat construction. The inner space of the "Keel" also reminds of the traditional Finnish wood church interiors. The "Light" is created by the narrow space between the two buildings which represents the special character of the Nordic light. The whole pavilion is a good example of modern architecture, which represents the harmony between the old tradition, the modern technology and the geographic character of the country by using the materials and relevant constructions and form language. Through the efforts of the

designers and architects wood as a material has not only succeeded in keeping its important position in the Scandinavian's life, but goes further and has developed its importance in the culture there.

From the history of the utilization of wood man can see how the development technology of the material wood in the sense of both new industrial wood products and the processing methods has changed the design with wood, and how the designers have transferred these changes of technology into their designs and made new products (architectures) which exclusively represent the material's character. Because wood is also a natural material and even has a longer history with human beings, what happened with wood in the industrial time will give a closer insight into the utilization of bamboo in the industrial context.

4.1.3. Bamboo utilization system in the industrial context

After the general discussion of the relationship between material and designer and the special concern to the most closely related material wood, the study on bamboo's utilizations in the industrial context will begin with the specification of the bamboo utilization system with the time and user context (Figure 4-14). In the pre-industrial time, the craftsman was the person who used the material bamboo to make thousands of things to fulfill people's daily life needs, but which in the industrial time has ceased from the main role in the society. Generally it is the designer and also the engineer who connect materials and human needs in the industrial context. But for bamboo such a kind of broken relationship between material and human needs has not yet been reconstructed.

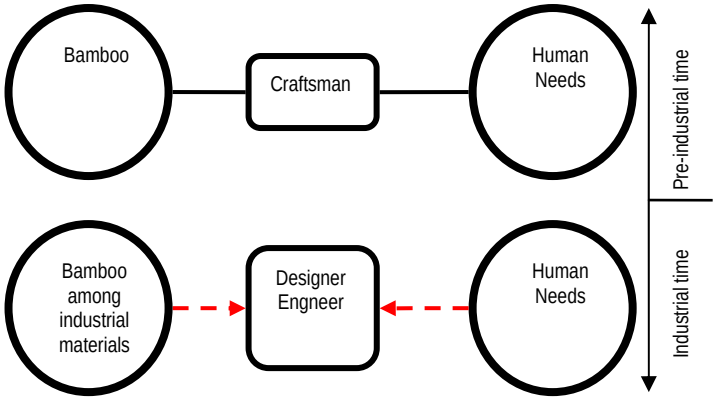


Figure 4- 14 Bamboo's utilization in different time contexts

In the industrial context, a designer who tries to fulfill the life needs by designing products will have to base his design on the industrial process, which means he has to choose the materials that are manufactured in industrial production and can be easily joined together with the other materials to be produced into an industrial product. If he wants to make a chair to fulfill the life need "sitting", he can choose many industrial materials like steel, plastic or engineered wood material other than bamboo. Which material the designer will decide depends upon many factors such as mechanical, chemical and physical properties of the materials; the processing methods of the material; the cost of the material etc. Even though bamboo has very good mechanical properties which attract designers and architects, the difficulties in using bamboo with other industrial materials frustrate them when they want to use bamboo in their works. When the Japanese architect Shigeru Ban, who is famous of his experiments on unusual materials in his designs, talked about the use of bamboo in modern architecture, he emphasized

> *"…Until then, I had not been much interested in bamboo, which has been used for many years in Asia and South America as building material. The reason was that no architect has succeeded in using bamboo as primary building structure in contemporary architecture, other than a Columbian architect Simon Velez who has poured concrete inside of bamboo tubes to make it a structural element. It is simply because nature of the material - its*

tendency to split when it is dry, and its random sizes and thickness, makes it difficult for the bamboo to be used structurally." (Ban 2002: 1).

The difficulty in using natural material bamboo has been investigated by the author during the 1st Chinese UNESCO-Creativity Workshop "Toys from Bamboo and other Materials" in Anji, China from 2nd to 16th March 2003 which was organized by the UNESCO organization 'Fördern durch Spielmittel e.V.' and the firm 'Happy Arts & Crafts'. About 20 designers and architects from 15 countries around the world have participated in this workshop which was aimed at designing toys for disabled children with on-site material bamboo. At the end of the workshop a questionnaire has been given to all the participants to collect information about the workshop in which three questions were designed to find out how much the designers know about the material bamboo:

1. Have you ever used bamboo in your design before? The reasons?
2. What can be the best way to use bamboo in your work?
3. What would you like to design with bamboo?

The answers from 20 participants differ from one to another, but they have something in common. The answers to the first question summarized in Table 4-1 can show the reason why designers and architects have not used bamboo in their design.

The answers (numbers of the answer)	Yes (7)	No (13)
The reasons	- cheap - beautiful out-looking - fast growing - easily transformable - eco-friendly	- No bamboo on-site - do not know how to treat it - the form is irregular - difficult to process by machines

Table 4- 1 The summary of a questionnaire on the question why the designer (architect) has (not) used bamboo as design material.

The lack of the material bamboo, the knowledge and the experience on it is the main reason for the lack of the design with bamboo. This could be explained from the other designers who have used bamboo in their design: for them bamboo is easy to get and the design works of bamboo are also rather crafts or artwork and less industrial products.

To help bamboo to be accepted in this industrial material utilization system, a proper reference of the structural and cultural aspects of bamboo is the key point. Only the "user" of the material who has appropriately understood the bamboo in the sense of its structural and cultural dimensions can really use bamboo in an adequate way. Designers should de-code bamboo's structure in a way that craftsmen in history had accomplished, only in the industrial context in which both the structural and cultural dimensions have new meanings. The aim of this chapter is also to help the designer to overcome the difficulty in building the new relationship between the material bamboo and the human needs in the industrial context. The disadvantages of bamboo's structural and cultural aspects will be taken as the breakthrough here and each of them can be generalized as two design principles from the material side and from the designer side (Figure 4-15).

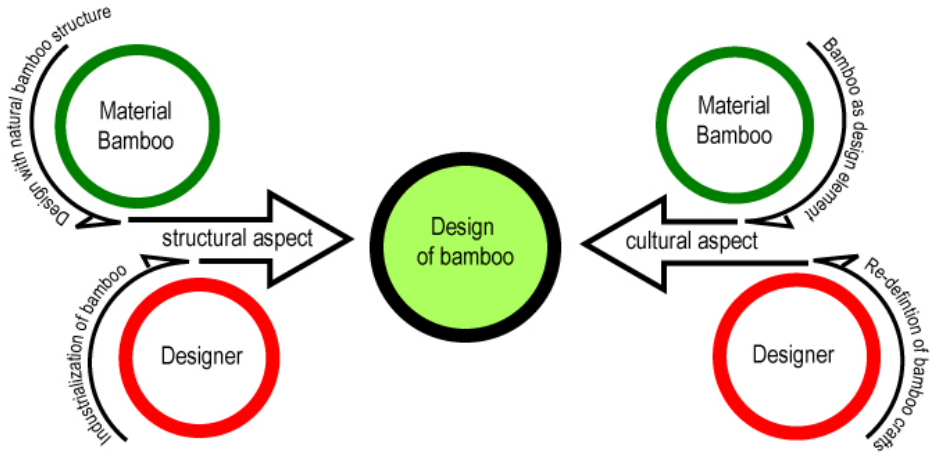


Figure 4- 15 Two different ways for finding the solutions with different references on structural and cultural aspects from different sides of material bamboo and designer

- **The structural aspect:**

The problem of bamboo's natural structure which has been regarded as the main hindrance for designer to use bamboo in their work can be industrialized from the material side, but could also be solved from the other side – the designer side as the challenge for him to design suitable constructions. Therefore the utilization of bamboo can be promoted from two directions:

From material side to designer side: the industrialization of bamboo is only the first step which has been discussed in the last chapter, but not the end of the process of using bamboo. It is just a preparation for the using and can lead to two results: one is that although the industrialized material bamboo has been produced by industrial process it lost the special properties of BAMBOO. Compared to other industrial materials these kinds of industrialized bamboo material will have no real advantage to be used in the end products. In other words, these industrial bamboo products will not really help bamboo to be used in the industrial world. Another result is that the industrialization of the bamboo material helps bamboo to be processed in the industrial process but lead to the loss of most of its advantages in the material properties in the end product, instead of enhancing the material characters of bamboo. That should be the real aim of the industrialization. After the industrialization of the material bamboo, the designers can use bamboo in different product design much easier and better. But after this preparation the industrial material bamboo should go further: it should be used. Only when industrialized bamboo material is appropriately used in the design which integrates bamboo's valuable material characters, it can be irreplaceable in the industrial society. Many designers and architects have already worked on this task and use industrialized bamboo material in their product designs and architectures. This is a hopeful light for bamboo's future in the modern industrial society.

From the designer side to material side: it is supposed to leave the bamboo's natural structure as a precondition for the design. Because bamboo has so many advantages in its natural tube structure – strength, lightness, elasticity and efficiency in construction, it is also meaningful to keep bamboo's original tube structure in the utilization system. The question is only how to find the way to integrate bamboo's natural structure into the outer industrial context, namely to join it with other industrial materials or components in the product design and manufacture. Because the tube structure of bamboo has irregular dimensions both in length and in circumference, it makes the design more difficult when it has to be connected to other materials. That should be a challenge for the industrial designer and the architect who are used to employ industrial standard material for their product design.

- **The cultural aspect**

Bamboo can be used in two ways: firstly bamboo itself as a wonderful plant . Its vital growth pattern, its elegant structure and its beautiful form have been highly praised and imprinted in the traditional culture in history as discussed in Chapter 2. These natural characters are nowadays still widely appreciated not only in Asia, Africa or Latin-America where bamboos are abundant, but also in Europe, where bamboos did not grow originally. In the history of culture the pure beauty of bamboo had fascinated artists, scholars and other intellectuals as well as common people, and so it does in the modern time. These features should be and also could be presented in the modern industrial world. Actually some modern designers and architects have begun to use these as a design element, as a form language in their design works. These works could be good examples to show how bamboo's cultural aspect can be used in the industrial world.

Secondly the bamboo crafts can be used, which means the traditional ways of using bamboo, the techniques and the ideas that had made bamboo change from a plant into thousands things used in people's everyday life. This kind of techniques is not just a technique but a traditional culture, like any other crafts which can be redefined in the industrial context in a way so that this can be kept and developed further.

4.1.4. Design principle I: Industrial prefabricated bamboo material as a preparation for designer and architect

For most industrial prefabricated bamboo materials as introduced in Chapter 3, bamboo's natural structure will be destroyed. For example in the production of ply bamboo the bamboo original tube structure will be split into pieces and then the surface layer from both outer and inner side will be cut away. The only useful part for bamboo board products is the middle part. The rest will be used as bamboo sandwich boards or more often just for fire. To assess these kinds of industrialization of bamboo not only 'good' or 'bad' can be used. It depends on what kinds of criteria are taken into account, under what context it is discussed. Although from the ecological point of view, which will be discussed in the next section, in this kind of industrialization the most important advantage of the bamboo structure is lost just because of the standardization, but if considering the economic context, the process could be a possible way for the people in developing countries to develop the economy there. By this way the bamboo can be used in producing industrially prefabricated material and thus get into the global economic cycle.

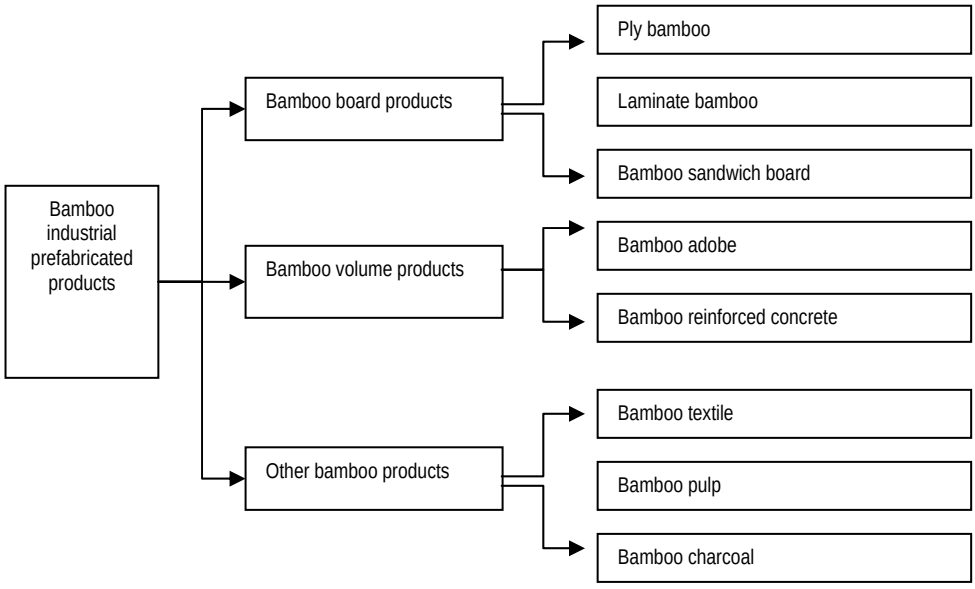


Figure 4- 16 Industrially prefabricated bamboo products

The question is how people use these industrially prefabricated materials further in consumer or capital goods. Just as an alternative or substitute for the hard woods products like floors or doors which have been shown in 3.3.2 will be not the real solution for bamboo in the industrial world. Finding the proper way to use industrial prefabricated bamboo products (material) in the product design and architecture should be the task of the designer and architect. On the one side the bamboo can express its structural advantages by a suitable usage in design and architecture; on the other side it is also the only way that the social culture can accept it in the modern industrial society.

Before one starts the discussion on which examples in design and architecture can show how to use bamboo (industrially prefabricated) in the different and proper ways in the industrial society, the industrially prefabricated bamboo products could be summed up as done in Figure 4-16. These products can be divided into three groups. The most common products found in the market are board products (Zhang 2001). Compared to wood board products like plywood, the processing is similar but the mechanical features are different. It was reported that glued laminate bamboo board for example has better physical properties like moisture contents, better surface hardness and anti-nicking property than those of the wood board products like MDF, solid wood board from soft and hard wood (Wang et al 2003). For this report the glued laminate bamboo board is used for molding, which is used as an industrial structure element for interior building and usually made of softwoods and hardwoods. Glued laminate bamboo for molding is a way to solve the problem of the worldwide shortage of timber resource.

This is up to now what happens with bamboo prefabricated products – they are used in the end products too close after prefabricated wood-based products. It is not bad that they are used as an alternative to wood products because bamboo grows so fast and wood shortage is so serious. But rather than destroying the bamboo's original structure which is so perfectly developed in nature, we should use it in a way that all its advantages like hardness, elasticity, lightness and its beauty should be presented in the end products. This will be discussed through the following examples.

4.1.4.1. Product design with industrial bamboo material

- **Bogner Bamboo Ski**

The ski is a very popular sporting device nowadays. It was originally designed to help people walking (sliding) on the snow surface. Through the long ski surface for both feet that people wear they are able not to sink into the snow, and because of the pressure and the friction between the ski plate and the snow surface, the snow will melt directly under the ski, which creates a very thin layer of water directly under the ski upon which the ski glides.

Figure 4- 17 Bogner Ski by Schwabe & Baer Entwicklungs GmbH, 2005 (ref. Schwabe & Baer Entwicklungs GmbH)

For skis the materials should be light, strong and elastic. Skis were originally wooden planks made from a single piece of wood. They are now usually made from a complex assembly of components including fiber, Kevlar, Titanium or composite materials, though many may still contain a wooden core. But the so called high-tech materials which scientists and engineers try to invent in the laboratory are already there

in nature – bamboo. Bamboo has almost all the features required for skis. Through the laminate technique bamboo can be turned into a plain surface without losing its advantages.

The first bamboo skis have been developed by INDIGO (Schwabe & Baer Entwicklungs GmbH) for the company BOGNER. The surface of the ski is made of laminate bamboo board (Figure 4-17). The core is made of bamboo-titanium (or bamboo-glass) sandwich material. The bamboo material not only fulfills all the tough technical demands like all the other high-tech materials, but also gives the product a very special natural appearance. The use of laminate bamboo combined with titanium and synthetic material (nano high-speed stone ground for the basement) show the world a totally new impression of bamboo as a material in the modern world.

Figure 4- 18 Bogner Snowsports Helmet by Schwabe & Baer Entwicklungs GmbH , 2005 (ref. Schwabe & Baer Entwicklungs GmbH)

The Bogner Snowsports Helmet matching the Bogner Bamboo Ski also used laminate bamboo as the structural element to get a high load resistance and lightness which are very important for protecting sportsmen (Figure 4-18). Laminate bamboo also shows the excellent deforming ability here. It is produced in a monocoque-inmold-process, outer shell and shock absorbing inner shell are jointed to an inseparable component. This creates a lightweight as well as an extremely solid composite. Side frames are made of 3D molded multilayer bamboo material (Schwabe & Baer Entwicklungs GmbH 2006).

The company Schwabe & Baer Entwicklungs GmbH stills developes snowboards made of laminate bamboo with the brand Indigo. From these products which are normally associated with modern, high-tech and fashion, the suitable uses of bamboo material in form of laminate bamboo board and bamboo-titanium or bamboo-glass sandwich board create a new picture of modern bamboo utilization: Natural high-tech. Here it is not "the material for poor people", but on the contrary, it is a valuable material for the modern people.

- **Bamboo furniture by Michael McDonough**

Michael McDonough is one of the first modern architects and designers who tried to use engineered bamboo board in their designs. Like other designers he is also fascinated by bamboo's fast growth, natural beauty and excellent material properties since he encountered bamboo in 1995. The sustainability of the material convinced him that bamboo could be the material for the future (Moed 1998). After his three years of research in possibilities of the bamboo material in product design he designed a series commercial bamboo furniture in 1998 – laminated bamboo chairs and tables. In his bamboo design one can see the potential of industrial prefabricated bamboo material in the modern furniture design.

In his bamboo chair he explored the deforming ability of laminated bamboo by using a chaste line structure – two fluent curves of bamboo strips go from the ground of the back leg to the armrest and the backrest, joined by horizontal bamboo slats. The table has special bell-shape legs for the support of the table plate. This was inspired by the unusual growth pattern "tortoise" that appears in some bamboo

species, and the laminated surface of the table shows the bamboo's naturally variegated color (Moed 1998).

Figure 4- 19 Laminated Bamboo Furniture designed by Michael McDonough in 1998 (ref. Roy Wright)

His laminated bamboo furniture designs have brought a new styling language to the traditional material bamboo. As a demonstration they have presented that the industrialized bamboo material can be well integrated in modern design.

- **Bamboo furniture design by Adapt Design**

Adapt Design is an Oakland based sustainable design company which devotes themselves to furniture design exclusively using the material bamboo, exactly from engineered ply bamboo. They use bamboo's material properties like: beautiful, enduring, light, ecological and sustainable in a modern and chaste form.

Their furniture designs from ply bamboo present a high deforming ability of the material. For example the design Spring Chair consists of a piece of ply bamboo board as the constructional element as well as the functional element. For bamboo's material strength and flexibility the design reduces the material and structure to an extreme degree, but at the same time reaches the ergonomic requirement of sitting. As a whole the Spring Chair has built a modern aesthetic of the traditional material bamboo.

Figure 4- 20 Bamboo Furniture "Spring Chair" and "Becca Stool" by Adapt Design, 2004 (ref. Adapt Design)

Another example by Adapt Design is the Becca Stool which won the OrganicAWARD by OrganicArchitecture in 2004. The design was decorated with the award because it has "pushed the limits

of imagination and dedication of ideas towards sustainability" (OrganicArchitecture 2004)[20]. The bamboo's material flexibility and strength are used in a simple form and construction. The design has its form inspiration from the traditional Japanese style and has interpreted it in the modern style of life. Its functional flexibility coincides with the bamboo material flexibility: it is adaptive to different using conditions: it can be used for seating like stools; as well as for storage like side-tables; it can be stacked together to build a shelf. Similar like the Spring Chair the Becca Stool has integrated its construction in the form and simplified the material and the form to get a harmony of the bamboo's special features in material and aesthetic and the design.

- **Bamboo-House Project between Finland and Japan**

The project "Bamboo House" was done to build a cooperation between the modern Finish designers and the Japanese city Hagi by using the material bamboo in the modern house. As a traditional material, bamboo has been used in Japan for a long time before the industrialization. Six young Finish designers chose this traditional material bamboo in totally modern designs as household objects or spatial elements which will be produced later in the city Hagi. In the end the bamboo objects were exhibited in a Bamboo House in Hagi in 2003 which is simply constructed with laminated bamboo and bamboo textile.[21]

Figure 4- 21 Divan bed "spring" by Krista Kosonen (left) and bamboo trivet "Kantava" by Mikko Paakkanen (right)

The result of the project was 10 objects made of bamboo, each of whom represented a combination of the material bamboo and modern life style. The special material characters of bamboo have been studied by the designers and later interpreted into diverse design objects to show nature of bamboo from its original shape to a more refined form. For example the "Spring", a divan bed made of laminate bamboo, was designed by Krista Kosonen who concentrates on the essential feature of the bamboo material in which the flexibility of the reed and the strength of the fiber are specially considered. And the "Kantava" designed by Mikko Paakkanen is a series of tables, chairs and trivets in which the structural and visual unique properties of bamboo have been integrated into the products. The combination of bamboo and other material like metal represents both the natural beauty of bamboo and the industrial precision of the processing. The products can be manufactured industrially and the dismountable leg structure minimizes transportation costs.

4.1.4.2. Architecture design with industrial bamboo material

Industrialized bamboo products have been used at first as replacements of relevant wood products in building constructions and other functional elements like floor boards and door boards because bamboo

[20] OrganicAWARD is one of the research activities run by the firm OrganicArchitecture in San Francisco, USA, to recognize sustainable design and architecture. More information about the firm OrganicArchitecture and the OrganicAWARD on the internet: http://www.organicarchitect.com/

[21] The more detailed description of the project and other furniture and product designs with bamboo can be found on the internet: http://www.bamboohouseproject.com/house/house1.htm.

is relatively easy to get and cheaper in price, as discussed in Chapter 3. In these kinds of uses bamboo loses its structural advantages and also its cultural identity in the modern world. To find bamboo's own personality in architecture and design, some architects and designers began to use the industrialized bamboo products in their design works, in which the special characters of the industrial bamboo material have been innovatively represented.

- **Bamboo roof by Shigeru Ban**

Shigeru Ban is famous for his innovative experiments on materials in architecture and furniture design. He has tried to use materials like cardboard tubes, paper and bamboo for construction and design which are commonly not supposed to be used in architecture. The first time he tried the material paper tubes in construction was in 1986 when he designed a display for an exhibition of Alvar Aalto. Because of budget shortage he had to give up using wood as the material for design. This had given him a chance to experiment using paper tubes in construction. The unconventional materials like paper tubes used in Ban's architecture show a large potential not only for construction but also due to their beauty of form – the lightness of the space; the efficiency in construction. Furthermore the materials are 100% recyclable.

Ban has tried natural bamboo tube as material for building in his earlier time but gave up, because of natural bamboo tube's irregular dimension and the difficulty in connection. This was also one of the reasons why he changed to the paper tube – an industrial recyclable material. It has the similar structure to bamboo cane but can be fabricated by industrial processing methods and thus has standard dimensions and homogeneous mechanical features. It can therefore be worked with mechanical methods like drilling, gluing and can be easily joined with other construction components like bolts or nails. In his works like the paper house 1995 in Yamanashi and the Japan pavilion in Hanover in 2000 he used paper tubes as the main construction material.

Figure 4- 22 Bamboo Roof at Rice University in Houston, USA, 2002/03, Shigeru Ban Architects (ref. Shigeru Ban Architects)

But bamboo is not out of his choice as construction material in his design. Other than natural bamboo cane he chose industrial prefabricated bamboo products like laminate bamboo boards and laminated bamboo mat boards. Both show Ban's special ability of using unconventional material in building. With the laminate bamboo board he has designed a roof construction for Rice Gallery at Rice University in Houston USA in 2002/2003. Laminate bamboo boards are commonly supposed to be used as flooring boards by the producers.

But laminate bamboo board for flooring is not the limit for bamboo. Compared to wood floors the only advantage is the hard surface of the material. The flexibility, lightness and load resistant have no way to

show in such kind of utilization. This has been changed by the Ban's experiment of using laminate bamboo for the roof construction. In his design the laminate bamboo board used in construction has to support the weight of the roof and the other loads from the wind or snow. Besides it has a special beauty in its material and construction. As the laminate bamboo board has its relatively homogenous mechanical features and standard form, Ban does not face the problems which the natural bamboo cane has. The roof structure is supported by columns which are composed by bundles of steel poles. The idea to use bundled steel poles as columns for supporting the roof comes originally from ancient China where the farmers grow and harvest the bamboo logs (McQuaid 2005)[22].

- **Madrid Barajas Airport**

The Madrid Barajas Airport was an international competition project which was initiated by the Spanish National Airport Authority (AENA) in 1996 to build a new airport with a capacity of 65-70 million passengers every year and 1.2 million square meters of building area. The team of Richard Rogers Partnership (RRP), Spanish practice Estudio Lamela and two engineering companies TPS and Initec have won the competition for the simplicity, adaptability and flexibility of their concept.

Figure 4- 23 Bamboo Roofs in the Madrid Barajas Airport by Richard Rogers Partnership and Estudio Lamela, 2006 (ref. Amparo Garrido and Richard Bryant/arcaid.co.uk)

Here bamboo as a construction material is not only important for the structure but also for the definition of the space and the atmosphere. The design of RRP concentrates on improving the experience of the passengers in the airport, on creating a peaceful atmosphere and to help passengers to get in easily and efficiently. The straight forwards linear diagrams and a clear progression of the space for departing and arriving passengers and baggage facilities are to help the passengers to orient themselves easily and efficiently. The wavy roofs are not only a form language but also as help in defining the space. Laminated bamboo board in a strip format can fulfill the organic construction perfectly – it is elastic, light and load resistant.

One of the most important factors of the concept is the special light concept. To maximize the use of natural light they designed a series of light-filled "Canyons" to bring the natural light into the lower levels of the building. The "Canyons" are spectacular full height spaces, spanned by bridges in which arriving and departing passengers, though separated, can share the impact of the impressive space (Richard Rogers Partnership 2005). Because of its bright color and natural texture bamboo gives the whole interior of the building a warm and bright atmosphere.

[22] This project contributed as a prototype for a permanent pavilion in Forest Park, St. Louis which is still under development, through which the bamboo could be recognized at a large scale by the public as a modern construction material with a special aesthetic value (Ban 2002)

Together with the "Canyons" the wavy bamboo roofs create spectacular rhythms of light. The head project manager of Richard Rogers Partnership, Simon Smithson, considers these special light rhythms as a way to slow down the perception of the airport experience to a human pace because they allow travelers to pause for a moment to bask in natural light (Grossman 2006).

- **Bamboo Furniture House by Shigeru Ban**

Another architecture designed by Shigeru Ban is the Bamboo Furniture House which was one of the 12 architectures in the project called "Commune by the Great Wall". In this project the Chinese company Soho invited 12 famous modern Asian architects to design 12 houses in the mountain side of the Great Wall near Beijing. Shigeru Ban was one of the architects who enrolled in this project.

Figure 4- 24 Bamboo Furniture House, Great Wall at Shui Guan, China, 2002, Shigeru Ban Architects (ref. Soho China)

His first idea was to design a one-story house surrounding a quiet courtyard which is much like the vernacular style of Chinese houses. In examining the local materials which are special for China he found the laminate woven bamboo mat which is normally used for the concrete framework. He got the sample of laminated woven bamboo mat and did boiling and bending tests, whose results showed that bamboo material had the structural strength between steel and timbers. Because of the limited budget he decided to use the furniture as the construction element. This idea he has developed for his other two projects: Furniture House 1, Yamanashi, Japan, 1995 and Furniture House 2, Kanagawa, Japan, 1996, in which pre-produced furniture units served newly not only as construction elements but also for space-defining.

The laminated bamboo lumber has been fabricated as the standard structure unit for the furniture like wardrobe, bookshelf and further on the furniture is used for the construction and space definition like the function of conventional walls. The laminated bamboo mat has been redefined as the modern building material with the special beauty of its surface texture, other than just for concrete framework. Here Bamboo proved again that it is not the "material for the poor".

4.1.4.3. Summary

Through these modern designs and architectures the industrially fabricated bamboo products have been used not only as an alternative to engineered wood products in which bamboo has somehow solved the problem of the increasing shortage of the resource timber, but more important it has shown its special material characters as well as its aesthetic features. As natural materials which have been processed by the industry, the industrially prefabricated bamboo products show a combination of both sides: the strong and beautiful structure and the familiarity to human being (as human being is still a product of nature) on

the one side, on the other side the standard and precise dimension of the material after the industrialization which makes it easier for the designer to use it in his design works.

Even if during the standardization the bamboo material has lost its structural advantages in a certain degree, it still compensates this kind of losses by a wider utilization of the material in the modern industrial society through the appropriate designs with the industrialized bamboo material. Through these modern works Bamboo can have its new life-form which totally differs from those bamboo crafts in the history. By using the products and living in the architecture the people can see, feel and experience the material bamboo along with other industrial materials like steel, cement, plastics and woods and so on in the modern life in a totally new industrial context, other than with conventional bamboo's uses in the handcraft context. Through these modern life-forms, Bamboo is now one part of people's everyday life in the modern industrial world.

4.1.5. Design principle II: The natural structure of bamboo as a challenge for designers and architects

On the one side bamboo can be processed into industrially pre-fabricated material (products), and then can be further used in the product design and architecture. On the other bamboo is a material which has already built its own structure during its natural growth, an efficient structure which has been optimized during the millions years of evolution.

For a long time since the industrial revolution the human being has robbed all the resources from nature for the industry and the economic development without regarding the future. If taking nature as a resource supplier, all the natural resources like mineral materials such as iron ore, water and crude oil also need a natural generation process before they are used in the mankind's capital development. In their book "Natural Capitalism" Hawken and Lovins argued that the natural capital, made up of resources, living systems, and ecosystem services, along with the other three types of capitals, namely the human capital, the financial capital and the manufactured capital plays a fundamental role in the economic system. For a future-oriented economic development the resource productivity of natural capital, also called eco-efficiency, is not only important but fateful (Hawken et al 1999)[23].

As discussed in Chapter 3.3.1 the research in the Institute for Lightweight Structures (Institut für Leichte Flächentragwerke) at the University Stuttgart has used *BIC* to measure the structure efficiency in different materials and constructions. The bamboo has the lowest value of *BIC* in tension compared to wood, steel and aluminum. That shows bamboo is already an efficient structure in construction. That's also why mankind has used such an excellent natural material for thousands of years since the beginning of civilization.

This elegant material with its excellent structure should be treasured when it is used by human beings. For its own special structure the material bamboo is different to those of human-made materials like steel, glass or aluminum. These human-made materials are easy to process, to deform, to reconstruct and therefore to standardize. They can easily be joined with other materials. This ability of joining with other components is very important for a material to be used in the industrial production process. Even another natural material, wood, which has little special structure through the industrialization, has been changed into several forms of industrial products, therefore can be well used in the industry.

[23] In the book "Natural Capitalism" the authors describe the new trends and reforms in the environment economics in which the use of the natural resources will be more efficient and the waste of the production will be reduced – a sustainable strategy for the human development nowadays. The book shows not only scientific studies on the topic sustainable development, but also the changes in the postmodern social culture which provides my study with useful information about the postmodern society. The whole book can be found on the internet: http://www.natcap.org/

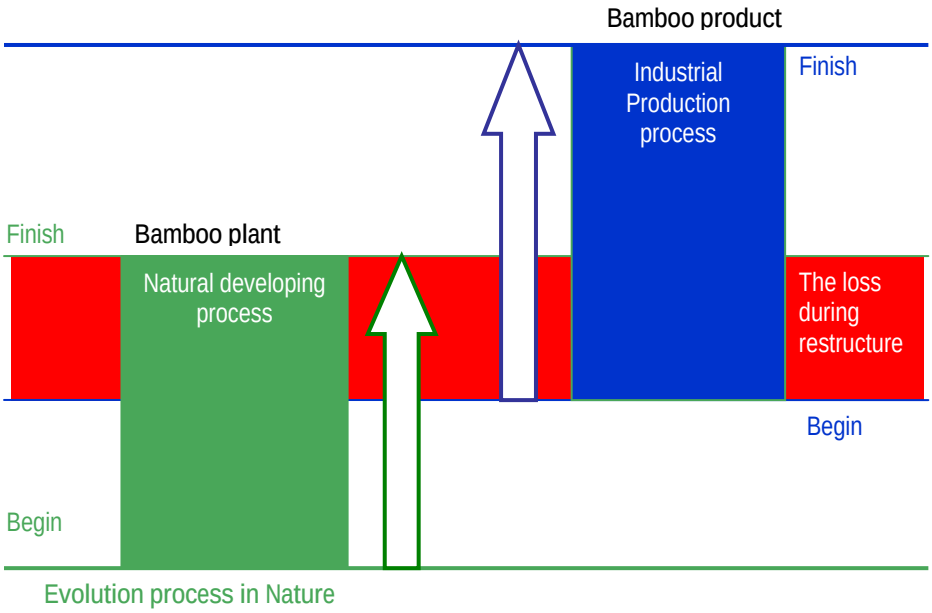


Figure 4- 25 The evolution process of natural material and the developing process of industrial product

For this reason one has tried to industrialize bamboo in diverse forms. The process of bamboo from the beginning as a plant in nature to the end as a product in the industry could be illustrated as in Figure 4-25. Through the evolution process in nature bamboo has already developed into an elegant structure, which in the human utilization still has to be re-structured to fit the industrial production. The industrialization of the bamboo material changed it somehow like wood to be fabricated as engineered bamboo products and therefore could be much more widely used in product design and architecture. But the process has its cost: the loss of the bamboo's own structure, which is one of the most important advantages of bamboo. To keep as much of bamboo's natural structure in the utilization in the modern society as possible is the goal of this section.

4.1.5.1. Bamboo joint: between the natural structure and the industrial environments

Industrial design from its beginning was the product development which is based on the industrial mass production. The task of industrial design is to use all the industrial methods (materials, processing, production and recycling) to establish the multi-faceted qualities of objects, processes, services and their systems in whole life-cycles (International Council of Societies of Industrial Design). In this narrow sense of industrial design it is difficult to include bamboo in the design process, if the natural bamboo structure has not been changed into a standard form of some kind. But in a larger sense design can be defined as activities of solution finding for problems in our industrial society, to build a harmonious relationship among all factors in a problem-system. Here the search for a better utilization of bamboo is the task of the design.

In the bamboo utilization system, one side of the material-designer relationship – the material side – has been discussed in Section 4.1.4. Through the industrialization of the bamboo the material design with bamboo can help bamboo to be easier utilized in the industrial society. It is now seen from the other side of the relation of the material bamboo and industrial design, in which the natural bamboo structure as a precondition of the system, that the task is to find and re-define the utilization's condition to accept the bamboo as a natural structure as much as possible and use this structure in the people's modern everyday lives. This can be described as the following mathematic function:

Bamboo Utilization Function $Y = maximum\ f(x_1, x_2, x_3 \ldots)$

With precondition $x_1=a$ (x_1 is bamboo's own structure; a is a constant)

How can bamboo's natural structure be used as much as possible, even its irregular dimension and the difficulty in joining with other elements by industrial standard methods, in the product design and architecture other than conventional handcraft but in the industrial context is a challenge for designers and architects. All the materials, from nature or industry, have to be included in the "using field" if they are to be used in this place. They have to be treated into a functional structural element and joined with other parts which are made of different materials into a whole functional system.

The thousands of years of bamboo's utilizations in those non-industrial fields show mature techniques at this point. Bamboo building elements can be joined very well with each other as well as other materials like wood or rattans. The diverse traditional processing methods mentioned in Chapter 3 let bamboo cane be drilled, be cut, be warm or cold bent at the joining points so that it could be joined together better. All these traditional treatments are handcraft. This means the handicraftsman has to treat each joint differently according to the dimensions of the different bamboo canes. This is difficult for the industrial processing which asks for all the structural components being standardized so that both the production of the components and the assembling of them can be mechanized to fit the mass production.

Figure 4- 26 Some bamboo connections

The joint is the key point for natural bamboo material to be used in the industrial environments. The principle of the bamboo joint in the industrial context is illustrated in Figures 4-27 and 4-28. To develop a new kind of structure (joint) to help bamboo's irregular canes to be joined with each other and with other standardized components (materials) is the most important aim of this chapter. After this it is then possible to design products and architectures with natural bamboo material.

Designers and architects all around the world have done research on this topic. They have tried to use different kinds of industrial materials as the joining elements which accept the irregular dimension of bamboo as much as possible and join them together as a function system. On the other side these industrial joints provide a standard regular surface for joining other industrial materials together to build a larger function system.

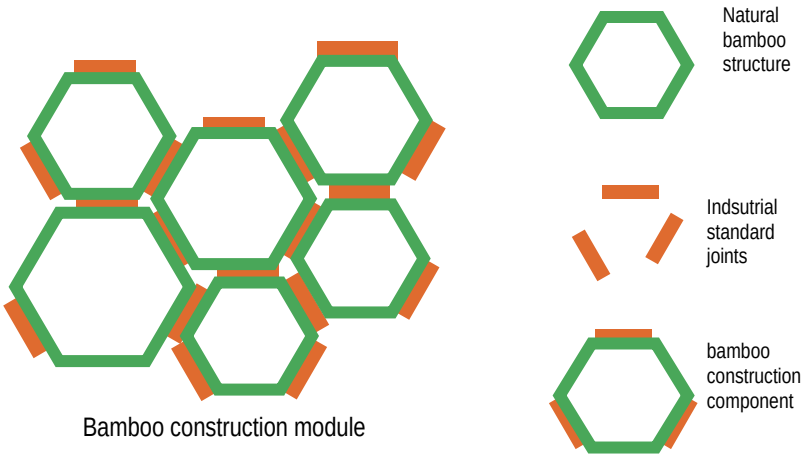


Figure 4- 27 Principle model I of bamboo construction system

As discussed in the last chapter the different researchers tried in different ways from different points of views. All of them together give a large contribution to the development of the utilizations of natural bamboo structure in the industrial environments, and help bamboo's natural advantages to be used to its full degree. Their efforts always inspire the other researchers to do their research on a higher level and push the limit of the bamboo utilization to a higher position.

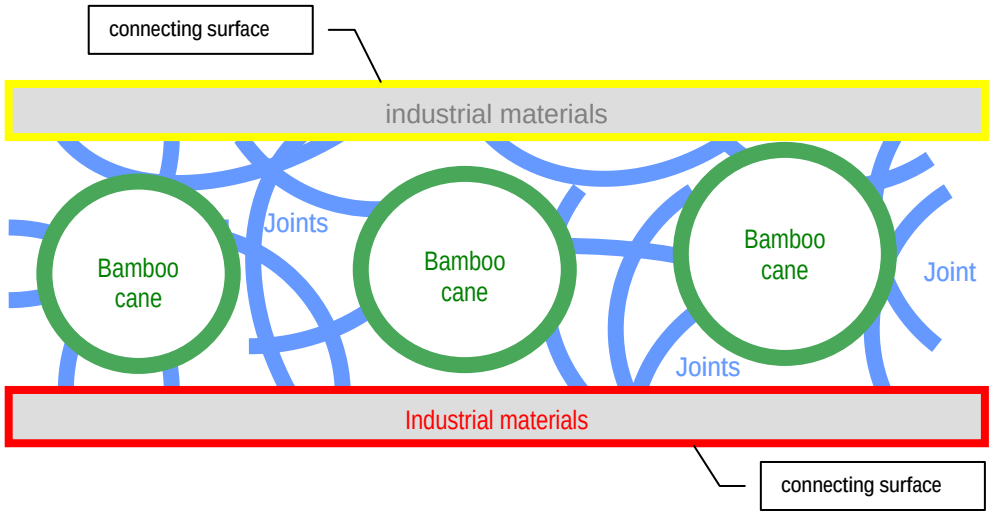


Figure 4- 28 Principle model II of bamboo construction system

4.1.5.2. Lightweight Structure: Bamboo experiment in lightweight construction

For its strength, elasticity and lightness there has been done several researches in Europe which is the only continent where bamboos do not natively come from. In Germany several universities and institutes have begun experiments on bamboo constructions since the 80s. This happened at first in the Institute for Lightweight Structures (IL) at the University of Stuttgart during the time when the research teams under the leading of Frei Otto did their researches on the lightweight structures. Bamboo, as one of the excellent lightweight structures (materials) from nature, attracted their attention, especially in the building structure. They experimented on the material properties as well as lightweight construction with bamboo

canes. The other scientists in Germany followed the principle of the IL and did their experiments in different universities or institutes.

Other than the researches in bamboo abundant countries in South America like Columbia, Mexico and Brazil, where the researchers have their orientation more on the practice, the researches in Germany concentrate much on the scientific meaning of the bamboo construction. They explore the possibility of how the advantages of bamboo material can be fully used in the construction. That is also why the researches at first came from the Institute of Lightweight Structure in University of Stuttgart. Because the institute has its research emphasis on the lightweight structures, the materials that accord to the lightweight principle will then be considered. The research on bamboo at that time also partly belongs to the several special research projects of the 'Deutsche Forschungsgemeinschaft' in IL (Sonderforschungsbereich 64 "Weitgespannte Flächentragwerke", Sonder-forschungsbereich 230 "Natürliche Konstruktionen – Leichtbau in Architektur und Natur").

Eda Schaur used the light weight construction principle in her research project in IL when she worked as a researcher there and together with the architecture students in the School of Architecture of Ahmedabad in India she tries several lightweight construction prototypes with bamboo. The aim of the research is try to explore the potential of split bamboo in the grid shell structure building. Testing on the grid shell structure was done to exam the mechanical properties of the structure. They concentrated the research on the whole bamboo structure and tried the bamboo grid shell construction with a 1:5 model. The connection of the bamboo was not the focus. They used the traditional handcraft methods with ropes which proved to be good enough for their experiments (Schaur 1985).

This was somehow different to the research of Bernd Baier in FH Aachen. For him and his students the aim of the bamboo construction research was to solve a social problem in the developing countries where many earthquakes happen and bamboos are abundant: to develop earthquake-resistant and cheap structures for them with bamboo which are easy to process and to assemble.

Figure 4- 29 Bamboo grid shell structure by Baier in Aachen

Bamboo has its advantages especially in tensile and compressive strength, but is also very light and grows fast and therefore is easy to get. The grid shell structure keeps its structural elements mostly under tensile and compressive stress, which has its advantage in earthquake resisting when compared to traditional a roof structure which has relatively fixed purlins, rafters or battens and is mainly under bending stress. So the combination of both was the concept of the experiment.

For this purpose they built a bamboo grid shell roof structure of 6x6 m large and 50 cm grid sectors and a bamboo wall structure and assembled them together to a bamboo house structure. Because the bamboo rods have limited dimensions (28-33 mm diameter; about 4 m length), they developed a connection which can join the bamboo rods to the length required (Baier 1985).

Another experiment was a grid shell roof construction with two levels of 6x6 m and 4x4m. The two roofs were then covered with a plastic membrane and assembled. This roof did work well after several years outside under different weathers. For the two experiments the working tools and methods were purposely restricted to a simple and cheap way so the realization could be possible for the people in developing countries. (Baier 1996)

These two researches can be taken as one branch of bamboo researches in Germany, with the scientific purpose of "High Design, Low Tech". "High Design" means that as a principle they want keep the research on a high scientific level and the use of bamboo's natural structure in the same principle the bamboo has, namely also lightweight structure, for example the grid shell structure as a construction has the same character as the bamboo's material structure: light, elastic, resistant. The "Low Tech" refers to their fulfillment of the construction to be kept simple and at a low cost. So that people in the developing countries can put their researches into the practice without too much preconditions.

One real example of this lightweight structure with bamboo in praxis, namely the bamboo grid shell construction, is the kindergarten in Fukuoka Japan designed by Japanese architect Shoei Yoh in 1995. This building has the similar construction principle as in IL Stuttgart, but the architect took the inspiration from the local bamboo weaving handcraft. With the help of the handicraftsmen Shoei Yoh has woven a huge grid shell with bamboo strips which has then been used as the frame structure for supporting the concrete roof.

Their academic intention in bamboo structure research differs from those of designer and architects in South American which mostly come from the practice and from some other designers and architects in Europe who try to use high-technology in the bamboo construction. These other constructions will also be discussed in the following sections.

4.1.5.3. Constructions with natural bamboo structure in practice

There are some new developments in the bamboo construction research from both sides: on the one side in Latin America where the bamboo construction has more practical reasons now has begun to put more emphasis on scientific and aesthetic sides of the bamboo construction whereas in Europe the architect and designer push the researches more to the practical side.

- **Bamboo architecture by Simón Vélez**

In Latin America some architects like Jorge Morán brought the bamboo construction in house building into the university as a research field, or like Simón Vélez changed bamboo construction to be modern and popular bamboo architecture and turned to be famous world wide. As bamboo architect Simón Vélez has devoted himself in building with bamboo more than 15 years ago. Before he designed the famous Zeri bamboo pavilion for Expo2000 in Hanover he had already built numerous buildings with bamboo in Columbia and some other countries in South America and Europe. The buildings range from the small one-family-house to large industrial halls, from experimental pavilions to a religious church. He is also called "Bamboo Architect" in Latin America. After many years of experience in bamboo buildings he has developed a kind of joint which lets bamboo carry and transfer the tensions loads to a high grade and at the same time without cracks in the bamboo cane.

In his solution he inlays a metal bolt in the one end side of each bundled bamboo cane and then fills this end side of the canes with concrete. One metal bolt then was "replanted" in each of the bamboo canes by the concrete to be connected with the bamboo cane. The loadings like the tension, the press as well as

the bending can be transferred though the metal bolts and concrete at the joining points. In the positions where the press loadings are too large, he uses more than one bamboo cane, often four to eight, binding them together to get a high stability, even though one cane is strong enough to resist the loading.

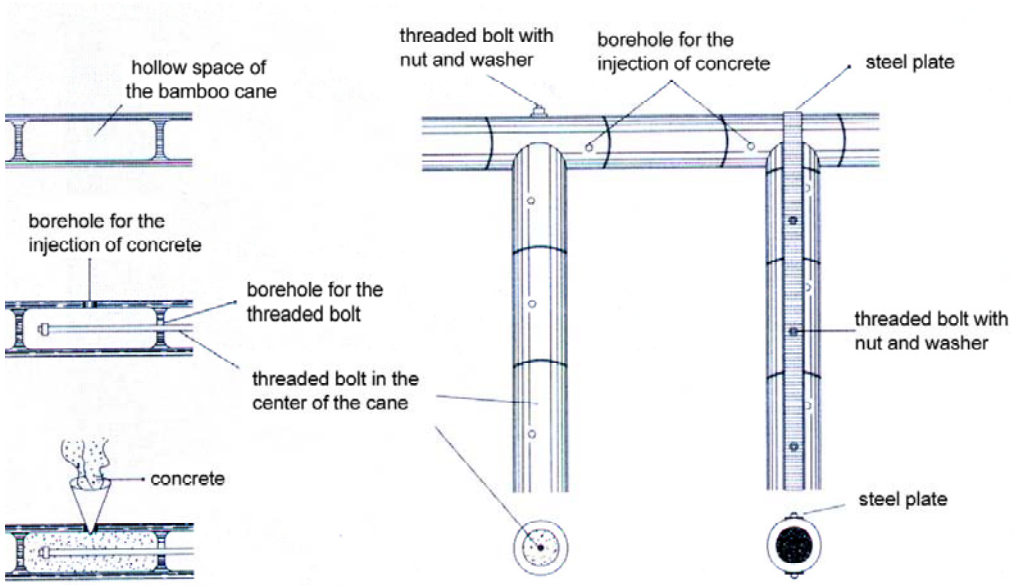


Figure 4- 30 Bamboo construction with concrete and steel bolt by Simón Vélez, 2000 (ref. Simón Vélez)

His methods for connections have proven as a mature bamboo technique in many of his practical building projects like the factory hall in Pennsylvania, Columbia and the Zeri pavilion in Expo2000 Hanover Germany (Figure 4-31). With the help of the concrete joint the Zeri pavilion can have 2 levels and 2,150 m² of sheltered surface area of which 1,650 m² are on ground level and 500 m² on the partial 1st floor mezzanine (Vegesack & Kries 2000).

Figure 4- 31 Zeri Bamboo Pavilion in Expo2000 Hanover designed by Simón Vélez

Its construction has passed the German Norm for construction and building even though a natural material like bamboo has never been permitted to be used in modern building in Germany. With its construction, its giant but slender form of a mushroom the Zeri Pavilion demonstrated to the world that the old traditional and natural material bamboo can also match the industrial standard requirements. For the Zeri Foundation on the other side it has special meaning: bamboo as building material represents their sustainable developing strategy for the future which was also the central theme of the Expo2000: Man, Nature and Technology.

From the aesthetic view another design – the bamboo cathedral by Simón Vélez - is more convincing. The construction is a metaphor for bamboo's natural structure: from the bottom to the top the bamboo cane reduces its diameter slowly to fit the loading. The bended form of bamboo canes in nature is also a result of the gravity on its structure, which in natural bamboo forests presents an elegant structural beauty.

- **Bamboo bridge by Jörg Stamm**

Architect Jörg Stamm from Germany with a carpenter education background made his experiments on bamboo construction in another way. After several years of working experience as a carpenter he got to know the material bamboo *Guadua* in Columbia and became interested in its potential in bridge construction. He began his real bamboo bridge project in 1995, in which he was assigned to build a bridge with bamboo *Guadua* that can resist the earthquake and flood in Coquiyo in the field Paez. For this task he used European traditional timber construction. After the information study in many wood bridge constructions Europe from mediaeval times to the very modern and the visit of the Institute of Lightweight Structure in University of Stuttgart and the RWTH Aachen he designed a cantilever bamboo bridge. These bamboo bridge constructions present a structural complicacy in which both the tension and press stressed bamboo canes combine together to reach a span of 22 meters (10 meters in the middle) and a width of 2 meters.

Under the dimensional restriction *Guadua angustifolia* cane normally is 6 meters long in use. Jörg Stamm designed a connection to join several canes one after another so that altogether they can reach the 22 meters length span. The connection is similar to that of Simón Vélez, in which he uses concrete as the fillings and threaded bolts in axis direction as reinforcement to transfer the tensile and pressing loadings. Several such bamboo canes are joined together parallel by using a strap and thread bolts. The finished bridge can support small cars up to 2 tons (Figure 4-32).

Figure 4- 32 Bamboo bridge in Pereira with 52 meters span designed by Jörg Stamm, 2001 (ref. Jörg Stamm)

After this project Jörg Stamm finished several further bridges with bamboo *Guadua* and set up a bamboo seminar focusing on bamboo bridge construction at the University of Pereira, in which he built a bamboo bridge with 40 meters span together with the students in 2000. His master in bamboo bridge building techniques was presented in a later bamboo bridge project in Pereira in 2001, in which the span

of the bridge reaches 52 meters. He continues with experiments on bamboo construction in house roofs and other industrial buildings.

His works in bamboo bridge building demonstrate a combination of the practical experience on material properties with a scientific knowledge basement. He gets his inspiration from the European timber construction and therefore concentrates more on the processing of the bamboo material and the connection detail. As Simón Vélez tries to develop new bamboo construction more or less from the architectural and aesthetic side, Jörg Stamm improves the bamboo construction from the technical and engineering side. Both of them orient their design strongly in the knowledge and experience of the local bamboo material and therefore also strongly depended on properties of the *Guadua*. Furthermore the processing of the construction must be done on the field, and can not be simply transferred to everywhere in the world as a standard technique.

But they represent a new movement of the bamboo construction – modernization of bamboo construction in the local areas where bamboo is abundant. The fine technique and design with the natural bamboo *Guadua* which the architects have demonstrated in their works convince the people there that the natural bamboo material can do as well as the industrial artificial materials.

- **Bamboo constructions at RWTH Aachen and Koolbamboo**

In Europe and Latin America some researches on bamboo construction continue from the theoretic side and go further closer to the praxis. The department of Housing Construction and Fundamentals of Designing at the RWTH Aachen has opened a lecture with the topic of bamboo as a construction material for architecture since 1999. The university lecturer Evelin Rottke and the assistant Christoph Tönges have done experiments on bamboo construction with *Guadua Angustifolia*.

Figure 4- 33 Bamboo connection designed by RWTH-Aachen (ref. Christoph Tönges)

This research follows the principle of lightweight structure which was begun at the Institute of Lightweight Structure in University Stuttgart. To maximally use the bamboo capacity of tension resistance they have developed a conical joint of steel to connect bamboo canes at the end side. For this aim they have cut the end side of bamboo around the circle to a regular wedge shaped cog. A threaded bolt was planted in the bamboo cane by wood or plastic filling. After binding the threaded bolt together

with a steel cable the end side of the bamboo cane turns out to be of a conical form and the threaded bolt is then fixed in the bamboo cane (Figure 4- 33).

The tension and press loadings will be transferred from the threaded bolt to the bamboo cane and further to other side of the cane to another threaded bolt. Then with other similar connections many bamboo canes can build diverse light weight space constructions. The researchers and the students have used this connection to build a simplest space framework, from which all the mechanical test demonstrated that the connection has fulfilled the task and all together can build a very light weight construction.

Based on the researches and experiments in RWTH Aachen, Christoph Tönges has set up his own firm to use these bamboo connection techniques in different real projects like a small bamboo pavilion and structures for advertisement. A similar construction method can be also found in the design works in Latin America, such as by the firm Koolbamboo from Florida in USA. It offers pre-fabricated bamboo structure kits for small pavilions or houses.

Figure 4- 34 Bamboo pavilion and its connection by Koolbamboo

This Hi-Tech connection has the disadvantage of the high requirement for the treatment work and therefore the high cost for the connection. Furthermore, the steel bolt, wood or plastic filling and bamboo cane are fixed together as one part, therefore the disassembling of the joint will also destroy the joint. The reuse of the joint to another bamboo cane with changed length is limited.

- **Bamboo construction by Bambu-Tech**

Another development in bamboo construction in building is the firm Bambu-Tech in Germany who has designed a special wood joint for connecting bamboo. Its concept is to develop a standard bamboo joint cap made of wood (can also be aluminum or plastic) which can match each end of the bamboo cane. By using glue or casting plastic the cap and bamboo can be joined together. This is somewhat similar to the bamboo connection of the Simón Vélez and Jörg Stamm in which concrete is used as the joining material. Different in the Bambu-Tech designs is that the cap has a much bigger diameter so that the cap holds the end of bamboo cane by both the outer and inner surface. With two inner slots of the cap and one outer slot of the bamboo cane the connection through glue or casting plastic can be stronger and more stable. The bamboo canes can be cut to a standard length like 0.5, 1, 2 meters so that they can be easily used as modules for the constructions. Joining elements like holes or screwed holes can be drilled or taped on the cap so it can be joined further with other standard construction components (Figure 4-35).

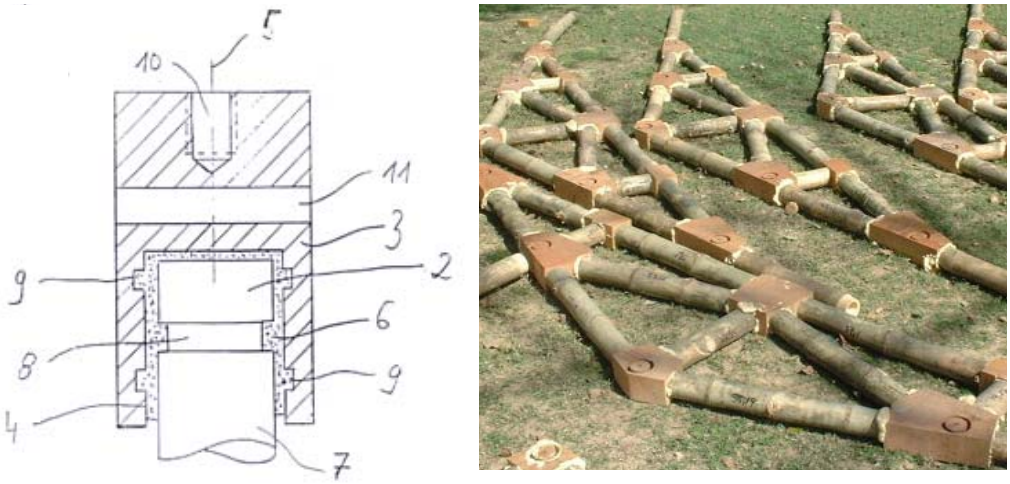


Figure 4- 35 The bamboo connection and the roof construction designed by Bambu-Tech (ref. Bambu-Tech)

Bambu-Tech also uses this joint technique for the wood rods connection, where the wood rods should be processed similar to bamboo canes. For the wood rods this connection technique is easier because wood is easier to process by the drilling machine. The bamboo species chosen by Bambu-Tech is the *Bambusa Balcoa* from India, which has been carefully selected and processed after the fell, so that the changes of dimension of the bamboo canes is kept very small. This is very important for the standard machine processing.

As a concept for the standard connection for the bamboo construction Bambu-Tech has demonstrated their solution from the industrial side. In the processing of bamboo cane Bambu-Tech uses machines to treat both ends of the bamboo cane to a standard form – from a somehow irregular oval section with changed diameters to a standard form with an outer diameter of 70 mm and an inner diameter of 50 mm. This requirement cane be fulfilled by natural bamboo canes only after careful pre-selection. This is also the reason why the techniques can not be used generally everywhere.

- **Bamboo joints by Shoei Yoh and Renzo Piano**

Both architects, Shoei Yoh and Renzo Piano, are interested in the natural bamboo material and its excellent mechanical properties, and have tried to develop constructions in which bamboo can be used as the main structural element.

The method of Shoei Yoh is in principle similar to that of the bamboo joint by Bambu-Tech. Different at Shoei Yoh is that the joint material is metal. The bamboo canes and the metal joint will be connected and fixed together by screws and nuts. So no concretes or glues are needed for this connection. The joint is a metal tube about 20 cm in length and with a diameter of 5 cm welded with a metal bar in the middle. The tube can be fixed to bamboo canes with two sets of screws and nuts in crosswise direction. The metal plate can also be fixed to a cylinder shaped joint element with 3 to 6 wings, then 3-6 bamboo canes can be joined together to a cylinder shaped element. Many of such structures connected together can build a bamboo construction. Shoi Yoh has used this connecting method to build a bamboo dome construction in Fukuoka Japan.

His connection methods used standard metal construction components which can be prefabricated by industry. The bamboo canes can be also pre-processed cut into pieces with a certain length and the holes can be drilled before the assembly. So the construction with bamboo can be assembled with a screw wrench and can be disassembled after use. One of the disadvantages is that the irregular difference of the diameter between bamboo cane and the metal joint tube make the relative position and the loading transfer from bamboo canes to metal joint tubes change from one to another. Another disadvantage is

that in the whole construction the metal connections are very dominant for their weight and volume. This somehow reduces the bamboo's lightness in the construction.

Figure 4- 36 Bamboo connections by Shoei Yoh (left) and Renzo Piano (right) (ref. Shoei Yoh + Architects; Renzo Piano Building Workshop)

Together with UNESCO Renzo Piano has organized a bamboo construction workshop in Punta Nave, Italy, in 1989, in which he tried to design with the several bamboo constructions with attendees of the workshop. With the industrial materials like aluminum and steel the bamboo canes can be connected into lightweight constructions like the Tensegrity structure and other lightweight roof structures. Like other scientific researches in IL Stuttgart, these experiments have not been put into real utilization. But they demonstrated – with an experienced architect – the potential of the bamboo construction and the lightness and the beauty of the bamboo connection.

- **Experiments on bamboo construction at IED**

To try to find a construction solution for natural bamboo canes, the author has done some experiments at the IED (Institute of Ergonomics and Design Research) at the University of Duisburg –Essen. The aim of this theoretical experiment is to explore the connection of bamboo canes with standard industrial joining components without destroying bamboo's own natural structure. Under the instructions of Professor Bernd Baier from the Institute for Constructive Design, a supposed bus station was constructed with bamboo canes (here with the *Phyllostachys pubescens*). The styling of the bus station is not the most important aspect, but the different connection methods. By using industrial standard components, the bus station construction can be assembled in a way without too many demands to the work techniques, and can be disassembled and re-assembled with simple tools. The standard metal components can be re-used after several years when the bamboo canes become out of order. The connection methods should not destroy bamboo's own structure so that its structural advantages could be fully used in the construction. This asks for a kind of flexibility of the connection: the joint should be adjustable in order to adapt itself to the difference of the bamboo's dimensions.

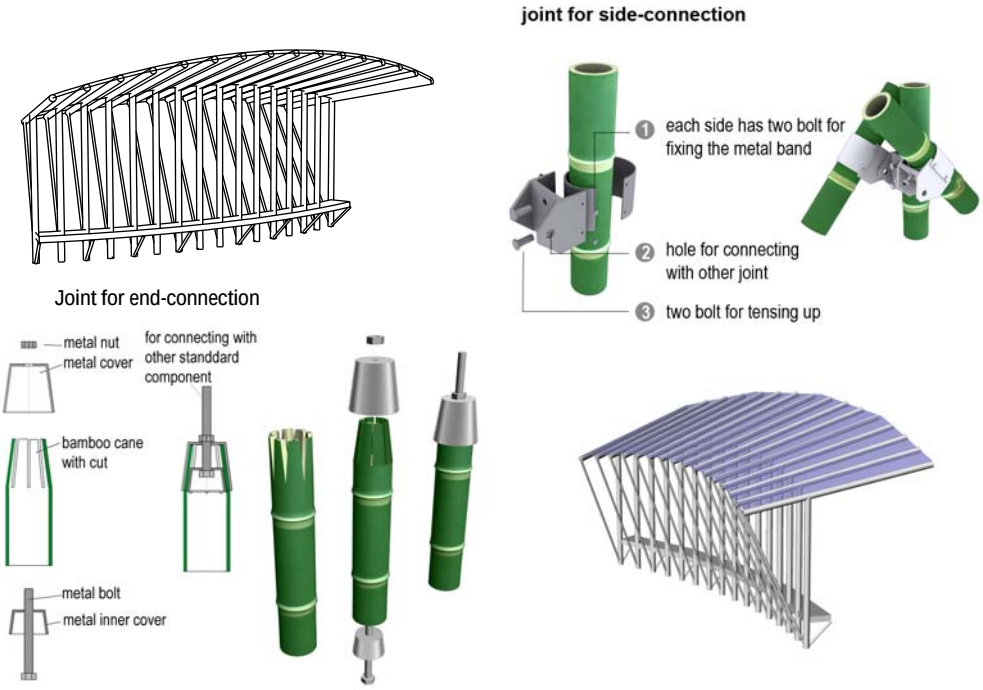


Figure 4- 37 Bamboo bus station: concept design for bamboo connection

4.1.5.4. Un-solved problem in bamboo construction

As to bamboo's irregular dimensions the methods used by the different researchers and designers are often dependent on the bamboos which they choose and the techniques are also not so easy to be transferred from one to another. This limits the bamboo cane in the construction in a large dimension. The different bamboo connections can be summarized in the Table 4-1:

connections	Represent	Connection type	Connecting components	Equipment requirement	Advantages	disadvantages
	Simón Vélez; Jörg Stamm	End and cross connection	Steel bolt; cement	Electric drill; handwork tools	Big tolerance on the irregular bamboo dimensions; can be loaded by pressure, tension and bending	Destroying bamboo structure by holes drilled on the bamboo canes; unable to dissemble and reassemble the connection; aesthetic disturbed through the cement
 	RWTH Aachen; Kool-bamboo	End connection	Steel bolt; steel rope; steel joint	Electric saw; wrapping fixture	Both tension and pressure loadable; flexible in building space framework; modern and elegant in appearance	Bamboo structure will be partly destroyed by sawing the cut on bamboo canes; high requirement and cost on the bamboo canes and the processing; the joint only partly re-usable after dissembling; only for end connection
	Bambutec	End connection	Wood; glue	Electric drill; lathe	Standardized wood joint element has similar material property like bamboo.	Bamboo's structure destroyed by processing into standard diameter; unable to dissemble through the glue. High requirement on the processing of the wood joint and bamboo canes
	Shoei Yoh	End connection	Metal bolt, metal joint element	Electric drill, handwork tools	bolts are standard component; can be loaded both under tension and pressure ; re-usable after dissembling	Bamboo's structure destroyed by drilling holes on the canes; could split under the fixing bolt; aesthetic disturbed through the metal bolts
 	Renzo Piano	End connection and side connection	Metal joint element, metal wire and band	Electric drill; handwork tools	Space saved joint element; flexible combination for the end and side connections; easy to assemble together; simple and elegant appearance	limited loading capacity; by the end connection holes will be drilled on bamboo canes; by the end and the side connections the loading is distributed to some points which are easy to break bamboo canes; the metal wire and band will be destroyed after the dissembling
 	Yu	End and side connections	Metal joint elements; metal bolts and nuts	Electric saw for the end connection	The joints are standard industrial components and are fully re-usable after dissembling; minimal destroying of bamboo's structure; flexible in building space framework; easy to assemble and dissemble	Small tolerance on the irregular dimension of bamboo cane; large space needed by the side-connection; special processing equipment required by the end-connection.

Table 4- 2 Different bamboo connection concepts in summary

To develop an ideal joint for connecting bamboo canes with other standard industrial structural components is always the key point for a wide utilization of bamboo in construction. There are many important requirements for the joint:

- Can be standardized so that it can be pre-fabricated in mass production
- Adapt to the bamboo's irregular dimensions (section form is light oval; diameter not same)
- Can be assembled and disassembled easily and is re-useable after the dissembling because natural bamboo as construction element has a relatively short life and should be replaced in certain time according to the using conditions
- Lightweight
- Low cost in comparison to the bamboo canes

These requirements are like barriers for the designer and architect to use bamboo with large design freedom in their works. But they are also the real challenge for them. Designing for designers is the topic for the researchers who work with bamboo construction. That means designing a universal connection for bamboo with other industrial materials so that all the designers and architects can easily use it in their works. This is different to the industrialization of the bamboo material in which bamboo's natural structure is destroyed by the processing to make the prefabricated bamboo product like ply bamboo. Designing a connection which adapts itself to the irregular dimension of the bamboo's natural structure so that the bamboo's structural advantages can be used in the construction as much as possible – this will be the real challenge for the designer and the architect.

As discussed in the Chapter 2, in traditional connections bamboo canes can be connected parallel, orthogonal and in certain angle by ropes, cords of rattan and fibers from natural plants. This can be still found in China and some other Asian countries on the building sites in scaffolds structures. But this needs handcraft work to treat every bamboo cane differently, and the workers also need a special experience with the material bamboo. This is difficult to be standardized by a machine.

The bamboo cane as a construction element for connection can be compared to the steel tube. But its material properties in connection are similar to those of wood. Compared to the steel tube and wood pole there are many disadvantages for bamboo to be connected to each other and with other material. For its material properties and standard dimensions steel tubes can be connected with other materials by welding or screwing; wood can also be connected well with other materials by nailing or screwing. For bamboo nailing and screwing can crush the cane easily and welding is impossible because the surface of the bamboo cane consists of high density phloem fibers. And the irregular dimension of the section also makes it difficult to connect to other standard components.

As a pole construction the most logical connecting points are the two end sides, so that the bamboo cane can use its material and structural potential like tension and press loaded capacity to its maximum grade. In the traditional bamboo construction there are no such restrictions, and they are commonly connected not at the end sides. This depends on many factors like bamboo species and the constructions. For the most common used bamboo genera for building like *Phyllostachys pubescens* and the *Guadua angustifolia,* which have their diameters of more than 10 cm, it is possible to use supplementary joint components in the cane and also to cut the cane to build notches for connection. To maximally use the full length of the bamboo cane the connection positions can be in the middle of the bamboo cane. Some species like *Phyllostachys bambusoides, Violascens* which are also often used for construction but have a smaller diameter, they are often connected by binding and without any cuts. So the connecting positions are normally in the middle, so they can get more fixture and stability. Also for parallel and orthogonal binding with ropes the connection points are normally in the middle of the bamboo cane to get a more stable connection. In the modern practical bamboo constructions the designers concentrate more often on these two end sides.

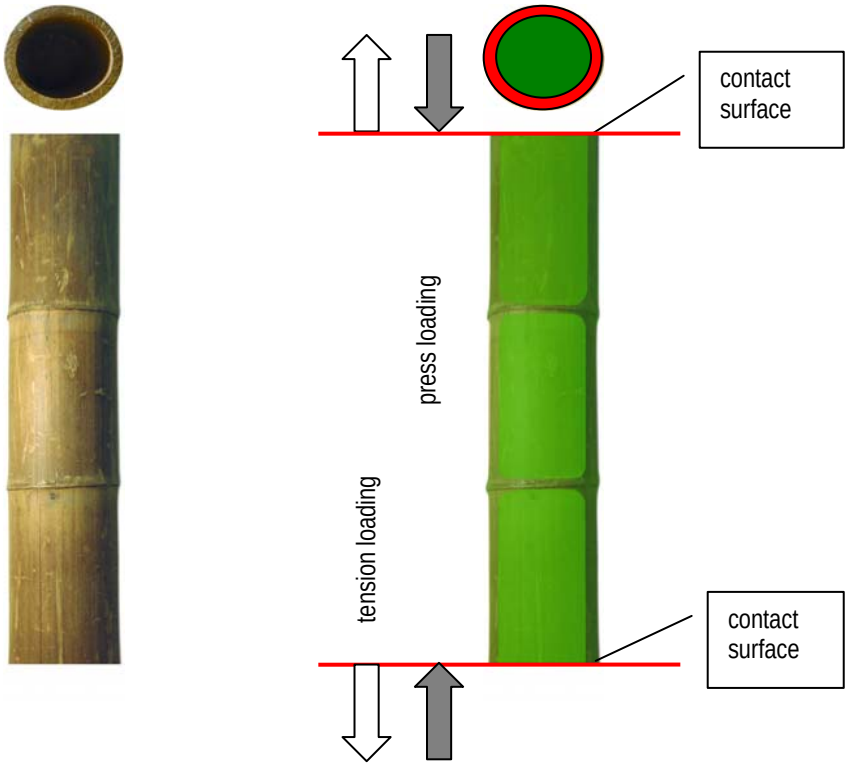


Figure 4- 38 Bamboo cane (Phyllostachys Pubescens) and section for possible connections

The Figure 4- 38 is to explain what kind of problems and possible solutions lie in the bamboo joint: Bamboo cane has flat end sides when it is cut down for utilization. These two sections are the only dimensionally mechanized surface where they can be connected to other standard materials. But for its small contact surface it is still difficult to use these two surfaces to fix them with other materials by gluing or other conventional, industrial connecting methods, and after the fixture the connections are also easy to be destroyed when they are loaded by tension, bending or tension. The experiments by Tropicasean (Figure 4- 39) use two surfaces as the contact surface and connect them with other large, even surfaces, or soft material (surface) like textile to build a board or tensegrity which has mainly just the press loading (Tropicasean 2004).

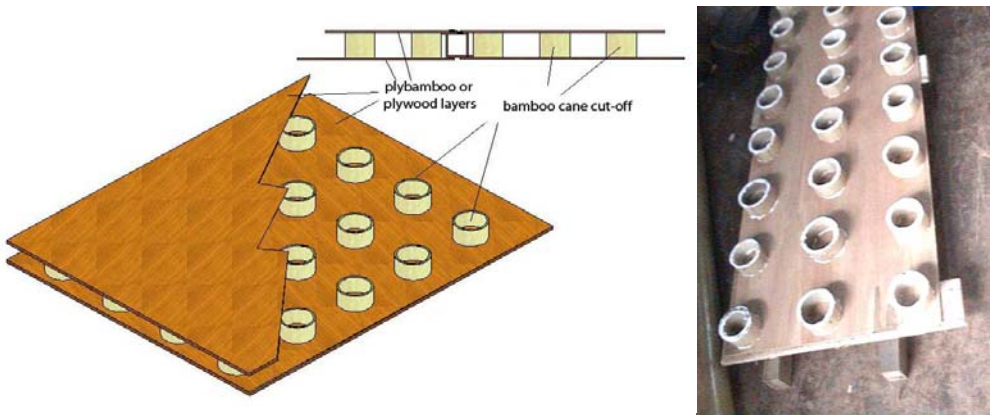


Figure 4- 39 Bamboo Ply Composite structure by Tropicasean (ref. Tropicasean)

Although the ideal bamboo joints are those without destroying the bamboo's original tube structure, but at the same time can join together bamboo tubes or bamboo tubes with other industrial construction components, this is so difficult that until now there are still no satisfying concepts which can be put into worldwide practice. There are some concepts which come from different standpoints and can build bamboo constructions with them, for example the artist Anton Versteegde from Belgium used rubber band to fasten the bamboo canes together without changing anything in the bamboo canes, whereas the firm Koolbamboo uses steel ropes and tubes for the joint. The principle used by Simóne Vélez and Jörg Stamm for the bamboo connections with cement and steel bolt, is similar to that of the Japanese architect Shoei Yoh, because both have tried to solve the problem of connection by using the typical industrial joining elements but at the same time destroy the natural structure of bamboo by drilling holes into the canes. All these joint concepts go one step further to try to combine the natural bamboo structure with standard industrial construction elements, but in principle they are not better than those methods in the traditional crafts. Those traditional methods, simply working with bamboo or rattan strips, are still widely used in the building industry in Asia, where the bamboo is used for scaffolds for the skyscrapers with hundreds of meters of height. The bamboo canes are joined with such simple, cheap bamboo or rattan strips without too many technical demands, and are easily disassembled after use. An industrial method to connect bamboo canes to other industrial construction elements should not just be a solution from the material perspective, but should also be a better way to solve the problem from the principle perspective, which is still awaited.

4.1.6. Design principle III: Natural bamboo as design element for designer

As discussed in Chapter 2.2 the cultural aspect of bamboo is, along with the structural dimension, another important dimension to understand the bamboo and an important decisive factor for an appropriate utilization of bamboo. From the historical perspective the cultural dimension of bamboo can be understood in two ways: firstly bamboo as a natural material. Its growth (history) in nature gives bamboo a beautiful form and elegant structure, makes bamboo a versatile, useful material in people's everyday life, and is a symbol for good personalities in many countries. Bamboo itself represents a special beauty from nature which has a close relationship with mankind. Its cultural aspect from this perspective means the multi-dimensional relationships to the people's everyday life as a plant, as a material and as a symbol. This could be an important aspect for bamboo as a design factor in modern utilizations.

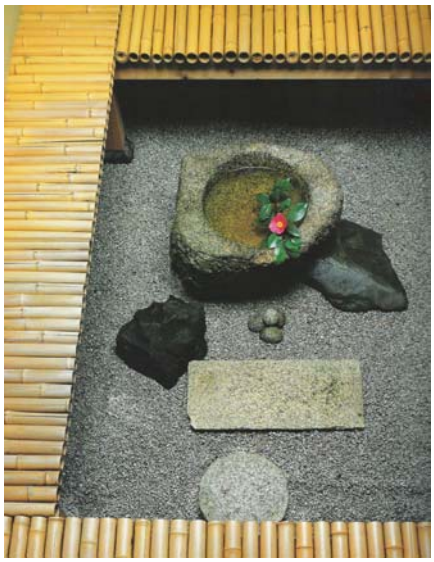


Figure 4- 40 Bamboo in Japanese garden (ref. Bess 2001)

The natural bamboo structure has been used in the tradition as a beautiful plant in the garden or house in Asia. The beauty of the natural bamboo plant in people's mind comes not only from its elegant form

but also from its features like vitality in its growth, resistance to natural hard conditions, self-possession; all these are accordant to a perfect personality. As a material bamboo's natural structure has been used in modern architectures and designs, not because of its mechanical advantages like strength and lightness, but its aesthetic values.

This aesthetic value can be seen in two ways of its uses: the one is the direct use of the bamboo plant in the architecture as a lively, beautiful plant. This originally comes from the East Asia countries like China and Japan, where bamboo was regarded as an elegant life-form in the harmonic atmosphere in gardens, but nowadays in the modern society bamboo plants are widespread all over the world, not only in Asia, but also Europe and the United States, taken as a horticultural specimen to complement and enhance the garden design. The second one is the natural bamboo cane or strips as design elements for architecture and product design. Examples for this can be found more often in Asia where the bamboo has its cultural and historical context. But more and more in the West, the designers and architects use bamboo in their design for its pure aesthetic aspect. Natural bamboo canes have been more and more widely used in architecture and interior design as a decorative element. Bamboo canes in their works often play a key role in the whole design and along with many other industrial standard materials represent a unique, elegant form of nature. The natural beauty as well as the historical context of bamboo contributes to the design works, the direct functions of the material bamboo canes like structural strength are secondary in the design. Its aesthetic and historical values are irreplaceable compared to other artificial materials and this gives the bamboo material the special chance to be used in the modern architecture and product design. Innovative using of bamboo's beauty in the modern industrial society will give the design of a product or architecture a special aesthetic character which comes exclusively from the material bamboo.

4.1.6.1. The bamboo plants as decoration in the modern architecture

- **Kengo Kuma's Great Bamboo Wall**

Kengo Kuma is the Japanese Architect who is interested in the special characters of materials in architecture and has experimented with different materials in his architectures. For him, the highest objective in his architecture is to "recover the place". Through architecture people can experience nature and time, which are the most important factors in the "place" in a deeper and more intimate way (designboom 2005). Another design aim is to "recover the tradition of Japanese building" in which the "transparency" is an important character. In his works the "transparency" has often been represented by using different natural materials for example wood, stone or bamboo. In his work Wood/Slats in 1999 the material wood was used as the characteristic design element in the architecture. Another project "stone museum" in Tochigi 2000 is another example of using a certain material as the medium to transfer the character of the whole architecture.

In 2002, together with 12 other famous Asian architects, Kengo Kuma was invited by the firm Soho China to participate in the architecture project "Commune by the Great Wall" to design a house in Beijing on the mountain side under the Great Wall. Similar to another Japanese architect, Shigeru Ban, he used bamboo as the representing material in his architecture. But different to Shigeru Ban, who used industrial pre-fabricated laminated bamboo mat as the functional building component "wall" and "furniture", Kengo Kuma used natural bamboo canes as the symbolic design element for the "wall" – optically dividing the space. Different from the "Great Wall" which was originally designed to isolate the country from the aggravation from outside and therefore characteristic in itself with its robust, thick brick wall, the "Great Bamboo Wall" was to demonstrate the lightness and transparency obtainable with bamboo canes. As bamboo has its irreplaceable place in the Asian culture and history, through the "Great Bamboo Wall" the architect Kengo Kuma has reinterpreted the tradition of bamboo in a totally modern style.

Figure 4- 41 Great Bamboo Wall by Kengo Kuma 2002, Bejing (ref. Soho China, 2002)

- **Bamboo pavilion by Rocco Yim**

Architect Rocco Yim was born and educated in Hong Kong. Hong Kong has its special position especially in two sides: as a geographic connection between the mainland China and the Western outer world; as the cultural connection between old Chinese tradition and the modern, metropolis culture. Both points have been expressed in many Hong Kong designers' works. Rocco Yim is one of those modern Hong Kong architects who have these characters. His recent work which has won the first prize in the design competition 'New Guangdong Museum' among the most famous worldwide architecture offices, demonstrates his strong concern with the local cultural context in his design. His concept came from the form of the traditional Chinese "treasure box", which is interpreted here as the basic form of the whole building.

Figure 4- 42 Bamboo pavilion in Berlin by Rocco Yim 2000 (ref. Rocco Design Limited, 2000)

In his early project in year 2000, he designed a bamboo pavilion for the cultural exhibition "Hong Kong – Berlin Festivals of Visions". Why he chose bamboo as the cultural symbol of the city Hong Kong? In Hong Kong bamboo has been used for a long time, since the beginning of the modern time as the building material for scaffolds. Even for the huge skyscrapers of more than hundreds meters, bamboo

scaffolds can be seen there accompanied by the growth of the most modern architectures in the city. For its lightness, strength, fast growth, resistance and cheapness, bamboo keeps its place as the scaffold material in the high-tech building industry. Like a huge dynamic sculpture in the city, bamboo scaffolds moving when the wind comes, giving the resident of the city a special impression. The city Hong Kong keeps growing and changing in an evident way by diverse new buildings having come into being in the last 100 years, the scaffolds change its place from one to another when the building is finished. If the architectures of the city demonstrate the history of the city Hong Kong, the bamboo scaffolds have accompanied the change of the city. However the architectures changed their styles and places, the bamboo scaffolds can always be found there. The people in the city see the bamboo scaffold in the city where a building project is set up, realizing the city is changing and growing. It is already a symbol of the city which marks its permanent changes.

In such a context it is not strange that Rocco Yim chose bamboo as the symbol for the city culture of Hong Kong. The pavilion was built in front of the "House of the world culture" ("Haus der Kulturen der Welt"), as a symbol for the exhibition and the event. As a temporary architecture the bamboo pavilion used the same connection method like the bamboo scaffold. This technique has also been a result of the evolution. It is simple, cheap, and can be de-assembled, therefore the bamboo can be reused the next time. This old traditional technique was combined with a modern architecture style by the architect, representing the elegance of the bamboo's natural structure and the whole architecture.

The bamboo canes have been used as a construction element as well as a form element. But as Rocco Yim has the motive to build a place and an atmosphere, the function of bamboo here is more symbolic than practical. The whole pavilion is more like a sculpture than a building, and the pavilion presents the transparency and the elegance of the bamboo structure.

- **Bamboo park house in Leipzig**

Bamboo as an architectural element became not only a popular theme for bamboo countries in recent years, but also for the countries where bamboo material can only get to by import. One example is the park house at the Leipzig Zoo designed by HPP Hentrich-Petschnigg & Partner Architects Leipzig. The park house is a mixed structure with steel and steel reinforced concrete and has a capacity of 527 park places distributed in five layers. Unconventionally, the architect used vertically parallel arranged bamboo (species *Guadua angustifolia*) canes for encasing the outside façade. Here the architect used the natural bamboo canes not only for decoration, but also as guardrail and safety barrier. The whole building has an organic curving outline which was designed to match its architectural surroundings: the zoo. This organic contour has been emphasized by using the organic material bamboo and together they build a harmonic symbol for the zoo visitors. The bamboo canes of the species *Guadua angustifolia* with 10-12 cm diameters have been arranged with 7.5 cm distance for its functional consideration: the space between the bamboo canes gives necessary ventilation and lighting for the inner space, but at the same time they present a beautiful rhythm from the outside and give the visitors an elegant appearance (Figure 4-43).

The natural bamboo canes as a building material are still uncommon in Europe disregarding their excellent material properties. The architecture received the Renault Traffic Design Award 2004 in Germany for its creativity in using traditional natural material in the modern industrial society.

Figure 4- 43 Park house Zoo in Leipzig, designed by HPP Hentrich-Petschnigg & Partner Architects Leipzig, 2004

4.1.6.2. Bamboo's natural structure in the product design

- **Bamboo furniture by Fernando + Humberto Campana**

The brothers Fernando and Humberto Campana from Brazil are two of the most famous South American modern designers. They have their special interests in the experiments on the different materials in furniture design (or better to say, between art and design), to give the conventional furniture objects like table, chair or lamp a totally avant-garde impression.

Their experiments include using industrially made materials like timber plates or textile in the furniture or interior design both as structural components and as form components, therefore giving the furniture or interior total new impressions. The materials used in their designs also have been defined in a new way. This can be found in their most famous work "ideal house cologne" in the International Furniture Fair (imm) 2004 in which they use industrial wood slats for the construction and form component which is normally used for industrial packaging.

Figure 4- 44 Bamboo furniture "bamboo acrylic" by Fernando + Humberto Campana

They also do this kind of experiments with the natural materials like bamboo, in combination with industrial materials like acrylic in furniture design. Their furniture "bamboo acrylic" is one of those

experiments in which bamboo canes (with small dimensions) are filled into an acrylic space frame and both together form a chair. The acrylic frame is the construction and function component in the chair – the chair does work well without the inlayed bamboo canes (Figure 4-44).

But the acrylic material serves at the same time as a transparent message box which presents its special material message by the special material features themselves. Through the transparency of the acrylic the whole box as a function and structure element drops back whereas normally in other furniture designs it has the dominant place. The acrylic frame now becomes the background or platform on which the bamboo canes play the key role. The bamboo canes are on the one side the message here: natural material; lightweight but strong; irregular but elegant form. On the other side the structure itself is also the message: the contrast between the coolness of the industrial standard material and the warmness of the natural material. Through such a kind of material contrast, the natural form and structure of bamboo here will not be interpreted as "imprecise", "raw" or "undeveloped", but positive taken as "natural", "friendly" and "elegant"

- **Bruno Winter: Semester project "BarCode"**

Bruno Winter, a student from the Kunsthochschule Kassel, has designed a garbage can with bamboo stem in a semester project "BarCode" for his exchange study at the University IUAV in Venice. This project was supported by the Vietnam organization "Craft Link Hanoi", which works for the low level social group non-profitably.

Figure 4- 45 Bamboo project "BarCode" by Bruno Winter (ref. designreport, 2005)

The design student uses the bamboo tube as the basic structure, cut the bamboo tube in such a way that the slits are side by side, so the diameter of the bamboo tube can be changed by pulling the slips. The changeable bamboo tube is the basic structure, in which a bag consisting of fully recyclable polymer foil is hanged. The diameter of the bamboo tube can be changed to fit the contents of the bag (Figure 4-45).

In this example the material features of bamboo have been excellently considered. Without any additional parts, the function of a changeable diameter has been solved by bamboo's own structure. That can work as a good example from a designer and for designers.

- **Bamboo bank: Dr. bamboozle**

The Belgian designer Sylvain Willenz studied product design at the Royal College of Art in London from 2001 to 2003. After that he worked as designer in Brussels on various projects from product design to interior installation. His works are characterized by innovative using of materials in design. The bench

and stool "Dr. Bamboozle" were his try with the natural material bamboo canes combined with the modern industrial material rubber (Figure 4-46). Bamboo cane has remarkable mechanical properties: strong, light and elastic. Besides bamboo cane has its elegant natural structure which is full of visual character compared to the rubber. But rubber has its advantages in design for its almost unlimited possibility in form and color, which are impossible with bamboo. These two materials have been put together in the design of "Dr.Bamboozle": the stool is about 40x40x25 cm and made of 6 or 7 pieces of bamboo canes with 40 cm length, connected by yellow rubber under the process of casting. Here the bamboo canes serve as the load bearing element whereas the rubber is not only the connecting element but also the design element for the color design. The fluidness of the rubber reached by the casting process has its advantages: adaptability. This is exactly what bamboo needs for connection. Because bamboo cane has irregular dimensions in diameters and forms, so the standard industrial joining methods are not suitable for connecting them. But with the fluid rubber, by casting the bamboo canes can be joined together regardless the difference of their dimensions. The same principle is used for the bench which has only bigger dimension of 100x40x30 cm.

Figure 4- 46 Bamboo bench and stool „Dr. Bamboozle" designed by Sylvain Willenz in Belgium 2002

The designer Sylvain Willenz has received the 1st prize in the design competition "Design for Europe Awards, Intérieur02" in Kortrijk, Belgium, in 2002 for the creative using of materials, especially the exotic material bamboo in the Western context.

- **Bamboo toys for disabled children**

To improve the using of bamboo in modern product design, especially toys design for disabled children, the 'Fördern durch Spielmittel e.V.' in Berlin – one member of the German Commission for UNESCO, together with the firm Happy Arts & Crafts Co., Ltd. and Anji city have organized an international design workshop "Toys for Disabled Children from Bamboo and other Materials" in the city Anji in Southeast China. As a natural material, bamboo is especially suitable for toys because of its ecological features: it is natural and healthy for children; by playing with bamboo toys the children get to know more about nature and are closer to nature. Actually bamboo has been used for making toys for a long time in history. The purpose of the workshop was to explore the material's potential in modern toy design with its educational aim: in the context of modern and special functional demands. More than 20 designers, architects and artists worldwide have joined this creative workshop to design new toys with bamboo and other natural materials for the rehabilitation of disabled children. More than 50 new toy concepts and prototypes have been developed by the participants and then have been presented in the Bamboo Museum in Anji. Along with the traditional bamboo crafts exhibited in the Bamboo Museum, the new toy designs have attracted special attention by the public because of their purposeful functional design for helping disabled children by playing with the toys. By this way bamboo has a new "life-form", which matches the life needs of the modern society. After the workshop and exhibition some of the designs have be developed further and produced into real products and sold worldwide by the firm Happy Arts & Crafts (Figure 4-47).

Figure 4- 47 Bamboo Möbius by Belgium designer Marc De Jonghe (left) and "cheeseburg adventure" by the author (middle and right) during the international design workshop "Toys from Bamboo and other Materials" for disabled children, China, 2003

4.1.7. Design principle IV: Redefining the bamboo crafts in the industrial context

From the historical perspective, the bamboo's cultural dimension could be the way how human beings treat bamboo, namely the bamboo crafts. Bamboo crafts represent how human beings (the craftsmen) treat bamboo's natural structure into useful things with simple tools, but high developed techniques and intelligence. The process from the bamboo's efficient and elegant natural structure to a man-made useful and beautiful handcraft is, like many other handcrafts, a kind of culture of human kind. Because of the economic reasons bamboo crafts have their difficulty of existence in the industrial society, but they have always kept their special value against industrial products. How to find these values of traditional bamboo crafts in the industrial context will be the main task for this part.

As discussed in Chapter 2, the ways bamboo was traditionally used can be divided into three large categories: bamboo as a plant; bamboo as a material and bamboo as a symbol. In the second category bamboo as a material can be used in the construction of buildings where bamboo's advantages like strength, lightness and resistance are demonstrated; or in the objects or tools for everyday uses because bamboo canes are elastic and easy to process. In both ways of the second category the bamboo needs to be processed, normally by craftsmen. The craftsmen developed a very high level of the technique in bamboo processing. In diverse utilizations the bamboo canes can keep their basic tube form and the craftsmen just cut, scrape or gouge the cane into different tube objects. But more often the bamboo canes will be split into splits, bars and strips. This is also possible because of bamboo's special structure which craftsmen can easily treat with simple tools, other than with materials like woods which are difficult to be split into strips with simple tools. They split bamboo canes into bars and scrape them into fine strips as basic structure elements with different section forms and dimensions. Then they weave them together into thousands of different objects which can serve people in their everyday life.

Figure 4- 48 Traditional bamboo baskets from Japan (ref. Hans Spörry 1890)

This kind of bamboo crafts has had its flourishing time before the Industrial Revolution. Even nowadays in some places where the industry has not yet been well developed and the people still live a rural life with objects made by craftsmen, the bamboo crafts still dominate an important place in people's everyday life. But in many other traditional bamboo countries where the industrialization rushes up every small village, this kind of traditional crafts has faded away since the industrial materials and products were introduced.

What happened with bamboo crafts is only one of the many traditional things which faced their disappearing in the industrial world. In the industrial society, where the economic principle plays an important role in deciding the existence of a thing, the bamboo crafts, if they are still defined as the objects for daily uses, have little chance to win their conventional place in the competition against industrial mass products. For a similar function there are many other industrial materials which can fulfill the task with better processing properties and lower cost by mass production.

But things like crafts can not just be valued by their practical functions, especially in the industrial world. For more than one hundred years the traditional crafts like wood, clay, textile, glass and metal crafts in different countries and places have been changed but are still kept in a way which can not be replaced by any industrial production. They are defined as a kind of applied arts in the modern society and therefore are accepted in the industrial world more for their aesthetic and historical values than their practical value. This kind of redefinition of traditional crafts gives them an irreplaceable reason of existence which can be a way for bamboo to find its own place in the industrial world.

The modernization of bamboo crafts is the process of the redefinition of traditional bamboo crafts in the industrial context. As the term "crafts" has been already defined as the handwork methods, the modernization does not mean to use industrial tools or machines to "produce", but on the contrary, to keep the handwork methods and their special value in the bamboo crafts. What changes is the adaptation to the modern life style itself in order to fulfill the complex needs of modern people. As Maslow's hierarchy of needs describes the complexity of human needs from basic physiological needs, security needs to the higher level of love/belonging needs and the esteem needs, the product design has also developed into a complexity of processing in which products are designed to fulfill these different needs of human beings. The history of design in the 20th century has also reflected this kind of changes of the function of products. From the Modernism in the beginning of the 20th century to the Post-Modernism

in the 70s, the product design reflects the changes of the human needs in a product from purely practical functions to a multi-dimensional complexity with direct, historical, individual, social and aesthetic functions[24] (Mukarovsky 1978). For the bamboo craft, it changes its role in the society from the pre-industrial time to the industrial time, from a utility with practical functions to a thing of applied art, which is based on its practical function but more important are its aesthetic and cultural meanings.

4.1.7.1. Crafts: the handwork techniques in the industrial world

Compared to industrial production the handcraft or craft refers to making goods completely by hands, or only with simple tools. It served as the main means for human being to get what they need for their everyday lives in the pre-industry time, from the simple tools with only practical functions to artistic objects for decoration or pure artworks.

Crafts can be divided into several large guilds like pottery, textile, silversmith, carpenter or glass making. Normally each guild is based on certain materials like earth, textile, wood or glass. The techniques, processing and tools which have been developed by the craftsmen are all related to the special properties of the material. The crafts have dominated the whole human society until the industrialization broke the rhythms by using machines in mass production. The whole traditional crafts of different guilds have suffered from these changes. What the craftsmen made traditionally has been replaced by machines, which have been powered by steam power and later by electric power and worked 10 times, 100 times faster than the hand workers.

Many early industrial countries where also the handicrafts had developed to a high level at that time changed their social structure. The handicrafts lost their place in the society for economical reasons but kept their influence in two ways: the one was that the principles and aesthetics of handicrafts were concerned with fitness and propriety; they demanded that materials and function should determine the design solution, took nature as the multitude of exquisite shapes, forms and colors (Naylor 1971: 147). This principle of crafts in the design process has also been accepted as a design principle for industrial products. In fact, as the machines replaced the hand workers in such traditional fields of handicrafts like ceramics, glass, silver and metalwork and changed them from hand workshops into half crafts and half industry manufactures in England from the middle of the 19th century to the beginning of the 20th century, the designers came mostly from the handicraftsmen and inherited the achievements of the handicrafts in those fields. The Arts and Crafts Movements in England aimed to fight against the industrialization because of its separation of the human's working process and the purely functional and mechanical styling without tastes, but at the end they only gave the industry an impulse: the industrial products improved themselves by accepting the aesthetic and cultural factors of crafts. Or in other words, the spirit of handicrafts was continued by being borrowed for the material shell of the industrial products.

About what kind of role in detail the handicrafts played in the industrial world, there were different arguments. Walter Gropius took handicrafts as a means to an end:

> *"Handicrafts are now changing their traditional nature. In future their field will be in research work for industrial production and in speculative experiments in laboratory-workshops where the preparatory work of evolving and perfecting new type-forms will be done". (Gropius 1934: 682)*

Art critics like Herbert Read also took a similar point of view; in his work "Art and Industry" it says:

[24] The Czech philosopher Jan Muskarovsky takes five factors relevant to the function of architecture: 1) Direct function which corresponds to use and function and defines the direct purpose of architecture. 2) Historical function refers to the new style of architecture and the reappearance of the early ones in history. 3) Individual function is the creative function which emphasises the personality and characters of the architecture. 4) Social function refers to the allocation of certain roles to the people who live in the building. 5) Aesthetic function stresses the creative and in certain cases also artistic design. It is borrowed here to describe an industrial design product.

> *"The conception of art as something external to industry, something formulated apart from the industrial process, something which the manufacturer can take advice on and import into his industry should he think fit" (Read 1934: 173).*

The designers like Ethel Mairet put this principle into practice in the textile industry and advocated the hand-weaver's importance to the textile industry (Harrod 1999).

Another way that handicrafts kept their influence in the industrial world is that some handicrafts survived after the industrial revolution but reduced their dimensions and volumes, and managed themselves in a special field where the industrial production can not reach. Or in other words, the handicrafts compensate the industrial world with their special forms and ways of making goods. In this way the handicrafts refer more to the form of arts and crafts which concentrated on the artistic value of the human's hand skills and techniques. This is what happened in the Arts and Crafts Movement at the time of the ending 19th century and the beginning of the 20th century in Britain. By the Arts and Crafts Movement the crafts had not got their triumph over industry but made its influence in the whole society, both in industry and crafts. Crafts ceased in many traditional fields to industrial production, especially in the time of the economic depression in the 30s. But in some branches like ceramics and textiles the crafts had still their role in the modern interior (Cumming & Kaplan 1991).

The different craft societies in Britain had tried to establish the crafts in the industrial society by public activities like exhibitions or special shops for craftsmen and crafts goods, in which they re-defined the crafts in the industrial society for their specific *artistic*, *emotional* and *intellectual* concerns; their creativity by the making goods; their honesty to the materials, the tools and skills; the harmony of humans and the things to make in the working process. For these features the crafts set their position closer to the arts than the industrial design, focusing more on the aesthetic than the function of the objects.

Consequently, another important function of the crafts in society is its pedagogic aspect in the arts education in schools. Art students learned crafts as a pre-course for their skills and feeling in the materials and their processing; this could also be found in the *Vorkurs* by the Bauhaus, where the design students learned the crafts of different kinds like metal, wood, textiles in the workshops as a way of preparation for their further design study. Not only in art or design schools but also in the general middle and high schools the pupils experience the different craft courses as a means to gain knowledge and experience in materials. In a society full of things made by machines, the handcrafts have been regarded as a useful way for a basic cultural education for the whole society (Hegemann 1965).

4.1.7.2. The historical and cultural aspects of bamboo crafts in the industrial context

Bamboo crafts, like any other traditional crafts in the world, have been developed into a kind of applied arts which have served people's everyday life from one generation to another, and at the same time recorded the history and culture of the local people. They are themselves a traditional, regional culture. Because bamboo is a local material with the connection to its geographic conditions, the developments of bamboo crafts also represent the changes of the local culture from a special perspective. In some places like Japan, bamboo crafts have been used in some traditional cultural events so that bamboo crafts have already represented this kind of culture. The most typical example is the Japanese tea ceremony which is taken as one of the most traditional in Japanese culture (Figure 4-49). The Japanese tea ceremony (chadō, or sadō) is a traditional ritual influenced by Zen Buddhism in which powdered green tea, or matcha, is ceremonially prepared by a skilled practitioner and served to a small group of guests in a tranquil setting. Colloquially it is often called Ocha among Japanese.

Figure 4- 49 Bamboo utensils for the Japanese tea ceremony. From left to right: Hishaku; Chasen; Chashaku; Natzume (a piece ofbamboo cane); Natzume (bamboo basket). (ref. Hans Spörry 1890)

The roles bamboo plays in the Japanese tea ceremony range from the atmosphere of bamboo to the practical tools made of bamboo. The feeling of the existence of bamboo during the tea ceremony begins with the garden, where the tea houses are commonly surrounded with a cluster of bamboos, as Nancy Moore Bess describes in her book "Bamboo in Japan". Important are the bamboo utensils used in the tea ceremony:

> *"There is a sense of peacefulness in the garden that surrounds the teahouse. Simple bamboo fences isolate the grounds from the world beyond, creating a contemplative retreat…" "Bamboo is a prevalent image in the tea ceremony. Like the ceremony itself, it is simple and elegant, rustic and refined, and is used throughout, both as material and as design motif." (Bess 2001: 80)*

Chasen is a tea whisk made of a piece of bamboo cane. Chashaku is a bamboo scoop for powdered tea, whereas Hishaku is a bamboo water ladle and Natzume a tea box.

Why choose bamboo as material for these utensils in the tea ceremony? Austin and Ueda explain this in their book "bamboo":

> *"The Japanese tea ceremony is intrinsically a simple thing. The refinements that have arisen within its framework are numerous and baffling to the Western mind. However, the ritual, which began as a movement away from artifice, derives from the simple act of making tea and offering it to a guest. Its prescribed utensils are also simple and made of common materials – bamboo, iron, pottery, and the like." (Austin & Ueda 1970: 159)*

Not only the material is special, but also the techniques, namely the crafts which make these bamboo utensils so special for tea ceremony that both things – the tea ceremony and the bamboo crafts are bundled together. Many Westerners are fascinated by the skill of how the Japanese craftsman make the bamboo Chasen (the bamboo tea whisk). For making a Chasen, a piece of bamboo cane will be cut into pieces about 20 cm long, and then one side of the cane (the head) is split, bended and smoothed into fine splines whose number range from 32 to 120 according to the types of the Chasen. About thirteen steps are needed and ten handwork tools are used for making this fine, elegant instrument, which is at the same time very simple and available at modest price (Figure 4-50).

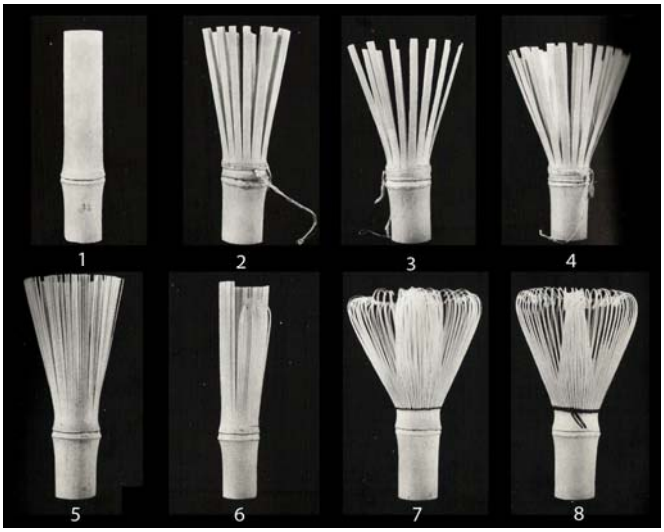


Figure 4- 50 The working process of making bamboo Chasen (ref. Austin and Ueda 1972)

The bamboo fan made of bamboo and paper, the so-called SENSU or UCHIWA in Japan, can be another example in which bamboo crafts are connected with traditional cultures (Figure 4-51). SENSU, originally designed and made for cooling in the summer time as a daily tool, has often been used in the performing arts like traditional dances or NOH plays. By folding and unfolding diverse SENSU of different motives in gestures and postures, the meanings of pantomimic actions can be clearly presented by the actors. SENSU is also an indispensable equipment for a Geisha along with the Kimono and the exquisite makeup which are regarded as one of the most important images of the Kyoto's Gion distribute. Similar but less spectacularly performances can also be found in different traditional regional Chinese plays like the Beijing Opera in which bamboo fans are often used as a typical accessory for scholars or intellectuals.

Figure 4- 51 Bamboo fan "SENSU" in Japanese traditional culture: in NOH play and with a Geisha.

What close connections with the traditional culture will such kinds of bamboo crafts have? Because the tea ceremony is regarded as one of the most important parts of the traditional Japanese culture and therefore is appreciated and supported by the government as well as the people, bamboo crafts for the tea ceremony are also accepted as the materialistic representation of this tradition. As long as the art forms like the tea ceremony, the Noh and the Geisha are still part of the important cultural forms, the bamboo crafts can always be found in these traditional culture forms as a part.

4.1.7.3. The aesthetic aspects of bamboo crafts in the industrial context

Traditional handcrafts differ from the fine arts and the industrial products. The beauty of the handcrafts is based on two important factors: the usage of the object and the handwork making of the object. Sōetsu Yanagi has explained that the beauty of the handcrafts comes from the familiarity of the objects made by handwork. From his point of view, the difference between a handcraft works and an industrial product in the sense of the aesthetics comes from two aspects: the aim of the work and the way how the work is made. Firstly to the aim of producing, even though both the handcraft and industry produce goods out of their practical usages, they have their different aims to do that. Since the industrialization the production of goods by the industry takes place in a capitalistic economy system, where the profit is the highest aim for everything. Under such impulse the functions of the product, and thereafter the quality, the beauty and the health of the products, come second. The greed for profit is harmful and dangerous for the usability and also the beauty of a work. This is also why, from his viewpoint, all the works will be done as often as possible by machines in the industry. On the other side, with handcraft works the craftsmen has always their honesty to the usefulness of the goods they make, and therefore they always have a higher aesthetic level than those made by industry. The second aspect is the way of producing goods in which the handwork also has a special aesthetic value the machinery work does not have. Closely related to the philosophy of the Arts and Crafts Movement on the social aspects of handcrafts, Yanagi emphasizes the beauty of handcrafts has a much higher level of beauty than the machinery works in the sense of the working process because the working process of handcraft make it possible to reach a higher freedom of the human representation, which according to Yanagi, is the highest level of all beauties of human beings. Even if by machines man can produce goods more efficiently and precisely, in which a kind of beauty of machines can be attained, but they have their limits exactly at this point for their perfection. Because according to his principle of aesthetics, the perfection is the end of the human freedom in the representation, which will quickly get boring by the experience of it. So he argues that the highest level of beauty is the beauty of irregularity, because the beauty of irregularity will not make people become tired of it, on the contrary, it motivates them to finish the process of the experience of the beauty themselves (Yanagi 1999: 57-75).

Handcraft has its special aesthetic value in the industrial world. Even if the world gets more and more technical and artificial in the sense of materials for our everyday life, the handcraft is something which makes us remember where the human being himself comes from and how he did so. It compensates the coldness, the rigidity and the dullness of the industrial products with its warmness, irregularity and character with its human handwork. This kind of aesthetics is likely to be found especially in bamboo handcrafts because of the material's properties. Due to a certain irregularity of the material structure, bamboo canes need to be treated respectively according to their different species and dimensions from piece to piece. The traditional bamboo crafts are exactly based on this kind of special material characters as many other traditional crafts. According to what kind of good he will make, a craftsman selects and treats every bamboo cane with different tools and more important the feeling and experience on the material. Bess describes how a Japanese craftsman is concentrated on the bamboo basketry making:

> *"For master craftspeople such as Sobe Kozan, creating fine basketry is about focus – the careful selection and preparation of bamboo, the precise execution of the design, the final lashing of the rim." (Bess 2001: 60).*

Such kind of working processes can only be executed by craftsman and impossibly by machines. Even if plenty of baskets or such kind of products for carrying things produced by industry can be bought for a cheaper price or with a much larger choice of colors, materials and designs, or with a much more precise form and dimension, a traditional bamboo basket made by a craftsman can always find its lovers in the industrial society, as long as the human being is still a piece of the natural world and not produced in the industry. The practical function, out of which it is made, plays an important role but is not deciding for its existence in competition with other industrial products, the most important here is a kind of spirit of bamboo handcrafts, namely the honesty to the material and the concentration on the thing itself which give bamboo crafts an irreplaceable aesthetic value that an industrial product can not have.

4.1.7.4. Redefining the bamboo crafts in the industrial world

The beauty of bamboo crafts more and more gets its acceptance in the modern industrial society from two perspectives: firstly, the traditional bamboo crafts with its original form have been appreciated and supported themselves by the society as a kind of traditional culture. In Japan, for example, the bamboo crafts and craftsmen, like many other regional traditional crafts and craftsmen, have been treated as national cultural properties and protected by the Law for Protection of Cultural Properties since 1950. Under such kind governmental protection, the bamboo crafts as well as the bamboo craftsmen will be supported and promoted not only by financial policy, but also through activities like exhibitions and propagations so that the bamboo crafts like many other specified traditional crafts can receive attention and recognition from the public in the modern society and therefore can be preserved and perpetuated as a national culture in this ever changing industrial world.

Secondly, there are some changes in the traditional bamboo crafts to the direction of the modern fine arts which have received their reputation not only in Japan but worldwide. The traditional bamboo crafts differ from the artwork in the fact that they are born out of a practical usage whereas an artwork, which is also made by hand, is an expression of the personality of the artist who made it. Even though there is a term called *artistic handcraft* whose work also has its practical functions, it is different to the traditional handcrafts in the sense of the aim of the work. For an artistic handcraft the functions (usages) of the works are at the second place in its importance and the name and the personality of the artist stand at the first. Therefore the price of such artistic handcrafts works is unaffordable for normal people for their everyday needs. For traditional handcraft works the usage for people's everyday life is the first place and the name and personality of the craftsman are no more important.

Whatever bamboo crafts keep in their traditional sense or change into a modern artistic crafts form, the bamboo crafts keep their way in the industrial world. Actually, in Japan for example, there are two professional associations, namely the Nitten (Japan Fine Arts Exhibition) and Nihon Kogeikai (Japan Craft Arts Association); both have their own special emphasis on the bamboo crafts. The former emphasizes art and sculptural beauty of bamboo crafts and the latter concentrates on the beauty in functional form and technical excellence (Figure 4-52). Most of the modern bamboo craftsmen belong to these two associations. Both of the directions could be a good way to keep bamboo material in the industrial world, even in a restricted dimension. Nowadays modern bamboo crafts (and arts) have received their attention through numerous exhibitions organized by different museums and galleries. Just in TAI gallery in the USA more than 30 Japanese bamboo artists and craftsmen have their works presented.

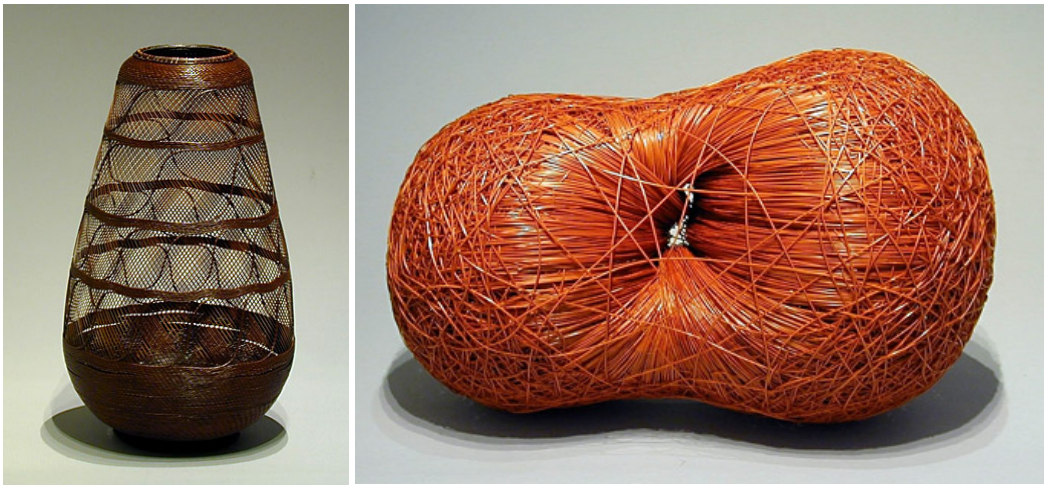


Figure 4- 52 Left: Modern bamboo crafts with traditional styles "Fragrant Wind" by Nakatomi Hajime, 2005; Right: Modern bamboo artwork "Born" by Monden Yuichi, 2005 (ref. TAI Gallery)

Nevertheless, both of them try to redefine the bamboo crafts from its original sense as a functional object to a modern version as an aesthetic object in which bamboo crafts as hand-made products maintain their own virtues against industrial machine-made products.

4.1.8. Summary

Instead of industrialization the modernization of bamboo gives the natural material bamboo the real chance to be re-used in the industrial world by systematic integration of design, material and the life needs in the industrial context. Through modernization of bamboo, in which the structural and cultural dimensions of the material bamboo are especially considered under the modern industrialized "user" conditions, bamboo can be much wider utilized than just as a wood substitute in the industrial world.

The four principles demonstrate the ways how the inner structural and cultural dimensions of bamboo can profoundly fit to the outer industrial using context, therefore giving bamboo a multi-dimensional utilization-space in the industrial context. From the structural aspect, the industrialized bamboo products such as ply bamboo or laminated bamboo are a kind of structural compromise from the material side, but have their compensation as they enable the designer and architect to use this natural material more easily and widely in the industrial context. This compensation can be useful only through the innovative and appropriate using of such pre-fabricated bamboo materials in the product designs and architectures and can build their own material identity, not just be a substitute of other materials. This way, the loss of the bamboo's natural structure can get its repay by much wider utilizations in the industrial world. From the designers' side, using the natural bamboo structure in their design works can also be a challenge for them. How to find suitable constructions which can integrate the irregular natural bamboo structure into the industrial using environments would be the key point to use bamboo in a most efficient way, in which the loss of structural advantages of bamboo can be minimized.

From the cultural perspective, bamboo can be used in the modern industrial society in two ways: firstly bamboo as a design element in the modern product design and architecture. In the long history of being used in human's everyday life, bamboo has been regarded not only as a useful material, but also as a symbol for the good personalities. This multi-dimensional connection between bamboo and human beings gives bamboo also a special cultural value, which can be well-used in the modern designs. Secondly the traditional bamboo crafts can be redefined in the industrial context so that the value of this tradition can be kept and developed further in the modern society. The development of the relationship between the craftsman and the material represents a high level of fine techniques and intelligence of craftsman in the re-construction of bamboo's natural structure into a useful man-made structure. The bamboo crafts, like many other traditional crafts, still have their own special value against the industry-made products. Through a new definition of the traditional bamboo crafts, they can be preserved and developed in the modern industrial society.

Design with bamboo is the key point of the re-entering of bamboo as a material into the industrial context, which serves as the basis for the appropriate cultural identity of bamboo in the industrial context. This would be the main topic of the next part.

4.2. Building bamboo's modern cultural identity through design

"Identity" as a word is a learned borrowing from Vulgar Latin *identitas*, ultimately from Classical Latin *idem* meaning "the same", one of whose meaning is "the knowledge of who one is". This word gets its popularity as it is combined with other definitive words like "Cooperate Identity", "Product Identity" or "Cultural Identity". Different definitions show different using contexts. Here the use of "Identity" in the discussion of bamboo is to describe how bamboo differs from other materials, so it should be called "material identity" of bamboo, but from the beginning on bamboo has been defined as a structure and a culture, a complexity of a plant, a material and a symbol, all of which have strong relations with human beings' cultural life. Therefore the world "material identity" is not really enough to describe bamboo's personality. The word "Cultural Identity" is a concept used to describe the cultural and social characters of a group or a community in which they differ themselves to the other groups. These cultural characters can be the languages, the religions and the customs which are others than the biological features like the color of the skin. Borrowed from this concept, bamboo's cultural identity is used here to describe the identity of bamboo in the human's social cultural life.

Bamboo has its long history along with the human's evolution. As discussed in Chapter 2, bamboo has been used as a plant, a material and a symbol in the history in countries like China and Japan. Bamboo played a very important role in everyday culture as well as in the high culture in art, literature and philosophy. Bamboo has a strong image in the history of human civilization in those places. Bamboo as a cultural being in history, which is characterized by the multi-dimensional connections of the material bamboo with human's everyday life, withered after the Western industrial culture was introduced. This is mostly because of bamboo's natural structure which was so efficient and elegant itself and could be easily processed with simple tools by craftsman, is now difficult to get processed by industrially standardized machines and is replaced by industrial materials. In many places bamboo is now used as "material for the poor", only for people who can not afford the standard industrial materials, only because bamboo is cheap and easy to get. Through the industrialization bamboo gets processed by machines and then can be integrated into the industrial mass production like in the wood industry. But this kind of industrialization has also its costs: bamboo loses its structural advantages in the processing and is treated only as a substance like wood. Furthermore, the further uses of those industrially prefabricated bamboo products like ply bamboo and laminated bamboo are often used as a substitute for the hardwood products which can not really be widely used in the industrial world and therefore by no means it could be as a cultural being in people's daily life again as it was in history.

Instead of in industrialization, in modernization, which is discussed in the last section, bamboo can be used based on its own structural and cultural dimensions and can get its acceptance as a material with its own characters. This would be the basis for bamboo to return to being a cultural being in the industrial context, or in other words, to rebuild the cultural identity in the modern industrial context, which will be the main topic for this section. At first the general relation between the material and the culture will be studied, which will be divided into two steps: the first step is how the cultural identity of a material was developed through its long time of uses in the human society. The second step will discuss what kind of role the design plays in building the cultural identity of the material. Consequently the bamboo's cultural identity will be discussed, to show how adequate utilizations of bamboo can change its cultural identity in the industrial context, in which design plays a key role.

4.2.1. Material and its cultural identity

Culture has more than two hundreds definitions. Different definitions reflect different theories for understanding the human activity or criteria for evaluating it. The English anthropologist E.B.Tylor defined culture in 1871: "***culture*** *or civilization, taken in its wide ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society*". This is maybe the most widespread definition of culture. Another commonly used definition is by UNESCO (UNESCO 2002: 9): "***culture*** *should be regarded as the set of distinctive spiritual, material, intellectual and emotional features of a society or a social group, and that it encompasses, in addition to art and literature, lifestyles,*

ways of living together, value systems, traditions and beliefs". These two definitions refer to culture as a complexity of material and immaterial things which relate to the human's social activities. In this text culture will be used especially referring to the relationship between material and its cultural meanings, namely how a material can influence people's cultural life, how its cultural identity has been formed and how it has been changed during the development of human culture.

Materials played an important role in culture. This already has its evidence in the history of ancient cultures of human beings. The ancient human kinds used stone and wood not just for making tools for hunting, they also used animal bones to record their activities or for divination. In ancient China (about 200 – 300 BC), the natural materials and substances: earth, water, wood, metal and fire have been assigned as the five basic elements for classifying all the natural phenomena. The doctrine of five elements has two basic relationships between these five elements: the generating circle and the overcoming circle. The generating circle has the following sequence: wood generates fire; fire generates earth; earth generates metal; metal generates water; water generates wood. In the overcoming cycle, wood overcomes earth; earth overcomes water; water overcomes fire; fire overcomes metal; metal overcomes wood. These principles of the five elements have been widely used in Chinese philosophy, Chinese music theory, Chinese medicine and military strategy (Fung 1976).

In the history of the Western culture the materials also played important roles. B.Reudenbach (2002) did research on the material's cultural meaning in the Middle Ages in Europe by studying the material hierarchy in religion. He has studied especially on the encyclopedias written during the time of 600 AC – 1300 AC, which is regarded as the most important illustrations and indications of the world at that time. In one of these encyclopedias, the *Etymologiae* by Isidors of Sevilla in 600 AC, the contents on the materials has an order not according to the alphabet but a factual one. Therefore the order of the materials reflected the value hierarchy of the materials. For example in the category stones, Isidors put the hard clump and the earth dust as the lowest level of the stones, then came marble as the middle class. The highest class of stones is gem. In metals, gold was ranked the top place, then silver, the while lead is at the end. For all the materials gems stand at the highest position, gold as the second. For the material orders Isidors explained: "*everything which is rare, will be great and valuable*". The specifications like the origin, the finding place, the processing of the materials were listed as well as the material's features like physical properties, color, density and application. Another author, Hrabanus Maurus, adopted the material hierarchy of Isidors in 900 AC. In his work *De universo* he ranked the metals with the sequence: gold, silver, iron and lead. The reason for this order was that he put more emphasis on features of the materials and especially the religious applications of the materials: gold represents the brilliance of the wisdom and the chasteness of the holiness, whereas iron stands for distress and adversity. Here the brilliance and the illumination of the materials play a key role in the rank of materials, because the bright and illuminated materials represent the brilliance of God. The glossiness and illumination signalize God and therefore bring the human closer to God. The similar kind of material hierarchy can be found in other religions like Buddhism in India, Thailand, China and other Asian countries; the Islam in the Arabian countries. There gold for its shining color is regarded as a representation of Buddha or Allah.

Similar to materials in religion is the distinction of the materials used in arts. According to Aristotle's view about the relationship between materials and art, the materials are only the means for a proposal. The task of an artist is to generate a form out of the formless material. Here the materials are regarded as a lower level of the art form.

The materials used in everyday life have a different order of meaning in the society. Gottfried Korff (2002) studied this theme in his research on the topic of wood as the material of Germany. He argued that the orders of materials in everyday culture are dependent on the uses of the materials, therefore they are empirical and context related. They are decided by the cognitive and emotive pattern of the materials, the principle of the processing the materials and the classification of their properties. The uses of the materials in the everyday lives interact with all the political, economic and social factors in a milieu, develop into certain patterns which are dynamic and change permanently in the course of time. The patterns of traditional materials like wood, bamboo and stone had a slowly developing process, which is

like the evolution process in nature. But after the industrial revolution especially in the 20th century the process accelerated radically because the rapid progresses in science and technology have led to more and more inventions of industrial materials like plastics, steel and glass. The uses of the industrial materials dramatically changed the patterns of materials in everyday lives. They broke the connections between the traditional materials to social life, building their new relations in the society.

Materials receive more and more attention for their influence on culture. One indication of this trend is that materials for everyday life have been used since the 1960s more and more in the visual arts. Wagner (2002) described the materials for everyday life as the indicator of the social sensitivity because the materials used have saved the information about the history of its uses. Therefore they give us the social codes. This transfer from the practical functions of the materials to the social realm, however, does not mean to input a new aesthetic sense to the materials for everyday life. It just shows another side of the everyday materials: the cultural meaning of the materials.

The increasing new industrial materials considerably expand the boundary of the modern everyday life, providing industry with endless new opportunities for their product manufacture, changing the traditional patterns of material in the society. This could be seen especially by looking into the history of the material plastics.

Plastic is a material family which covers a range of synthetic or semi synthetic polymerization products, including some well-known types like celluloid, Rayon, Bakelite, Polystyrene, PVC, PET, Nylon, acrylic, polyethylene and Teflon. Although people learned to use natural organic polymers like waxes and shellacs for centuries, the real beginning of the human synthetic plastics was in the 19th century. The Celluloid which was invented by the American inventor John Wesley Hyatt in 1863 brought a breakthrough of using plastic in products like dental pieces, combs and other jewels like decorative goods which were formerly made by the natural expensive ivory, tortoiseshell and animal bones for its low prices but good material properties. Moreover the celluloid had its new utilizations in such products as waterproof shirt collars, cuffs, false shirtfronts and movie films. The Bakelite, invented by the Belgian born American chemist Leo Hendrik Baekeland in 1903, was the first thermo set plastic. It was originally used for electrical and mechanical parts for its cheapness, hardness and durability, but later came into widely use in consumer goods in the 1920s. PVC, known for its most common use in plumbers and gutters, is in its normal form stiff, strong, warm and weather resistant. Nylon, invented by the Du Pont Corporation in 1930, was another breakthrough in the plastic's family. It was famous first of all in making women's stockings and later also for making engineering gears. PET is well known for its use in the modern life in the making of bottles for soft drinks such as Coca-Cola.

The uses of plastic in products are everywhere to seen. If asking someone about plastic, he may not know any chemical properties of the material, but he would surely come up with some products he uses everyday in his life which are made of plastic: his toothbrush when he cleans his teeth in the morning, the computer in his office, the radio or TV set for entertainments, the shopping bag and packaging of the products in the supermarket. Just with a glance at some products man can almost find that some part in a product is always made of plastic.

The wide uses of plastic products in people's everyday lives make plastic one of the most important materials in modern everyday culture. Through the products the designers developed plastic as a material finding its multi-faces in different forms, colors and functions. Some factors of the material have decided the popularity of plastic in product design: The one is the plasticity, which gives the product design with plastic a total freedom: it can be deformed to whatever forms the people want to by getting heated to a certain temperature. This makes the processing of plastics easier and cheaper than of metals, but in the normal form plastics have stable properties like stiffness, strength and resistance against warm and weather. The second is the unlimited potential in product design, like colors, transparency and surface texture which gives the designer a large freedom in design. The third is the price, maybe the most important factor which makes plastics so popular in the modern society.

Plastics were developed during the time of the First World War with a proposal that they could help to overcome the availability of natural materials and in the interwar time to minimize the use of metals for economic reasons. Plastics succeeded in bringing a social change that it made more goods possible to be produced with a low price so that they were available for more people in society, such as combs, hairbrushes, buttons, and shells for electric devices like the radio. At this point the wide uses of plastic brought a democracy of the consumption.

But at the beginning of the uses of plastics in products the design played different roles in the development of the products. For those products which formerly were made of other natural materials like ivory, animal bones and woods, plastics were at first used as cheap substitute materials, the design for plastics was just to imitate their predecessors. It was also the reason that later plastics got the name of a "cheap imitator". For those fields where plastics were used for new products like electric devices or machines, they then had more free space to play in the design. Design with plastics therefore demonstrated a very wide range of quality. Companies and designers have tried to explore the potentials of plastics in product design and gave the material a new aesthetic meaning. Raymond Loewey designed the Fada Baby Radio in 1930s in which the material Phenolic (Bakelite) shows its new visual language in its styling and construction which were based on the material properties in processing. The designer gave the material a new meaning which was normally defined by the electrical insulators or cheap products like jewelry, handles and cutlery (Sparke 2004). The company Braun in Germany ran a rational, geometric form language with plastics in electrical products like the radio or the razor. Kartell in Italy experimented on the techniques in processing plastics in furniture designs which also gave plastics a new aesthetic in the context of traditional furniture.

But in a worldwide view the development of plastics in material science and technology has brought an ever-increasing use of plastics in everyday life. The cheapness of plastics as a material provides wide ranges of utilizations of plastics and also leads to the degradation in aesthetic quality. Even if some of the companies and designers try to define the new design characters of plastics products, plastics as general materials for products in everyday culture turns out to be the synonym of cheap, substitute, characterless and kitschy. Roland Barthes (1972) described plastic as an idea of endless form changing than as a material. The almighty plastic was invented as a material of imitations. Its appearance destroyed the old material hierarchy. It allows the luxury objects which were made of noble materials now to be made of cheap plastics, and then turn to be everyday goods. Barthes went further and argued that plastics should be not just a kind of substance which can imitate other materials. Plastics are important not for its origin, like any other natural material like gold, silver or jewel, but the material of utilization. They are invented to be used. The everyday life uses are the character of the plastic.

So for such a material people should not discuss too much about where it comes from or how much it costs. The important aspect is how it is used for making goods and how it is used in the people's everyday lives. Plastics give the designer only the unlimited possibility in form making, in color changing, in surface texture variegation, and most important of all a low cost. For a material to its user – designers - plastics are like some kind of democracy, which gives the designers a maximum freedom in realizing their imagination into designing products. Design plays a key role in defining the characters of the material in the social life. In what kind of forms plastics are used in the products decides how the material will be accepted in the people's everyday lives. This democracy in materials also had an evident disadvantage like democracy had in politics: the abuse of the material. Everyone can use plastics in making goods, good or bad designed. Unfortunately the bad things are much more present than the good ones. The material plastic has to bear the bad reputation: the material of imitation, the characterless material. This negative identity in the everyday culture just reflects the poorness of the imagination of the designers who have made such things with plastics.

4.2.2. Bamboo as material and its cultural identity

Natural materials differ from industrial materials mostly in two perspectives in relation to the human beings: the history and the process. For the natural materials, they have a long history in nature and also

in human's society which ranges from the beginning of the human civilization until the pre-industrial time. The process of natural material is handcraft. The handcraft characterizes the natural material in its process from a raw material to an object. On the other side the industrial materials have only the short history in the culture which began with the industrial revolution. The processing of the material is the mechanized mass production. The progress of science and technology gives the human beings more and more freedom in many ways, one of which is that more and more industrial materials have been invented for their special physical, chemical or mechanical properties which the natural materials have not. But the acceptance of the industrial material in the human society is something different. At the beginning of the industrialization the industrial materials had difficulties in getting an adequate place in society. The industrial materials were at that time totally new and had no connection to the cultural context in history. What they can is their material properties and mostly low cost in production. This made them just a cheap and efficient substitute for the natural material and brought their negative image in human society: lacking own characters in aesthetics. The Arts and Crafts Movement was one of the most influential activities which were set up against industrialization. Although the movement itself was more than just advocating traditional arts and crafts and often referred to the social and political ideals in which the workers should master machines and not be just a salve of the machine, the main argument was the "soulless" machine-made industrial materials and the products in society. This also reflected that the industrial materials still lack cultural context in human society.

But the situation has changed during the ever-accelerated development of technology in the 19th century. On the one side more and more industrial materials have been invented by human beings and are used in society, on the other side the natural materials – even though they have been used by humans for thousands of years, still had to give up their place in human life. It is now what Herbert Simon called an "artificial world". Now it is not the industrial materials but the natural materials that have difficulties in getting into the human society. Natural materials like bamboo, wood or stone are replaced by steel, plastics, glass and concrete. The handcraft traditions in processing of the natural materials have also been replaced by the mass production with machines. Through the efforts of the industrial design, the industrial materials have found their own style and adequate form in human society, not just imitating the natural material as in the beginning of the industrialization. They have built their own cultural identity: Industrial materials and their products which were criticized by William Morris at the beginning of the 19th century as "soulless, ugly and inhuman" are now regarded as modern, well developed, high-tech etc., whereas the natural materials and their processing handcrafts are now considered as "undeveloped, poor, imprecise".

Compared to the industrial materials the natural materials have many disadvantages when they are put into the industrial context: they are restricted in chemical, physical and mechanical properties. They have their own natural structure which is difficult to be processed and standardized by machines. It is also reasonable that natural materials have such "disadvantages" for human's use: they come from the natural world. They are the result of the natural evolution process and their form and structure are also the result of their effort to adapt themselves into the natural, not the human world. The handcrafts can be regarded as the human's respect to the natural materials in reference to their natural structure, form and their limitation. In the industrial world they are not so "useful" like artificial materials because the latter are "born" to be used by human beings: the aim, the process, the properties of the industrial materials all marked with "industrial". But the natural materials still have their "advantages": they have passed through the million years of the evolution process on earth and proved to be suitable to their environment. Their form and structure have proved to be most efficient in the relationship of achievement / expense. They are the best solutions in nature. The researches of bionics have demonstrated how wonderful the natural world can be and how much human beings can learn from the natural evolution. Actually the developments of technology own a lot to nature: the architecture and civil engineering learn the natural principle in the construction of houses and bridges. Furthermore, if man observes the whole utilization system in a large scale, namely the whole earth as a system, the natural material always has a better acceptance on earth than those artificial materials. Ecologically the natural materials need little energy in producing. They are also easier to be decomposed after the usage and then reused in nature.

To change the negative identity of the natural materials in the industrial society the design should again play the key role, as it did in the beginning of the industrialization for industrial materials. This time it is conversed: the design should be the connection between the natural material and human's life, find the utilization place for the natural materials in the industrial world and thereafter build their cultural identity in the industrial society. This will begin with the study on the situation of traditional bamboo's culture in the modern world.

As discussed in Chapter 3.1, the traditional utilizations of bamboo in the modern world have dramatically changed since the industrialization. The traditional bamboo culture, which is based both on the bamboo's natural structure as a plant and on the utilizations of bamboo as a material, has also changed a lot. The cultural meaning of bamboo in the modern society has also been changed in two fields: as a symbol in the local culture because of the changes of the local culture; and as a material in the everyday culture because of the increasing use of industrial materials. The following section will study these two changes of bamboo in the modern society.

4.2.2.1. Bamboo as a symbolic metaphor

Bamboo culture lost its trace in society during the industrialization in those countries where bamboo has its flourish in history. From one side, as explained in Chapter 3, industrial materials like steel, glass, cements and plastic replaced bamboo in the fields from house building to household tools. Bamboo goods could not fight against industrial products as a whole, and also could not be used so well in the industrial producing process like the other "human-made" materials. Even if traditional bamboo crafts can be found in some places like in Northeast India where the industrialization is still not so high and the traditions can keep their way in the people's lives, in general this kind of applied art has begun to fade away.

Like any other handicraft based mostly on the material the craftsmen used and the processing which they developed especially for the certain material, bamboo crafts have a long history of the evolution process, strongly depending on the properties of bamboo materials. The techniques of craftsmen and the tools they used for making bamboo goods all demonstrate their high respect to the natural material properties.

On the other side, since the traditional fine arts, like traditional Chinese brush painting, calligraphy and seal cutting which are considered as the three most important traditional Chinese visual arts and also have similar forms and importance in Japan and Korea, have changed their position in the modern society, the bamboo as a sign in the fine arts has also changed.

The artists and litterateurs who traditionally were the operators and the supporters of the traditional fine arts were far more than professional persons. They were a group of intellectuals or meritocracy who could become government officers by passing through the Imperial Examination. Their position depended on their knowledge of writing and literature and brought wealth and honor to their whole family. As government officers they were proud of their education and self-cultivation and saw themselves as Junzi (meritocracy). They kept themselves quite different to those hereditary colleagues or those who got their position by buying. Their wishes to differentiate themselves as a special group, as intellectuals were often represented in their arts or literature works. For most of them the traditional Chinese arts and literatures were not just hobbies but rather an accomplishment. They got the training for these arts when they were children in schools and also the level of these artistic accomplishments was important for them as an intellectual.

This kind of intellectuals as a social class in its original meaning does not exist any more in China sin the modern time, but has its new form more like the West. They are persons out of academia, from natural science as well as social sciences. But artistic accomplishments are not necessary for them. The traditional arts and literature are also studied in a professional academic way, as a subject or major in the art schools or universities. But like other Chinese traditions and culture, their influence in society can not match to that in history. On the one side traditional culture is under the cultural impact from the West

through industrialization. On the other side the traditional arts and literatures, after they changed into a professional academic form, lost their traditional sense in which arts and literature were at first a a way to represent a highly cultivated personality and accomplishments.

The traditional Chinese arts and literature still have another way to keep their place and importance in modern society. Children are asked to learn calligraphy and Chinese traditional poetry as well as literature in basic and middle school, as a tool to help children learn the Chinese language, traditional Chinese culture and history. Traditional Chinese brush painting can also be learned there. By these ways the traditional Chinese arts and literature keep their influence in society, through which also bamboo as a symbol has its acceptance.

Many famous artists and litterateurs in Chinese history are still well known in the public, such as bamboo as a symbol in their artworks and what bamboo signified. In the modern society bamboo as a symbol can not only be found in the traditional arts but also be found in new media like architecture and design. With the historical context it is well accepted by the people for this.

4.2.2.2. Bamboo in everyday culture

Other than the symbolic meaning of bamboo in the human society in East Asia, the bamboo as a useful material and a beautiful plant has a much more common and wider sense in the world, not only in the traditional bamboo countries but also in those places like Europe.

In those countries where bamboo has been used as a material for a long time, bamboo lost its boom it had before. Traditional bamboo goods are replaced by other industrial products. For example in China the writing and drawing tools traditionally were brushes whose holders were exclusively made of bamboo canes. This can be seen even from the Chinese character for the brush is "笔", which has the symbol of bamboo "竹". This character keeps no change, but it means not only the brush, more commonly it means the pen, pencil or ball pen, because the writing method and style have changed. Nowadays people in China as well as in Japan and Korea, where in the history brushes were the exclusive writing tools, mostly write with the pen, pencil and ball pen for their convenience in writing and recording messages. The brushes are now only for the calligraphy or painting, no more for practical writing.

This change results in the changes of bamboo as holder material in brush making. Although there were some pens and ball pens made of bamboo canes in China, most of them are now made of industrial materials like plastic or aluminium. This is also because of the production methods: the brushes were made by handicrafts so the craftsmen could adjust the brushes according to the difference of the bamboo canes. This can not happen in the industrial pen manufacturing. So bamboo gives up its place in the modern writing culture in China, just keeping its trace in the Chinese character or in calligraphy.

Another example are the chopsticks. The Oriental eating culture is different from that of the West in one most obvious thing: the eating tool. Whereas in the West knife and fork are the tools for eating, the Eastern people use chopsticks for eating. In his famous work "the Empire of Signs" Roland Barthes described chopsticks as one of the important signs of the Japanese eating culture. The chopsticks represent the elegance of the Oriental eating process: by using the chopsticks people have corresponded the movement of the five fingers and choose and carry the food to the mouth. The simpler the tool is, the finer techniques of controlling are and the more elegant the process can be!

This process is possible because of dividing the cutting of food and eating the food in the East. Other than in the West where people use knife and fork for cutting the food into small pieces which are small enough for the mouth to eat, the Asian people let all the cutting be made in the kitchen by the cook, and on the eating table the guests are served all prepared food, so they can just use chopsticks to eat. Compared to the brutal cutting and predatory ripping which knife and fork do, the chopsticks just show and choose the food the people want to eat. The relationship between the food and the human beings is no more as prey to predator like in the West, but a harmony of substances and the users (Barthes 1981).

In Chinese the character for chopsticks is "筷", also with the symbol of bamboo "竹", because in the ancient time the chopsticks were made of bamboo. This Oriental eating culture with chopsticks did not change even after the industrialization. This is taken as an important national character for the Orient. Bamboo also stays the main material for chopsticks, with some exceptions like wood, plastic or even metal. There have been changes in the chopsticks making process, which was early done by handicrafts and now is by machines.

The form of bamboo chopsticks is basically a round stick. Normally its top is slightly cone-shaped for picking up the food; the other side of the chopstick has a square form, so that it will not roll away when it lies on the table. There is a special stand for supporting chopsticks on the table, so that chopsticks will not touch the table surface directly and keep clean. Besides the functional side of the bamboo chopsticks, craftsmen have taken bamboo chopsticks as a medium for the artistic motives: they engrave small graphic or Chinese characters of good wishes for eating.

Since the last twenty years there has been a change of the lifestyle worldwide, especially in East Asia, namely the working and living rhythms turn to be always faster and faster during the economic development. One of the symptoms is that more and more one-off products have been invented and produced to fit the ever changing lifestyle. The one-off chopsticks and lunch box are one of them. To get a lower production price, one-off chopsticks are more and more made of wood than bamboo, because the manufacture line for wood is simpler and has lower costs. But the quality of the this kind of fast product is much lower than the bamboo chopsticks, furthermore, the fast wood chopsticks production has an enormous consume of wood resources for those one-off chopsticks export countries. For example just in China there are 5 million cubic meter woods used for producing the one-off chopsticks. Now the Chinese government is calling for reducing the inland consume and the export of the one-off chopsticks. Due to the fast growth, bamboo comes back as the material for chopsticks. The developments of the manufacture technology for bamboo chopsticks are promoted and supported by the government.

4.2.3. Building the modern cultural identity of bamboo in the industrial context through design

4.2.3.1. Design, material and the cultural identity

Through numerous products the industrial materials get into the people's everyday lives. By using the products in their daily lives people get to know the characters of the materials. On and on the material and its characters turn to be one part of the everyday culture of society. The different applications of the same material in diverse products give different meanings to the material in everyday culture. Even the same material in the same product can be used by the people in different situations in which the meaning of the material can be explained in different ways in the culture.

The process material – products – use of the products – cultural being can be divided into two phases (Figure 4-53): the first phase is that from the material to the product. Design plays a key role in this phase in which the designer develops the material into a product which has certain functions to fulfill a certain task. The second phase begins with the uses of the product to the material as a cultural being, in which the users decide the process. The users are everyone who uses the products, bringing the product into the context of different factors such as history and custom, finishing the cycle of material utilization. Whereas the designer creates the functions of a material, the users give cultural value to a material.

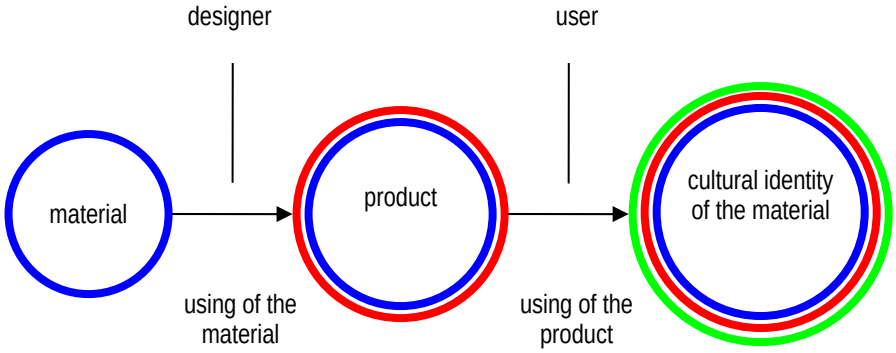


Figure 4- 53 The material and its cultural identity

The uses of different materials have formed their cultural identities in society. For the traditional materials, through the long history of the utilizations the material has found its adequate forms in architecture and products. But for the new industrial materials which have no context in human's utilizations, the users – namely the designer and architects - need time to find the appropriate form for them. Therefore in the beginning these materials had difficulties in the human's everyday culture. For example the cast iron has been used as the material for building structures since the 18th century. For its mechanical properties in the processing this material got its popularity during the industrialization. But the first use of the cast iron in constructions gave the people a negative impression. Gottfried Semper criticized that the iron as a building material had only its technical advantages but no aesthetic character if compared to the natural building materials like stone, brick and wood. No convincing example in iron buildings he could find for its beauty in the architectural aesthetic. The material was mostly used in the industrial constructions like factory buildings, railway bridges and railway stations, which are always associated with the impression: disturbing, boring, cold, uncomfortable and oppressive (Semper 1849). The similar happened with plastics as discussed in the previous chapter: plastics for their unlimited ability in deformation were used in the beginning just as cheap alternatives for expensive natural materials. The replacement of the noble natural materials like gold, jewels and ivory by plastics lead to the degradation of such products and thereafter the degradation of the material.

As the uses of the material (products) decide how they are recognized and conceived in the social culture, and the designers and architects are the key figures who design the products and architectures, so the designers and architects play a key role in building the relationship between the material and its cultural identity. That means finding the adequate forms of the material – namely using the material adequately in the products and architectures, through which the material can have a proper identity in the human's social lives. The following part is to show how design can change material's cultural identity by studying the history of some industrial materials like plastics, brick and cardboard.

4.2.3.2. Changing the material's cultural identity through design

- **Plastics**

The design can build a new context of the material in the human society by using it in the products and architectures. It can also re-build the relationship between materials and their cultural context in the human society. In the history of the material plastics there are many examples for that. As plastics have been widely used for consume goods in the interwar time, plastics had the negative identity in the everyday culture: imitation, cheap, tasteless. These impressions have been slowly changed by the designers and companies. Through their innovative using of plastics in product design the material has succeeded in getting a new cultural identity.

Tupperware is the famous brand name of home products which are exclusively made of the material plastic. The products include preparation, storage, and serving products for kitchen and home. The company was founded in 1964 in the USA and later spread worldwide to be an international leader of the branch. At the beginning the company founder, chemist Earl Tupper, intended to make containers made of plastics for the household to contain the food air tightly. His patent "burping seal" was a remarkable aspect of the Tupperware. A number of aspects have contributed to the success of the Tupperware. But the managing director of the Tupperware Germany Hans Robert Adelmann pointed out that although the direct marketing seems to have decided the success of the Tupperware, actually the most important factors are the user oriented product design and the communicating strategy between the products and the users. The company produced household goods with plastics, like many other companies at that time, for the easy deformation and cheapness of the material. Different is the use of plastics: all the Tupperware products design begins with the family daily life, especially with house wives. What they need for their housework and what they wish for their surroundings are the most basic factors for designers at Tupperware. The considerations of the user needs are further transferred into the design of the product and then represented in the functional and aesthetic aspects of the end products. Peter Zec (1997) figured out that the design of the Tupperware has succeeded in transferring the inner beauty of the products to external aesthetics at the moment when the users use the products. The inner beauty is the function and usability of the products. Through the outer appearance – the material, the structure, the colors the Tupperware products reach a high level of design quality. By using the products in their own house the users have experienced by themselves this perfection of the design.

> *"Accordingly, the special quality of Tupperware design is to be found in the use of the objects, which is manifested in a consciously intended form and is cultivated by its application as a lifestyle." (Zec 1997: 137)*

Another important factor of Tupperware is the communication method for the products and the user. The direct marketing is for the user an efficient way to bring the products to the users. By "live" performance at so called "Tupperware Parties" the housewives can see and use all the Tupperware products in a real family like their own. Experience by using is the best way for the users to learn how the products work and how the "life-form" is then formed by the program. The communication between the design and the user is here most efficient. The information which the designer has considered about the functions and how to use the functions can be learned here not just like with many other products by reading the user manuals, but by doing. By this way the Tupperware launches the closest position to its users (Figure 4-54).

The relation between the material plastics and its identity in the people's daily lives has also been rebuilt by the innovative design. Given that plastics had so many negative examples in the people's everyday lives, Tupperware has used the "cheap", "imitating", "characterless" plastics and reached its success not only in sales of the products, but more important in a high quality of the lifestyle. The simple but elegant form, the transparent structure and the friendly colors give plastics a total different aesthetic impression. Its negative identity in everyday culture has been changed in Tupperware: here, plastics is no more a sign of cheap things, no character, only an alternative for the expensive materials, on the contrary, it is a modern material for a high quality of the products, design and usability. This new identity of the material is the result of the design effort, which is based on the user's experience and his expectation, as well as the perfections of design and production. That is also why Tupperware has its stable growth in more than 40 years of its company history: the longer the users use the Tupperware products, the more satisfied they are. This longevity of the Tupperware products has also changed the prejudice that plastics products always have a short life cycle.

Figure 4- 54 Food container "Stuffables" by Tupperware and the Tupperware Party "A Taste of Tupperware" (ref. the Tupperware catalogue "Foundraiser 2006")

Plastics used in the Tupperware are not designed to produce a luxury, an outer appearance. For this purpose plastics can never match the materials like gold, jewel or stainless steel, which are valuable just for their well-born origin. If trying to use plastics in such a way, they will never get rid of the bad reputation of the "material of imitation". Here plastics and their special characters found their adequate place in the products: cheapness of the material make the "democratic design" possible, namely a high design quality in mass products which are accessible not only for rich people but for everyone; the ability of deformation gives the designer a large freedom in the product design, fulfilling the maximum function of the products with simple structure and minimal material expense. The ability of easy to get help Tupperware products to have an exiting and cheerful impression in the household, adding a happy atmosphere to the family life.

Another example is the company Authentics which produces household goods mostly made of plastics. The firm philosophy is that "AUTHENTICS embodies enthusiasm for the tasks of day-to-day life" by manufacturing simple, functional and industrially produced design products for everyday use. The origin of the company was actually a wood products manufacturer which was founded by Fritz Pfizenmaier in Baden-Württemberg in 1910. At the time when the designer Hansjörg Maier-Aichen took over the management in 1975, the company had already registered its brand "Artipresent" as a typical German company for wood household goods with good quality but simple form and design for more than 10 years. Maier-Aichen developed a new collection with name "AUTHENTICS" along the "Artipresent" and later in 1996, after a reconstruction of the firm, "AUTHENTICS" became the company name. From that time on the company concentrated its products exclusively on the material plastics – the typical "cheap material" at that time.

Figure 4- 55 AUTHENTICS products: pedal bin TIP designed by Konstantin Grcic; eggcup EIKO designed by Chritina Shäfer (ref. AUTHENTICS, 2006)

What the company wanted was to redefine the material plastics by design: through unusual design, the material plastics received a new value and emotionality in more than hundred products in several household categories like Kitchen, Tabletop, Waste Management, Bathroom, Sports and Travel. All the products represent the material plastics from different ways: its deforming ability; high-tech in the production; the different colors. All these characteristics show the spirit of the modern home life.

Cooperating with worldwide, modern, famous designers like Konstantin Grcic, Stefan Diez, Edward Barber & Jay Osgerby, Tord Boontje, Ed Annink, Shin Azumi, Marti Guíxé, AUTHENTICS became a design company and reached a leading position in the market. The products are identified in the market for their functional and simple formed designs with translucent and colorful recycled plastics. Their effort to change the prejudice against the material plastics by design has received its rewards: The Company is famous and successful worldwide. Many of its products have received diverse design prizes all around the world like IF, reddot, designplus, good design Chicago. The company won the European Design Award 1997. Another interesting thing about the success of the company is that the products by AUTHENTICS are the most plagiarized products in its sectors worldwide (Figure 4-55).

More and more famous companies and designers have used plastics for their product design. For these designers the unlimited deformation ability gives them also the free space in design creativity which is impossible with other "noble" materials; the cheapness of plastics makes it possible for their design to be realized into products and to be accepted by the market. Through the innovative use of the special properties of materials and the new processing technology, the "cheap", "characterless" plastics demonstrate totally new visions: versatile; chameleonic; lively and friendly in everyday life. Design plays the key role in the redefinition of the material plastics: the harmony of both – innovative design and plastics demonstrates the material plastics' new and modern identity in everyday culture.

- **Brick**

There are numerous other examples in the material utilization history in which the design has changed the cultural identity of the material. The brick is another example: the building material brick is artificial stone made by forming clay into rectangular blocks which are hardened, either by burning in a kiln or sometimes, in warm and sunny countries, by sun-drying. Bricks were originally invented for those places lacking natural rocks. Bricks have been used for building for more than five thousand years in East Asia and India. In Europe the fired bricks have been used in the Roman Empire and had been introduced to many other places of the Empire by the Roman Legions. In the 12th century the brick reached its flourishing time: an architecture style called "brick gothic" whose buildings were almost exclusively built of bricks was widely spread in Northern Europe like Denmark, Germany, Poland and Russia. However, the bricks have been treated as an inferior substitute of the natural rocks like granite and marble. The use

of bricks has been restricted in the field of industrial buildings or pavement in the modern architecture since the beginning of the 20th century. On the one side the material brick always recovers the old handcraft tradition, on the other side the construction of the bricks represents a solid, heavy impression. This is against the principle of the modern architecture: light and transparent (Weston 2003: 93-97). This situation had been changed by the modern architects who have tried to explore the potential of this traditional building material. The Shaft XII of the Zeche Zollverein in Essen, Germany, which was built in the 1920s, was taken as one the most beautiful industrial buildings in history, presented a successful use of bricks in the modern industrial buildings. The architecture is a masterpiece of the many innovations in the history of architecture: its functional planning of the whole building's group, its rational construction with iron frameworks and not at least the harmony of the aesthetic and function in the industrial architecture. Even if the style of the architecture resembled the Bauhaus and the modern movement of architecture at that time, the original concept of the architects Fritz Schupp and Martin Kremmer was to design a monumental architecture for representing the economic wonder of the Zeche Zollverein. The bricks used for industrial building were not new at that time, it was even taken as one of the standard industrial building materials because the refractory bricks were widely used in the metallurgy and glass industries for lining furnaces, but here in the Shaft XII the bricks show their highest aesthetic value in the combination with the iron framework. The rational designed iron framework combined with the bricks and glass demonstrates an elegance of the functional industrial architecture, redefining the brickwork in a modern architectural aesthetics. Optically the iron structure defines a "line frame", which was filled alternately with the "face" of the bricks and the glass. Compared to the flat glass surface bricks have a fine and rich textural impression. These three materials all together represent a beautiful graphic impression. The Shaft XII was also regarded as the best example for other, later industrial architecture designs (Figure 4-56).

Figure 4- 56 Zech Zollverein Shaft XII designed by architect Fritz Schupp and Martin Kremmer

Other than the industrial buildings two famous architects did their most effort in changing the bricks as building materials in the modern architecture: one is Alvar Aalto, the other is Luis Kahn. In his work Baker House in Massachusetts' Institute of Technology, Alvar Aalto used the whole outer façade of the building with bricks. For him the bricks have a special textual impression for architecture. Other than concrete which has a flat surface the bricks always have an expressional power. The use of this material in the modern architecture presents also a warm and interesting effect. To enhance this textural effect he even used the clinkers irregularly in the whole façade, and let the bricks lay a little aslant in his other work, Säynätsalo Town Hall. Other than Aalto the American architect Louis Kahn used bricks more for its constructive potential and thereafter for the aesthetic value in construction. Kahn has expressed his philosophic words on the material bricks:

> *"If you want to build with bricks, you must ask him what he wants and what he can work. The bricks answer: I like an arch. And you say: but the arch is difficult to build, and it is also expensive. I think you can also be used like concrete for your opening. However the bricks say: I know you are right, but as you ask me what I like, I like an arch." (Wurman 1986: 152)*

Kahn respected the constructive potential of the bricks. He took the opinion that man should take full advantages of the material and not just use the bricks as decoration. The "Nature" of the material can be properly presented only when the bricks have been integrated in the whole construction. In his work, the library of the Philips Academy in Exeter, Kahn presented the harmony of the bricks in construction and architecture. The inner load bearing system is reinforced concrete. The bricks were used for outer walls, not just decoration but itself also a loading construction – parallel to the inner reinforced concrete construction: through the nearly flat brick arches the weight of the windows is transferred onto the brick wall supports. For this arch weight-transfer-system the brick supports were designed to get its width reduced from the bottom to the top of the building. This wall load bearing system was then presented by the brick structure and the form. The bricks were not only useful because of the load bearing construction but also beautiful for the fine structure which harmonized with the function and structure.

Figure 4- 57 Baker House in MIT by Alvar Aalto

Before these two modern architects who especially used bricks in the their architectures, the American architect Frank Lloyd Wright had already used bricks in many of his residential buildings like the Darwin Martin House in Buffalo and the Robie House in Chicago. Even if Wright is not a typically modern architect like Groupius or Mies van der Rohe, he is regarded as one of the most prominent and influential architects in the first half of the 20th century in America. His works which are so-called organic architecture was concerned with the contexts of the architecture a lot: the relationship between architecture, the site and the people. His principle of using materials in architecture reflects this philosophy: he argued that the materials should represent such a harmony between architecture, its environments and its resident. For example in a wooded region the material wood has been more often used whereas bricks should be applied prevalently in a rocky area. This environment and social context plays a key role in the choosing of the material for the architecture.

Through these examples of brick architectures, nowadays the brick becomes a favorite building material for public and residential architecture. The brick is no more regarded as an inferior substitute for expensive natural materials, but on the contrary as a modern material widely used in the modern architectures. Its special features like architectural richness in texture and color, the warm and familiar feeling to the people are different from the other industrial building materials like reinforced concrete, glass and iron, which are often perceived as rational and cold. This is also why more and more residential houses use bricks as the building material.

Material identity in the social culture has been defined by its uses but the designer can change the material identity in the everyday culture. Through his design the designer decides how the material will be used in the product or the architecture: on the one side the improper use of the material in the product will lead to the wrong image of the material in the society, on the other side the innovative use of the material will give a new image to the material, therefore a new definition of the identity of the material in the social culture. This can be found in many of the modern industrial designs and architectures. Many designers use the materials in an unusual way, thus giving the material a new identity.

- Cardboard

Cardboard is a term used to describe a variety of heavy wood-based types of paper, notable for their stiffness and durability compared to other kinds of paper for writing or printing. Different cardboards like corrugated board or carton board have been developed mostly for the packaging of food and small consumer goods, as well as for larger goods and shipping cartons. As a material for packaging, cardboard has been accepted by the human society as a secondary and temporary material. It is "born" making package which is to protect the goods in transport. After the good arrives at the place it belongs to the task of the cardboard package is over and it will be "thrown away after use" or in a larger sense "recycled after use". The cardboard is everywhere in human's everyday life but nobody pays attention to it. The short life cycle of the cardboard package represents the industrial consuming culture: a fast process of everything. Even though it is so important in the industrial society, the material cardboard in the everyday culture is then defined as a secondary or ignored substance through the products – cardboard package.

The Japanese architect Shigeru Ban is famous for his unusual uses of unconventional materials in the architecture. His philosophy is to build a free and open space with innovation in the structure and construction of the architecture. He seeks to challenge the existed construction methods by using easily obtainable off-the-shelf materials like cardboard tubes to reach a totally new structure of the architecture and therefore also the new vision of it. He has experimented using cardboard tubes in his architecture since the middle 1980s when he was assigned to design an exhibition of Alvar Aalto in Japan. At that time he was impressed by the cardboard's load-bearing capacity and its potential in construction. His designs with this industrial ready made material range from the residential houses to churches and pavilions. One of them, the project "paper log house" - the temporary houses for the people after natural disasters like earthquakes have been realized in different places in Japan, Turkey and India from 1995 to 2001. What Ban wanted in these projects was to provide a low budget and fast housing solution for the people there, which can be easy built in use and recycled after use, the industrial ready made material cardboard being just the best candidate for this purpose. But low budget and temporary does not mean low quality as people thought about the refugee shelters: ugly, chaotic and dirty. On the contrary it should also be well designed and beautiful.

> *"Refugee shelter has to be beautiful." as Ban said, "Psychologically, refugees are damaged. They have to stay in nice places" (McQuaid 2005: 78).*

Here Ban has redefined the refugee house by his innovative use of cardboard in a high level function and aesthetics, through which the material itself has also demonstrated a new identity: useful and beautiful (Figure 4-58).

Figure 4- 58 Paper log house for refugee in Kobe, Japan 1994 (left) and in Kaynasli, Turkey 2000 (right) by Shigeru Ban (ref. Shigeru Ban Architects)

Ban's other project with cardboard tubes is the Japan Pavilion in EXPO 2000, Hanover, in which both the architect and the material received the most influence in the world (Figure 4-59). Under the motto "man, nature and technology" Ban used again the recyclable material cardboard in designing the pavilion in order to produce as little waste as possible. Based on his long time experience in cardboard architecture in small dimensions, he has explored the potential of the material in construction and succeeded a great leap in paper architecture. On a building area of 3000 square meters the architect Ban, together with his construction consultant Frei Otto, designed a grid curved shell structure of 42 meter span, 89 meter length with cardboard tubes of a diameter of 12.5 centimeters. The wave form of the construction raised the resistant ability in the lateral strain and at the same time added elegance to the structure. The material – cardboard tubes - here presented the unusual ability in construction which normally should be the task of steel tubes or reinforced concrete. The prejudice against the material cardboard as a secondary and recycled material has been changed by the architect for his innovative uses in the architecture. The "recycled" is not a disadvantage, but a valuable virtue: environment-friendly. The cardboard got a new cultural image in the people's eyes: strong, elegant, modern and environment-friendly.

Figure 4- 59 Japanese Pavilion in EXPO2000 Hanover designed by Shigeru Ban 2000

4.2.3.3. Design as the key role in building bamboo's cultural identity in the industrial context

A material is more than just a substance man can use for making goods, therefore the definition of the material is not only its physical, chemical and mechanical properties. A material is not only a material as long as it is not only viewed (defined) in the process of producing something, but further in the process in which it is used in the human's daily life. The properties of the material are transferred into the goods it is made for and turn to be one part of the goods. While the goods are used by people in their daily lives the material and its properties as well as its processing are also experienced by the people who use the goods and thereafter as a part of the everyday culture of the human beings.

This process which forms the cultural identity of a material is a natural process from the historic point of view: whatever a material is used for in the human's life, it will form its cultural identity: Different materials have their own cultural identity in human society, the same material in different using environments could also have different meanings in the different culture. But from the designer's point of view, this process can be changed by innovative use of the material in the design (Figure 4-60). The design can change the material's cultural identity. What design does in changing the cultural identity is not to change the natural properties like chemical, physical and mechanical properties of the material, but change the use of the material. 'A material is cheap' means that the cost for producing the material is low compared with the expensive material. But it often means that this impression comes from the improper uses of the material in the products (and architecture). This happened especially in the phase of the industrial revolution when many of the new industrial materials were invented. Imitation was the task of these new materials, which caused a negative identity of these materials. With the intended purpose of the designers and architects who concentrate themselves not only on the material's special properties but also on the human's everyday life and culture, they succeeded in changing the material's cultural identity in human society and built new identity.

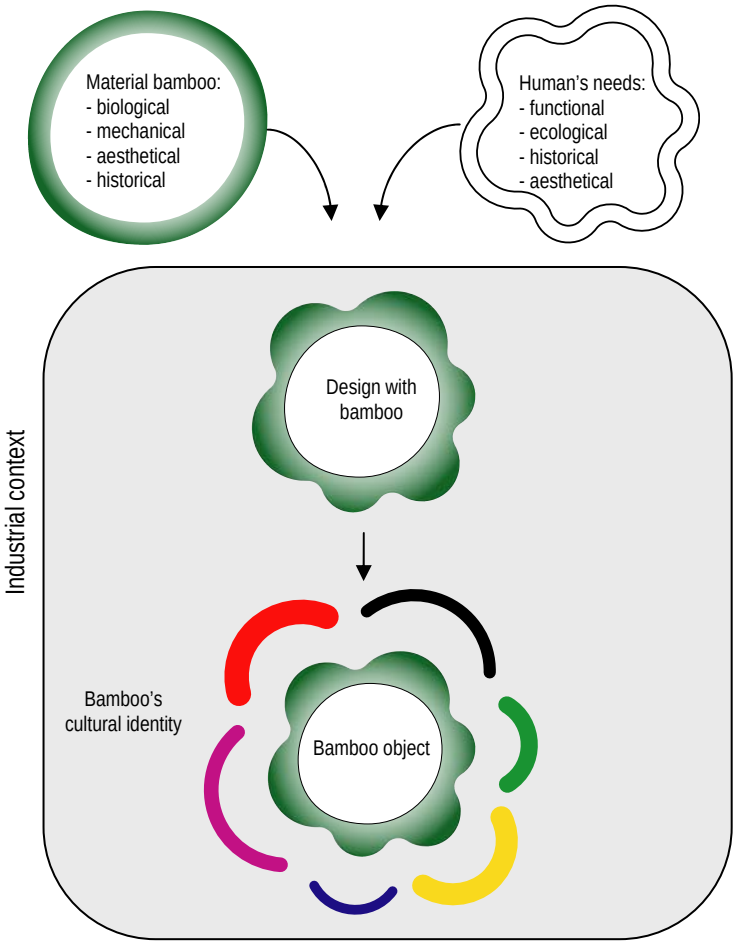


Figure 4- 60 Bamboo's cultural identity in the industrial context

Only through the appropriate design bamboo can get into the modern industrial world by its appropriate utilizations in diverse products or architecture. We can not return back to the pre-industrial time to get the early glorious time of traditional bamboo culture. For bamboo, design plays an important role in deciding what kind of cultural identity a material can have in the industrial society. Industrial materials shown in the last section like plastics, brick and paperboard have demonstrated how design can change the cultural identities of these materials. Each material has its particular characteristics which can not be simply replaced by other materials in the products. One of the tasks of the designers here is to find the proper ways to represent its material characters in the utilizations, so that the material can get its own identity in the everyday culture in society.

For the natural material bamboo it is more complicated than for industrial materials like plastics or aluminum. While those industrial materials themselves have pure material properties and little historical context before they were used in the product design, bamboo has already had a highly developed structure from its natural life, and a long history in nature and with the human beings. These structural and cultural dimensions make it more difficult and also challengeable for designers to design with bamboo as discussed in Section 4.1. Through the modernization of bamboo in the industrial context the broken relationship between the material bamboo and the human needs during industrialization can then be rebuilt. Other than the industrialization of the material bamboo which concentrates mostly on the standardized industrial working process, design considers more the harmonizing of the bamboo's inner structural and cultural dimensions with the outer industrial using context.

Through innovative design with bamboo in architecture and product design, in industrialized form as well as in natural and handcrafts form, as discussed in Section 4.1, bamboo can not only get wider but more appropriately utilized which is important for bamboo to get its relevant identity in the industrial context. A new cultural identity for bamboo in the industrial society is thereafter the consequence of the adequate utilizations of bamboo in the industrial context. As the utilizations of bamboo range from high-tech modern products like Bogner's Bamboo Ski to social house buildings in Columbia, the roles of bamboo in the people's daily life in the modern society also vary from field to field. The identity of bamboo in the industrial context is therefore a complexity with diverse faces. What kind of identity bamboo can have after the modernization of bamboo in the industrial context, which should be a thing other than "material for poor"? I will discuss this question from different perspectives as: technical, aesthetic, ecological and historical.

4.2.3.4. The new cultural identity of bamboo in the industrial context

- Hi-Tech material from nature

'Bionic' is a German word coming from the words "Biologie" and "Technik", which means the principles derived from biology and used for technical applications. As a scientific field it is more like the English term "biomimetics". Another English word "bionics" has another derivation from the word "biology" and "electronics", which refers to the application of methods and systems found in nature to the study and design of engineering systems and modern technology. The technology transfer between the life forms in nature and the synthetic constructs is desirable because nature is a result of an evolutionary process, in which all the life forms have been developed under the evolutionary pressure and therefore become highly optimized and efficient. Although the term of bionics was coined by Jack E. Steele in 1960 at a conference in Dayton, the transferring process from nature to the human's own development has happened already in the early time of the human's civilization. There are many examples from the pre-industrial time to nowadays in the modern technology to show how people have learned from nature: the airplane was originally an effort of imitating the bird; the lightweight constructions for human's buildings also have the similar principle and numerous examples in nature. In 1948, the Swiss engineer George de Mestral was cleaning his dog of burrs picked up on a walk when he realized how the hooks of the burrs clung to the fur; he got the idea for the Velcro, one of the most widely used joints in clothes and other technical fields.

The lightweight construction in nature is a very important field in the bionic. There are many structures in the natural world which accord to the principle of the lightweight structure, like the form of the trees and flowers, the skeletons of animals and even the growth of cells. In the research on the building of vegetal rods at the Institute for Lightweight Structure in the University Stuttgart, Frei Otto praised that all the vegetal rods in the construction have a high resistant capacity under tensile, bending and buckling stress. They are all elastic and have a similar load bearing behavior although they are different in size and shape. Among all the vegetal rods bamboo is the best in size, lightness and strength (Otto 1985). According to the function-structure principle bionics, bamboo can be regarded as an excellent example of nature: it grows very fast, faster than any wood plant on earth; the stems or "culms" are inner hollow tubes connected regularly by nodes which makes it very strong but very light; the radial structure of the stem also accords with it function – at the peripheral zone the vascular bundles are small and densely grouped where the static stress is the largest, on the inside the vascular bundles are larger and looser where the transportation of the nourishment is the main work. It is a structure with minimal material expenses and maximum achievement. The structural features of bamboo have attracted researchers from all over the world, not only from those countries where bamboo has a long history of utilization in the handcraft context, but also from the industrially developed countries where bamboo does not grow originally. The scientists and engineers are fascinated by the material properties and structure of bamboo. This "high developed product" was taken as an important example from nature which human beings can learn a lot from in their own development of technology. In biology Walter Liese from the University of Hamburg began his research on biological properties of bamboo like the anatomy of the stems in the middle 1950s and his continued research in the field serve as a scientific basis for the bamboo's

utilizations. The Institute of Lightweight Structure at the University Stuttgart had begun with the researches on the constructions with bamboo since the beginning of the 1970s, which has been followed by numerous researchers from different institutes and universities in Germany on bamboo in the fields of architecture and construction. In the other countries in Europe like the Netherlands, England and Italy bamboo is one interesting topic for the architects and civil engineers. J.J.A. Janssen finished his dissertation on bamboo for the building structure at the TU Eindhoven in 1981 and formed a research group for the utilization of bamboo in construction. The Vitra Museum has included bamboo in its famous design workshops in Boisbuchet in Southwest France and made experiments on bamboo construction for many years.

Bamboo as a natural material has always had its high respect in the field of bionic. The scientists, engineers, architects and designers are inspired by this wonderful piece of nature. Its growth pattern, its construction and micro-structure is better than many of the industrial materials and products. But the utilizations of the material bamboo in the industrial society are still not so convincing as the bamboo itself. When Eda Schaur explained why the building with bamboo is not so popular than the other materials, even though bamboo has so many advantages, she argued that two points should be the reasons: the one is that the buildings with bamboo, compared to other industrial materials, has relatively short durability; the second is that the material bamboo is still regarded as "the material for poor". The first problem, as she suggested, can be solved by careful selection and preservation of the bamboo canes. The second problem is because there is still no modern, representative bamboo building throughout the world (Schaur 1985).

This situation has changed a lot in the last twenty years through the efforts of the modern architects all around the world. The research on engineering and construction help the new design and architecture with bamboo from one side, from the other side the design and architecture with bamboo also push the technical borderline of the material research. One interesting example is the Zeri pavilion designed by Simón Vélez. It was planned to be built in the EXPO2000 in Hanover but at first was not accepted by the German building bureau because bamboo's mechanical properties, as a natural material, are not stable and there is no test on the material properties and bamboo construction. After the team consisting of researchers from different German research institutions did the test on the 1:1 prototype of the pavilion in Manizales in Colombia, the German building bureau was convinced of the material's mechanical properties and the construction designed by Simón Vélez. They gave the Colombian architect a special permission to build the Zeri pavilion in EXPO2000 Hanover (Dethier 2000). This was a symbol of the acceptance of the natural material bamboo in the industrial world: nature is not only the inspiration for the human's creativity in the world of "everything made in industry" but also part of the human society, as it was in history before the industrial revolution.

The research of bionics helps people on the side learn more from nature, on the other side also help people to become more willing to accept the natural world as a highly developed system. The acknowledgement of bamboo in the scientific world is a good preparation for the material bamboo in the modern industrial culture. Any new improvement of bamboo in the product design and architecture will receive its attention and applause in industrial society. One example is that the civil engineer Christoph Tönges, in cooperation with the TU Aachen, has developed the bamboo joint and construction in Germany which has combined nature and the industrial technique in an elegant space structure (see Section 4.1). This development has received its high attention and appreciation in the academic community as well as in the public society. His company CONBAM and the bamboo construction have been presented in the Hanover Industry Fair 2006 as one of 20 most innovative research groups along with the famous German research organizations like Frauhofer Institute and Max-Plank-Institute. Furthermore the CONBAM has also been selected as one of the innovative places in the event "Germany - Land of Ideas". Their presentation in the design fair in DESIGNMAI 2006 in Berlin also received a special acknowledgement in the public (Tönges 2006).

Not only the bamboo's natural structure can be used in the industrial context to create a modern impression, its natural structure can also be treated into industrialized bamboo products and further used

in diverse modern product design and architecture. Even such kinds of industrialization of bamboo lead to a certain degree of the loss of the bamboo's own structure, but on the other side, if it is then innovatively used in product design, it can still compensate this loss with the remarkable advantage that it gives designer and architect more freedom in using it in their designs. The simple industrialization does not necessarily mean the development of technology until it has been connected with the innovative design in product and architecture. The industrialization of bamboo which results out of the economic and technical reasons has often lead to the degradation of the material bamboo by using bamboo products as a substitute for relevant wood products. Only through the innovative design with such industrial bamboo products, which have been presented in Section 4.1, the industrialization of bamboo has reached its aim: to create a new, modern identity of bamboo with a new technology. And therefore the re-construction of its natural structure can get repaid. In fact the industrializations of bamboo do not get their social acceptance so well before such kind innovative designs come into being. For example the Bogner Bamboo Ski is an example where laminated bamboo has been combined with high-tech materials like fiber, Kevlar, Titanium in the most modern working process to meet the extreme mechanical requirements of the ski sport on the one hand, and to give the product a natural sensibility. For its innovative using of the natural material in the high-tech context the design has received numerous design prizes and has been introduced to the public through different media from sport, design, technology, life style et al.

- **Environment-friendly product for the future**

The term ecology came from the German word 'Oekologie', which was coined in 1866 by the German biologist Ernst Haeckel; the word is derived from the Greek *οικος* (oikos, "household") and *λόγος* (logos, "study"); therefore "ecology" means the "study of the household (of nature)". One of the most important principles of ecology is that each living organism has an ongoing and continual relationship with every other element that makes up its environment. An ecosystem can be defined as any situation where there is interaction between organisms and their environment. In an ecosystem, the connections between species are generally through the so-called food chain, in which each species plays one of the following three roles:

- *Producers* - usually refers to plants which are capable of photosynthesis , or other organisms such as bacteria in the ocean that are capable of chemosynthesis.
- *Consumers* -- animals, which can be primary consumers (herbivorous), or secondary or tertiary consumers (carnivorous).
- *Decomposers* -- bacteria, mushrooms which degrade organic matter of all categories, and restore minerals to the environment.

In this food chain each individual species consumes the preceding one and is consumed by the one following. The biomass is the term to describe the total living biological material in a given area or of a biological community or group. Biomass is measured by weight or by dry weight. The term 'primary productivity' refers to the ability of producing biomass of the plants and the secondary productivity refers to the living matters produced by consumers and decomposers. As an example the forest has about 1/3 of the land area of the earth and the most dense biomass and high productivity. The total production of the world's forests corresponds to half of the primary production. An ecosystem is unstable when the load capacity is overrun and is especially unstable when a population doesn't have an ecological niche. This will lead to an ecological crisis in which the environment of a species or population evolves in a way unfavourable to that species' survival. An ecological crisis can be caused by three factors: the first is the degradation of the environment quality like the increasing of the temperature that threatens the species' needs. The second is the increased pressure of the predation; and the third is the overpopulation of the individuals in the ecosystem.

The world of human beings is only one part of the whole ecosystem of the earth. Even though mankind has been proud of what has been achieved in the making progress in technology and engineering since the industrial revolution in the 18th century, it can realize the price for such an achievement is the

unconcern of the predation of the natural resources which are important to keep the whole ecosystem stable and healthy. The environment gets from bad to worse because of the huge consume of the natural resources by the industry and the ever increasing waste from the industry. People use the natural resources for their industry without caring for that these resources are the important biomass for the food chain of the species. The whole ecosystem on earth has been dramatically destroyed by human beings. In the book "Natural Capitalism" Paul Hawken, Amory Lovins and L. Hunter Lovins (Hawken 1999) argue that there should be four types of capitals which are important for the economy development:

- human capital, in the form of labor and intelligence, culture and organization
- financial capital, consisting of cash, investments and monetary instruments
- manufactured capital, including infrastructure, machines, tools and factories
- natural capital, made up of resources, living systems and ecosystem services

The first three capitals are used by the industry to transform the natural capital into products. But the natural capital has been undervalued and too narrowly defined for a long time: It was regarded just as the natural resources like oil, minerals, timbers or fish etc., whose values have been calculated as only a small part of the end product because they are just a common issue and can be gained from nature without payment. Actually, as Hawken defined, the natural capital includes all the familiar resources used by humankind: water, minerals, oil, trees, fish, soil, air et cetera. But it also encompasses living systems, which include grasslands, savannahs, wetlands, estuaries, oceans, coral reefs, riparian corridors, tundras and rainforests.

The undervaluation of the natural capital and the unconcern of the whole ecosystem in the using of it have lead to the abuse of the natural sources since the industrial revolution. The deterioration of the ecosystem is threatening the whole life-supporting system which is not only critical to the human beings but to all the life-forms – producers, consumers and decomposers. The assets of human beings are not only the house, the cars or the money he has, but the environment, the water, the air, the temperature and the sunshine. All these are under risk because of the un-ecological development of the economy. According to the UN report, each year there are another 6 million hectares productive dry land turned into worthless desert, which will be as big as Saudi Arabia after three decades. About 11 million hectares of forest is yearly destroyed by human activities, this means after 3 decades it will be the same area as India. And most of the destroyed forest is converted into low-grade farmland which can not even support the farms who settle on them (World Commission on Environment and Development 1987).

Nowadays the environmental problems more and more catch the awareness of human beings. A sustainable development has been put up to be a long term responsibility for the whole human society – for the developed countries as well as the developing countries; for the government as well as the public. On the one side various non-government organizations have been set up and different movements or campaigns have been organized to call for the ecological consciousness in society. The "ecology movement" is considered as one of the most influent social movements which emerged at the end of the sixties and had awoken the publics of the whole world, especially in the Western industry countries to concern the environment degradation under the economic development of the human beings. The ecology movement has evolved and branched out to different means of effecting change. There is the political branch with the Green parties. Organizations like Greenpeace were more radical, taking direct action against environmental destruction. Its views on people, behaviors and events centered around political and lifestyle implications of the science of ecology and the idea of nature as a value in itself. "Ecology movement" is an umbrella term for different groups, ideologies and attitudes.

On the other side, the UN together with diverse commissions and organizations has made efforts in developing a sustainable development strategy around the world. As defined by the World Commission on Environment and Development (WCED) in 1987 the sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The United Nations Conference on Environment and Development, also known as the Earth

Summit, held in Rio de Janeiro in June, 1992, was one of the highlights of the series of activities. 172 governments participated and with 108 at level of heads of State or Government. Some 2,400 representatives of non-governmental organizations (NGOs) attended, with 17,000 people at the parallel NGO Forum, who had so-called consultative status. The conference has widely discussed the environmental problems and decided that all the people on earth should work together for a sustainable strategy for the future. The influence of the conference in the world can be seen soon: the Kyoto Protocol which was first brought up in 1997 has been put into force since February 2005 and is now regarded as one of the most important environmental politics. Countries like Poland, France and England have included principles of sustainable development into their laws. The European Union has also proposed the sustainable development as one of its objectives.

The word "ecological" is now not only a word spoken by the politicians but one of the most popular words in the public and can be found everywhere in the industrial society. "Ecological Design" (short "ecodesign") is not only one of the design fields in which designers use ecological materials, but takes into account the whole life-cycle of the product, namely its procurement, manufacture, use and disposal and considers how the environmental impacts will be during the life-cycle of the products. It becomes more and more a responsibility for all the participants in the whole life-cycle of products, not only in the production, but also in design, in use, disposal and recycling. On the other side, products which have special consideration on the ecological factors will receive much higher acceptance in the law as well as in the public. An example for this is the automobile industry: since the last 50 years the speed of global warming accelerated dramatically because of the human's activities and as a result there are more frequent natural disasters like the Indian Ocean Tsunami in South Asia in 2004 and Hurricane Katrina in the USA, 2005. The increased amounts of carbonic dioxide and other greenhouse gases like methane and nitrous oxide (IPCC 2001) are the primary causes of the human-induced component of warming. They are released by the burning of fossil fuels, land clearing and agriculture, etc. and lead to an increase in the greenhouse effect. The emission of the automobile is one of the main contributors. To cut down the air polluting emission by cars diverse laws have been enacted, like the "California AB 1493" in the USA and the European Emission Standards "Euro I – V" ask for that the emissions of all the cars sold in USA and Europe must meet the according standards in these places. This has a big influence on the automobile industry. Manufactures have to invest more power into the research of reducing the polluting exhaust gases. And the new design concept, for example the city mini car "Smart" from Daimler-Chrysler, has put up a city mobility concept, in which through the reduction of two seats of the standard four seats of a car the gas consumption can be cut down evidently. This new car brought the company not only a sales success but also a good market image. Another way is the new technology like the so-called "Hybrid electric vehicles" which uses an on-board rechargeable energy storage system (RESS) and a fuelled propulsion power source for vehicle propulsion to reduce its pollution exhaust gases and petrol consumption. One example is the Prius from Toyota with "Hybrid Gas-Electric" technology which has been rewarded with numerous awards like the 2005 European Car of the Year and the North American Car and Truck of the Year in 2004 for its new technology in concern to the ecological factors in automobile design.

Ecological factors become more important in product design. Whether a product is sustainable or not is also one basic criterion for good design. The jury of the IF International Forum Design, Herbert Lindinger (1992), has put up the criteria for the assessment of good design as the following:

- practicability
- safety and security
- long durability and availability
- ergonomic requirement
- originality in technology and design
- harmony with surroundings
- **Environmental aspects: the product should be sparing of energy and resource in manufacture and use; minimal waste and recyclable**
- visualization of use or function

- high quality of design
- stimulation of sense and intellect

The "Industrial Design Excellence Award" (IDEA) organized by the Industrial Designers Society of America (IDSA) and the magazine "Business Week" has its five criteria for excellent industrial design, one of which is the ecological factor:

- Innovation: how is the design new and unique?
- Aesthetics: how does the appearance enhance the product?
- User: how does the design solution benefit the user?
- **Environment: how is the project ecologically responsible?**
- Business: How did the design improve the client's business?

With the Japanese design award "Good Design Award", the criteria for good design are divided into four categories: "design", "user", "industry" and "society". The ecological factor is to be seen in the "society": "It (good design) puts the principles of 'ecology design' into practice" and "It (good design) contributes to the realization of a sustainable society".

With this ever-growing emphasis on the ecological design, Bamboo as a natural sustainable material has captivated designers and architects for its ecological features:

- It grows fast and needs only 4-5 years for its maturing whereas wood normally needs 50 years. Reducing the pressure of deforestation by overuse of wood becomes possible
- It has a strong subterranean rhizome system which is very good for water and soil fixation
- No additional energy is needed for "producing" the bamboo: compared to industrial materials it can be recycled by nature after the utilizations, therefore no ecological damages for the environment occur

As an ecological material bamboo has an incomparable advantage to the industrial materials. This helps bamboo to be accepted in the industrial modern society. All the new industrial bamboo products and architectures have this ecological feature as one of the most important reasons for their acknowledgement in the public. As the Bamboo Ski from Bogner received its red dot design award in 2004, the juries gave their reason as follows: "The bamboo ski design combines the natural resource of bamboo with components from the field of modern racing ski manufacturing such as titane, glass fibre and phenol. The ski's core and surface are made of bamboo, which is processed untreated and unpainted. *Bamboo is the fastest growing natural resource, environment friendly and very durable.* It gives every product an individual touch and a natural appearance. Thanks to its natural surface, it appeals to the senses of touch and smell (Zec 2004)." The IF had also emphasized its material novelty while giving the BOGNER SKI the IF Gold Award and noted it as "*Natural high-tech. When developing the BOGNER SKI the emphasis was on using a natural, fast-growing regenerative material as an alternative to the materials customary in the industry. Thanks to the special properties of bamboo grass, such as high tensile strength, torsion and pressure load, not to mention its light weight, it is decidedly superior to comparable materials* (IF International Forum Design 2004: 106)."

Another example is the ZERI pavilion in the EXPO 2000 in Hanover. Under the motto "Man, Nature, Technology" the EXPO2000 Hanover had its special emphasis on the sustainable development for the whole ecosystem of the earth. The exhibitor ZERI (Zero Emissions Research and Initiatives) is a non-governmental-organization which tries to build a global network in seeking solutions to the ever-increasing problems of the world, such as the poverty in developing countries and the environmental pollution in industrialization. The ZERI foundation is famous for its numerous projects worldwide in seeking sustainable solutions for the society, with emphasis on using the natural materials in the economical development. For the EXPO 2000 the ZERI has been offered to build the pavilion by the organizer to present ten of the projects run by ZERI foundation. It is then not a surprise that ZERI chose bamboo as the building material of their pavilion, because bamboo can represent their philosophy and works at best: the natural material bamboo has all the advantages from an ecological point of view.

It helps milliards of people in the developing countries to have a shelter, without any damages on the environment. On the other side, through the EXPO 2000, which is regarded as one of the most important events to show the newest development of the world, the bamboo has convinced all the people in the world that it is not only a material for the poor but a modern building material for the future.

- **Sustainable solution for the poor**

For a material the highest achievement is to be used where it is really needed, whatever for the rich or poor. For the people in many developing countries food and housing are still the most important things. Hundreds of millions of people in rural areas urgently need a place to live in. To solve their problem of food and house they can not act like in the Western countries. They can not afford a house resembling the standard of the industrial countries. In the rural villages they are abundant of bamboo resource but without any industry or with a very low level industry for building. Using bamboo as material is the easiest, cheapest and most reasonable way to live. Actually that is what has happened for thousands of years there: people run a life with their natural environments. They live simply on what they can get from nature. The traditional handcraft is based on the properties of the material. Without industrialization they also develop their handcraft technique during the evolution. Even nowadays the tradition of using bamboo in growing their houses can be found there.

But the lifestyle has changed through the globalization. People who live even in the remotest location also face the influence from other parts of the world. The uses of bamboo in their lives have changed even though the economic conditions have not developed to a high level.

Design with bamboo in a modern but economic way for the people there is necessary. Getting the materials and working on the materials to build their houses should all be finished as much as possible on location. In such areas bamboo can be found everywhere around their living place. It is easy to grow, to harvest and to process (in a handcraft context). For them, the most important thing is how to use bamboo in a simple way to build houses and to make things for their modern everyday lives.

Modern industrial design principles should be changed to be suitable for the conditions there. "Design for Needs" is the highest goal there. The basic life requirement – a shelter for people - still is the most important task facing the governments and organizations there. It is also the responsibility for designers and architects: under certain restricted conditions (economic, as well as technical) to design houses which can fulfill the demands of modern everyday lives. Hassan Fathy, one of the most famous Egyptian architects, has devoted himself to this principle through his clay architectures which combined Arabic house tradition with the modern lifestyle. For such a task, bamboo as a natural material has its versatility: it is not only a material that can be processed into valuable engineered bamboo products, but can also be used as a natural material which is low-cost and easy to get for the poor people. Architects and designers in South American countries like Columbia, Ecuador and Brazil have tried to build houses with natural bamboo material in different projects since the 70s.

Latin America has the tradition of using bamboo in building since hundreds of years. The *Guadua* as the absolute dominant genus in Latin America plays a key role in the utilization. For its large size (length up to 30 meters and a diameter up to 20 cm) and stable quality the *Guadua* has been used in house building and other construction like bridges. It was reported by Oscar Hidalgo Lopez that about 6 million Columbians in town and country – mostly in the marginal areas of big cities - live in homes partly or totally built with *Guadua* (Farrelly 1984).

Guadua in Latin America is similar to *Phyllostachys* in Asia. The traditional use of *Guadua* in building construction is also similar to that of *Phyllostachys*. As Dunkelberg has reported the traditional bamboo construction in building houses in South Asia from the European researcher's view in his dissertation,

Lopez (1981) has already done long years of research on the traditional bamboo's utilizations in construction and published books in this fields.

The traditional bamboo construction in housing can still be seen everywhere in Latin America, whereas the modern bamboo construction has been developed there. They range from the very simple rural house to urban modern buildings and the building technique also changes from the simple handcraft to modern engineering. When Jorge A. Gutierrez did his study on the topography of building construction with *Guadua* in Latin America (with focus on Columbia and Ecuador), he divided the *Guadua* building construction into four groups: Rural housing, urban traditional housing, urban marginal housing and urban engineered housing, regarding the social status of the house owners. Different patterns of bamboo buildings demonstrate bamboo as a local material with more than 4 hundred years of history can not only supply the poorest people with sufficient shelter because of its low cost, but also fulfill the construction requirements in such geographic conditions. Compared to other materials like wood, reinforced concrete, the bamboo *Guadua* and its constructions have proven adequate in building houses on steep hillsides with frequent earthquakes through the long time of the evolution process there (Gutierrez 2000).

The modern bamboo utilizations in Latin America in the building construction grow from the old tradition and inherit the old tradition; therefore they have very strong practice intentions. As a sustainable strategy for the designer and architect, there the most important thing is to use this local material to solve the practical life problem as their forerunners: building houses. Different is only that they interpret it in a modern context: new structure and new form. And the development of bamboo using in construction was conducted mostly by professional architects and designers from the practice. They have very concrete tasks and therefore the functional and economic aspect of the bamboo construction has the priority over the aesthetic and scientific meaning, even though some of them also have a very high value of both the latter sides. The way the designer and architect use bamboo in building is also different to that of the European researchers, they do more trial-and-error design processes than applying some scientific theory at first. This is also accordable to their practical objective.

One technique is remarkable in the construction: the ***bahareque***. It is a wattle-and-daub technique that normally uses timber poles for the wall structural frames and two different procedures for the walls. The bamboo canes or splits are woven to a space structure to hold mud or some other materials in it. And the outside surfaces of the structure will later be plastered with mortar. This technique is in principle like the bamboo reinforced concrete, but with none-industrial material. This technique is widely used for the wall construction as a tradition since for hundreds of years and proved to be an efficient method for house building. On the one side it uses the tensile and bending strength and at the same time mud for keeping the interior warm and cool (Figure 4-61).

The bamboo canes as whole tubes are used in supporting the house basement or roof construction. This is a very similar way to the one in Asia, like the "Ganlan" building tradition. The bamboo canes are mostly under press loading in supporting structure whereas in the roof construction they are mostly under tensile loading.

Depending on the economic situation these old traditions are kept in different ways in the modern time. For the people in the urban marginal areas like those around the cities Guayaquil, Manizales in Columbia, the living condition is most critical. They come mostly from the rural countries and have an aspiration of changing their status quickly in the near future. The house they live in is taken as the poorest and culturally most rejected in the society. Bamboo can be found there as the cheapest material solution for building. The dwellers use bamboo themselves from original cane used for posts to spit woven strips used for wall, roof and floor in a very immature manner, without any fine techniques in the building.

Figure 4- 61 Bahareque for the wall construction (left. ref. Jörg Stamm) and a residential estate constructed from bamboo in Manizales, Columbia (right. Ref. ZERI Foundation)

Several projects have been run to help the poor people there to better their living conditions. One project run by an organization called "Viviendas Hogar de Cristo", which was founded and run by Jesuit priests, has tried to design and produce a pre-fabricated house mostly made of *Guadua* for the people living in edging area of Guayaquil. The factory of the organization produces seven prefabricated panels made of woven bamboo strips and laths with which people can assemble together to build a two-room basic house by themselves. The roof is made of simple corrugated iron. This simple prefabricated packet can keep its cost as low as 360 USD. With a discount from the organization the poor family can normally afford it (Gutierrez 2000).

J.H. Arcilo Lozada has reported on a social residential estate project in a Columbian small town Manizales near of Bogota. The project run by the 'Instituto de Credito Territorial' of the Manizales region had the aim to set up new estate in such areas with low housing density, on expropriated ground and on steep slopes, in order to keep the cost low and to reduce the housing shortage of the town. Bamboo was taken into account for the project as building material, because the town Manizales is abundant of bamboo *Guadua* and has a long tradition of using *Guadua* as building material. Growing fast; flexible; light weight; durable. For this project bamboo is especially good for its construction on the slopes and resistant to earthquakes. The I.C.T. built the concrete foundation with 6 to 7 meters for each household. The dwellings consist of living room, bedroom, kitchen and WC, with light and ventilation. The house was erected by the residents themselves in association with the I.C.T. and other residents (Lozada 1985).

In such projects which are normally also aimed at solving the housing shortage of the low-level social groups and based the techniques much on the tradition the architects it is also often tried to integrate the tradition into the industrial context, either using the industrial producing process like pre-fabricated construction components or modern life standards for housing.

- **Material with history**

The historical context of bamboo can have both positive and negative sides in the modern society in countries like China, Japan and Korea where bamboo has a long tradition of utilizations. On the one side the traditional bamboo goods have been considered as "out of time", "obsolete" and have been replaced by the industrial products. And the bamboo handcrafts are also taken as "low quality" and "imprecise".

On the other side, the bamboo has always had its positive influence in nowadays everyday life in history. This does not refer to the practical uses of bamboo as a material, but more often means the symbolic function of bamboo. Bamboo as a metaphor for the good personalities in history has been inherited into the modern culture. Poems and literature about bamboo are one of the most important cultural wealth and are learned by pupils in school and are studied by scholars in university. Because of the importance of bamboo in history, people in the modern society have a special respect for bamboo as a wonderful plant. The respect to bamboo is of course based on bamboo's aesthetic as well as biological and ecological characters which in the modern society are similar both to the countries with bamboo traditions and to the countries without those, but in history bamboo plays a special role in the cultural development. This history of bamboo in the culture defines bamboo in a broader dimension which can connect bamboo and culture in the modern society. This can explain why the new design concepts with such historical contexts will be accepted in those places. One example for this is the architecture competition in Taiwan in 2005. The international competition was held to request a design proposal for the 228 National Memorial Park commemorating the 228 Incident happened at the end of World War Two. The objective of this project is not only the hope to recover the memories of 228 Incident that are gradually forgotten but also to consider the historical meaning of the incident, coming out of pursuing justice, respecting lives, and truth of social harmony. They hope to gather the strong living force of Taiwanese and take peace, democracy and freedom as a new vision and walk from the sadness of the history. They also hope the proposal could supply culture, ecosystem, and educational function for recreation and arouse the local prosperity (228 National Memorial Park, 2006).

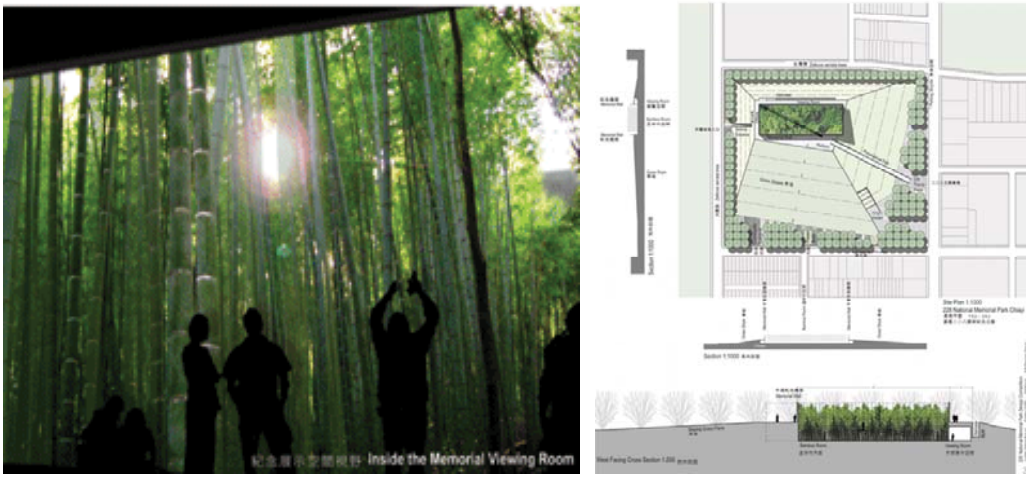


Figure 4- 62 Architecture concept for 228 National Memorial Park in Taiwan 2006 (ref. 228 National Memorial Park)

The winner was a design team from UC Berkeley consisting of Prof. Judith Stilgenbauer and graduate students Kit Shihting Wang and Calder Gillin (Figure 4-62). Their concept Conceal/Surface is about time, growth and the inevitable revelation of historical truths. A bamboo room was the central part. It is a partially sunken courtyard planted with bamboo (*Phyllostachys pubescens Mazel*) and enclosed in a semi-translucent glass walls offering veiled views of the bamboo within. Two glass panes separate a road in the courtyard from the bamboo plants which let visitors go and view through in the bamboo plants. The growth pattern and the history of *Phyllostachys Pubescens Mazel* were researched by the design team. This bamboo species was introduced in Taiwan 250 years ago and is naturalized as a local bamboo species in Taiwan. And it is the favorite among the people there for its straightness, vitality, resilience and honesty. The *Phyllostachys Pubescens Mazel* was borrowed here as a metaphor of the historical truth, which even under political pressure can not be stopped to grow. It is also taken as a symbol of hope for the future development of the nation: pursuing justice, respecting lives, and truth of social harmony.

The historical context in the sense of the traditional bamboo handcrafts has its different situations in the modern society in different places in the world. In those countries like Northwest India the

industrialization still stays on a low level and the bamboo goods are exclusively made by craftsmen, so the bamboo crafts have been developed and preserved very well. Whereas in those counties like Japan, Korea and China the industrialization stays on a high level and the traditional bamboo goods by craftsmen are always seldom to see in practical life. But it is kept in ways like souvenirs, decorative objects and art objects which represent the traditional culture and are preserved together with other local traditional cultures in the modern society. Through the fuse with modern life style the traditional bamboo crafts begin to enter people's everyday life.

- **Natural beauty: Aesthetic aspect**

From the perspective of the Bionic, nature has been and is always a good prototype for human's design. Through million years of the evolution all the creatures in nature have optimized their form and therefore are also logical, reasonable and beautiful. This principle in nature, in which the form and its function do correspond to each other, has been used by Sullivan to prove his famous principle of modern design:

> *All things in nature have…a form, an outward semblance, that tell us what they are, that distinguishes them from ourselves and from each other. Unfailingly in nature there shapes express the inner life, the native quality, of the animal, tree, bird, fish…it seems ever as though the life and the form were absolutely one and inseparable…whether it be the sweeping eagle in his flight or the open apple-blossom, the toiling work-horse, the blithe swan, the branching oak, the winding stream at its base, the drifting clouds, over all the coursing sun, form ever follows function, and this is the law." (Sullivan 1947: 207-208)*

Nature itself is a complexity which is full of design and has been used as the resource pool for human's design since the beginning of the human civilization. From the lotus leaves the ancient Egypt had learned to build their column capitals. In the modern time many architects and designers have always taken design inspiration from the world of nature – from the form of the shell to the skeletons of fish, from the shapes of flowers to the horns of rams. Powers described this kind of inspiration coming from nature:

> *"Patterns of all kinds reveal themselves to the eye, some on the surface of animal skins, leaves or tree bark, others in the geometric arrangements of seed heads, snowflakes, the spirals of a shell or the movements of the planets and stars in the sky. Still deeper versions of these patterns can be seen with the microscope. The diversity of inspiration from nature is astonishing, and designers have always borrowed from these structures in the course of solving problem or just gratifying their own sense of order. (Powers 2000: 30).*

As the result of a long time of evolution the natural world has a special beauty because it has proven adequate for its environment and reasonable, otherwise it would not have survived till now. The natural world presents therefore a high level of aesthetics compared to the human-made world. Actually the achievements of human beings own a lot to the natural world.

Alongside with the Modern Movement the principle "form follows function" has often been interpreted into a geometric and rational style doctrine in architecture and showed the inspiration of the modern people by the beauty made by the industry – for example the high dimensional precision in production. On the other side the Nature always shows numerous examples with high aesthetic value. These two counterparts are showed principally in the Figure 4-63. The organic architecture in which the form of the design is strongly inspired by nature has always shown its strong influence among the architects and designers. Le Corbusier has designed the famous chapel at Ronchamp in 1950 with its organic roof form, which was inspired by a crab shell he picked up on Long Island. Frank Lloyd Wright was famous for his design philosophy, the so called "organic architecture" – architecture "of Nature, for Nature", which has been represented by his work the Solomon R. Guggenheim Museum in New York in which all the classic building structure elements floors, walls and stairs are fused into a white spiral structure from bottom to top. The Sydney Opera House designed by Jørn Utzon was an architectural metaphor to the sea shell.

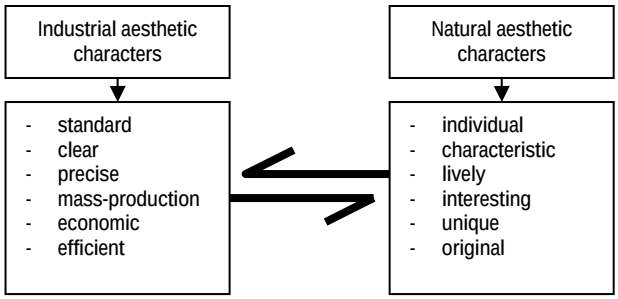


Figure 4- 63 Industrial and natural aesthetic characters

Especially the architecture and product design in the modern time show again this kind of trend – learning from nature. The form and construction principles of nature have been borrowed by different designers and architects in their design works. Compared to the modern industrial form language such as: standard, clear, precise, mass-production, economic and efficient etc., objects from nature have their own form language like: individual, characteristic, lively, interesting, unique and original. These natural, aesthetic characters play a more and more important role in influencing the most recent architecture and product designs because nowadays in such a world in which the technology and industry dominate the whole society with its cold, even unfriendly ways they represent in the human's everyday life. Furthermore the technical improvement in materials and their productions do not always mean to lead to the form of a cubic box with straight lines and even surfaces, on the contrary, they give the designer and the architect more freedom in using them to build their own individual forms. The irregular forms and structure which are characterized by almost every object in nature, also the bamboo, are now not a disadvantage but a special virtue of nature. Modern designers like Fernando + Humberto Campana and architects like Herzog & de Meuron are now looking for the way in which this kind of natural irregularity can be integrated into their works to achieve compensation of the disadvantages coming from the human technology, or in another word, to harmonize the modern technology and natural beauty in their designs (Figure 4-64).

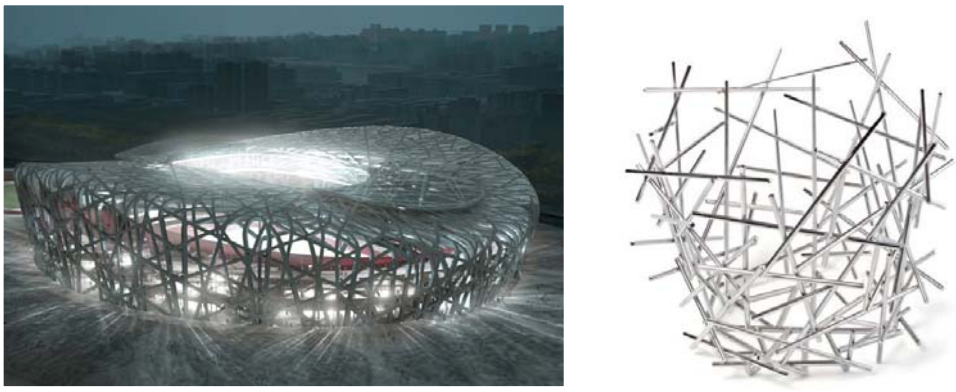


Figure 4- 64 Modern designs with inspirations from natural structure (left: Olympic Station 2008 in Beijing, ref. Herzog & de Meuron; right: Blow Up - Citrus basket designed by Fratelli Campana for Alessi)

Bamboo as an elegant plant from nature has its aesthetic value acknowledged not only in those traditional bamboo countries, but also in Europe and the USA where no bamboo grows originally. This natural beauty can be found in the gardens as a garden plant at first. For example in Germany there are more than 40 species of bamboo that have been implanted (Bambus-Centrum Deutschland 2006). But more and more, bamboo as a design element has found its uses among designers and architects for its beautiful form and structure. Just some pieces of bamboo canes are used in the high modern interior design. Alongside concrete, stainless steel, glass and ceramic, all of which have extreme geometrical and simple forms, bamboo brings a special natural and human feeling into the living space to balance the

cool, rational atmosphere with its natural origin, the natural colors which change in the course of the time and the irregular form and structure.

Figure 4- 65 Bamboo used in one interior design in Passagen 2007, Cologne

4.2.4. Summary

The industrial materials like steel, plastics and bricks have built their own cultural identities in the society when they are used in diverse products and further bought and used by the consumer (user). The way how the material is used decides how it will be accepted in the society and how its cultural identity could be. As discussed in the last section, the history of plastics has demonstrated how negative the cultural identity of a material could be made by an inadequate definition of the material in the utilization. Plastics would always have been considered as a material of cheap, characterless and imitation, if it were not for designers who continually use plastics in new products. Through the innovative use of the material in their design work, designers invent a new "life-form" for the material and it will appear in people's life with a totally new character which is harmonized with its properties and human's needs. And only by this way the material can build its own cultural identity.

Bamboo is a material with a natural structure and a long history of handcrafts which may not be suitable to be used in the industrial context like the industrial materials. But compared to industrial materials bamboo is also a material with a high value in reference to ecology, bionic, history and aesthetics in the industrial context. The only problem is to find adequate "life-forms" for bamboo. This will be the task for the designer and the architect, who can design the new way bamboo is used, in which its material advantages are harmonized with the modern human's life needs. This new "life-form" of bamboo should not just simply inherit the traditional bamboo handcrafts which have their handcraft processing context, nor be the imitation of the "life-form" of other industrial materials which have their own structural and historical context. A new "life-form" of the material bamboo in the industrial context is based on the appropriate design of bamboo in the industrial context, which has harmonized the bamboo's inner structural and cultural dimensions and outer modern human needs in the industrial time. It is a high-tech material from nature; an environmentally friendly product for the future; a sustainable solution for the poor; a material with history; a material of natural beauty; and much more in the future, as the human needs are always changing and designers then always keep up this kind of changing with new designs of bamboo. A new cultural identity of bamboo is then just the result after this kind of modern design of bamboo has been used in people's everyday life and further turned to be a part of the everyday culture.
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Chapter 5

Summary and Outlook

It is not the material but how it is used that matters – a Chinese old saying

5. Summary and Outlook

5.1. Summary

Bamboo is a material with structure and culture. The traditional bamboo utilizations, which have harmonized the natural structure of bamboo and the creativity and techniques of the craftsman and have built a glorious bamboo culture in history, lost their importance in the industrial world because its natural structure does not fit the industrial standardized mass production. A modern utilization of bamboo and consequently a new bamboo culture in the industrial context can be realized only when the relationship between its inner structural and cultural dimensions and the outer industrial context have been rebuilt in a bamboo utilization system in which the material bamboo, designer and human needs are considered.

This utilization system did work quite well in history. This could be found in how bamboo has been used and how bamboo has become a cultural being in the history of many countries where bamboo grows. In history the craftsman is the person who connected the material bamboo with human needs, namely using this natural structure with simple tools but fine techniques and the creativity in making goods to fulfill people's daily life needs in which bamboo's natural structure has been highly respected. These practical uses of bamboo in human daily life have formed a kind of material (bamboo) culture which represents both the special natural structure of bamboo and at the same time the ways how crafts re-structure it. For this kind of culture a German word "Alltagkultur", which refers to all the things along with its utilizations and habits for everyday life, could be used to describe it. Bamboo culture means more than bamboo's uses as a material with practical utilities, but furthermore, as a beautiful plant in itself and a symbol in arts, literature and philosophy which show in another way how bamboo's natural structure has been respected by human beings. The traditional bamboo culture represents a harmony between bamboo and human being.

This relationship which seems so natural in history has been broken in the industrial time. Bamboo's natural structure which has proven strong, light, efficient and easy to process is now the most important disadvantage to many industrial plastic materials which can be processed by standard machines and used with other standard components. Bamboo got lost in the industrial world. The industrialization of bamboo as a way to help bamboo re-enter the human's everyday life has its orientation more in economy and technology, but is not the real solution to the problem. In the industry bamboo's natural structure

has been degraded into standard substances and then used as the substitute for wood. Bamboo culture which in the history represented a harmonic relationship between bamboo and human needs could not be found in such a way in the industrial context.

Modernization of bamboo in the industrial context is to solve the problem in a systematic way. Between bamboo's structural and cultural dimensions and the outer industrial context a new relationship should be built by designers, who should take the place of the craftsman and is responsible for re-connecting the material bamboo and human needs in the industrial context. Design with bamboo as the first level of the modernization would be impossible before the structural dimension of bamboo has been re-positioned in the industrial coordination system: the industrialization of the material bamboo is then regarded as an adjustment from the material side to help bamboo suit the requirement of the industrial using conditions. Most important for this is the consequent design with the industrialized bamboo material in which bamboo's own material characters and its processing can be fully taken into consideration, not just as an imitation of others. Examples have demonstrated how designers can achieve this through the innovative using of the material in modern products and architectures. From the other side, the designer can also move himself closer to the material. Why does an industrial design in the industrial world still need to use a natural material which is irregular and difficult to be treated by machines in his designs, even if he has so many industrial standard materials? The sense in doing that is to keep bamboo's structural advantages in building construction as much as possible in its utilizations. This is something like a challenge for the designer who is accustomed to using standardized industrial contexts. The key point in designing with natural bamboo structure is to design the joint and its construction which can use standard industrial connection elements and at the same time incorporate and absorb the bamboo's irregular dimension. Numerous experiments in different countries with different emphasis have been undertaken and the progress in these works is inspiring. Even though the ideal joint and construction have not yet been developed this direction shows the ideal utilization of bamboo in the industrial context.

Modern design with bamboo has another meaning in which bamboo's cultural aspect is specially considered. Bamboo's cultural dimension sometimes is negatively interpreted as "handwork, uneconomic, imprecise, and underdeveloped" because it is connected with the traditional crafts' working process. But bamboo's cultural meaning goes wider than just bamboo crafts: the bamboo plant has an influence on the traditional culture because of its natural beauty in form and structure. This will still get its acceptance in the modern industrial culture. Many designs in architecture and products have demonstrated how bamboo's aesthetic aspects can be appropriately used as a design element in the whole work. Not only designers from traditional bamboo countries, where bamboo's cultural aspect has been widely acknowledged, but also from countries like in Europe where bamboo culture has no historical meaning. Even though the traditional bamboo crafts can be redefined in the industrial context, traditional bamboo crafts still have their practical utilities as first aim, which will cause big difficulties for its existence in the industrial context because for the same utilities the other industrial materials like plastics or metal can be more cheaply mass produced and therefore can be sold for a much lower price. But when bamboo crafts are defined as an applied artwork which represents the special material properties and the fine techniques of the craftsman, this character will give bamboo crafts a special value other industrial products can never have. Furthermore bamboo crafts have a close relation with the traditional culture in many fields. It is like a material medium which carries the immaterial culture like that in the Japanese tee ceremony.

These four design principles help to build a new relationship between bamboo and designer in the modern industrial context. The consequence of the design with bamboo is the second level of the modernization of bamboo: the modernization of bamboo's cultural identity. With the help of design, a material is experienced by people in their daily life. How its cultural identity will be built in the social culture depends therefore on how it is used in the product (architecture) and how the product (architecture) is used (experienced) in people's everyday life. Design can change the negative cultural identity of a material by appropriately using the material in a design which demonstrates a harmony between the material's characters, its processing method and the human needs. The appropriate application of the material in design plays an important role for the success of the product on the one hand; on the other hand the success of the product will contribute a lot to how the cultural identity of

the material will be built. From the histories of some industrial material like plastics, brick and cardboard, one can see how design plays a key role in building a new cultural identity. A modern cultural identity for bamboo can be the result of the modern design of bamboo which reflects both bamboo's structure and cultural dimensions and the new human needs in the industrial context: bamboo in the industrial context is a natural material of modernity, history, high-technology, sustainability, ecology and beauty and much more, depending on the how designer can use it in meeting the ever changing human needs in the future.

5.2. Outlook

Bamboo in the modern industrial society is in its narrow sense a question of how to treat and utilize bamboo, but in a larger sense it could be a case study on the question of how we, the human beings in the world of modern industry and technology consider our history and ourselves as a natural life-form (a creature, an organism or in German "Lebewesen") who is still not born in industry. All the paradox in bamboo is like a "sign" from nature: it transfers messages to us and makes us think about our development in the industry, our development with technology. This study does not mean to vote against the development of technology and industry, one the contrary it considers the progress of technology as the irresistible process, so do the people where nowadays industrialization happened in the developing countries. What this study wants to present, is the idea that the development of the technology in today's degree should be more than to just get more power and ability which nature can not, it should be more compatible with nature (we are living on Earth with other creatures) and the culture (we have a history which has formed who we are now) – an ecological and sustainable development. Another idea is what designers should and could do in such a progress: from the beginning of the modern design Bauhaus School to the hfg ulm, the social responsibility has always been defined as the most important task for the designer. As the connecting figure between the development of technology and the social life of human beings, the designer should not just function as a one way train, which only transfers the new technology into society, he should also form a much wider perspective – from the human needs, from the whole world which human beings also belong to, from the whole evolution process in which we now stand at one point only – to spend his efforts in making life better as a designer.

How to utilize bamboo in our industrial world is getting more and more attention from different social groups in the whole world. The international organization INBAR (International Network Bamboo and Rattan) has built a global network of partners from the government, private, and not-for-profit sectors in over 50 countries in improving the social, economic, and environmental benefits of bamboo and rattan. From its foundation in 1997 the INBAR has worked for a global sustainable development through bamboo and rattan. Along with the fundamental research on bamboo's biological properties and cultivation, new product and architecture design to help bamboo being more widely and adequately used in the developing countries is also an important strategy of the INBAR. By its diverse conferences and numerous training workshops, the new processing technology and new utilizations of bamboo are explored and propagated among the global network (INBAR 2006).

The Vitra Design Museum is famous not only for its architectures designed by Frank Gehry and diverse exhibitions on furniture design, but also for its numerous summer design workshops on different fields of design. Together with Centre Georges Pompidou the Vitra Design Museum has invited many famous artists, designers and architects every year to organize a number of workshops in the Domaine de Boisbuchet in South France. Bamboo has always been one of the main themes of the workshops. In 1999 the "bamboo architect" Simón Vélez was invited to lead the workshop in which an experimental bamboo pavilion has been built. Design competitions and workshops have been organized to promote the new concepts of using bamboo in product design and architecture. As discussed in Chapter 2 and Chapter 4 the international design workshop "Toys from Bamboo and other Materials" organized by the 'Fördern durch Spielmittel -Spielzeug für behinderte Kinder e.V.' together with the firm Happy Arts & Crafts Co., Ltd. and Anji city was another example of how bamboo as a natural, traditional material can be newly used for people's modern life in the special field: toys for disabled children through the creative designs by designers from all over the world.

New exciting information on the design of bamboo is the "2007 bamboo international building design competition" organized by the Bamboo Technology and Bamboo Hardwood Vietnam, Ltd., sponsored by the International Network for Bamboo and Rattan (INBAR), International Bamboo Foundation (IBF) and Bart Trudeau (Trudeau Architects). The designs are categorized into 12 groups such as Family Houses (moderate priced dwellings), Custom Houses (high end specialty), Affordable Housing (lower cost), Hybrid Houses and Buildings (with other green building materials), Tree Houses and Pole Houses, Resort Houses (beach, mountain, lake), Temporary, Portable and Emergency Relief Structures, Urban Buildings (residential, commercial, mixed use, penthouse), Commercial, Public Buildings and Infrastructure, Pavilions, Conference Centers, Roof Structures (for gatherings), Park and Garden Structures and Structural Art Installations. It is amazing that about 240 designers, architects and offices from 64 countries worldwide have submitted their design concepts. In these design concepts both the natural bamboo structure and the industrialized bamboo board products are applied in the modern building design. All of them have from one side made an enormous progress in exploring the techniques and design in using bamboo as a material in architecture design, from the other side it promotes bamboo as a modern building material among designers and architects, later among the whole society as the winners of the competition will have the chance to realize their design concepts in Maui, Hawaii (International Bamboo Building Design Competition 2007).

We can believe that in the future bamboo will receive more and more acceptance and importance in the whole society through the fact that more and more modern designs of bamboo are getting into people's everyday life. That will be not only the triumph of bamboo, but the fruit of the whole effort and the evidence of the harmony of our development.

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