Innovated Building Material`s Interactions with Structural Form in Architectural Projects

Begüm Mozaikci

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Prof. Dr. Elvan Yılmaz
Director (a)

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Architecture.

Assoc. Prof. Dr. Munther Moh`d
Chair, Department of Architecture

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Architecture.

Assoc. Prof. Dr. Munther Moh`d
Supervisor

Examining Committee

1. Asst. Prof. Dr. Halil Z. Alibaba
2. Asst. Prof. Dr. Munther Moh`d
3. Asst. Prof. Dr. Polat Hançer

ABSTRACT

Interpretation of building materials into architectural form, is gaining greater interest and attention due to the conservation of architectural heritage. This study highlight, the influences of technological developments of building materials and their interactions with structural form in architectural design projects. Architectural form and decisions can potentially effects by introduced new materials and this study focus on the interaction of new material and structural form, moreover it is more focus on contemporary architectural forms including construction methods and technology used. With the innovation of new material and improvement of the existing materials properties this thesis aimed to argue about what is happening to the building material and structural forms relationship in the context of architectural design projects. The practical constraints of the design projects in the process of realizing them which is building materials will be discuss in the whole research. This study prepared to draw a attention of the architect’s and architecture student`s to the influences of technology and building materials on architectural design projects. This will be done by documentary researches related to the Technology, Building Material, Structural Form, Form and Structure in architecture field and deep investigation of six selected materials with respect to technology factors in their existing time through the years will be discuss to show bulding material and structural from relation modification respect to time.

Keywords: Building Materials, Structural Form, Structure, Form, Technology and Architectural Design

ÖZET

Mimari mirasın korunması adına mimari form üzerinden yapı malzemeleri ile ilgili yapılan yorumlar büyük ilgi ve önem kazanmaktadır. Bu çalışmanın amacı yapı malzemelerinin teknolojik gelişme ile gelen etkilerinin stürüktürel formla ilişkisinin mimari tasarım projeleri çerçevesinde incelemektir. Mimari form ve kararlar büyük bir ölçüde yeni tanıtılan malzemelerden etkilenmektedir. Bu çalışmanın odak noktası yeni malzemeler ve stürüktürel form ve bunların birbiriyle olan ilişkileridir. Bununda ötesinde çağdaş mimari yapı malzemeleri, formları, inşaat teknikleri, kullanılan teknoloji ve bulunulan zaman incelenmektedir. Yeni malzemelerin gelişimiyle ve var olan malzemelerin geliştirilmesiyle, mimari tasarım projeleri çerçevesinde yapı malzemeleri ve stürüktürel form ilişkisine ne olduğu tartışılacaktır. Tasarım projelerin gerçeğe dönüşmesinde pratik (Kullanılabilirlik) kısıtlayıcı olarak yapı malzemeleri tartışılacaktır. Bu çalışma mimarların ve mimarlık öğrencilerinin teknolojiye ve yapi malzemelerinn mimari projelere olan etkisine dikkat çekmek için düzenlenecektir. Bunlar mimarlık alanındaki teknoloji, yapı malzemeleri, stürüktürel form, form ve stürüktür ile ilgili kaynak taramaları ve seçilen altı malzeme ile ilgili tecknolojik gelişmelerini zaman içerisinde göz önüne alınarak yapılan detaylı araştırmalarlar ile gerçekleştirilecektir.

Anahtar Kelimeler: Yapı Malzemeleri, Stürüktürel biçim, Stürüktür, Form (Biçim), Teknoloji ve Mimari Tasarımlar

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CHAPTER 1

INTRODUCTION

1.1 Overview of the Study

Existence of human being through their history of civilizations, provide answers to their needs and demands, by struggling to determine the livable spaces. This effort can create livable spaces; it’s become a physical fact, through the structurally formed materials. Building materials are the abandon part of the structural form, to build a livable shelter. In fact, human being remembers the architectural products in his/her mind with their build materials and forms (Baktir, 2006).

Through the historical process of design in architecture, it is obviously seen that applications, forms, types, knowledge’s, of material usages may change. In fact, the principal reason of this development was defined as human being`s search for “new” from the beginning of their existence. On the other hand, the principal reason of searching for “new” can be clarified by human being desires or development of technology to build human beings demands, requirements, needs,…etc. (Baktir, 2006). However intensive searching for “new” may be seen with the beginning of Industrial Revolution; such that its considerable influences on architecture may not be disputed. (Cotterel, 1990).

With the development of industry the existence systems may change and religious things lose its power on society. Human being change`s in their social life may show itself in architecture as a different need in buildings. The pressure of religious buildings were decline and religious buildings give its place to public buildings which respond the public usages such that museum, exhibition, train station, etc. Because of this needs some new facts such that standardization in production, assembly of materials in site was developed. To make use of steel, curtain glass, reinforced concrete, lift, ventilation, lighting systems, etc. will be enables the high rise/large span buildings construction.

According to Lawson "The practical constraints are those aspects of the total design problem which deal with the reality of producing, making or building the design; the technological problem. For the architect such problems include the external factors of the bearing capacity of the site and the internal factors of the materials used in constructions." (Lawson, p.103, 2006). Lawson deals in his book which is called "How Designers Think, the design process demystified" about the constraints of the projects. With the words of Lawson which is already stated above it is obvious that instead of functional, aesthetical and formal constraints in the process of designing and realizing projects there is a very important constraints which is called as a practical constraints. Technological problems and materials that will be using in the construction of the design projects may consider as an important constraints. Without considering the improvements, developments and discoveries in the material industry it is difficult and moreover it is impossible to build practically apparent projects. In architectural design, to be designing a project which must considered all the important features such as aesthetic, function and formal organization instead of all these the feasibility of the design is also important. If we cannot practically build a design projects and if it is stand on the paper only somehow it is not useful and feasible design.

The nineteenth century, synonymous with the Industrial Revolution, is a pivotal period in the development of materials. This period is marked by the development of structural theory and materials science (Heyman, 1998). More generally, the economy of Western nations grew with the development of first the steam engine, then electricity, and finally the internal combustion engine. These technologies in turn led to the development in the railroads, steam ships, and industrial manufacturing. All of these developments in some way are products of the ascendance of iron and steel as the primary materials of the new age, replacing stone and timber. During the nineteenth century, modern plywood was developed, aluminum was discovered, the first plastics invented, and reinforced concrete emerged as a distinct material (Brookes, 1978). “These materials variously challenged the primacy of iron and steel in the twentieth century.” (Brookes, p.65, 1978).

Within the development process of material, together with vernacular materials and new materials developments, etc. it has many development`s effects on structural forms of the buildings. This is because these improved and new materials are gives us chance to milk the pigeon in building design.

Architectural form and decisions can potentially effect by introduced “new” building materials and this study highlights the influences of technological developments of building materials and their interactions with structural form in architectural design projects will be takes into consideration during the whole research. Moreover it is more focus on contemporary architectural forms and materials including construction methods and technology used. This study prepared to draw an attention of the architect's and architecture student`s to the influences of technology and building materials on architectural design projects.

1.2 Aims and Objectives of the Study

As is known development shows itself on everything, and it is same in architecture although as an architect all must follow up the developments to respond to the user`s desires, as a designers.

Actually architecture is a something that it holds technology in, because human beings can also design the technology as such design is something that holds everything in its body. However with the faster development of technology after industrial revolution this sentence has been lost its idea. Because if the architect who can follow recent technological developments more he/she is the architect who can design projects which are takes people eyes on. There is a big dilemma in the architecture world. Some architects believes that architecture must hold everything in its own body, designing is something that above everything, on the other hand there are architects who believes that technology is the power which controls everything. In the figure below you can see this dilemma frankly. The starting point of this research is planning to throw a light for this dilemma. Building materials are something that effected by the technological development. The design, form, and structure decisions may effect by the building materials. Construction methods and equipments have direct relationship with technology. The figure below shows that relationships between design, form, structure, construction method, equipment, building material, technology and architecture. Currently the starting point of this research aim has been spread out from these relations. This thesis aimed to find the place of technology with its investigations.

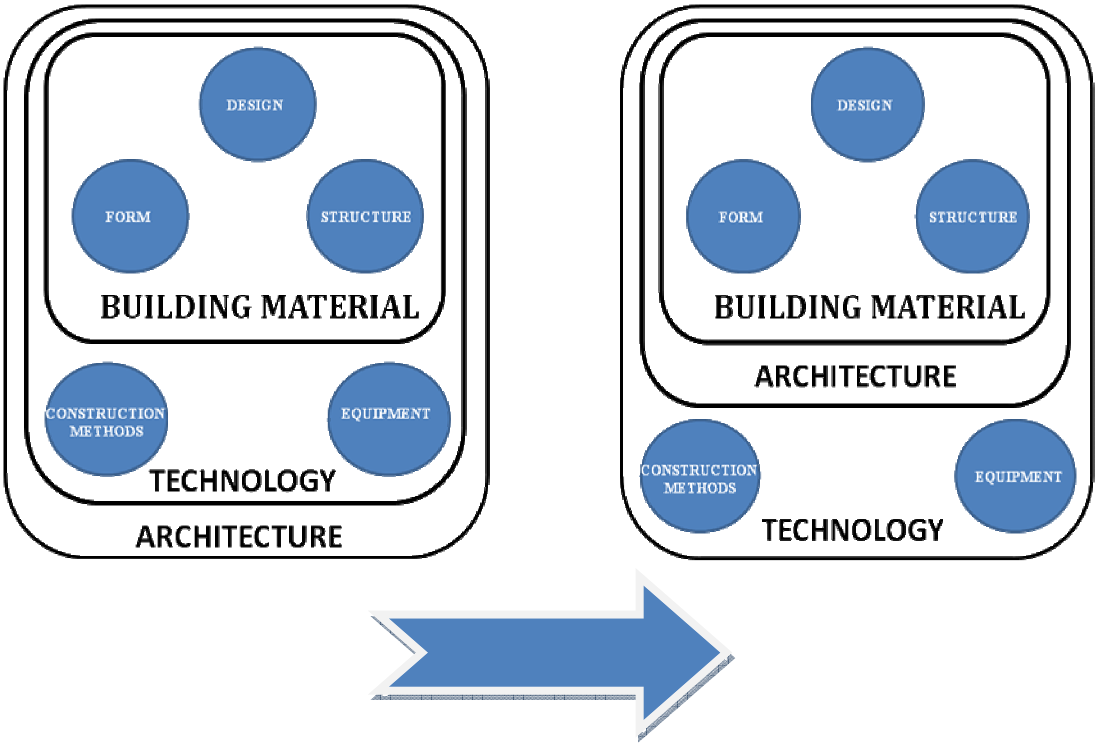


Figure 1: Technology - Architecture relationships through the Industrial Revolution

Nonetheless with the faster development of the technology the technological problems of the design projects have been spread out. These problems may consider as a practical constraints of the design. Practical constraint is aspects of total design problems which are related with its realization process of the projects. In architectural design, to be designing a project which must considered all the important features such as aesthetic, function and formal organization instead of all these the feasibility of the design is also important. If we cannot practically build a design projects and if it is stand on the paper only somehow it is not useful and feasible design. This thesis has been planned to abate this situation with its suggestions.

All the researches that have been done up to now shows that building materials, structural form, technological development and architecture subjects have not been examined all in one of the research yet. The aim of this study is integrated to fill the gap of this deficiency in architectural world. This study prepared to draw an attention of the architect’s and architecture student`s to the influences of technology and building materials on architectural design projects. Also most of the studies on development in architecture do not interpret why or how developments of technology may affect great features on design especially about building material and structural form decisions in contemporary architecture. This study focuses on, the influences of technological developments of building materials and their interactions with structural form in architectural design projects. Within these this research was conceived to find an answer for these questions which are stated below,

- Why have structural forms evolved as they have?

- What influences the process of creating structural form?

- How does development of material affect structural form decisions?

- What are the principal relationships of material and structural form interaction from architectural point of view?

- Is the material restrictive element in designs process which is affects structural form decisions?

- What are the developing technology yield/yields on architecture as a consideration of material and structural form?

- What influence the development of structural material and form in architectural life?

- How do structural materials develop to form new geometric shapes?

These questions will be used as research objectives through the whole research.

To achieve those objectives initially it is planned to identify and define building material and structural form apart from each other. Thereafter it is emphasize on how the knowledge`s from these research can be used toward in the chapter V to have discussion of relationship`s of building materials and structural form in the context of architectural design projects, essentially it is aimed to show building materials and structural form interactions within the influences of technological development in the architectural world.

Consequently the product of this thesis will be to provide an effective theoretical base for building material, structural form and technological thought knowledge in architecture.

1.3 Research Methodology of the Study

The research presented in this thesis is a part of wider study that sought to determine how the technological development`s effects building materials and how this development may effects structural form and building materials interactions in architectural design projects? Research methodologies includes a documentary research, to developing a new approach that sought respondents` general opinions about the influences of technological developments of building materials and their interactions with structural form in architectural design projects will be takes into consideration during the whole research.

1.4 Thesis Outline

This thesis has been structured so that each chapter is largely free-standing and this will allow to reader to make easy reference to material. The order of the chapters begins by considering the building materials and structural form interactions within the influences of technological development in architectural world.

The rest of this thesis is organized as follows:

Chapter II It contains literature survey. This chapter will give brief definition of building material, structural form, structure and form. On the other hand how they relate to other fields where technology and design are considers in this process too. Some of these books and some papers are related to the research areas that have been published in the last 20 years which are summarized in this part.

Chapter III generally provides information about “Building Material” and idea of “new” and the reasons of its development, the development in the usages of the building materials, position of the building materials in the architectural design projects, technology and architecture interactions and discussions about material`s alternating materiality properties such as dematerialization and immaterialization are summarized in this part. In the part of “the development in the usages of the building materials” five different building materials has been selected for the investigation. These are stone, concrete, glass, wood, steel-aluminum-other metals and plastics. They can be selected through their percentage of usages in the constructions through all over the world.

Chapter IV focuses on structural form definition frankly. This chapter examines the structure and form relationship in architecture. The content include definition of structure/form, architectural structures/forms and its contents, general types of structures, structural systems, structural components, structural elements an classifications, relations of structural systems with used materials, architectural form and types, philosophy of form and structural form and their appropriateness are briefly examined in this chapter.

Chapter V is aimed to show the relationship between materials and structural form and with the innovation of new material and improvement of the existing materials properties it is aimed to argue about what is happening to the structural forms and building material relationship in the context of architectural design projects. This will be done by investigation of six selected materials with respect to technology factors in their existing time through the years in fact those materials has been examined in chapter 3 in more detail. Therefore the influences of technological developments of building materials and their interactions with structural form in architectural design projects will be bring out.

Finally, Chapter VI provides the conclusion and future directions about research field.

CHAPTER 2

LITERATURE SURVEY

It is of some interest to briefly review the historical evolution of the various developments in technology through building material, structural form, structure, form and contemporary design approaches in architecture. Specifically the branch of structural materials and structural form interactions within the influences of technological development, and their effects on architectural design has been planned to review in this section.

If someone is looking for a clear definition of building material and structural form in architecture and how it relates to the other fields that also imply technology, it turns out that there are several related fields, and there is considerable overlap among them, in fact all has reflections on design approaches in architectural projects. For this reason all must be reviewed step by step for brief understanding of their relationships in between them.

Several important directions can be noted in building materials and structural form interactions in architecture. For one, it began with the observation that a material newly introduced into the building industry is likely utilized as a replacement to and in the shape of established materials (Cotterel, 1990). Within these Cotterel mentioned that, the Greek Doric-style of architecture clearly exhibits details that are typical of wood construction, reinforcing the proposition that the stone temples of

Greek antiquity derive from a timber building system. The Romans are the first civilization to exploit the arch, a form more appropriate to stone's strength properties than it is use as a beam in projects (Cotterel, 1990).

Heyman used strong examples to prove his dissertations about structural form and structural material. Such as Abraham Darby, Jr., an English iron founder built Ironbridge, the first all-cast-iron bridge in the world, over the Severn River at Coalbrookdale, England, in 1779. This bridge has a semi-circular arch form; a characteristic of stone arches, and has connections typical of timber construction. The first iron beams were not fabricated in England until 1796 (Heyman, 1998).

Nonetheless Heyman focuses on reinforced concrete systems structural form too. Around the turn of the twentieth century, reinforced concrete building systems were characterized by a hierarchical structure of column, beam, floor beam, and floor slab. The form of this system is typical iron or wood frame construction. The flat slab was invented in the first decade of the twentieth century. It introduced a two-way plate system to structural design (Heyman, 1998).

Dooley has been focused upon such issues to advance the development and application of a new material, today's designers can benefit from knowing how materials, such as steel and reinforced concrete, were first introduced (Dooley, 2004).

Nonetheless Baktir has been focused on building materials in her research thesis which is titled as "Yapı malzemellerindeki teknolojik gelişmelerin mimari biçimlenmeye etkileri” in Gazi University. Baktir has been focused only building materials innovations in fact nano technologies and computer technology`s effects on building materials in the context of architecture has been examined in the research thesis. Baktir had not been discussed any structural issues about architectural projects. However in this thesis it is aimed to discussed the influences of technological developments of building materials and their interactions with structural form in architectural design projects (Baktir, 2006).

Structural material and structural form are inextricable features in architectural design process. So, their connection with each other must be understood well, to have a successful togetherness in the architectural projects. Nevertheless great emphasis must be given to understand importance of these features for architectural designers.

However to explore structural form as itself in case of necessity it suggests to investigate entirely on form or structure before focusing directly on structural form. Because it is somehow combination of two cardinal approaches in design, these are “structure” and “form”, nonetheless “form is an inherently philosophical topic by the definition simply it is shape/figure.” (Cinici, p.32, 1998).

Even if we consider apparently material or quantitative conditions governing the creation of form, such as the relationship between material properties and structural form, the thought processes used to generate form can constitute a philosophy of design by default (Dooley, 2004).

Whyte in his book “Aspects of Form: A Symposium on Form in Nature and Art” traces a collection of papers and examining the relationship between natural and man-made form in art. Whyte`s has a philosophical method of approaches while he deals with form (Whyte, 1951).

Ted Ruddock records the development of arch bridges from 1785-1845 in his book “Arch Bridges and Their Builders”, it is specified that how the development of arch theory, particularly in France, has been affected the design and form of arch bridges (Ruddock, 1979).

Schodek "Structure” book define the structure as “is device for channeling loads that results from the use and/or presence of the buildings to the ground.” (Schodek, p.4, 2001). The study on structure certainly involves coming to understand the basic principles that define and characterize the behavior of physical objects subjected to forces.

About structural form there are a great many studies have been done. One famously view on this study was originated from Mainstone by book which is named “the development of structural form’, its focused on the importance of analysis, geometry and static and how this knowledge gave designers more “choice” to create structural form. Mainstone prime interest in this book is,

> “*a rounded and creative understanding of the pattern and processes of development and, thereby, also of future possibilities in structural form. In doing this, chronology cannot be ignored. Time and place have always partly determined objectives, precedents and available means*.” (Mainstone, p.5, 1998).

Mainstone traces the developments of the major structural base forms, such as domes, walls, slabs, beams, tension structures, etc.

Mainstone stated that, “Development is… a historical process. New developments build upon those that went before. But there are so many cross-currents, borrowings, influences, and interactions that there is no single linear progression.” (Mainstone, p.6, 1998). Mainstone does credit the influences of function, construction process, material property, technology, and knowledge has direct pertained to the development of structural form in architecture.

For Mainstone, the principal influence on form is static as such stated that

> “*The over riding requirements governing the choice of form for the complete structure are geometrical ones concerning the relative disposition of elements in space. With the wide choices of materials, internal details and methods of construction available today, these are not usually onerous requirements*.” (Mainstone, p28, 1998).

According to this statements Mainstone was more concerned with the effects of form on material choices rather than the development of forms for specific materials, as same as objectives of this research (Mainstone, 1998).

On the other hand Mainstone, as a historian of building technology, noted that designing was a very different activity from seeking a scientific explanation for a particular category or experience. Mainstone wrote “the essence of structural design as being the very human activity of making particular kinds of choice.” (Mainstone, p.121, 1998).

Clear definition about structural form in architecture noted by Unay, traces structural form;

> "*as the geometrical configuration of the space involved by the structure. However, within a similar external visible geometry, different structural actions could be responded by structure under the same kind of loads. Various capacities of different materials, internal detailing of cross-sections, the manner and sequence of construction and the dimensions of the structure can cause different structural actions in similar overall geometry of the structures. Therefore, the geometrical configuration is only one aspect of the structural form*." (Unay, p.3, 2002).

According to this statement it is obvious that pertain between structural material and structural form in architecture is undeniable.

Sandaker, purpose in writing "reflections on span and space" is to develop theory of criticism for architectural structure and deals with form in his arguments are within the context of aesthetic entity. Sandaker argument about the link between structure and form are limited to statics and geometry. Sandaker has been stated that strenght+stiffness properties = resultant form. Nonetheless, he is stated that "The efficient use of structural materials means to seek stiffness and strength through geometry rather than through mass and dimension… Structures become efficient when the members resist loads by setting up axial forces (or surface forces) rather than bending forces." (Sandaker, p.86, 2000).

Through Siegel else`s eyes in the book "in Structure and Form in modern Architecture" he proposed a theory of criticism of architecture that relates the aesthetic clarity of structural expression or appropriateness to construction process and methods (Siegel, 1975).

The strong string between the material and form frankly seen by the Angrisani, statements, “material with which an architectural work is made are the essence itself of the building activity.” (Angrisani, p.3, n.d.) A design comes into begin and grows with a given material: the material has to accompany a design since its very initial phases because it represents the starting point, rather than the destination, of the technical and formal reasoning leads to execution of architectural works.

Gordon presents a philosophy of structure and structural form designs at the end of his book entitled Structures, or why things don’t fall down. Gordon bases his philosophy on the work of H.L. Cox, who was an exponent of the mathematical study of the philosophy of structures in the 1970s. Gordon argues that structural design should be governed by shape, weight, and cost. Gordon discusses the relative efficiencies of tensile and compressive structures, pointing out that the weight and efficiency of tensile members is a function of length and size because of the necessity for heavy end fittings. And also reviews the merits of: monocoque versus space frames, pneumatic structures, and other structures (Gordon, 1978).

Therefore, materials can be considered as the “basic elements” of architecture, since they make it tangible and perceptible by senses; they represents the entities which have materially shaped the placed inhabited by mankind, which have interacted, as time went by, with the building techniques, re-shaping and modifying them in order to continually adjust the same to their own characteristics, but also allowing to shaped and modified by them (Angrisani, n.d).

Ashby's Materials Selection in Mechanical Design presents a detailed model for the material selection, within the design process in architectural project. Ashby has created charts that compare different combinations of material properties and attributes from which materials can be selected that best meet the designer's specified criteria. Ashby's book uses a broad array of examples that include structural applications in design projects. Ashby emphasizes the interaction between function, shape, material, and processing (Ashby, 1999).

Bell and Rand provide a book named "Materials for Architectural Design". They present a foundation for a strong design sensibility intertwined with material knowledge. It makes a thorough study of each material's properties, history, permutations and production techniques. They provide an illustration to show how their application informed each building's ultimate form (Bell & Rand, 2006).

There are several important directions can be noted about the development of materials science and its role in the development of materials. For one, from Gordon's with his book "The New Science of Strong Materials". Gordon traces the advances made in the knowledge of materials science from World War II to the 1970s. Gordon shows how this knowledge was used to develop materials such as plywood and fiber reinforced composites. Gordon also demonstrates the value of understanding materials science to explain the behavior of conventional materials such as steel and natural wood (Gordon, 1976).

According to these statements it is obvious that, the technological thought is an important feature that direct effects the development of structural material and form in architecture, during the existence of human civilization.

Technological thought is an important subject related to the development of building material and structure. Confessedly, it is confirmed by the statement of Dooley “The subjects of technological thought has grown its importance in parallel with the increasing in industry” (Dooley, p.48, 2004).

Layton and Reynolds have both written about the development of technology in America, examining the cultural and contextual influences on technological change that were distinctive from other parts of the world, particularly Europe (Layton, 1971 & Reynold, 1991).

Basalla analyzes the merits of the evolutionary model applied to technological development in his book “The Evolution of Technology”. Basalla`s book includes interesting chapters about the influences of socio-political factors and economics on the development of technology (Basalla, 1988).

Mui K. provides a statement about architectural design and technology relationship. Mui stated that “design is a process to achieve an aim or to solve a problem through research, analysis and creativity. Throughout each century, design has reflected the evolution of culture and technological development” (Mui, p.96, 2005).

Mark book`s, “Architectural Technology up to the Scientific Revolution”, is a suitable overview of the historical development of stone construction. Meanwhile Mark`s book explains how construction concerns influenced the development of arch, vault, and dome forms. Consequently, Mark directly explores development effects of technology on structural material and these affects explored on structural form, already time consumed during these developments (Mark, 1993).

Hartoonian book`s, “Ontology of Construction”, examines the influences of construction technology in architectural design in more philosophically (Hartoonian, 1994).

Besides these Sandaker subordinated the extents to which structural requirements or technology limitations influences form to being a component of architectural form (Sandaker, 2000).

By Picon “In French Architects and Engineers in the Age of Enlightenment”, recorded the transformation of architects from a classical, beaux arts system of design and having to adjust to the functional imperative of the Industrial Revolution such as iron and other new building material (Picon, 1992).

Peters “Technological Thought is Design`s Operative Methods”, has been developed a refined theory that “the construction process has a role in the progress of building technology”. Peters has put forward a model of technological thought based on what he calls matrix thinking, which emphasizes lateral, rather than vertical, thinking. The distinction here is in the details, whereby the ‘detail’ in structural design, is as important hierarchically as the overall system (Peters, 2000).

On the other hand Etienne Gilson, in his book “Forms and Substances in the Arts”, provides another perspective for material understanding in architecture. The materials to which architects give form are not things like bricks, wood, etc. Rather, the materials of architecture are design solutions; these design solutions, considered abstractly, are organized into the plans for buildings, and, considered concretely, are organized into the buildings themselves (Gilson, 1966).

Petroski presents theory about the role of failure in design within technology. Petroski posits that failure and technological progress are inseparable. Petroski uses a wide range of examples to demonstrate the causal effect of failure on design, from bridges to forks to aluminum can pop-tops (Petroski, 1994).

With the all mentioned literature arguments above the relationship between building materials and structural form interactions within the influences of technological development in architectural design projects has been recognized. However all these literature research shows that building materials, structural form, technological development and architecture subjects has not been examined all in one of the research yet. The aim of this study is integrated to fill the gap of this deficiency in architectural world. This study prepared to draw an attention of the architect’s and architecture student`s to the influences of technology and building materials on architectural design projects.

These references above can be used as a basis for further research in order to integrate building materials and structural form, and technological thoughts in architecture more substantially into the substance of this thesis.

CHAPTER 3

ANALYSIS OF BUILDING MATERIALS AFTER INDUSTRIAL REVOLUTION

According to Angrisani statements “Materials with which an architectural work is made are the essence itself of the building activity.” (Angrisani, p.2, n.d.). Therefore a design comes into being and grows with a used material.

The purpose of these section is to give an overall view of the development of the material`s usages and idea of “new”, position of building materials in architectural design procedure, effects of technology in material (in the parts “when materials meets with technology”) and to have a discussion about material`s alternating properties such as “dematerrialization” and “immaterialization” . Nonetheless to recognize the idea of building materials developments in architecture it is needed to look the development in the usages of the building materials through history. And how this process of technological development may affect the building materials through the years? In this context the aim of this chapter is to focus more on the development of the building materials after industrial revolution.

The six different materials will be investigated through the development of the usages within the years. These materials are stone, concrete, plastics, glass, aluminum-steel-other metals, and wood. The reason of choosing these materials is, they are the materials that has been used generally in all constructions or at least one of them has been used in any of the construction as such the building material selected through their percentage of usages in the constructions all over the world (Baktir, 2006).

It is included in this section the significant advances in processing technologies; the invention or incorporating inter-disciplinary technologies that helped to advance the development of the materials; and relevant economic and production data. Furthermore these usages of materials for certain trends or characteristics will be indicating key mechanisms of development for each material (Dooley, 2004).

3.1 Idea of "New" and the Reasons of Its Development

The objective in making buildings is far more than making shelter and the feeling of having a place to live, to define themselves a space and being disconnected from the outer environment. In human nature, there is a feeling of wanting to be control of components, material, nature, air, gravity…etc. This effort keeps developing itself during the whole time of arranging the space. Knowing that the material have a variety of special features and they can be used in other conditions and places, these are a chiefly origins of new searches in architecture.

When it looks at the development of material, it's adverse in two different conditions as the development of existing material and the discovery of new material. Technological development and new approaches in material, its countenance new searches in architecture and have been opened new constitutions ways. In this stage it's needed that to define "new", and to argue about the reason of "new" approaches.

“New” can be defines as to develop something which already exist or it can be named as finding something which has never been found before. New;

- Something that has never been done before.
- Something on an upper grade development.
- Something that which someone has nor don’t.
- Something which already exists, but it’s become new by adding other methods into it.

Formation process of “new” can be through;

- The discovery of “new”.
- Innovations in the usages of the existing materials, through with development of performance and through the adding of some changes on it.
- Development of the varieties of the original material

Each step in formation of “new” process, is newer that the one before. It is right to say that “new” is directly tied with time that it’s made. If we evaluate it over process, something on an upper grade development while it was first discovered in its time.

Shortly, it is right to say that something can be defined as “new” according to time that is discovered.

A state which is made on its time as new, may becomes old with the time flows. As Atabas clarified; “today’s advanced material-edifice-technology, is going to be tomorrows standard material-edifice-technology.” (Atabas, 2000).

New had a bond with time in fact it has bond with place and culture. Based on the blossom stage of societies; in a place where the conditions were new, can be old in another place.

The most important reason of the new can be infer by technological development. With developed technology, being board of something which already exist, not finding it enough, being able to cope with the new age period, being creative, trying to get an income from existing sources can also be counted in the reason of “new”. These reasons bring new ways of searching with them.

Consequently the intensive searching for “new” may be seen with the beginning of Industrial Revolution; such that its considerable influences on architecture may not be disputed. (Cotterel, 1990).

3.2 The Development in the Usages of Building Materials

To the best of our knowledge’s the stone is being heavy, the ceramic being fragile however the works that is done on materials may changes with the development of physics and chemistry fields, therefore some concepts in material property to undergo a change. Such as, ceramic is being produced with the high fragile resistance, glass can be permeable for desired rays and it’s become opaque to the unwanted rays. Nevermore glass fragility property can be decreased. Plastics, flammable property is lost therefore it’s become the materials that are showing different performances. To be taken into consideration in varying properties of materials, with the possibilities to be used in new shapes and areas, are the main sources for the new researches in architecture.

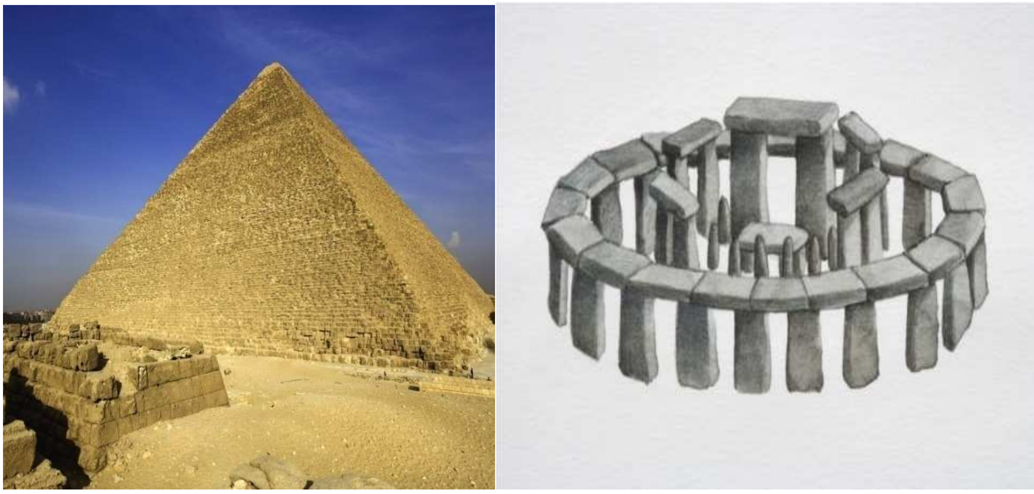
3.2.1 Stone

Stone is the oldest building material known to man. The origins of stone date back to a period nearly 4000 million years ago. Stone has a long history, it is using from ancient times to today. Stone have been among the all other materials it is the most important structural materials throughout history. The first stone structures were probably made by stacking found rocks to make walls. Megaliths are evidence that men learned how to maneuver large stones, using earth ramps to make such distinctive structures as dolmens (Dernie, 2003).

Picture 1: Dolmen Lanyon Quoits at Cornwall, England
[http://stonepages.wordpress.com]

Stone is a naturally occuring material. “Man’s first structural materials were those readily at hand: stone, wood, earth, vines, bamboo, and other naturally occurring materials that could be fashioned into shelter or fortification” (Dooley, 2004).

Tools to work the stone improved during the Bronze Age as evidenced by the squared surfaces of the beams and columns of Stonehenge and the great blocks used to construct the pyramids in Egypt. As Sebestyen mentioned that “brick and stone are among the oldest materials having been used in the ancient Babylon and Egypt.” (Sebestyen, p.23, 2003). The Egyptians built simple arches, in the construction of the pyramids two stones leaned against one another, and at some time they began to make arched vaults with brick (Dooley, 2004). It must be recognized that there were few material choices available at the time. The reason to use stone was probably for its constructability, strength and durability reasons in its period of time in fact stone has been using as a structural (as a load-bearing) reasons too.



Picture 2: Giza pyramid and Stonehenge photos [http://www.greatbuildings.com]

However at the present day stone has relinquished its position as a structural (load-bearing) material. It is much favored in specific functions, such as cladding for curtain walls, in gabion system to fill in the steel cages, bonded masonry, form-molded stone to fill in between concrete and stone walls, and floor paving and sculptural and decorative purposes. Such that it is obvious that the application techniques of stone may changes with the new demands and searches.

Herzog de Meuron is the best known architect who used stone gabion in his projects. The projects Dominus Winery in Napa Valley, California can be masterpieces for this trend. It is cost effective compared with traditional concrete or reinforced concrete walls and they offer potential to use small pieces of local stone, furthermore the construction process is simple (Dernie, 2003).

Picture 3: Dominus Winery in California by Herzog de Meuron
[http://www.greatbuildings.com]

According to Dernie,

> “*In the past stonemasons would have worked and selected the stones on the site. At the present days, with the possible exception of large restoration projects, the stone is worked in the mason`s yard, reducing the levels of skill required on site, where the efficient and safe erection of pre-prepared masonry are the prime concern*” (Dernie, p.12, 2003).

Today with the development of technology most efficient stone production yards may have a range of tools, from traditional items to computer aided machines (CAD/CAM) in fact numerically controlled water jet cutters and robot arms are used in cutting and shaping the stone (Dernie, 2003).

To sum up, stone is the earliest material that it is used in construction of architectural products. The reason to use stone in ancient times was probably for its constructability, strength and durability reasons in its period of time in fact stone has been using as a structural (as a load-bearing) reasons too, however today stone using as a covering material instead of using it as a load bearing structural element. Nowadays new materials supersede the structural work of the stone. In the future it seems that stone will be use as a covering or decorative element instead of its structural applications or with the invention of technology may be the disadvantages of the stone will be solved. As such every day more advantageous materials will be invented to cover the place of stone. For instance stone is a heavy material it is better to use lightweight materials instead of stone. If it is possible to rich same structural form with light material it is better to use it.

3.2.2 Glass

Glass is a material which has been in developed through the history. As Sebestyen mentioned that “glass has been known since early times so it`s fully justified being considered as a traditional material.” (Sebestyen, p.5, 2003).

Glass is an ancient material, dating back more than 5.000 years. It is believed that the material originated around 3500-3000 BC in Egypt and Easter Mesopotamia with the creation of beadlike forms that were valued as highly as precious stone. Around 1700-1600 BC during Egypt`s 18th dynasty, artisans developed the skill to creating translucent bottles, jars and the first window panes for buildings. This process used heat to transform sand, seaweed, brushwood and lime into a range of forms and colors (Bell & Rand, 2006).

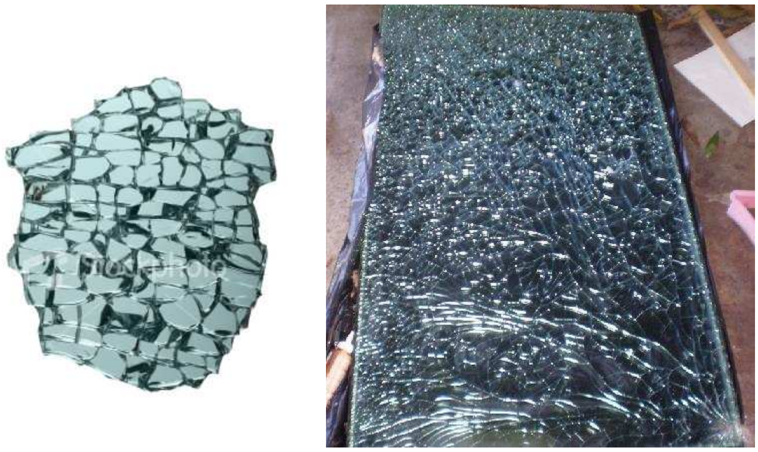
Natural glass is formed by volcanic eruption. Natural glass is composed of three elements; they are sand, soda and lime furthermore fifty other elements are added to the mixture in production of different types of glasses. In recent times the average glass consist of about %70 sand (silica), %13 lime (calcium oxide), %12 soda (sodium carbonate) and %5 additives (Wigginton, 1997).

Glass performs a significant function in space divisions and heat and sun control. At first glass was used in buildings for sunlight and ventilation needs, even with the development in production sector, it was used in windows, in double glazing windows, in whole transparent facades as a curtain wall, in structural glass systems, and as a cladding in shell systems. During the twentieth century the curtain wall emerged with new types of glazing. However, on the facades of the skyscrapers, linear glass fixing components were still presents. Furthermore, the ambition was to develop all-glass facades with uninterrupted glass surfaces. Gradual progress in material and systems achieved this objective (Wigginton, 1997).

“If the facade is shaped as an uninterrupted glass surface, we use the expression “all-glass”. In the 1920s Le Corbusier and Mies Van Der Rohe attempted to develop all-glass systems but the technology evolved only gradually and at a later date” (Sebestyen, p.25, 2003). In this contexts such façade`s becomes possible by the revolution in material industry as such by fixing the glass panes at the corners only, then the glass facades is suspended by stressed cables to the structures or an alternative solution for all-glass facades may used, its glue the panes at their corners to the load-bearing frames (Sebestyen, 2003).

All these developments become feasible by technology. Thus within this process the unfavorable points was faded by developed production techniques in material industry. Mass production of the sheet glass, the development of steel frames, cable structures, fixing devices and systems as well as of elastic and elasto-plastic sealant changed this and resulted in a number of innovative solutions and systems

(Sebestyen, 2003). For instance glass is a material which is not strong against the pressure; however with chemical methods it's become stable under the pressure. Thus with the technical developed in glass properties, while its breaks, it turns into many small pieces to reduce the danger (Kolarevic, 2003). Also this type of glass can be called as a "safety glass". The low tensile strength of glass can be improved by its thermal or chemical toughening. Thermally toughened glass fractured into small pieces and thereby reduced risk in the case of glass breakage (Sebestyen, 2003).



Picture 4: Safety Glass [http://ths.gardenweb.com]

At the present days, the problem of energy in world, cause a development in existing materials production so, it is intended to produce an energy efficiency material. In the frame of this context this development in reduction of energy usages was effects glass development too. Glass can control the sunlight rays which have been passed in. Glass coated by one or by several thin coating layers may be heat and light absorbent and/or reflective. "These properties have been affects the appearance of the buildings and even eventually its colors too" (Sebestyen, p.25, 2003). In glass technology has been reached to the analytical levels in physical and chemical properties. As Nouvels mentioned that, as we look to the glass it does not referencing any basic transparent looks anymore. It has more sophisticated identity. And it becomes more sophisticated sooner. It will present more thermal insulations with a couple of small cm. (Nouvel, 1998).

The thin coating like organic and inorganic materials was applied on the glass surface to respond the needs for thermal insulation. The use of additives in the glass production, like organic materials can increase the properties of glass as anti-fog, anti-freeze, not to hold a water, unpolluted, styles in glass production. (Arribart & Buffat, 1992). It is more prevalent for economical solutions and thermal optic reasons inorganic materials can be added in glass to respond the needs.

Photochromic, electochromic, thermochromic (Low Emissivity Glazing), holographic, and liquid crystals used glasses were defined under the group named "smart glass". Glass is able to impress itself even from environmental effects; as such smart materials may uses. These glasses changes their colors, transparency, light permeability according to the current of electricity, heat, light which may comes from outside.

From this group of "photochromic glasses" is actually polymer essential. The glass parts of sunglasses are made by photochromic glasses. As such sunglasses glass when the light gets stronger the lens gets darker, as such these glasses mostly produced from silver dusts. When the light falls it takes dark silver color and becomes transparent under shadow. Heat and light permeability is around %50. It has another model which has light and heat permeability around %40 however it has sensitive thin plastic coating in between double glazing (Kienl, 2002).

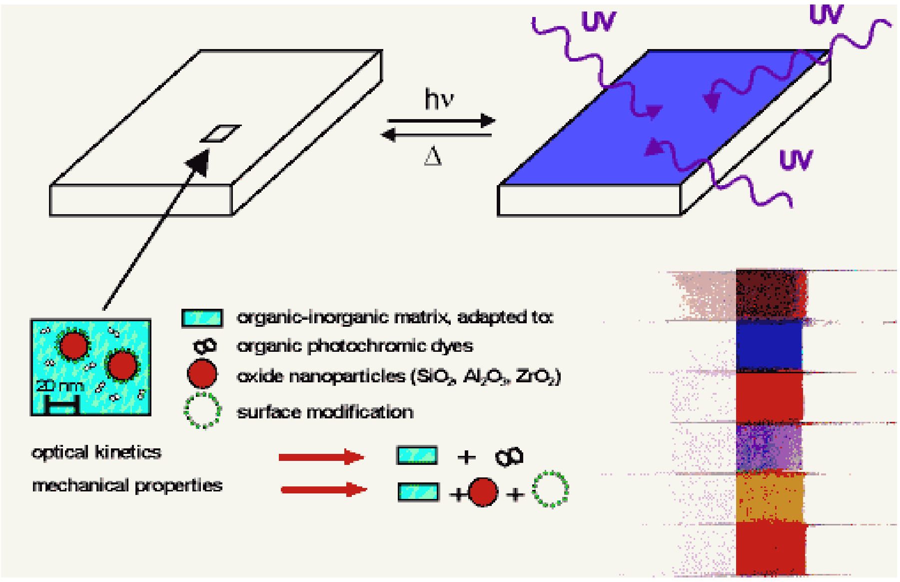


Figure 2: Photochromic Coating Glass on the glass surface [http://www.solgel.com]

Thermochromic which defines as Low Emissivity Glazing glasses have been reformed their surface colors against the environmental temperature. When the temperature is increase its changes to opaque white. Its levels of opaqueness will fix according to the temperature. Thus this kind of glasses is polymer essential, as such inorganic materials are used as an ingredient in their production process (Kienl, 2002). A typical double glazed window loses heat in three ways: by convection, by conduction, and by radiation. However the radiation accounts for 2/3 of the heat loss while conduction and convection heat transfer account for the remaining 1/3. (Wigginton, 1997). Focal point is for improving the thermal performance of windows has been to control the thermal radiation losses. The use of transparent films decreases the amount of heat transferred by conduction and radiation.

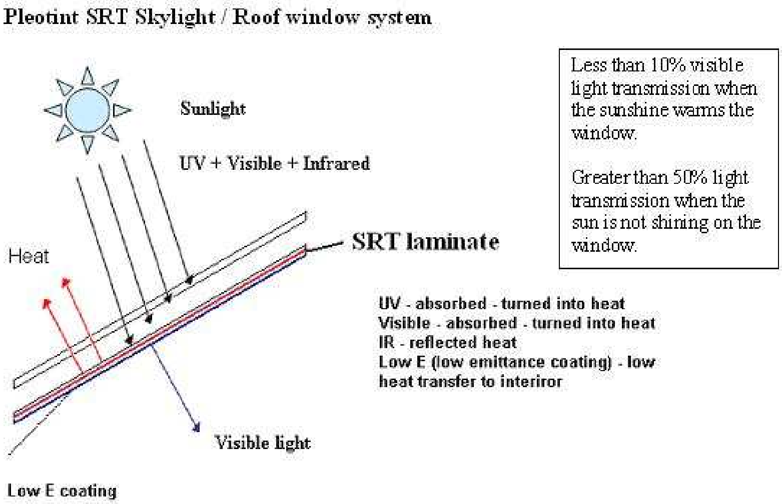


Figure 3: Thermochromic Glass [http://www.pleontint.com]

Electrochromic glasses are the glass that gets its color dark from the low currents levels of electricity. Inorganic, organic material and some metal oxide materials are used its production (Kienl, 2002). It is separates from thermochromic and photochromic glasses with these properties as such electrochromic glass needs a low voltage for their activation, and in all conditions it is homogenous, with long lasting memory it does the right thing in right time.

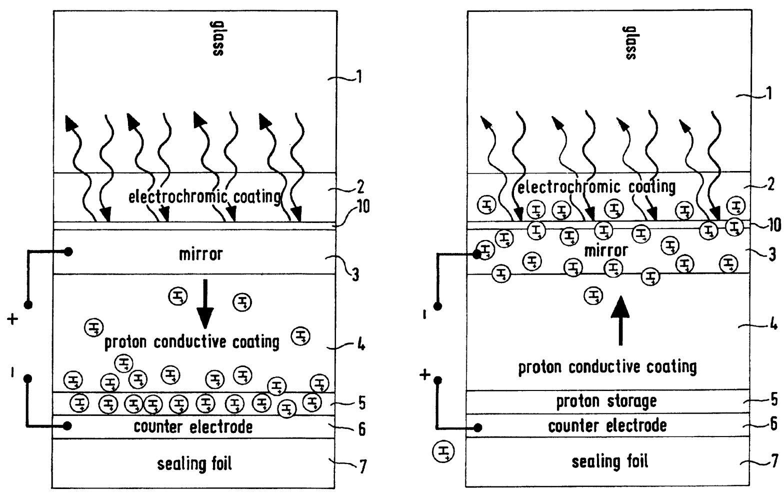


Figure 4: Components of Electrochromic Glass [http://www.freepatentsonline.com]

Holographic glasses coatings will filter the lights then conduct electricity to separate the infrared rays from them to reflect them back (Kienl, 2002). In the implementation of liquid crystals, as a result light has been polarized.

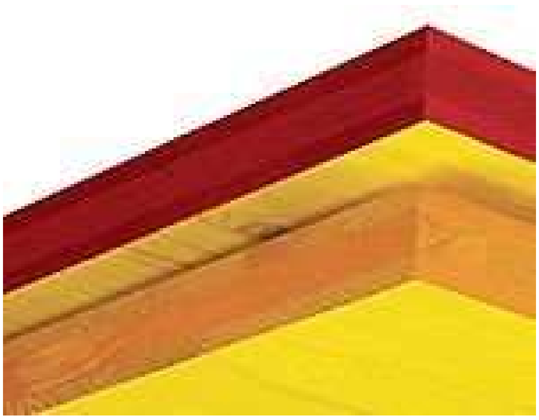
Picture 5: Holographic Glass [http://www.hologramm.com]

To sum up, firstly glass has been used as a small sculptural object such as bottles, jars then the usages developed and it is used as a vertical surface covering for small windows before industrial revolution Because of its transparency it is suitable to use in covering of the windows. Then it is using to cover whole wall of the buildings in the beginning of 1900 as a curtain wall. Nowadays it is using as a structural members in the constructions but still there is another material which is helping glass for carrying of the load. There is no whole glass structure in the world. It is desire to have whole glass structural systems in the future. With the development of technology it seems that it will be happen.

3.2.3 Wood

In the ancient times wood has been used in a small shelters building. The tent structure main structural element has been made by the wood. Then some small houses build by wood. Wood is a material which offers the designers of buildings a creation of very lightweight buildings which are simple to construct.

Especially the development in glue and laminated wood technologies are strengthening the usefulness of wood which is the one of the oldest natural building material. “Glued Wood Panel” (GWP) was provided through the innovations in production technologies nonetheless with adding some chemical additives it is become more durable against the fire (Ayan, 2002).



Picture 6: Three Layers of Glued Wood Panel [http://img.archiexpo.com]

Glued wood panel is lighter than many advanced structural materials and it has ability to pass more than 40 meter large spans. GWP named wood have more density than compared to normal wood thus the reason of this is using of glue. Another important property is it can take into any shape that desired. It is used in column and beams in any form and also it can be produces in the shape of the geodesic domes to compose it. It has ability to have more heat and acoustical insulation nonetheless it has more ability to resist against the fire than steel. It has been tested under 300 degree Celsius heat thus it has resistance of 80 minutes. It is the value which is closed to the concrete`s. With its ingredient of glue it shows high performances in the conditions of humidity. It is not influenced from steam of acid and base. (Sebestyen, 2003).

Architect Niels Torp made Olympic Stadium in Norway at 1992. This building is the project which has been passed larger spans of the world ever made with wood material. For this stadium more than 13.000 of chairs were made and glued 2000 m3 of wood were used in the construction. Dome shaped roof structure has been strengthened with wood beams.

Picture 7: Olympic Stadium, by Niels Torp, 1992 [http://www.wikipedia.com]

Apart from being strong against the fire, it is most important property is being of environment friendly because wood is natural material in fact it exists in the nature. Architect Shigeru Ban has many studies about transformation in the usages of the materials. Within these studies he used “paper” as a building material. There is an attempt to use the paper rolls as a building materials in fact these papers are used for textile industry to compass the fabrics. Shigeru Ban used paper rolls to support earned structural systems in the project named “House of Paper” (Mori, 2002). Shigeru Ban talked that “I did not invent new material; I just used the existing material in another shape” (Mori, p.58, 2002).

Picture 8: "House of Paper", by Shigeru Ban, 1995 [http://www.archilab.org]

To sum up, wood has been used in the construction of small shelters from ancient times to 1850s. Then with the glue technology in wood industry it become material which is used to pass large spans. As it is mentioned there is an attempt to use the paper rolls as a building materials in fact these papers are used for textile industry to compass the fabrics. It seems that in the future most light structure of the buildings will be made with wood with the improvement of its properties by technology.

3.2.4 Concrete

Concrete is a plain and unpretentious material, already some 2,000 years old. Reinforced concrete on the other hand, has a relatively short history and is quite a different sort of material. Concrete is widely used material in building construction, it is used to build variety of elements of a building like foundations, footings, columns, beams, slabs, walls, bridges, roads, etc (Wigginton, 1997).

Within the process of development it is obvious that in concrete constructions with minimum amount of material; large openings were covered like a big shell. With the advance usages of material the thickness may decrease up to 5-6 cms, thus this will rich the system to be an economical in construction process. Weakness, aesthetics and easiness properties of the concrete may appears as a membrane effects in the shell systems. In his most project`s Felix Candela and Heinz Isler has been used concrete masterly. For instance Feliz Candela were decreased the thickness of the concrete shell into 4cm. Furthermore the reason of expensiveness of frameworks in concrete shell making, new application methods may discovers. As such the pneumatic frameworks are the important development in the stage of improvement. Pneumatic membrane will constitute a surface to carry the shell`s concrete systems. Consequently, the construction time and tools may decrease to minimum levels. Also you can see Heinz Isler concrete thin shell project below.

Picture 9: Examples of Concrete thin shell by Felix Candela, Spain
[http://www.greatbuildings.com]

Picture 10: Example of R.C. thin shell which is made by architect Heinz Isler, 1969, Spain [Chilton, p.121, 2000]

Concrete is an evolved material which had been used many additives to reached the advance levels in its structure. One of these developments is to making the concrete more durable than it is. With its additives concrete may appears as more useful rather than steel; as such these types of concretes may calls “high performance concretes” (Oz, 2002). High performance concrete is made from mixed chemicals and minerals; nonetheless fiber’s essential plastics are mixed in it instead of steel.

Picture 11: Petronas Towers, Cesar Pelli, 1998 [http://www.wikipedia.com]

For instance in Petronas tower this types of mixture was used to increase the strength of concrete. In towers, columns, and bearing walls constructions concrete were used. Micro silica and other additives had been added to the concrete to increase its strength under the load. With its hardening property %50 of the wind pressure was reduced on the building according to the similar property steel. To rich the highest levels in skyscraper construction will be proved by advance technologies in material industry as it is in Petronas towers.

Compared to other building materials concrete gets in shape easier than the others. This property of concrete tried to improve with the additives; as such the designs which constrain the boundaries of concrete were done. Valencia Opera house in Spain made by Santiago Calatrava is a masterpiece of concrete architecture with its materiality and design relationship.

Picture 12: Valencia Opera House, by Santiago Calatrava, 2005
[hhtp://www.wikipedia.com]

The most radical example in the development of concrete can be “Litracon” which means light transmitting concrete. It was developed by Hungarian architect Aron Losonczi in 2001 however first implementation was done in 2004. Concrete changes it property and with the light that comes on it, as such it gains another characteristics.

Type of concrete which is known as Litracon is produced from glass fibers' contribution and it's used in prefabricated blocks shape. Thousand of glass fibers' were used in its structure and these fibers' places parallel to each other on both sides of the blocks. Compared to concrete the dimension and numbers of fibers' are less. For this reason Litracon may shows homogenous property. The glass fibres allow the lights to pass between the surfaces as parallel to each other therefore the light from bright side of the blocks, may transfers light without having any changes in its color. Scientists said that it has high thermal insulation values. In theoretically, the light transparent concrete structure walls can be in 1-2 meter depth. Moreover, the wall which has 20 meter thickness can be used. It is the product which is in experimentation period; however it is produced in blocks to be sold in construction sector (Gokbayrak, 2005).

Picture 13: LiTraCon design, by Aron Losonczi, 2001
[http://www.metaldesign.wordpress.com]

"Litracon" may have different effects in space nonetheless; the relationship between light and space can be redefined with Litracon concrete to improve the spaces qualities. With the reason of this designers/constructors will show more interest to the Litracon in the future. The space which needs natural light like office building or spaces that needs controlled sunlight's like museums can be potential spaces for Litracon material.

Another radical invention about concrete can be a "Bendable Concrete". With the development in material industry, it is lay to open way to the scientist`s ideas. The researchers tried to improve the concrete properties such as its breaking, snapping, and stability characteristics properties.


Picture 14: Benable Concrete [http://www.umich.edu]

The bendable concrete was invented by Michigam University and it is strengthened by mixture of fiber. It is still having researched on it however it is %40 lighter than normal concrete and it has 500 times more than impulsive resistance (Glynn, 2005).
With these properties in designs/constructions many problems will be prevent. The effects of earthquakes on the buildings can be decreased with the improvement of bendable concrete; as such it is being flexible to obstruct the damages in the earthquakes condition.

To sum up, concrete is a 2,000 years old material. Reinforced concrete has a relatively short history and is quite a different sort of material. Concrete is widely used material in building construction, it is used to build variety of elements of a building like foundations, footings, columns, beams, slabs, walls, bridges, roads, etc (Wigginton, 1997). Firstly normal concrete invented, and then reinforced concrete, precast and prestressed concrete has been invented in the sequence of its order. Used materials in the constitution of the concrete have not been changed only the usages of these materials have been changes with the technology and some new additives has been added to the ingredients to rich the high qualities. As it has been mentioned that in the previous paragraphs Litracon, bendable concretes has been produced to respond the needs with the technology. Also with the technological developments in the formwork industry the concrete can be used in the construction of the very complex forms and this will be developing day by day with the new technologies in formwork industry. The usages widely improved by the technology. In the future the disadvantages of the concrete will be solved by adding additives in with the technology.

3.2.5 Steel, Aluminums and other Metals

Metal is one of the oldest materials to be manipulated by man and has been used for its strenght and versality reasons. For centuries metals have been shaped into tools, weapons and different practical object (Bell &Rand, 2006).

Moreover some of the ancient periods had been token its names form the used metals in that time for instance as an age of bronze. Metals have been used as decorative facing materials in the oldest times. The first known metals that used in buildings are; iron, bronze, copper, zinc, lead and brass. However at the present day different alloy`s of steel, aluminum and titanium has been found. Steel that it has contains more than 10 % of chrome, to be denominate as a stainless steel. At the same time stainless steel alloys may contains manganese, chrome, nickel, carbon, silicon, nitrogen. Stainless steel was found in 19. Century and it was used in the architectural works at the beginning of the 20. Century. Normal steel production can be same as the stainless steel production but stainless steel may differ from the normal steel with its thickness and last procedures that applied on the surfaces (Sebestyen, 2003).

At the present day steel has much different uses than 19. Century. Carbon is the main substance which is used in all steel products. Increase in amount of carbon will increase tensile strength and strength of the steel. Phosphate, manganese, copper, nitrogen, sulfide and many other elements may changes the steel property. Welding, mechanical fitting, painting, polishing,..etc. are the technologies that is used to convert steel into different products. With the uses of different proportions of these components and innovation in prefabrication methods are helps to invent new alloys, new building materials, and new methods in applications (Kolarevic, 2003).

The last point that reaches in steel development is carbon nanotubes; in fact these carbon tubes carry the load more than a billion of their own weight. These nanotubes are used through the world by the designers and constructors in their projects because they are more durable and more powerful than steel (Kolarevic, 2003).

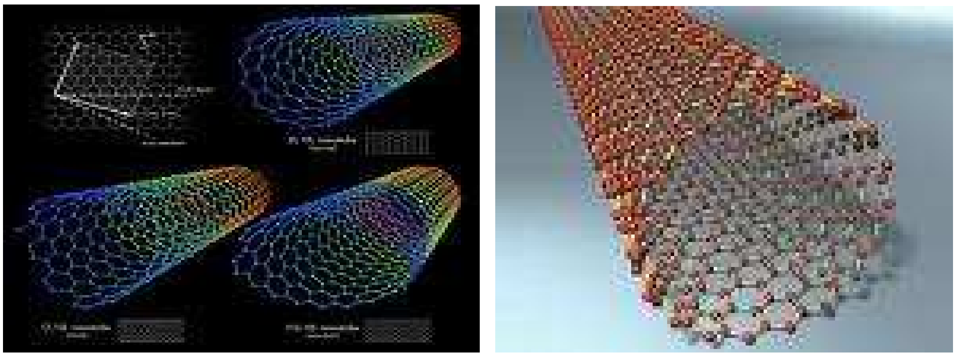


Figure 5: Nanotubes view [http://mrbarlow.wordpress.com]

Developments, as well as that of steel, developments of metal building materials are affected specially from the development of space and weapons industries. The metal because of the characters, in the building’s façade it`s perform as a complex form in fact the most important property of this metal is the lightness. However the biggest disadvantage is that; the value of thermal conductivity is high. The most common use of metal components in buildings is in, panel form, and grid shaped applications and uses as an alloy (Zanchi, 2000).

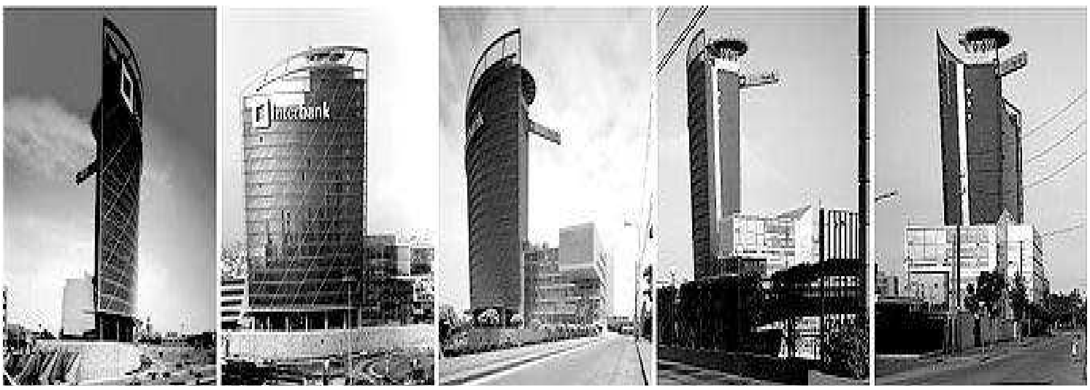
Metals that are produced in Panel form, the insulation and outer façade element has been used in a complex way. Different sizes may be available on the market. Moreover, with new cutting and pressure systems in the desired textures; like transparent, like different permeability of light may produce. These features in architecture used in new expressions. This new façade panels are in low density and in general used in polymer based insulation materials. The building that is made by Herzog & de Meuron in Paris Reu des Svisses, the metal application are appears in grid form. When the grids are closed the building gets in big factory outlook. When the grids are opened the façade elements which supply light and shadow into the interior space are appears. These shadow elements on the building façade helps to generate different transparency effects in the building. The grids use to offer a multifaceted application for designers and the most important features of the materials is matter in any form has to accommodate the façade form. The metal alloys components mixed with different rates, to obtain products with high performance property. In between these productions most innovative metal material is alloys of anodized-aluminum in fact it is offering coloring products. The others are, copper based alloys, stainless steel or titanium alloys (Zanchi, 2000).

In terms of power and strength, the titanium alloys are more lasting than the steel, can be compared much lighter than weight of aluminum and it is the metals that has the highest resistance among all the metals (Zanchi, 2000). Of this nature and use of computer technology in material production may helps in use of metal material as cladding on roofs and facades.

Picture 15: Herzog de Meuron, Paris Reu des Svisses Apartment building Metal grids on the exterior facade [http://housingprototypes.org]

Titanium corrosion resistance is based on its permanent oxide film on its surfaces, in fact against titanium hunger to oxygen with the surfaces which are rich to the air and moisture immediately rich the permanent oxide film surface to prevent rusting. This case is valid for all metals and the metals which are covered by oxide film gives 100 years guarantee. Within the process of titanium covering production, naturally oxide film layer are formed in fact its thickness`s will be increased by the anodizing. The metal colors which is seen depending on thickness of the film layer, embraces reflection process of light. Light in the receiving path of film layer is reflected in part, broken and absorbed. Reflected in the different phases of rays given to titanium color which is creates the light effects. With the increase in the thickness of film layer the color may changes. By applying the physical process on the natural surfaces of the metal as such shining and matte surface effects can be given to the material surface (Kartal & Timur, 2004).

Peru Interbank Center is a masterpiece of titanium covering which is designed by Hans Holleins. More than 18 meter long of satin finite titanium tubes was used and the diagonal grid elements were used to completely embracing the curved façade (Kartal & Timur, 2004).



Picture 16: Peru Interbank Center, Hans Hollein, 2000 [Baktir, p.38, 2006]

The extension of museum of Van Gogh which is designed by Kisho Kurokawa was used 0.5 mm thick titanium panels in the facades and the roof with different dimensions. Titanium “linear” expansion coefficient is lower against other metals, more than 20 meter long titanium panels were used to cover roof without any conjoin from its width (Kartal & Timur, 2004).

Picture 17: Van Gogh Museum extention building, Kisho Kurokawa, 1998
[http://www.wikipedia.com]

Titanium used in a successful way in Frank Gehry's design. In fact Gehry aim is to capture the sculptural forms in his projects. To capture this effect Gehry were used titanium cladding in his desired form on the steel structures.

Picture 18: Guggenheim Museum, Frank O. Gehry, 1997
[http://www.wikipedia.com]

To sum up, first metals have been used in making of crock, pottery elements, and dishes in the ancient times. Moreover some of the ancient periods had been token its names form the used metals in that time for instance as a period of bronze. Then metals have been used as decorative facing materials because it is expensive to obtain them so they are just using as a decorative element in the buildings. Then steel produced in the factories. Then the use of steel as a primary structural material in the constructions in the late nineteenth century because cheap methods used for manufacturing it on a large scale were developed. Today it is using as a structural members and as a covering element in the architectural works. Especially the resistances have been developed through the technology. For instance it becomes more durable under heat through the years. Also it becomes more durable for many environmental factors which affect it badly. In the future all problems of metals will be solved by the technology.

3.2.6 Plastic

Plastics is not just the newest of the primary construction materials available to the building designer today, it is also the most challenging. The basic building materials- brick, stone and timber- are natural raw material with a history as long as man. Even metal, glass and concrete are produced from natural materials and their basic principles have been understood from ancient times. Plastic has no such pedigree. There is no deep wealth of experience in its use, nor is it yet associated with any clear cultural meaning. It is unique in being an entirely manmade material, a product essentially of the 20th century (Macdonald, 2001). Plastics are synthetic materials, which are not found on the earth naturally. They are chemical combinations of various ingredients, most derived from petroleum. The ingredients are liquid in the manufacturing state but when its put together under heat and pressure they are capable of formed into various shapes. The end product is solid and it has resistance to pressure, moisture and corrosion.

Actually plastic is not the name which is given to the material. The term plastic is often used interchangeable with polymers, which mean a substance with large molecules made by combinations of many small molecules of one or several substances under heat and pressure. Therefore different names of plastics indicate different chemicals groups of polymers. Polymers are consists of long-chain structures formed by the chain of monomers. In the chain of polymers there are thousands of monomers. The properties of monomers has diagnostics interactions on material`s property (Zanchi, 2000).

The plastics which is produced by polymers has, chemical resistance, good thermal and chemical insulating, good strength to mass ratio, light, flexible, healthful in fact they are available in wide range of colors and in variety of forms. The most important reasons for the widespread use is its ease processing, and lightness so it is ease to carry and ease to storing. Despite this features they are not environment sensitive materials because of its ingredient petroleum also they are frangible under the pressure and flammable against the fire.

The development of technology in material industry provides plastic, which has been lost its flammable, permanent features to shows different performance of property to increase the material quality. Today, plastic and its derivative, which is composite properties gained membranes, are used especially in pneumatic, tensile structures as in panel or film layer shapes (Sebestyen, 2003).

Films, with it's develop production technology are the materials which has been produced by synthetics and are presenting new façade technologies to construction industry. These films are produced by PVC, Polyurethane and ETFE (Ethylene Tetra Fluoro Ethylene) and also they can be transparent, can be shaped in variety of forms, and they can be applied as in pneumatic or mechanic structures.

In pneumatic structure applications in between two or three film layers are filling with air which gets rid from moisture and with the pressure they put the material into the desired shape. The number of layers used in this system is increase with how much it increases the system`s thermal insulation capacity. There are many examples which have used ETFE film layers.

Eden project which is designed by Nicholas Grimshaw were used three layers of ETFE films in its structure. Also it is the masterpieces project which has been used ETFE layer. The films are produced by production companies in determined dimensions. In interior spaces PVC films were used (Zanchi, 2000).

Picture 19: Eden Project, by Nicholas Grimshaw, 2001 [http://www.wikipedia.com]

In Munich Stadium projects Herzong de Meuron was used two layers of ETFE which is changing its colors.

Figure 6: Munih Stadium, by Herzog de Meuron, 2005
[http://www.greatbuildings.com]

The main material in production of layer`s synthetics is petroleum. Therefore, together with the positive features that it is discussed there are some negative features which arising from the use of petroleum. As already it's know the extraction of petroleum may damages the natures. Petrol is a source which has an end and its recycling as a plastic is expensive also its harmful to environment and it is treating to the human health.

Polyethylenes (PE), Polypropylene (PP) are recyclable materials. Polyvinyl chloride (PVC) is the most used plastic type in fact it has many harms to the nature and human health. Also Polyurethane (PUR) is not a healthy material (Sebestyen, 2003).

To sum up, plastic has no such pedigree like stone or wood. There is no deep wealth of experience in its use, nor is it yet associated with any clear cultural meaning. Plastic has been used in many products making for instance, as kitchen appliances, frames of windows, material of bottles, box,…etc. It is not using as a structural element in the constructions, it is just using as a covering and decorative element in the buildings. It is unique in being an entirely manmade material, a product essentially of the 20th century (Macdonald, 2001). With the development in material industry PVC – Coated polyester has been produced to be used as a cheaper alternative for smaller, less permanent, structures. Also many other types of plastics have been produced and will be producing in the future to respond the demands. May be in the future with the development of the technology plastics can be using as a structural element in the constructions by improving its properties.

3.3 Position of Building Materials in the Architectural Design Projects

Materials with which an architectural work is made are the essence itself of the building activity. A design comes into being and grows with a given material: the material has to accompany a design since its very initial phases because it represents the starting point, rather than the destination, of the technical and formal reasoning which leads to the execution of architectural works. (Angrisani, n.d.).

According to Lawson;

> "*The practical constraints are those aspects of the total design problem which deal with the reality of producing, making or building the design; the technological problem. For the architect such problems include the external factors of the bearing capacity of the site and the internal factors of the materials used in constructions*." (Lawson, p.103, 2006).

Lawson deals in his book which is called "How Designers Think, the design process demystified" about the constraints of the projects. With the words of Lawson which is already stated above it is obvious that instead of functional, aesthetical and formal constraints in the process of designing and realizing projects there is a very important constraints which is called as a practical constraints. Technological problems and materials that will be using in the construction of the design projects may consider as an important constraints. Without considering the improvements, developments and discoveries in the material industry it is difficult and moreover it is impossible to build practically apparent projects.

Also Lawson has been continued his words with "For those designers who are fascinated by the materiality and process of making things, these practical constraints can offer major generative design ideas." (Lawson, p.170, 2006). In architectural design, to be designing a project which must considered all the important features such as aesthetic, function and formal organization instead of all these the feasibility of the design is also important. If we cannot practically build a design projects and if it is stand on the paper only somehow it is not useful and feasible design. To abate this kind of designs it is suggested to considered improvement, development, revolutions, discoveries and newness in the materials industry from starting point of the design projects till to the end.

Lawson said that “In a way material dictates the concept….and material are not interchangeable …..to me the material really is the starting point of the story.” (Lawson, p.171, 2006). Lawson used story as a design process. It is obvious that above all it is more useful, beneficial to start designing a project from considering a material first.

“Calatrava is also fascinated by the properties of materials rather than just the structural configuration of his works.” (Lawson, p.171, 2006). It is obvious that the properties and abilities of the materials are important in the process of designing an architectural project.

Therefore, the materials can be considered as the “basic elements” of architecture, since they make it tangible and perceptible by senses; they represent the entities which have materially shaped the places inhabited by mankind, which have interacted, as time went by, with the building techniques, re-shaping and modifying them in order to continually adjust the same to their own characteristics, but also allowing to be shaped and modified by them. (Angrisani, n.d.).

To look the development process of building materials within the frames of being new, it is obvious that people find new ways of using the materials and develop it.

Within the development procedure of the materials people were get to know the unprocessed material at first hand and then explore the limits of know materials to forming a new materials.

“In design the thought is important, the word of the design is very important and also the process of the thought coming into life and their comprehension of material are in critical condition.” (Arolat, p.5, 2000). With this statement it is obvious that, material has an active role in design process. Material is an architectures concrete expression apparatus in the effort of creating an accommodation; material is the criterion which affect a design at the point when thoughts turn into life (Arolat, 2000).

The different social classification in old Egypt reflects on building design as a selection of building materials according to the projects types. Stone blocks have been used for construction of pyramids, meanwhile for the workers villages’ construction different material such as clay used (Protoghesi, 2003). The aim of the stone that used for pyramids is to symbolize the permanence of design; by reason of social class difference in villages clay used as a building material in fact clay is not a long lasting material as stone. The key objective here is to show permanency and transience hierarchical differences between social classes. At this point the material which symbolize permanency, contrary to clay which is tentative building material are both used to convert a design thought into real.

Material is an architect’s tool which is used to convert a design thought into real. When being close to a building firstly the mass, the outer layer dimensions, and the material that form its surfaces are recognized (Baktir, 2006).

As Rohe argued about,

> "*there are important things from brick to learn. How could something useful for all aims and be sensitive as that much? Its texture, pattern and shape are made with such intelligence. What a rich view on a basic wall! All materials have their own characteristics property*." (Rohe, p.148, 1938).

It is same for reinforce concrete and steel. Everything is not with material itself just, it is indicate how designers used to it. "New materials are not always superior. Every material is bound to what we want to do with it. This must be remind, everything is not in the material itself and that its matter of how we used that material" (Rohe, p. 145, 1938).

As Mies clarified that, "the meaning loaded on the shaped material, shapes up on the architectural expression", (Miess, p.21, 1991) because the material is deformed and will exist with the meaning we load on it. In order to overlapping between the material itself and the meaning we have loaded on it; It's not what the material is but it's what it wants to be, also its limits and how we shape it; that's the important. (Miess, 1991).

The most successful example of forming the material according to required aims was seen in Gothic architecture with the usage of stone. The most important characteristics that easily remembered for stone are massiveness. However in Gothic architecture, to feel churches religious power and to make the religious ideas higher, the designers have been waste extra effort to make the stone look thinner and weaker. Long and thin columns, big holes opened in stone walls, the ornamentation on the towers, and the view of the tower getting thinner as it raises nonetheless the tower looks weaker and higher than it is (Yurekli, 2000).

Picture 20: Stone usages in Gothic Architecture [http://www.cs.columbia.edu]

3.4 When Materials Meets With Technology

The pivotal development in building materials started with industrial revolution. The Rational and positive thinking and development in technology, bring innovations in social life quality too. With the development of industry the existence systems may change and religious things lose its power on society. Human being changes in their social life may show itself in architecture as a different need in buildings. The pressure of religious buildings were decline and religious buildings give its place to public buildings which respond the public usages such that museum, exhibition, train station, etc. Because of this needs some new facts such that standardization in production, assembly of materials in site was developed. To make use of steel, curtain glass, reinforced concrete, lift, ventilation, lighting systems, etc. will be enables the high rise/large span buildings construction. With the assistance of physics and chemistry fields the existing techniques in material industry are improved. In fact the developed techniques put in shape the materials with pressure and heat (such as steel, glass and brick). Nonetheless, new materials started to form with the development in inorganic chemistry (such as concrete). All these developments gives rise to improvement in building material which are used in building construction and new materials inventions, and new production systems in building material industry.

“New” is made through the inventions as it has been mentioned in the previous part. With the discovery of electric and steam power many improvement were made in industrial field. With the study that had been done in attribution of electric and magnetic to get down to rock bottom of lighting, energy and transportation industries. With the starting of steam power using, systems that leaning against spool in elevator technology and development in new energy sources and the developments in steel and iron industries were supporting these formations.

In the antiquity period, the boundaries of a space which is used as a shelter determinate by the wall, roof and window elements. At first Romans were used this small and expensive material which is glass; it is used to get enough sunlight in internal spaces and to used to protect themselves only. With the direction of development in glass production technology, the position of glass in architecture has been changed. Some concepts in architecture has been changed too, such as glass used as a shell in building construction instead of window only and with steel skeleton system large spans were build. Anyhow more flexible, enlargeable, prefabrication, assemblage, and boundary concept between interior and exterior spaces were changed. Construction sector became mechanized and along with this, instead of using human power machine power was used, although standardization in building material was formed. Specially with starting of cast iron using, constructed by both steel and glass building which is Crystal Palace is an recognizable features of the time. The building was defining a space in transparent membrane shell. Prefabrication was first used in this building in fact the glass was made in factory and its assemblage on the iron skeleton was made on the site. Crystal Palace was the first with its techniques, application system of the material, and with its construction technology in the time.

In the construction of crystal palace, 550 tons of cast iron, 3.500 tons wrought iron, more than 300.000 meters of glass and for walking paths more than 200.000 meters of woods and wooden beams were used. Building geometry is completely situated on modular system and its structural system based on repetitions, according to the needs (Dooley, 2004). Prefabrication, standardization, modulation, and fabrication are all discovered by the technological development and all used in material production industry to responds the architectural needs.

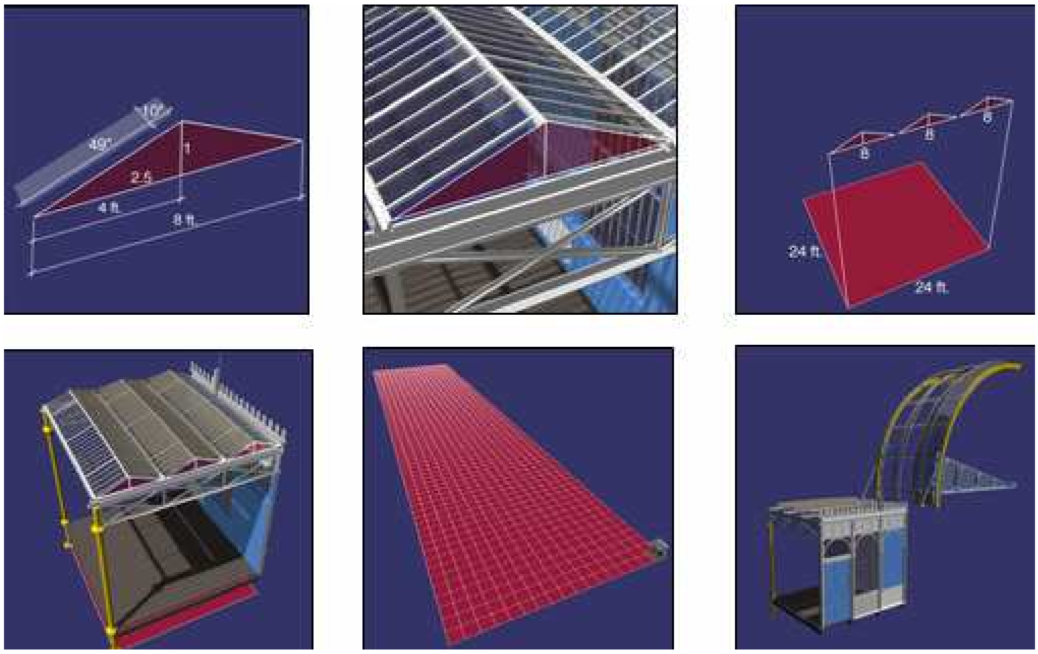


Figure 7: Crystal Palace Glass application details on the structural system, Joseph Paxton, 1851 [http://www.iath.virginia.edu]

Renovation and development of traditional materials are one of the methods that used to enhance the building materials limits. In accordance with the original characteristics of existing materials, continual searches were done to increase its usage areas and to develop materiality characteristics of building materials. Most important reasons of these developments are to accommodate the period needs.

In addition another development method has been seen in material industry is describe through; with the developments in army industry, space industry, car industries, physics and chemistry sciences, may effects developments in material industry too. The most important industry which had a most innovations is weapon industry. Even though with the second world war when the atomic bomb and new innovations were made in the weapon industry, most people were scared. However these efforts in weapon, army, space and other industry are helped the building industry to rich the higher standard in soonest time. Associate works were arising between different disciplines. The substance edifice had been searched; some studies on atomic particles were made and the atoms and neutrons are separated from the substance general combination. (Spiegel & Meadow, 1999).

The investigation on substance`s atoms, was realize the electron transfers between the atoms. Nanotechnology was developed with all these innovations in industry. According to the requirements that its needs for the arrangement of material`s atoms was formed.

Technology is developing with a not followed speed. In this context all these developments in technology are also affects the relationship, renewals and transformations in architecture field. In recent years, most spoken innovation is nanotechnology in fact most scientist said that nanotechnology shows its effects on architecture area too. The word "nano" means "very small, faint". The word Nanotechnology defines as the techniques that arrange the atoms. (Addington & Schodek, 2005).

We are at a point in history when technology allows for the "design" of specific materials to fit the unique needs of a building. Frank Gehry signature, metal panels are a great example: each is individually engineered for its precise position in the building. Such technology has introduced a period of new expressionism in the glory of material industry and their material qualities (Bell & Rand, 2006).

Today, materiality is an exciting and quickly expanding concept in the design process. Materials have also entered into new realm of distinction with this onset of advancement in engineering and technology (Bell & Rand, 2006).

3.5 Discussion About Material`s Alternating Materiality Properties

New materials, new production techniques of these materials, and the search for new forms enabled smaller, lighter, smarter and more effective materials to be produced, also making them more responsive to environmental stimuli. The material, which could be reformed or reshaped in a wide variety of ways with the advancements in the physics and organic chemistry sciences, is starting to get questioned after computers and hence better information flow get involved in the process. The very common terminology about the material's existence like "transparency", "lightness" and "elasticity" is now becoming bigger as the new terms like "dematerialization" or "immaterialization" start to get in. As a result of electronic media and computer technology, these new terms are meant to refine the material free of its physical properties and actually imply non-materiallity. Nowadays characteristics based on fleeting, speed and evolution, has moved the production process of construction into another dimension. In fact, sound, light and video images have already started to get used as materials now.

Consequently this part aims to discussed about material`s these alternating properties which is dealed in the previous paragraphas as a dematerialization and immaterialization. Many architectural projects has been used in this sections to give brief understanding of the subjects.

3.5.1 Dematerialization

If the material is in raw material shape it is formless. Then it takes form, an expression with process of works with it. Evaluation of materials as a substance of neutral and inanimate is wrong as such it can be said that materials has their own spirits. To materialize (to become concrete objects) designed object`s it is necessary to ask the material what it wants to be? In this case identity has been gained to the material. Each material has its own natural character and structure. First of all, these characteristics of the materials should be known. Because the material according to its character it is compose its own volumetric and spatial form. In this formation it has potential ability to constitute a "new" with its own compositions (Baktir, 2006).

In architecture, the form gain attribution through the way of material putting forward and generally the material loads meaning to the architectural form. For instance if undertake the natural stone material, first thing comes to our mind about stone is its heaviness, monumentality or its permanence. These thoughts are developed through thousands of years of experiences. Likewise glass has been bearded the meaning of transparency and fragility. Whereas, with the applications that applied on its surface of the natural stone, it`s gains different interpretations such as rough, dull, shinny…etc. Similarly with the development in technology glass has opaque usages up to the amount of transparency usages. Therefore, while the material is the same material but its meaning that loaded on the form may changes (Sener, 1996).

Thence, while a technological development in material production is offering new innovations, it has been arisen new arguments with them such as actuality of the material, reality and artificiality. The innovations in production technology and physics and chemistry sciences have been simplifying the artificial productions too. Natural materials, especially the ones who had same appearances with the implementation of chemical processes it have become the materials which have high environmental resistance. In this point, the materials may put into the shape according to the desired aim; likewise desired aims may change characteristics of the material to rich the aim. Although different materials and systems has been used in the buildings however in the situation of having a homogenous shell cladding as a clothing on the buildings it is obvious that the diversity in between variety of materials and systems cannot be recognized and simplicity is reached.

The concept of "dematerialization" which means constitution of building under the supplemental homogenous shell, it's appeared with the reducing of buildings perceptual attributions which depends with material itself. Peter von Meiss in his book "Element of Architecture" defines dematerialization as, sculpturality of cavity, form and geometry (Meiss, 1991).

According to the Angrisani space is first matter rather than the architect himself, if a sculptor uses clay to create, a poet uses words and an architect uses space. When shaping space, the contemporary architect designs more and more complex and from time to time immaterial and spectacular works. In fact Angrisani is stated that,

> "*we are witnessing, on the one side an increase in the performance contents of the buildings which are obtained by using complex*

technologies - including mass-media - new materials and construction techniques, on the other a dematerialization of the building itself which becomes lighter and lighter, more and more transparent, more and more instrument of seduction, almost an object of urban narcissism." (Angrisani, p.2, n.d.).

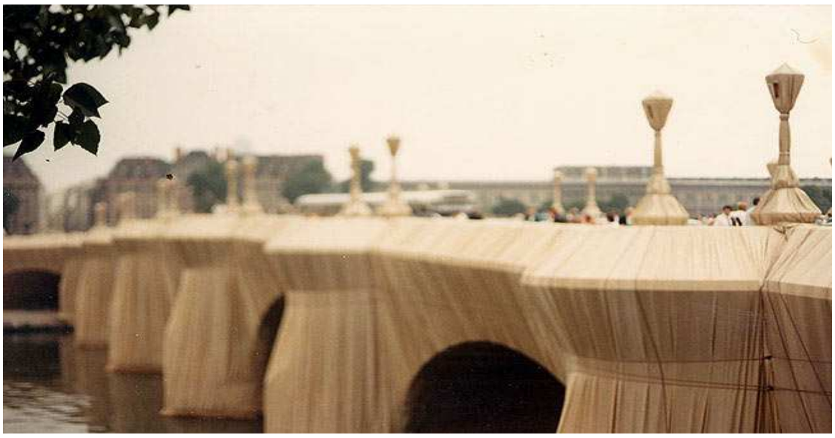
Dematerialization is not a new concept in architecture. With the industrial revolution the usages of big glass surfaces could lay out the material of glass dematerialization. Hence the building may appear as the form of transparent shell. In this period the Crystal palace is the symbolical structure and far away to become the prototype which has been fabricated in the industry its exhibits advanced technology`s lightness, transparency and dematerialization (Sener, 1996).

Picture 21: Crystal Palace project, Joseph Paxton, 1851
[http://jeffmetal.blogspot.com]

The enshrouding of building with dematerialization idea, without structural and functional reasons, it is provides concepts with a formal and geometrical meanings.

According to Miess the aspect of having dematerialization through form and geometric organization which artistically to become sculptural can be seen in Bauhaus movement. Here the column convey vertical lines, fencing to the rail, walls and the floor are expressing the horizontal planes. With the following of Bauhaus trend the final step of dematerialization comes with completely painting of white in Building (Meiss, 1991).

To truly understand dematerialization, the interaction between cladding and structure must be understood. The one of the significant features of the dematerialization is the idea of clothing; it is not changing the view by cladding, it is the thing is to define the covered object. To understand dematerialization which is partly artistically shaped sculptural non-materialized expression it is helpful to explore the projects of Christo and Jean Claude whose are artists. These to artists, in their projects of Pont-Neuf bridge in Paris at 1985 have been used polyamide fabrics and fibers for clothing on the building (Hasol, 1999).



Picture 22: Christo & Jeanne Claude`s project of Pont-Neuf bridge, 1985, Paris [Hasol, p.65, 1999]

In these two artist`s projects it is obvious that in the clothing and covered object there is an overlap between them. In this case in the visual world of our time dematerialization can be ensured by the skillfully obtained simplicity which is obtained through non-materiality. Thus the word clothing, this has mysterious meaning, its helps to expose new expressions in architecture. Christo and Jean-

Claude in German in the building of Reichstag which has been used as a parliamentary building it had big fire and it become unavailable to use in fact the artists found new coating which has high resistance against the environmental effects and then covered the whole building in between the dates 25th June to 6th of July (Hasol, 1991).

Picture 23: Christo & Jeanne Claude`s project of Reichstag Parlimentary building, 1995 [Hasol, p.68, 1999]

As Miess specified that in dematerialization which means the property of having the building which has been clothed with the layer of material, in fact it is more appropriate to use heterogeneous and /or artificial material for its covering. The materials that have different characteristics from each other used in the shell structure to cloths the building. In such a case each material`s may bilks from its own property to work as a single “skin”. As such, the surface of the building becomes non-materialized and through this it originates simplicity.

In projects of Sainsbury Center for Visual Arts by Norman Foster the dematerialization may stand out. The characteristics of building about dematerialization specified by Kenneth Frampton to perceive the building as an apparent and definite and it is defined as an completely covered shell which is not permeable to the air. In Foster`s building whole structure has been clothed by the shell and it has not giving any clue about the interior organization herewith its takes interest on (Frampton, 1995).

Picture 24: Sainsbury Center for Visual Arts, by Norman Foster
[http://www.wikipedia.com]

Jean Nouvel`s Tour Sans Fin project in Paris, the effects of dematerialization made by material intensity in fact the building external appearance goes through the materiality to non-materiality. The materials that have been used in tower are set up from down to up, dark granite, polished granite, grey colored stone, silver colored glass panels and at the peak point of the tower transparent glass panels were used. Thus, the raw material has been processed in each step of layer and the visual perception of material becomes transparent to reach the non-materialization.

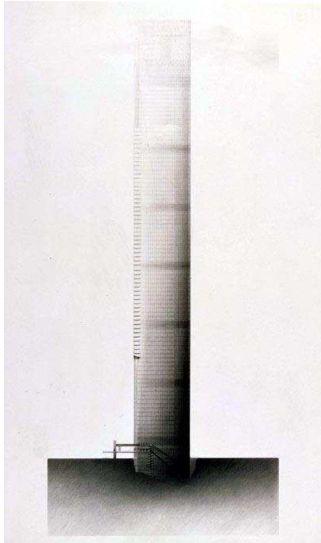


Figure 8: Tour Sans Fin, by Jean Nouvel [http://jamesstump.com, http://www.dezeen.com]

When the building`s floor increase, the materials that were used to applied from dark color to light color and from ground to sky opaque to transparent materials were used to generate different visual effects. Dematerialization can be seen through the stages starting from ground to peak point of the tower.

Most the time dematerialization mentioned as transparency. As Jean Nouvel`s Cartier Foundation for Contemporary Arts project`s has, the materials placed from opaque to semi-transparent to transparent with the consciousness ability of design. Also in Herzog de Meuron`s Signal Box project the building through its transparent glass cladding its lay out all internal organization (Bermudez, 1995).

Picture 25: Jean Nouvel, Cartier Foundation for Contemporary Arts, Paris [http://media.wwd.com]

As it is seen in these projects, dematerialization is an approach of having different effects in architecture. At the present day, with the using of developed technology it is obvious that the desired effects of dematerialization have been reached such as purity and simplicity. In our time there is a dominancy of visual perception. In this visual world with the support of technological development the buildings becomes sculpturally shaped forms and non-materialized. On the other hand the visual world fleets by the rapid changes and provisionality (transience) of the digital information's to reflect them to the interdisciplinary fields.

3.5.2 Immaterialization

With the development in information technology and material science as a result of the integrations the information technology flows getting in front of the materiality developments. With computer technologies new dimensions can be gained to the architectural expressions. Most important reason of this development is, dynamism in our daily life and with communication devices speed and temporality reflection changes.

Electronics and computers can be entered in all areas of human life. Firstly in buildings computer and information technology flow can take its place such as sound, writing, image, digital telephones and cables integrated into the fiber optic networks. However, perhaps the most extraordinary circumstances is that the working of these information's systems as like as human being nervous system, as a part of whole building although arising of new materials which can gives reactions to the environmental alerts is the subject of matter (Dilekci, 2000).

Immaterialization is the combination of buildings and environments under a system based on information flow. The usage of immaterialization can be effective in the process of development of architectural expression and also in the formation of end product. Whit this shape some items of architecture is constantly changed depends on the environmental effects and to become in a manner which respond to the environment (Bermudez, 1995).

With new material technology many combinations of sensations has been seen in the buildings and new materials are producing to provide this impacts on the buildings. One of them is the concrete which has been named "Chronos Chromos Concrete", with its ingredients of electrocromic substance and cable system which has been passed at the bottom layer of concrete and has a electrical current thus through the color changing of cables the graphics and writings can appear on the concrete surface. These graphics and writings depend of the organization of the cables on the bottom layer of the concrete (Dilekci, 2000).

Picture 26: Chronos Chromos Concrete [http://infosyhthetics.com]

The project of Homografhies which is designed by Rafael Lozano Hemmer, is an example of immaterialization which shows sensitive impression of the interior space. The system that is worked in the Bartlett Architectural School is consist of 144 units of interactive fluorescent lamb which is placed on the ceiling also this system is consist of interaction between the lambs and computer system. Lambs which have been placed on the ceiling can change their positions according to the perceived movement.


Picture 27: Rafael Lozano & Hemmer`s designed Homographies building interior view [http://interactivearchitecture.org]

With the result of consumption culture dominancy in our era and the aspects of information's technology temporality, the non-materiality and imaginary (virtual) may takes place instead of materiality and reality. Production of new buildings continues in our world on the other hand another expression of architecture is produced (Bermudez &Hermanson, 1996).

To the aim of creating the desired effect in the buildings mostly the shell structure is used. Because the façade is the most important parts which has been perceived from exterior. In this context the shell of the building, instead of having surface texture it has views of image on the façade`s surface. The shell system of the buildings can be used as a TV screen. During the usage of shell system of the building`s as a window which is opened to the virtual world, it has been loosed its own characteristics of materiality and form. In this point dematerialization and immaterialization may shows similarity in between them. In immaterialization the building shell has been reached to the non-materiality and purity position which has been reached by the dematerialization too (Bermudez, 1995). In this context the project`s of Jean Nouvel and Bernard Tschumi is the first examples that has been used the building facades as screen.

Bernard Tschumi`s project of Glass Video Gallery in the Holland Groningen at 1990 has been completely consist of glass and some elements for combinations of glasses. It is the pavilion which has video monitors inside therefore some music videos can be showed on the screen. In this project there is a mirrors to reflect the views from videos, herewith it is tried to compose an infinite space (Baktir, 2006).


Picture 28: Glass Video Gallery, Bernard Tschumu, 1990 [Baktir, p.56, 2006]

With these reflective surfaces the effects of ambiguity and variability on the building`s facades has been composed in fact abstract systems is presenting on the building`s facades such as television images or electronic images. Reflections are consists of many layers of glass and these reflections has been reached to the immaterialization through the reducing of rigidity of building surface`s. Especially in the night time images that reflects on the building façade`s can take the place of architectural elements.

With the developments in the electronic and computer technologies anyhow IT (information technology) industry may carries to the different dimension. Variation that’s gets from computer technology, may shows itself as a changing on the building`s facades. New façade`s are giving new expression`s to the buildings in fact the façade`s can designed as a layer of shell on the whole building. These layers of shell can be transformed to the projection screen. Building`s façades may respond to the environmental, meteorological, day-night, and seasonal changes through image, light, movement changes. The point that it is reached through the electronic development is that, the materiality effects on the projects were loosed through the innovations in electronic industry (Dilekci, 2000). The surfaces that is used as a screen provides a continuous changing with the reflection of electronic images on the building`s surfaces. This aspect`s may rejects the decorous form and cavity of perception (Bermudez & Hermanson, 1996).

Picture 29: Mehrdad Yazdani, Cinemania Theatre, Los Angeles [http://faculty.arch.utah.edu]

Jean Nouvel`s project Agbar Tower that was made in Barcelona has 4.500 numbers of different colored windows, in fact they are named as LED (Light Emitting Diode) and they are semiconductors, while the electric current passed on them they emits photon materials and there is an central computer which controls all these impacts on the building`s facade. This system may provides colorful views on the building`s surfaces in the night time, contrary in the day time tones of red and blue may reflects in the specific times.

Picture 30: Agbar Tower, Jean Nouvel [http://www.mediaarchitecture.org]

Toyo Ito is the architect who used immaterialization in their projects most. In buildings Ito`s used screen of light, movement, film, television, video and computer on the building`s facades. In the Tower of Wind project, thousands of lambs, twelve rings of neon light and thirty numbers of projectors have been used around the building although with all these the façade becomes transparent shell on the building. These lightings has been controlled by the computer systems in fact it is converting the environmental effects of existing zone to the image on the building`s facades.

The effects of immaterialization may show itself as an aspect that relates with visuality. Buildings are responding to the environmental effects or alert that is made by system through the light radiant visuality of digital image. To give this effects on the facades, the materiality of the materials that consist to have the building has been loosed in the wholeness of the system and therefore immaterialization has been provided on the building`s surfaces.

Picture 31: Tower of Wind, by Toyo Ito, 1996 [http://www.wikipedia.com]

The development in the electronic and communications systems has been stand in front of us as a new architectural expressions which was loaded on the building`s facades. At the present day temporality, variability and abstraction concept which have dominancy in our time may changes its way through the using of different materials with different shapes in the projects. The concept of materiality is again interrogating nonetheless the abstract effects may stands out and replacing of materiality with non-materiality effects may perceived (Baktir, 2006).

The result of arguments about the concept of materiality has been retreated from its physical characteristics to non-materiality concept, may effects the formation of architectural products through the changes in the material`s physical properties such as lightness, flexibility and transparency and the used materials becomes non-materialized and abstract to reached the immaterialization and dematerialization concepts.

3.6 General Conclusion of the Chapter

Human has been used building materials to create shelter or restricted boundaries to protect themselves from environment thus this is a continuously developing effort of humanities through the history. Technology is the most effective factor which affects this process of development. To practically realizing a design projects which can stand on the ground it is conceived that the improvement, development, discoveries and newness in material industry must be considered from starting point of the design process till the end.

Technological development is forcing us to search for a “new”. The developments that affect these innovations are relatively physic and chemistry sciences and development of nanotechnologies.

With the development of technology the meaning that has been loaded to the existing material were changed. For instance, glass has always been know with its transparency however today it is possible to see opaque and semi permeable glasses. With glass it is possible to have massive volumetric expressions.

The development in the physics and chemistry sciences has been opened a way to improve the properties of the existing materials and production of new materials. All these developments has been presented a newness into the architecture field however has been brought up a debate of material`s “original or fake”. Also materials materiality properties have been changed. In this research the abstract concepts “dematerialization” and “immaterialization” are emerged in the process of building material`s development.

Consequently this section has been gave an overall view of the development of the material`s usages and idea of “new”, position of building materials in architectural design procedure, effects of technology in material (in the parts “when materials meets with technology”) and to have a discussion about material`s alternating properties such as “dematerrialization” and “immaterialization” . Nonetheless to recognize the idea of building materials developments in architecture it is needed to look the development in the usages of the building materials through history. And how this process of technological development may affect the building materials through the years? In this context this chapter has been focused more on the development of the building materials after industrial revolution.

The six different materials have been investigated through the development of the usages within the years. These materials are stone, wood, glass, concrete, aluminum-steel-other metals, and plastics. The reason of choosing these materials is, they are the materials that has been used generally in all constructions or at least one of them has been used in any of the construction as such the building material selected through their percentage of usages in the constructions all over the world (Baktir, 2006).

Finally all the collections and works that have been placed in this chapter will be used as a base knowledge for chapter 5. Guide relating to properties of building materials can be found in appendix A that is authorized by authority called CIB

(CIB, 1964, CIB, 1972, CIB, 1983, CIB, 1993). Also in Eastern Mediterranean University, Department of Architecture ARCH 248 (Building Materials) lecture notes which is collected by Assist.Prof. Dr. Munther Moh`d can be useful notes about the knowledge related to properties of building materials (Moh`d, 2003).

CHAPTER 4

DEFINING STRUCTURAL FORM IN ARCHITECTURAL WORLD

This section focuses on structural form definition frankly. This chapter examines the structure and form relationship in architecture. The content include definition of structure/form, architectural structures/forms and its contents, general types of structures, structural systems, structural components, structural elements an classifications, relations of structural systems with used materials, architectural form and types, philosophy of form and structural form and their appropriateness are briefly examined in this chapter.

4.1 Structural Form and Its Contexts

Architects and engineers create structures that envelope the functional requirement of the clients. In the critical stage of the design process, the choice of the structural form and material may changes the way of the design project to the success.

The main purpose of this dissertation is to focus on the influences of technological developments of building materials and their interactions with structural form in architectural design projects. In the view of this circumstance structural from and its context will defined in this chapter. Structure and Form are both will be investigated separate from each other for better understanding of the subject. Also the concept of form and structural form will be investigated as a philosophically too.

Structural form is dictated by structural needs, primarily to support gravity and lateral loads, and usually also the need to provide a building envelope for shelter against the elements. Carefully designed structural form can exhibit the stark beauty of controlled strength, even to the point of excitement. Structure can define the visual impact of a building, as in the case of large exposed columns, which give the appearance of strength and solidity, or the case of tall slender columns, which can create an elegant loggia effect. Architectural form can be decorative and sculptural and it often uses traditional iconographic styles, as well as proportions and details from classical antiquity. Structural form is neither decorative nor sculptural because it arises from a melding of creativity coupled with mathematical rigor and economic restraints. The ability of structural engineers to determine loads and calculate stresses in structural elements has allowed for the creation of new, elegant structural forms. Structural engineers, acting as structural artists, such as Robert Maillart, Felix Candela, and Heinz Isler, made building forms of striking appearance, while expressing purely structural engineering ideas of efficiency and economy (Saliklis, Bauer, Billington, 2008).

Picture 32: Robert Maillart`s project of Schwandbach bridge and Felix Candela Valencia Oceonagraphic project [http://www.wikipedia.com]

Also structural form was defined by the Unay with these words “The structural form of buildings can simply be defined as the geometrical configuration of the space involved by the structure” (Unay, p2, 2006). However, within a similar external visible geometry, different structural actions could be responded by structure under the same kind of loads. Various capacities of different materials, internal detailing of cross-sections, the manner and sequence of construction and the dimensions of the structure can cause different structural actions in similar overall geometry of the structures. Therefore, Unay said that the geometrical configuration is only one aspect of the structural form (Unay, 2006).

However to reach the aim of the dissertation, after focusing directly on structural form; in case of necessity it suggests to investigate entirely on form and structure to understand the context of structural form better. Because it is somehow combination of two cardinal approaches in design process, as “form” and “structure”.

4.1.1 Form and Architectural Form

The brief definition of the “form” is shape or figure. It is an inherently philosophical topic (Dooley, 2004). If it is compared to the shape, “Form (Lat. forma Eng. mould), refers to the external three-dimensional outline, appearance or configuration of something - in contrast to the matter or content or substance of which it is composed” (Meiss, p. 183, 1991).

Another comparison of from and shape has been asserted in the book of Ching. Ching said that “While form often includes a sense of the three-dimensional mass or volume, shape refers more specially to the essential aspect of form that governs its appearance.” (Ching, p.34, 1996).

According to Francis D. K. Ching;

> “*form is an inclusive term that has several meaning. It may refer to an external appearance that can be recognized as that of a chair or the human body that sits in it…….. In art and design, we often use the term of form to denote the formal structure of a work*.” (Ching, p.34, 1996).

Ching define form in a general point of view then looks to the term of the form with the eye of designer obviously form denote the formal structure of a work.

Architectural form is dictated by architectural purposes rather than general meaning of form as such it is the practicalities of spatial organization and control of the flow of occupants. Besides architectural form is concerned with the sense of space a structure creates, its symbolism, and its relationship to its setting. (Saliklis & Bauer, & Billington, 2008).

According to the Edmund N. Bacon "Architectural form is the point of contact between mass and space." (Ching, p.33, 1996). As such obviously form is a communication tool between the space and mass.

Nonetheless according to the Mainstone;

> "*there is no unique relationship between structure and form if, by form we mean simply the geometrical configuration of the structure. Different structural actions in response to the same loading, different strength and different stiffness may all be associated with a single visible external geometry*"(Mainstone, p.83, 1998).

Within the frame of these words structure and from has been tied to each other to constitute an architectural space in the process of design.

Frampton defines "form" through the used material "By material "form" we mean the geometry of the volumetric envelope of an element with a view to making it capable of production, resistant, manipulable and capable of assembly in order to serve and delight man" (Meiss, p.184, 199). To illustrate their point of view, Frampton has been used the example of brick which used for thousands of years and it has never lost its contemporary usefulness.

> "*The requirement of the wall and brick combined together to envelope the architectural space. Nonetheless Louis Kahn said that*

> *"if you ask a brick what it wants to be, it would say "an arch". And sometimes you ask concrete to help the brick and brick is very happy*" (Meiss, p.184, 1991).

It is obvious that in architecture form gain its attribution through the material however it is proved by the words of Kahn and Frampton in Miess book`s of "Elements of Architecture". According to the Miess discussion in his book "With the dome, brick is at its best position but Kahn does not say that brick demands the vault, but he identifies the sublime use of brick in architecture when its outwits gravity" (Meiss, p.184, 1991).

According to Frampton; Form is an expressive element in the process of making design and realizing it as such he support this with these words;

> "*The gap between what was past and what was yet to appear marked a definite end to the concept of techne (Greek word for technology), whose classical language was already distilled, leaving room for architects to conceive form (geometry) as an expressive element*." (Frampton, p2, 1994).

4.1.1.1 General Types of Form

Firstly it is helpful to deal with the generators of form before focusing on the types of the form. Point, line, plane and volume are the prime generators of the form. The definitions that have been stated below have been collected from the book which is named "Architecture form, space and order" by Francis D. K. Ching.

Point indicates a position in a space. A point extended becomes a Line with properties of; Line, Direction and Position.

A line extended becomes a plane with properties of; Length and width, Shape, Surface, Orientation and Position.

A plane extended becomes a Volume with properties of; Length, width and depth, Form and space, Surface, Orientation and Position.

All of these relations can see in the fig. 4.1 below.

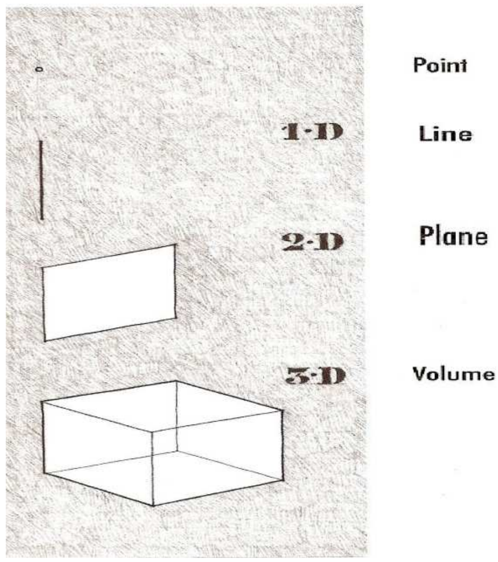


Figure 9: According to Ching the illustration of Prime Generators of Form [Ching, p.3, 1996]

Forms have characteristics of being easily distinguished in their environment as a three-dimensional mass element. (Cinici, 1988).

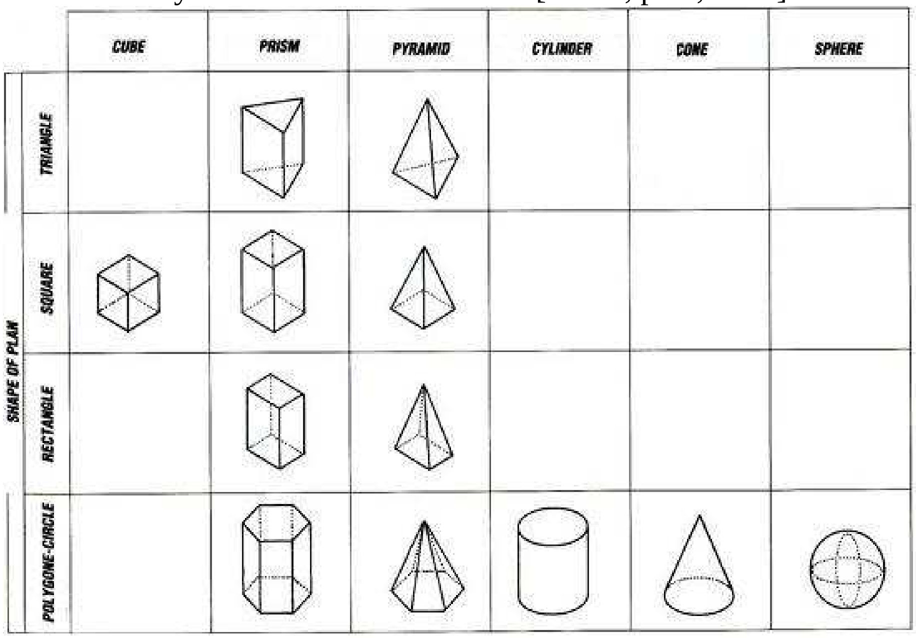
To understand the abstraction concept`s of shape it is suggested to deal the visible attributions. Generally according to the Krier the visible attributions of the shape stated as its geometrical structure (Krier, 1991).

Square, triangle and circle are named as the primary shapes.

Figure 10: The primary shapes illustration [hhtp://www.istockphoto.com]

According to the Onat the shapes that are derived through the primary shapes can be called as primary solids. (Cinici, 1988). These primary solids are the sphere, cylinder, cone, pyramid, prism and cube.

Table 1: The Primary Solids shown in the table [Cinici, p.16, 1988]



According to Platon, primary geometrical shapes are the shapes which have been easily defined. And according to Platon primary shapes are triangle, square, circle, cylinder, cube, pyramid, cone, and sphere (Ching, 1996).

The primary shapes can be extended or rotated to generate volumetric forms or solids which are distinct, regular and easily recognizable. Circles generate sphere and cylinder; triangle generates cones, prism and pyramid; square generate cube. (Ching, 1996). In this context Ching argued that “the term solid does not refer to firmness of substance but rather to a three-dimensional geometric body or figure.”(Ching, p42, 1996).

There are regular and irregular forms. Regular and irregular forms are using to generate new forms. According to Ching regular and irregular forms defined below.

“Regular forms refer to those whose parts are related to one another in a consistent and orderly manner. The sphere, cylinder, cone, cube, and pyramid are prime examples of regular forms.” (Ching, p.46, 1996).

“Irregular Forms are those whose parts are dissimilar in nature and related to one another in an inconsistent manner.” (Ching, p.46, 1996).

There are many approaches to generate regular and irregular forms. Actually it is possible to use methods of transformation, subtraction, addition, centralization, rotation, articulation,…etc to generate regular and irregular forms (Ching, 1996). Furthermore in the context of dissertation aim; it is right to deal forms which effects material and structural decisions in the process of design. In this section the idea of “formlessness” are explained.

The new trend in architectural form organization is the idea of “formlessness”. Actually it is right to argue about this “formlessness” idea in this section.

General characteristics of “formlessness” idea can be identified as below;

- Familiar material used with unfamiliar positions, displaced.

- Variety of the material type through the parts.

- Sequence of view. (Sculpture like, aesthetic approach)

- Fragmentation exist.

- Idea of crack between buildings.

- Envisage unity or wholeness as a result.

As results of “formlessness” enterprise, confront us with our epochal trends “deconstructivism”. It explains with the one sentence, it is trend to make impossibilities; possible with the opportunities of technology in all phase of the architecture (Leatherbarrow & Mostafavi, 2005).

The formlessness has been applied pressure on the materials properties and also hardening the structural formation of the building materials. In the future most probably the designers will want to apply pressure to the boundaries of building materials ability to get the impossible form.

The building`s of Frank O. Gehry is an masterpieces of this trend. For instance Gehry`s own house in Santa Monica has been used unfamiliar positions and displaced forms. According to Gehry “the breakthrough for me in this house was the idea of cracks between the buildings, wedge-shaped cracks that serve to differentiate the parts of the pure forms and suggest that they are complete forms because of this cleavage.” (Leatherbarrow & Mostafavi, p. 196, 2005). In this context wholeness of the forms has been postponed.

Picture 33: Gehry`s own house in Santa Monica [Leatherbarrow & Mostafavi, p.196, 2005]

4.1.1.2 Philosophy of Form and Structural Form and its Appropriateness

“From is an inherently philosophical topic.” (Cinici, p.32, 1998). In this context philosophy is the study of general and fundamental problems concerning matters such as existence, knowledge, truth, beauty, law, justice, validity, mind, and language (Teichmann & Evans, 1999). Also Teichmann and Evans clarified the word philosophy with this statement “Philosophy is a study of problems which are ultimate, abstract and very general. These problems are concerned with the nature of existence, knowledge, morality, reason and human purpose." (Teichmann & Evans, p.1 1999). However philosophy is a wider study so in this point it is more than enough to deal its general context and meaning.

On the other hand even if we consider apparently material or quantitative conditions governing the creation of form, such as the relationship between material properties and structural form, the thought processes used to generate form can constitute a philosophy of design by default (Dooley, 2004).

"The idea of form as the characteristic principle of a thing dates to at least 550 BC." (Whyte, p.230, 1968). As such form is a characteristic principle which needs to be examined in further research because when we speak of structural form there is the inherent idea that the form must reflect its structural purpose. Why should structure look like? What should structural form look like? According to these words it is obvious that form can be shape through its appropriateness to the desired needs. The matter is to find an appropriate form to shape the function of building. Form is ultimately the conceptual product of our imagination, and the material product of our ability to manipulate and process materials. Therefore, structural form has both metaphysical and mechanical limits (Dooley, 2004).

In 1214, Robert Grossteste, an English philosopher, defined form as a "thing that is what it is" (Whyte, p.231, 1968). According to these words it means that form is an inert concept whose shape in specious way or without materiality. Samuel Taylor Coleridge, a nineteenth-century English metaphysician and poet, makes this interpretation more explicit. Coleridge wrote,

> "*No work of true genius dares want its appropriate form. The form is mechanic, when on any given material we impress a predetermined form, not necessarily arising out of the properties of the material; as when to a mass of wet clay we give whatever shape we wish it to retain when hardened*" (Coleridge, p.46, 1907).

However, the concept that a thing is what it is could be interpreted to mean that appropriate form is merely that which is producible. Therefore, appropriate structural form need are that to satisfies the most basic security and serviceability requirements, such as a large irregular stone placed on two supports to make a bridge, as such it is an appropriate use of material because its respond functional desires.

According to the Dooley, the fact that the act of manipulating material relates directly to a material’s processing attributes and their relationship to material properties. Nonetheless Dooley continues his words with the example; clay is a material which is getting hardened after applying on the surface. As such Dooley argued that “if the form was created when the material was in a different physical state there is an apparent disconnect between material properties and the final form” (Dooley, p.116, 2004). Therefore, form is what it is as Grossteste said, except it has an inherent characteristic of the process by which it was made.

In 1593, Francis Bacon stated, “The Form of a thing is its very essence” (Whyte, p.231, 1968). Bacon defined form as the objective conditions on which a sensible body or quality depends for its existence and the knowledge of which enables it to be fully reproduced. For instance the stone used to make the bridge may have been formed in a sensible way geologically, but as a structural component, it was simply a conveniently found object suitable for the purpose. The stone cannot be reproduced, though suitable stones could be found to make other bridges. Either the maximum size stone that can be found and moved, or the ultimate strength and dimensions of the stone will limit the size of such bridges. As a technological thought, it was a great and expedient idea to use a conveniently found object to traverse an obstacle, but its use is limited unless it can also be sensibly extrapolated from this simple bridge that perhaps other materials can be used, or longer bridges can be made using the same material if used in a different way (Whyte, 1968). Therefore, form has limits related to the availability of materials, the ability to process and build with those materials, and material properties.

When Bacon has been said that the "Form of a thing is its very essence," it seems that he has been seen form similarly to Grossteste, except we know that Bacon, unlike Coleridge, interprets form to also reflect knowledge and sensibility. As such, form is more than just what is apparent, its physical outward appearance.

S.P.F. Humphreys-Owen explained that;

> "*Our appreciation of form is partly sensory, but we can be helped by measurement and calculation to gain some confidence that what we perceive is not entirely unconnected with the outside world… The science of Geometry could interpret form, by discovering that the essence of the form is a certain relationship between dimensions in space. Geometry is an abstraction of all properties of matter other than that of 'occupying space.' Other sciences introduce, successively, other properties*" (Whyte, p.8, 1968).

He has been mean by other sciences mechanics, dynamics and physics.

Humphreys-Owen is inferring that a material has Gestalt qualities; what Konrad Lorenz described as "the characteristic quality of the whole can be dependent on the universal interaction of literally all its parts, thus proving the naïvety of the… atomistic assumption that a part, though isolated experimentally, would behave exactly as it did in the context of the whole" (Whyte, p157, 1968). Christian von Ehrenfels is the first man who discussed the concept of Gestalt qualities around 1890. These Gestalt qualities were used to define a theory of perception in the early twentieth century by Max Wertheimer, Wolfgang Koehler, and Kurt Koffka.

Nonetheless, the concept of a Gestalt-quality seems to embody the idea of what appropriate form could be (Whyte, 1968).

Consequently, to interpret all these arguments Coleridge assumes that the clay will behave the same regardless of “what form it is in”. However, the idea of a Gestalt-quality means that form is a part of a whole, not the whole. As such form may effect`s from many variables. These variables can be material, structure, etc. For appropriate form all these variables must be revised. Appropriateness of the form may depend upon the desired needs which can be named as a variables besides these variables can changes according to the design projects for instance sometimes material can helps us to rich the desired needs. Also appropriateness of the form may vary from design to design. Sometimes one form can be an appropriate through the demands however sometimes that form cannot be appropriate for desired functions; as such in this context desired functions can be a variable according to the project. For instance by Robert Maillart’s Tavansa Bridge in Graubünden, Switzerland; Maillart learned from previous bridges at Zuoz and Bilwil that the concrete in the spandrels of these arch bridges was not in compression. This material was not helping to transfer load to the arch, so Maillart eliminated the material. Thus he created a new form of arch specific to reinforced concrete (Whyte, 1968).

4.1.2 Structure and Architectural Structure

According to Schodek “Structure” book define the structure as “is a device for channeling loads that results from the use and/or presence of the buildings to the ground” (Schodek, p.2, e.d. 2001). The study on structure certainly involves coming to understand the basic principles that define and characterize the behavior of physical objects subjected to forces.

Also Schodek continue his explanation about structure with the words through "In first states that structure is a real physical object, not an abstract idea or interesting issue. A structure is not a matter of debate; it is something that is built" (Schodek, p.3, e.d. 2001).

The simplest way of describing the function of an architectural structure is to say that "it is the part of a building which resists the loads that are imposed on it. A building may be regarded as simply an envelope which encloses and subdivides the space in order to create a protected environment" (Macdonald, p.1, 2001).

The surface which forms the envelope of the building is the walls, the floors and the roofs. These surfaces are received various types of loads such as snow, rain, wind…etc. Also floors are exposed to the gravitational loads of the inhabitants of the building nonetheless most of these surfaces have to carry their own weight (Macdonald, p.1, 2001).

Building surfaces has a non-structural and structural (self-suporting) covering which is determined from external look. As Macdonalds said that "the location of the structures within a building is not always obvious because the structure can be integrated with the non-structural parts in a various way." (Macdonald, p.1, 2001). For instance igloo is a good example for self supporting (structural) compressive envelope because the structure and the space enclosing elements are one. On the other hand in tepee the structural elements and enclosing elements are entirely different from each other. Poles used as a main structural elements which carry the whole building nonetheless skin of fabrics or hides has been used as enclosing elements on the main structural elements (Macdonald, 2001).

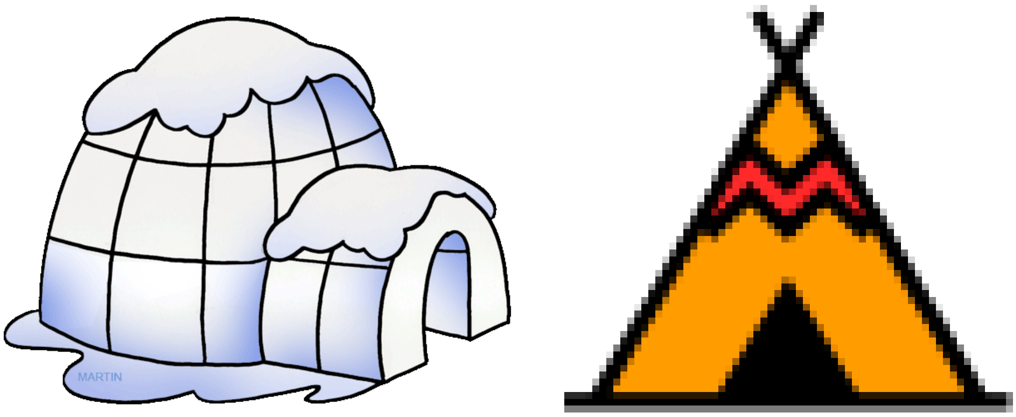


Figure 11: The Igloo and Teepee simple illustration
[http://nj.gov/education/njpep/assestment.html]

In construction, a structure principally receives, transfers and discharges loads while providing a framework upon and within which to support a given function. The most important requirement of structure is that it ensures structural security. Structures are subject to different stresses – tension, compression, moment, shear, torsion and fatigue. These stresses are caused by static and dynamic loads classified under three general categories: dead load, live load and dynamic load. Basic geometrical, strength and stiffness requirements ensure the security of a structure by maintaining structural stability when subject to specified load conditions (Dooley, 2004).

Structure to perform its function of supporting a building in response to whatever loads may be applied to it, a structure must be possess four properties: it must be capable of achieving a state of equilibrium, it must be stable, it must have adequate rigidity and strength (Macdonald, 2001).

4.1.2.1 Structural Systems

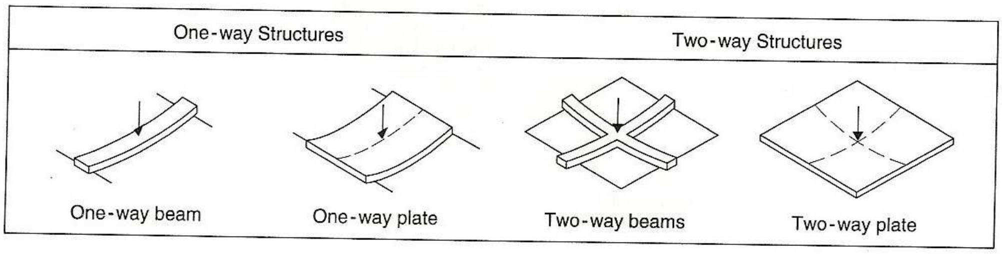
Structural Systems are complete structural models with inherent structural stability that satisfy function-defined requirements for enclosing or spanning space. Systems can be designed from the laws of mechanics and geometry in the absence of a defined material or material properties. Therefore, Systems are not conceptually bound to the present state of knowledge of materials, processing and construction (Dooley, 2004).

Nonetheless Schodek in the book of "Structure" said that "A very basic way of distinguishing among structures is according to the spatial organization of the system of support used and the relation of the structure to the point of support available" (Schodek p.6, 2001). Therefore, generally there are one-way and two-way formed systems.

One-way systems: "the basic load transfer mechanism of the structure for channeling external loads to the ground act in one direction only" (Schodek p.6, 2001).

Two-way systems: "the direction of the load transfer mechanism is more complex but always involves at least two directions" (Schodek p.6, 2001).

Table 2: According to Schodek the simple illustration table of the two types of structural system [Schodek, p.6, 2001]



The cable-supported roof shown in Figure 12 is an example of a non-material System model. This figure comes from Heino Engel’s book, Structure Systems. In this book, Engel defines a System to be a design principle, which is an incorporated into a design (Engel, 1997).

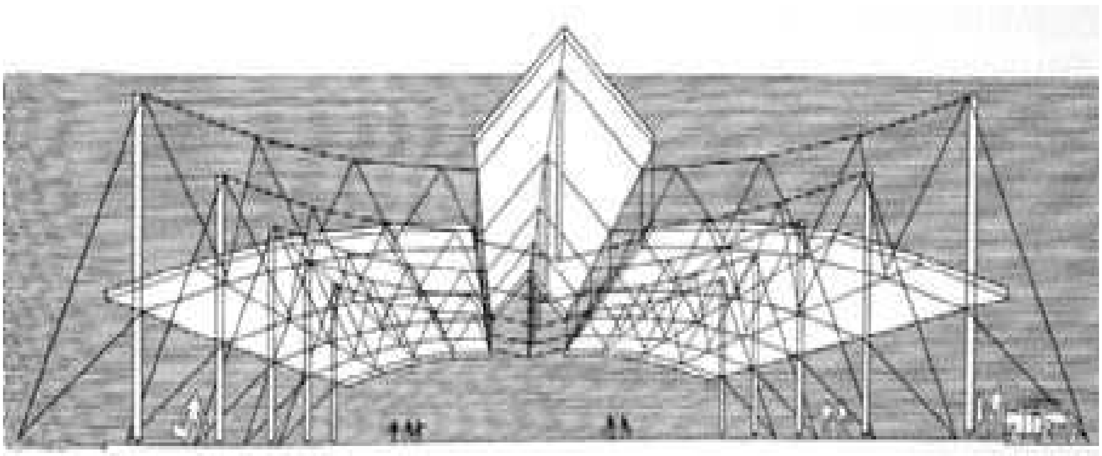


Figure 12: Wire and Surgace model of Cable supported roof, the model is not material specific [Engel, p.20, 1997]

Developments in materials, processing technologies, general knowledge of structural theory, or simply a historically original design problem, can lead to the invention of a new structural system as such Engel’s book provides a useful typology of structural systems. This typology could be used as a basis from which to determine general categories of systems. Engel has created his typology of structure in the absence of function and material.

Engel groups structural systems into the following five categories plus a separate category for hybrid systems (Engel, 1997).

Form-Active Structure Systems: adjust to the forces, acting mainly through material form. Such systems are in a condition of single stress, subject to either compressive *or* tensile forces. Arch, tent, cable and pneumatic structures are types of Form-Active Structure Systems (Engel, 1997).

Vector-Active Structure Systems: dissect forces, acting mainly through a composition of compressive and tensile members. Such systems are in a coactive stress condition, subject to both compressive and tensile forces. Flat trusses, curved trusses and space trusses are types of Vector-Active Structure Systems (Engel, 1997).

Section-Active Structure Systems: confine forces, acting mainly through cross section and continuity of material. Such systems are in a bending stress condition, subject to forces generating internal moment and shear stress. Beam, beam grid, frame and slab structures are types of Section-Active Structure Systems (Engel, 1997).

Surface-Active Structure Systems: disperse forces acting mainly through extension and form of surface. Such systems are in a surface stress condition, subject to membrane forces. Shells, plate, and folded plate structures are types of Surface-Active Structure Systems (Engel, 1997).

Height-Active Structure Systems: collect and ground forces, acting mainly to transmit vertical load. Such systems do not have a typical stress condition. Bay-type, casing, core, and bridge high-rises are types of Height-Active Structure Systems (Engel, 1997).

Hybrid Structure Systems: are composed of two structural systems with dissimilar mechanics for redirecting forces. When the two systems are combined, a new, hybrid system is created. Superimposing or coupling two systems makes a hybrid system. Engel does not consider a hybrid system as being a unique or characteristic structure type because they do no possess an inherent mechanism for redirection of forces, develop a specific condition of acting forces or stresses, or command structural features characteristic to them (Engel, 1997).

4.1.2.2 Structural Components

Structural Components are the parts that make up a System. For instance the above mentioned two-hinge arch were part of Gustave Eiffel's Douro Bridge located near Porto, Portugal, then the trussed bars of wrought iron would constitute the Components of the System. If the arch were made of reinforced concrete with a box section, then the chords and sidewalls would be the Components.

The uniform, outward appearance of well designed shells often belies the fact that the shell is actually composed of elements with different structural functions. A 'pure' shell would only transmit compression and be subject to hoop stresses (Dooley, 2004). However, shells with apertures or free edges need compression or tension rings, and stiffening edge or transfer beams. The drawing of Robert Maillart's Cement Hall, shown in Figure 13, clearly shows different structural components – vault, cantilevered transfer beams within the section of the vault, and edge beams, which are only discerned by revealing the placement of the reinforcing steel.

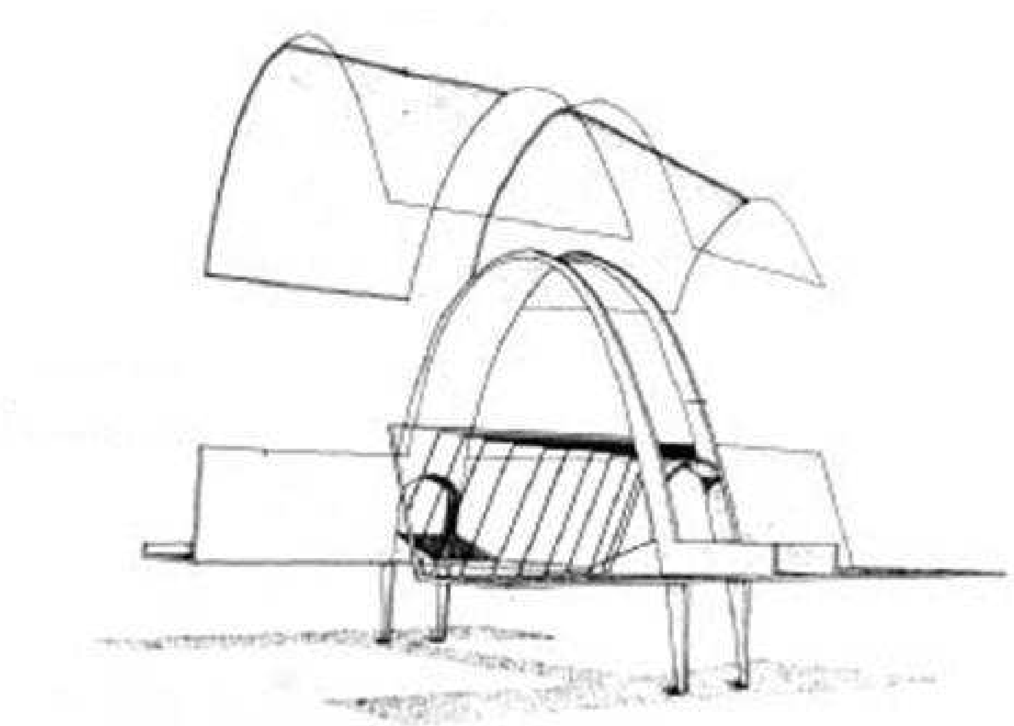


Figure 13: Cement Hall, early R.C. thin shell, the images shows arrangement of R.C. concrete in the shell structure [Billington, p.115, 1997]

As such Engel's model can also be a useful tool to inform material choice for the designer, and the conception of Component Form for the developer. Figure 14 shows an example of a Structural System from Engel in which different components are used, each variant clearly exhibiting properties that would encourage the use of one material versus another, or, in the case of the developer, one Component Form model over another. This figure illustrates the great flexibility a designer has to adapt different materials to different Systems, or, conversely, the System to the material.

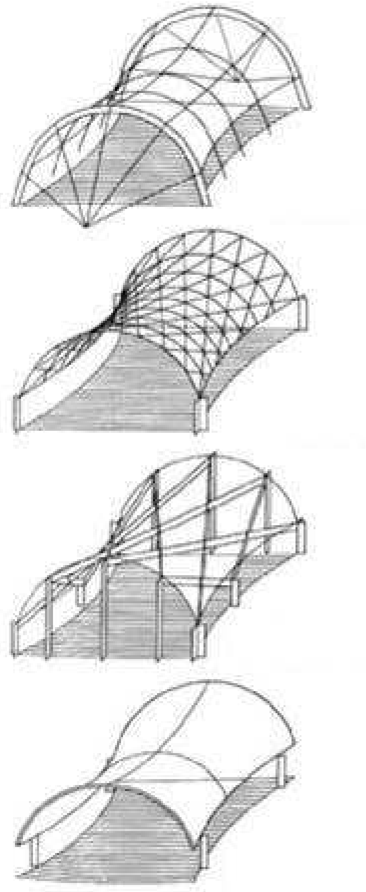


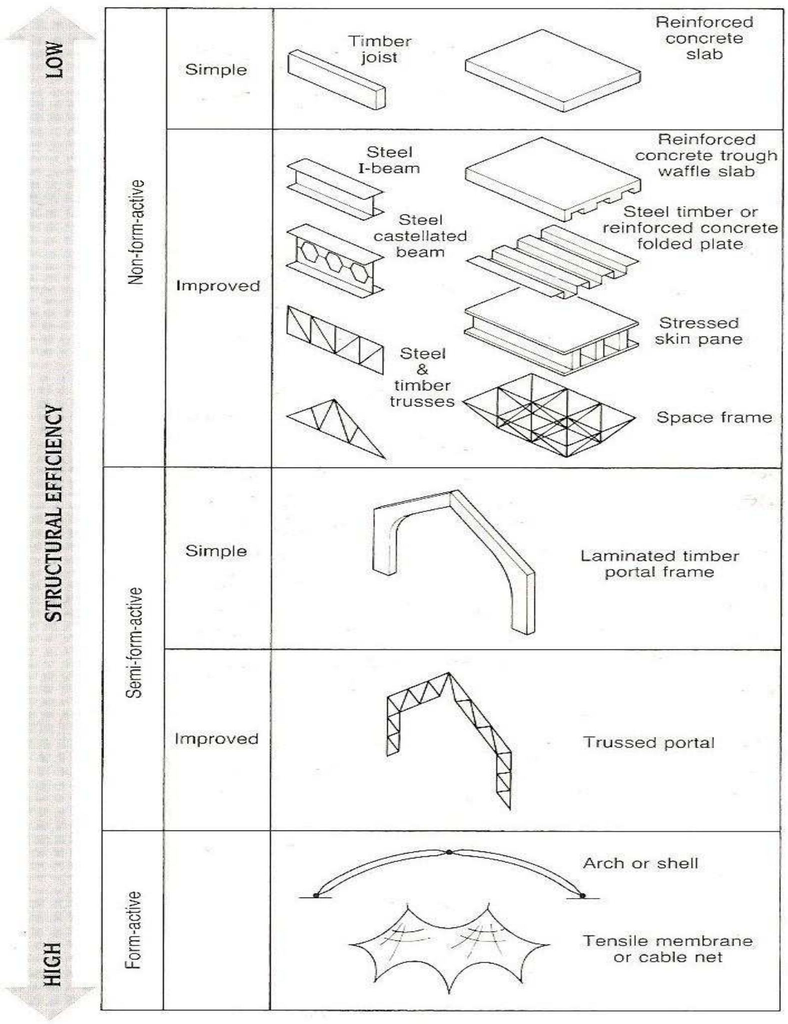
Figure 14: Shows examples of structural systems from Engel in which different components has been used [Engel, p.85, 1997]

4.1.2.3 Structural Elements and Classification

Briefly structural elements can be defines as the constituent parts of composite materials. According to the Dooley "The geometric arrangement of those Elements is described as Material Architecture." (p.45, 2004). There are various methods in the classification of structural elements as such it is depends to the desired features.

One of the classifications made by Macdonald in his book`s of "Structure & Architecture". Macdonald classification of structural elements has various devices which can be used to improve the efficiency of structures, and it can form the basis of a classification systems. The primary categorization is between form-active, semi-form-active, non-form-active, further elements are classified according to the degree of improvement which is presents in their cross sections and longitudinal profiles.

Table 1 According to Macdonald the classification of structural elements with the simple illustration in table [Macdonald, p.46, 2001]



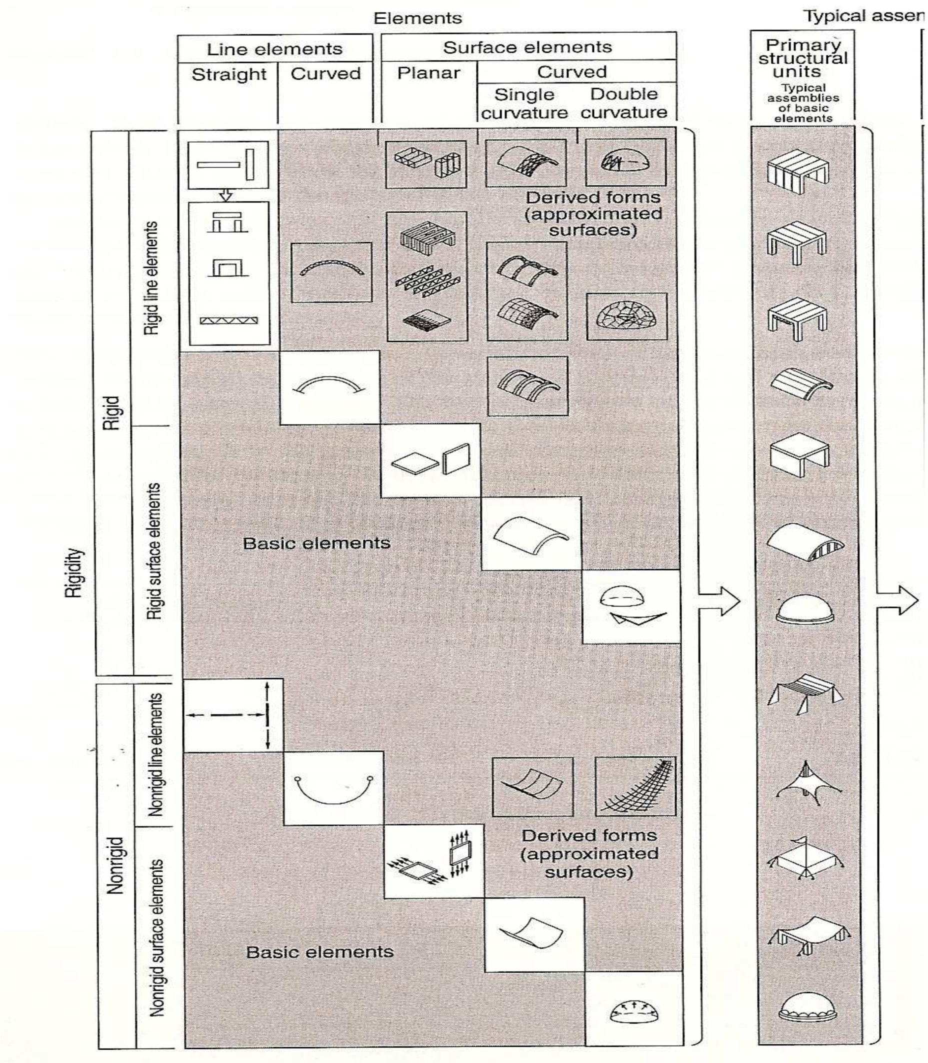
According to Macdonald

> *“this systems links the form, and therefore the appearance, of a structure with its technical performance and provides a basis for reading a building, or indeed any artifact, as a structural object. This is an important consideration for anyone involved with either*

the design of building or with their critical appraisal" (Macdonald, p.46, 2001).

By the way of addition Schodek classified the structural elements according to the geometry and primary physical characteristics. Typical primary structural units and other aggregations are also illustrated.

Table 3: According to Schodek classification of basis structural elements according to geometry and primary physical characteristics [Schodek, p.5, 2001]



4.1.2.4 Types of Structures

In this part the three basic types of structural arrangement will be briefly described. They are post-beam structures, semi form-active structures and form-active structures.

Post-beam structures are assemblies of vertical and horizontal elements, contrary they are not form-active; however the form-active structures are complete structures whose geometries conform to the form-active shape for the principal load which is applied, and arrangements which are not fall into either of these categories are called semi form-active structures. Furthermore they are described in more detail below (Macdonald, 2001).

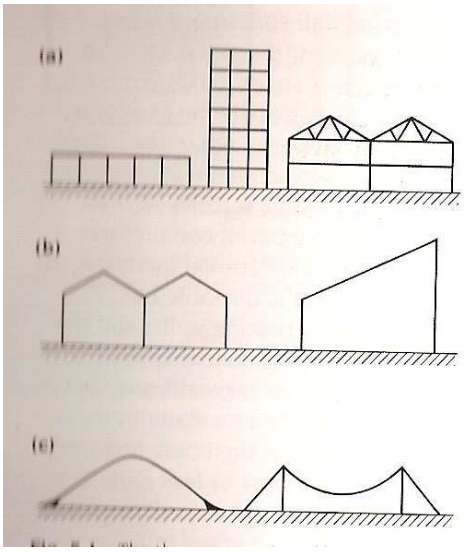


Figure 15: The three category of structural types illustrated, (a) Post-beam structure, (b) Semi Form-active structure, (c) Form-active structure [Macdonald, p.47, 2001]

Post-beam structures are either load bearing wall or frame structures. Both are used structural forms and within each type a fairly wide variety of different structural arrangements, of both continuous and discontinuous types are possible. A large range of spans is also possible depending on the types of elements which are used. Post-beam structures are consisting of two main elements which are post and beam. Post and beam are “Non-form active”. Nonetheless "Non-form-active" elements, like beams, are subjected to bending stresses only. (Macdonald, 2001).

According to Macdonald words for larger interior spaces there are must be used frame systems instead of load-bearing structures. “Where greater freedom to plan the interior of a building is required or where large interior spaces are desirable, it is usually necessary to adopt type of frame structure.” (Macdonald, p.50, 2001).

Nonetheless irregular plan forms are possible however, in multi storey versions the plan of the structural elements must be more or less the same at every level so as to maintain vertical continuity of the structures.

Post is a vertical support structure. Columns do not have to be round. Here are examples of columns in our community.

Table 4: The table of exaamples of columns in our community [http://www.pennridge.org/beamstruct.html]

		
Rectangular columns in front of School support the overhang at the entryway.	Tapered columns on this bungalow style house; support a large overhanging roof.	Classical style columns support a wrap-around porch

	
Though these column chimneys at Moravian Tile in Doylestown, PA do not support anything other than their own weight, they are capable of supporting other weight (with a proper foundation below).	This large column at Grand View Hospital in West Rockhill Township supports a water tower.

The beam is a very sturdy structure. A beam is a horizontal pole. It is usually shaped as a rectangle so there is more balance between the poles. A beam is held up by one or two columns. If there are two columns, they are placed on either side of the beam. If there is one column, it is placed in the middle of the beam so each side is balanced. Beams are found in many places - in buildings, in homes, and in moving structures.(Macdonald, 2001).

Table 5: The table of examples of beams from our community [http://www.pennridge.org/beamstruct.html]

	
These monkey bars at Elementary School are made of horizontal beams supported on four columns.	This covered bridge in Perkasie, PA is a beam bridge.

	
A table uses a simple beam framework (seen above) to support the table top. Sturdy tables designed to hold a lot of weight use triangulation with the legs to support additional weight on the structure.	This small bridge or culvert is actually a beam bridge over three cement pipes used to allow water to pass from the local creek.

In construction of post-beam structures many materials are used. Such as reinforce concrete, steel, timber and combination of them.

Relatively with post-beam structures with steel material it is possible to make prefabrication in elements for ease of transportation and site erection. Especially with steel it is very simple.

An early example of this was the Crystal Palace erected for the Great Exhibition in 185l covering an area of 7.3 ha (18 acres) with prefabricated components of cast iron and timber on a 24 ft module. None of these weighed more than 1 ton so that they could comfortably be lifted with a system of horse drawn or hand-winched block and tackle.

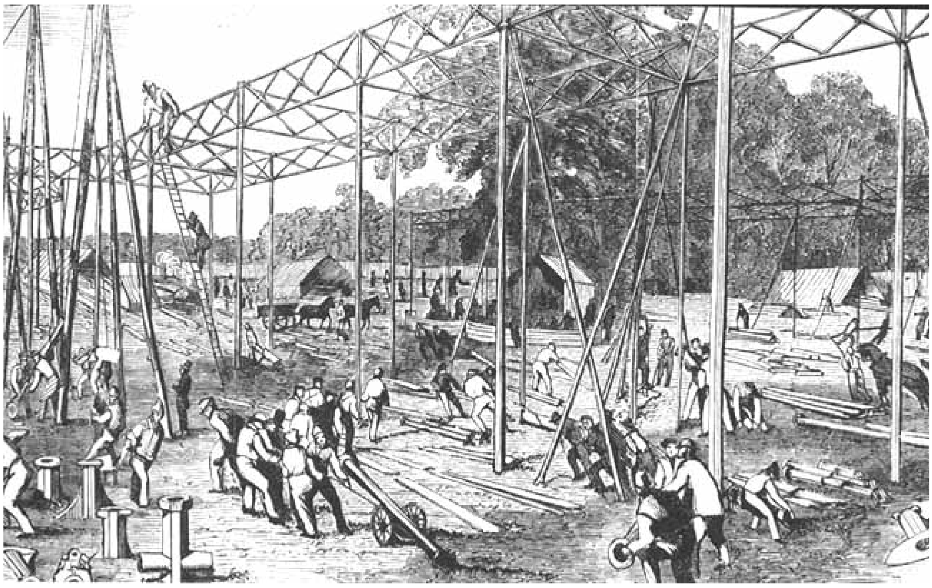


Figure 16: The early construction of Crystal Palace
[http://www.corusconstruction.com]

This form of flat beam structure is most appropriately used where the minimum volume of space is required within the desired clear height. The achievable span is then directly related to the depth of the beams which, for normal loadings, would require a depth to span ratio of approximately 1:15 for solid web steel beams.

Beams may be solid web or truss forms, offering a variety of opportunities for architectural design.

Mies Van der Rohe's Crown Hall building on the Illinois Institute of Technology campus defined a new architectural vocabulary in the 1950s with the black painted solid web steel beams and columns expressed on the outside.

This refined use of structural steelwork as part of the architectural vocabulary was progressed in the 1960s by the American architects Skidmore Owings and Merrill on a series of industrial buildings and in the UK was pioneered by Team 4 on the Reliance Controls plant in 1965 at Swindon.

Later, as the level of building services increased with the introduction of new technology, trussed beam solutions were more favoured, following the example of the SCSD (Southern Californian Schools Development) System for California School building where the mechanical and electrical services are co-ordinated within the roof trusses.

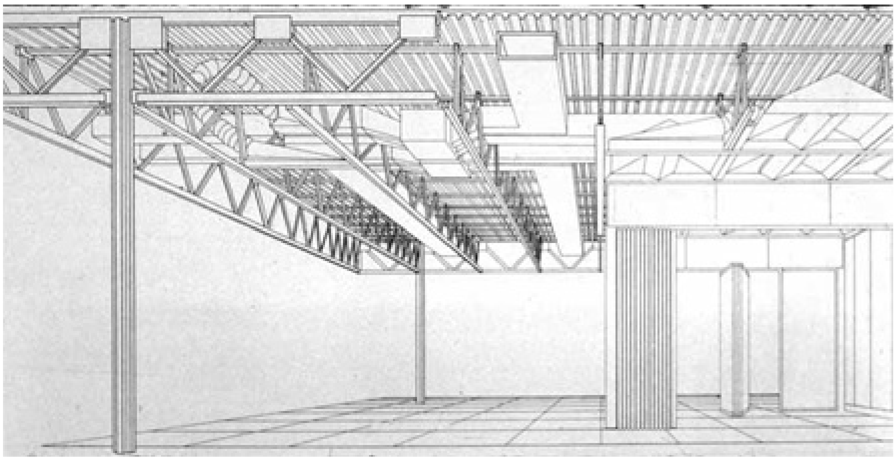


Figure 17: Trussed beam solution [http://www.corusconstruction.com]

However with reinforce concrete materail it is more easy to form the post-beam structures with the help of formworks. A typical arangement of elements in real construction sites are placed below.


Picture 34: Post-beam structure frame system photos
[http://www.column&beamstructures.com]

Semi form-active structures have forms whose geometry is neither post-beam nor form-active. The elements therefore contain the full range of internal forces types such as bending, shear. Below you can see example of semi form-active structure.

Picture 35: Example of semi form-active structure building
[http://www.homepages.ed.ac.uk]

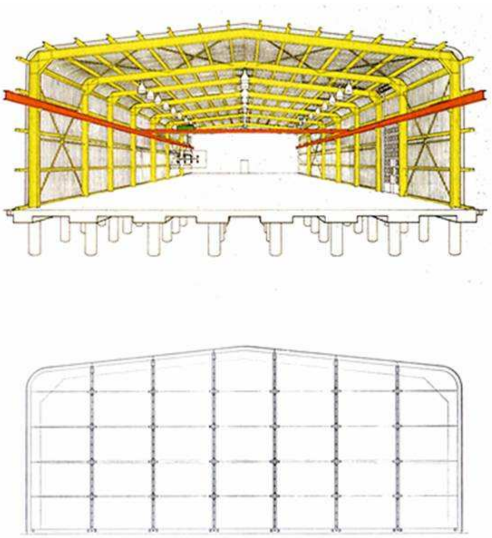


Figure 18: Example of semi form-active structure illustration in detail
[http://www.homepages.ed.ac.uk]

According to Macdonald semi form-active structures usually adopted a support systems for buildings for one or two reasons. Semi form-active structures may be choosen because it is necessary to achieve greater efficiency than a post and beam structures allow, or because a long span is involved or because a applied load is light. (Macdonald, 2001). Therefore, large spans can be made with this structure.

Form-active structures refers to a structural element, such as a column or arch, in which the shape of the longitudinal axis, in relation to the pattern of applied load, is such that the internal force is axial. (Macdonald, 2001).

Form-active structures are normally used only in circumstance where a special structural requirement to achieve a high degree of structural efficiency exist, either the span involved is very large or because a structure of exceptionally light weight is required. (Macdonald, 2001).

They have geometries which are more complicated than post-beam or semi form-active structure types and they produce buildings which have distinctive shapes.

The technical problem posed by the long span is that of maintaining a reasonable balance between the load carried and the self-weight of the structure. The forms of longest-span structures are therefore those of the most efficient structure types. In the pre-industrial age, the structural form that was used for the widest spans was the masonry vault or dome.

The development of reinforced concrete in the late 19th century allowed the extension of the maximum span possible with the compressive form-active type of structure. Reinforced concrete has a number of advantages over masonry, the principal one being its capability to resist tension as well as compression and its consequent ability to resist bending.

Concrete domes can be good example for the idea of form active structure. Because of this ability, compressive form-active structures in reinforced concrete can be made very much thinner than those in masonry. This allows greater efficiency, and therefore greater spans, to be achieved because the principal load on a dome or vault is the weight of the structure itself.

Figure 19: A dome 3d illustration [http://www.atlasphotos.com]

Compressive form-active structures are also produced in metal, usually in the form of lattice arches or vaults, to achieve very long spans. Notable recent examples are the International Rail Terminal at Waterloo Station, London, by Nicholas Grimshaw.

Picture 36: International Rail Terminal at Waterloo Station, London, by Nicholas Grimshaw, 1993 [http://www.e-architect.com]

The Millennium Dome in London by architect Richard Rogers at 2000, which is not a dome in the structural sense, is perhaps the best known of these. In this building, a dome-shaped cable network is supported on a ring of 24 masts. The overall diameter of the building is 358 meters but the maximum span is approximately 225 meters, which is the diameter of the ring described by the 24 masts. The size of the span makes the use of a complex form-active structure entirely justified.

Picture 37: The Millennium Dome in London by architect Richard Rogers, 2000 [http://farm4.static.flickr.com, http://www.thecityreview.com]

The cable network to which the cladding is attached consists of a series of radial cables, in pairs, which span 25 meters between nodes supported by hanger cables connecting them to the tops of the masts. The nodes are also connected by circumferential cables which provide stability. The downward curving radial cables are prestressed against the hanger cables and this makes them almost straight and converts the surface of the dome into a series of facetted panels.

This characteristic simplifies the fabrication of the cladding. In fact, being tensile, form-active elements, the radial cables are slightly curved, and this curvature had to be allowed for in the design of the cladding, but the overall geometry is nevertheless considerably less complex than that of an anticlastic surface.

According to Macdonald, most form-active vaulted and cable structures have technical shortcomings. They are difficult to design and build and, due to their low mass, provide poor thermal barriers. In addition, the durability of these structures, especially the cable networks, is lower than that of most conventional building envelopes. (Macdonald, 2001).

Futhermore according to Macdonald most efficient type of structure is the form-active ones. In this section the three basic types of structure has been briefly examined and some visual examples has been used to explain them frankly.

4.1.2.5 Relations of Structural Systems with Used Materials

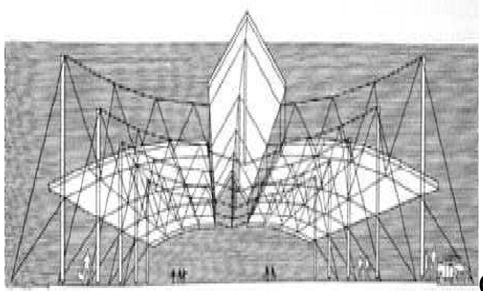
In this section the six selected materials which were examined in the chapter 3 will be evaluated through their appropriateness in the structural systems. These materials are stone, glass, concrete, wood, aluminium-steel-other metals and platics. With this the relationship of the structural systems with used materials will be shown and for each structural systems most appropriate materials will be stated in the table 7 below. As it is know for every material, the every structural system can not be appropriate. It is importand to use appropriate materials for needed structural systems.

Consequently table shows that concrete and steel are major structural materials that have been used for most of the structural systems. However glass and plastics can be used mainly as a surface covering material instead of structural systems. If the ductility problem of glass will solved it could be widely useful as steel and concrete. Nonetheless for more specific information it is suggested to take a look on the table 8 which is stated below to give brief idea about which material can be appropriate to use in which part of the buildings.

Table shows that concrete and steel can be used in many parts of the building constructions. However glass and plastics are not much useful material in the through parts of the buildings.

These two tables can be used in all process of the architectural design projects.

Table 6: Shows appropriate materials for selected system

Structural Sytems	**Appropriate Materials** (Through most appropriate to least)	**General Comments**	**Architectural examples**
Form-active	• Stone (for compression stress) • Concrete (for compression stress) • Steel (for tensile stress)	There must be one direction load transformation within the same system. It is either compressive or tensile stresses.	 Stone vault in form-active structure[http://www1.cs.columbia.edu]
Vector-active	• Steel • Wood	There must be both of the compressive and tensile stresses within the same system. There is two direction load transformation	Ca Cable supported roof [Engel, p.20, 1997]

Section-active	• Concrete • Steel • Wood	There must be compressive compressive, tensile, bending and shear stresses within the same system.	 Concrete section –active system, main structural elements has been shown such as slab, beam, column [http://www.column&beamstr.com]
Surface-active	• Steel • Concrete • Stone	Generally membrane, shell plate, folded plate can be considered as surface-active.	 Sydney Opera House concrete shell surface-active structure has been shown [http://greatbuildings.com]

Height-active	• Steel • Concrete	All types of stresses have been found in this system. All highrise building has this system in its body.	  Agbar Tower steel highrise building for height-active structure system. [http://www.mediaarchitecture.org]
Hybrid	• Steel • Concrete • Wood • Stone	Combination of two structural system needed for constitition of hybrid system.	 ROM building its combination of two different system [http://www.wikipedia.com]

Table 7: Shows appropriate parts of the building for selected material

Materials	**Appropriate parts of the Buildings for selected materials**
Stone	As a, Vertical Support Element Vertical Partitions Elements (Walls) Horizontal Beam and Slab Elements (Floors, Roofs, for instance in dome, arch and vault form for roofs)
Concrete	As a, Vertical Support Element Vertical Partition Elements (Walls and Frame Systems) Horizontal Beam and Slab Elements (Floors, Roofs) Below Ground Element Below Water Element
Glass	As a, Vertical Partitions Elements (Walls) Surface Element (Roofs, Floors)
Wood	As a, Vertical Support Element Vertical Partitions Elements (Walls and Frame Systems) Horizontal Beam and Deck Elements (Floors, Roof) Horizontal Beam and Surface Element (Roofs only)

Steel, Aluminium, Other Meetals	As a, Vertical Support Element Vertical Partitions Elements (Frame Systems) Horizontal Beam and Deck Elements (Floors, Roofs) Horizontal Beam and Surface Element (Roofs only) Below Ground Element
Plastic	As a, Vertical Partitions Elements (Walls) Surface Elements (Roofs)

4.2 Equilibrium and Force Relationship in the Structural Form

In discussing of structural form the two fundamental concepts of “equilibrium” and “force” need to be considered.

As it is mentioned before, structure to perform its function of supporting a building in response to whatever loads may be applied to it, a structure must be possess four properties: it must be capable of achieving a state of equilibrium. (Macdonald, 2001). The ensuring of equilibrium is basic the designers must begin and end their calculations through these principles; the various forces in and around the structure must be put into a state of balance so that it is stable under all circumstances of loads. Structural form must be capable to achieving a state of equilibrium under the action of applied load (Harris & Li, 1996).

According to Macdonald for equilibrium the internal configurations of the structure together with the means by which it is connected to its foundations must be such all applied loads are balanced exactly by reactions generated at its foundation (Macdonald, 2001).

Also the gravitational force is an important feature that effect`s the equilibrium of the structure. The gravitational forces generate by its own weight and that of its contents act vertically downwards.

According to Harris and Li “the concept of force is the basis of all structural principles, it is classically defined as anything that changes or tends to change the state of rest of a body or its uniform motion in a straight line."(Harris & Li, p.8, 1996). In this context in buildings, force is the external loads on the structural form and plus its own weight, which includes internal forces in the structural members.

Despite the famous statement by one celebrated commentator, "the buildings are not machines."(Le Corbusier, p.125, 1986). Architectural structures must be capable of achieving equilibrium under all directions of load.

The famous law for the action of forces to be in equilibrium was discovered by Isaac Newton. In this context Harris and Li in the book`s of "Masted Structures in Architecture" was supported the idea of Newton through these words "It was Isaac Newton who pointed out that if equilibrium is to be maintained, all the originating force actions must be resisted by equal and opposite reactions." (Harris & Li, 1996).

Nonetheless the internal Forces in the members can take only five different forms, namely tension, compression, shear, bending and torsion (Macdonald, 2001).

4.3 General Conclusion of the Chapter

This section has been focused on structural form definition frankly. This chapter has been examines the structure and form relationship in architecture. The content include definition of structure/form, architectural structures/forms and its contents, general types of structures, structural systems, structural components, structural elements an classifications, architectural form and types, philosophy of form and structural form and their appropriateness has been briefly examined in this chapter.

Finally all the collections and works that have been placed in this chapter will be used as a base knowledge for chapter 5.

CHAPTER 5

RELATIONSHIP OF BUILDING MATERIALS WITH STRUCTURAL FORM

In this section it is aimed to show the relationship between materials and structural form and with the innovation of new material and improvement of the existing materials properties it is aimed to argue about what is happening to the structural forms and building material relationship in the context of architectural design projects.

This will be done by deep investigation of six selected materials with respect to technology factors in their existing time through the years to show building material and structural from relation modification respect to time; in fact those materials has been examined in chapter 3 in more detail. Therefore the influences of technological developments of building materials and their interactions with structural form in architectural design projects will be bring out.

5.1 The Discussion of Relationship's Between Building Material and Structural Form in the Context of Architectural Design Projects through the Years

Building material and structural form are an important features in the process of realizing the projects. The relationships between them has been seen apparently as such without respect to building material resistance it is impossible to build structural form which is standing on the ground.

From the past to the present material may effects the structural form decisions in architecture with the effect of technology. Usually materials are playing an important role in the constitution of architectural forms for instance some form has not been realized up to present's days because of the insufficiency of existing materials property in the existing times. Therefore technology has been playing a big role in the constitution of the structural from. Firstly with the development of technology the materials industry has been developed and then these developments show itself on the designing of structural forms in the projects. For better understanding of the influences of the innovated building materials on structural form decisions in architectural design project it is suggested to take a look on each material development processes with respect to technology factors in their existing time through the years. Nonetheless the industrial revolution`s effects on these development processes of the materials has been showed by the architectural examples.

5.1.1 Stone

The first stone structures were probably made by stacking found rocks to make walls. Megaliths are evidence that men learned how to maneuver large stones, using earth ramps to make such distinctive structures as dolmens. Stone has been used as a one piece to constitute a form and it is obvious that the form which has been obtained, are the imperative (Dernie, 2003).

Picture 38: Dolmen Lanyon Quoits at Cornwall, England
[http://www.stonepages.wordpress.com]

Stone is a naturally occuring material. “Man’s first structural materials were those readily at hand: stone, wood, earth, vines, bamboo, and other naturally occurring materials that could be fashioned into shelter or fortification” (Dooley, 2004).

Then square surfaced beams and columns have been used in the construction of Stonehenge and the great blocks used to construct the pyramids in Egypt. It must be recognized that there were few material choices available at the time.

It is important to consider that the Greek's decision to use stone was taken in the context of material availability and knowledge at the time. The craftsman's knows the property of stone which is compressive in structural from; as such they use this knowledge to originate appropriate form with available materials. Therefore, that material is stone and the best form is the arch for that material. It was a cultural imperative that the temples be durable and last, at least figuratively, for eternity. Furthermore, stone was also amenable to integrating the structure with the architectural ornament of the aesthetic language used for design. In accordance with these words, loss of structural efficiency can be balanced by efficiency of the building system. The sculptural ornament of Greek architecture could be carved directly into the structural material. Therefore in any case, all three requirements – structural, durability, and aesthetic, could be satisfied by one material, which is stone. (Dooley, 2004).

In the pre-industry age the structural form which was used for the widest spans was made with masonry system a vault or dome form. Masonry is a traditional system which is consists of stones materials in compression.

The most successful example of forming the material according to required aims was seen in Gothic architecture with the usage of stone. In Gothic architecture stone has been used to constitute a form of vault, dome, etc. In this point stone has been used in many pieces to shape the forms such as dome, vault. Therefore the usages of the stone have been developed (Yurekli, 2000).

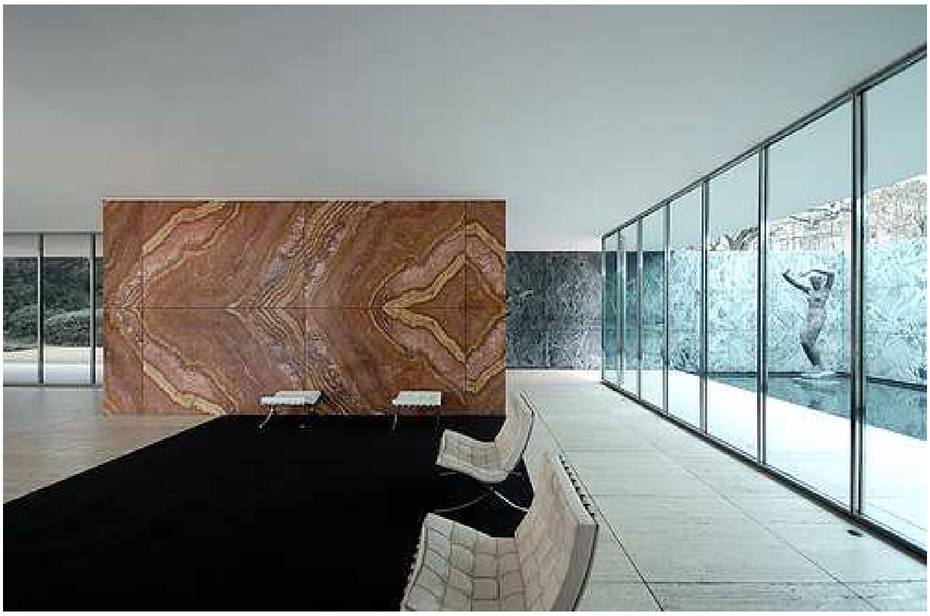

Picture 39: Stone usages in Gothic church [http://www.cs.columbia.edu]

The reason to use stone before industrial revolution was most probably for its constructability, strength and durability reasons in its period of time in fact stone has been using as a structural (as a load-bearing) reasons too. Because it is the only material that was existed in its period of time to carry a load in the form-active structures.

However at the present day stone relinquished its position as a structural material. Because it is very heavy material instead of stone it is better to use new invented materials after industrial revolution. Also with stone it impossible to rich three storey height as such it is not respond the today`s need. However today stone using as a cladding material instead of using it as a load bearing structural element. Nowadays new materials supersede the structural work of the stone.

Such applications of stone cladding were famously explored by Mies Van Der Rohe in his design for Barcelona Pavilion at 1929. The building has been build in a linear form which is suitable for steel I-beams and concrete beam and column, in fact whole building structural load has been carried by the steel and concrete structures.

However many types of stone claddings has been used on the surfaces of the vertical elements. In such a case stone has been used as a cladding material instead of its structural work in the buildings.



Picture 40: Stone cladding wall inside the Mies Van Der Rohe`s designed building which is Barcelona Pavilion at 1929 [http://www.wikipedia.com]

For instance the Mario Botta`s Chapel of Santa Maria degli Angele at Monte Tamaro in Switzerland (1996) is a only the image of traditional stonework that can be translated into cladding design of the stone material. Its clad-concrete structure appears as traditional load-bearing masonry, like carved space. However the buildings structural form made with reinforced concrete material.

Picture 41:Mario Botta`s Chapel of Santa Maria degli Angele at Monte Tamaro in Switzerland (1996) [http://www.botta.ch/Architecture/Sa%201996_188.jpg]

Picture 42:Side view of Mario Botta`s Chapel of Santa Maria degli Angele at Monte Tamaro in Switzerland [http://www.botta.ch/Architecture/Sa%201996_188.jpg]

In Picture 42 it is possible to see stone cladding better. Most of the visitors of the building guess that the building build by the whole stone material however it is not. The structural material is concrete. Also the structural form of the building has been designed through the ability of the stone material because the starting point of the project is to create a project which has impression of stone construction as all the chapel`s has in the ancient times. The building can be made by the stone but to pass that much span it is needed to locate big columns and beams to carry the load of the building in such a case it is waste of space and material. Therefore it is not wrong to say that it is economical to use stone cladding on the surfaces of the buildings in fact it is possible to cover all forms with stone but it is not possible build every form structurally with stone (Bell & Rand, 2006).

Picture 43: Detailed view for the stone cladding on the walls
[http://www.botta.ch/Architecture/Sa%201996_188.jpg]

5.1.2 Wood

Wood construction can be trace d to the beginning of civilization tough archeology in the crude structures of the pit dwelling, simple earth structures covered with wood members for shelter. Other early wood structures include yurts, teepees. The teepee and yurt main structural element has been made by the wood. Early structures in Greece, India Northern Europe and Japan were then typically constructed of masonry walls with timber roof. (Bell & Rand, 2006).

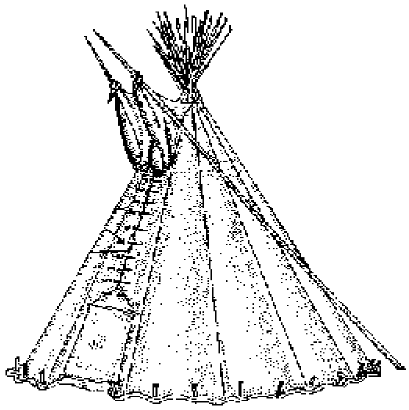


Figure 20: Shows a structural wood element of the teepee form ancient times [http://www.wikipedia.com]

In the Middle Ages braced wood frames began to be used for walls. Then some small houses build by wood. The hand – hewn practice of the cruck frame and the braced frame were early timber farming methods that evolved in many countries (Bell & Rand, 2006).

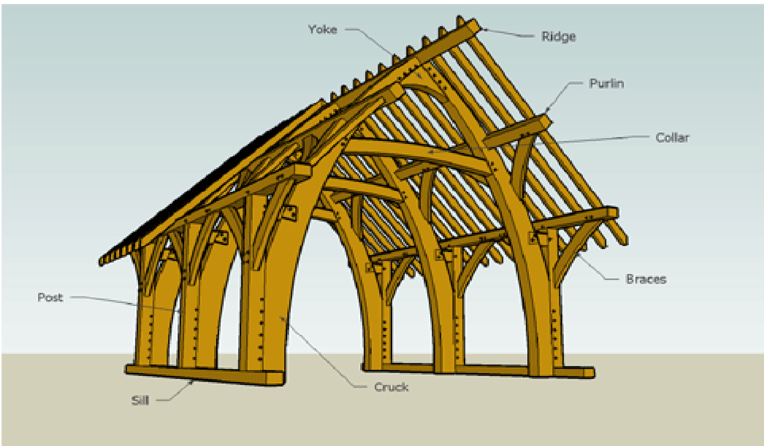


Figure 21: Timber Framing structural system [http://www.timberstructures.net/timber-framing.html]

Their Norwegian name "stavkirke" refers to churches whose structure rests on vertical logs as columns. Their roofs are covered with scale-looking wooden tiles and are decorated at angles with beautifully carved dragons underlined by Norwegian skies. Wood is a material which offers the designers of buildings a creation of very lightweight buildings which are simple to construct as such it can be rich by wood more stories than stone because of its lightweight (Sebestyen, 2003).

Picture 44: The wooden shurch photo from middle age
[http://www.middleagesbuildings.com]

By the mid 1800s large timber framing began to disappear due to the invention of wire nail and circular saw and the existence of sawmills that could inexpensively produce smaller pieces of lumber. Under the light of these developments in 1830s in Chicago, a new methods of wood system which is called balloon framing has been evolved which requires less skill to construct and less time to build than timber framing (Mori, 2002).

Picture 45: The picture of Balloon Framed timber building
[http://www.hereandthere.org/oldhouse/balloon-framing.html]

Partially a result of the incipient industrialization occurring in the young nation, the balloon frame was based on much lighter precut two-by-four-inch studs positioned sixteen inches apart and held together by factory-produced nails. Although light, the frame was very strong and able to withstand heavy winds, since the stress was spread over a large number of studs. The factory production of nails and mill cutting of standardized lumber reduced costs and increased availability of materials to individual builders. These houses were constructed quickly and easily, requiring only two workers using basic carpentry techniques. The method allowed many urban workers in America to build their own homes, in contrast to Europe where traditional construction techniques kept the rates of home ownership low for most of the nineteenth century (Bell & Rand, 2006).

Afterward with the development of technology new inventions made such as glue technology in wood industry. Especially the development in glue and laminated wood technologies are strengthening the usefulness of wood which is the one of the oldest natural building material. “Glued Wood Panel” (GWP) was provided through the innovations in production technologies nonetheless with adding some chemical additives it is become more durable against the fire (Ayan, 2002).

Architect Niels Torp made Olympic Stadium in Norway at 1992. This building is the project which has been passed larger spans of the world ever made with wood material. Approximately 2000 m3 of wood were used in the construction of structural system. Dome shaped roof structure has been strengthened with wood beams. To take this structural from wood flexibility has been increased by new technologies. Wood cannot resist under the bending force still sculptural forms has not been made with wood. However dome, arch, semi circle shaped forms has been become possible to build with wood with the development of technology in material industry.


Picture 46: Olympic stadium, Niels Torp, 1992 [http://www.wikipedia.com]

As it is mentioned before in chapter 3 there is an attempt to use the paper rolls as a building materials in fact these papers are used for textile industry to compass the fabrics. It seems that in the future most light structure of the buildings will be made with wood with the improvement of its properties by technology.

5.1.3 Glass

Glass is an ancient material, dating back more than 5.000 years. It is believed that the material originated around 3500-3000 BC in Egypt and Easter Mesopotamia with the creation of beadlike forms that were valued as highly as precious stone. Around 1700-1600 BC during Egypt`s 18th dynasty, artisans developed the skill to creating translucent bottles, jars and the first window panes for buildings. This process used heat to transform sand, seaweed, brushwood and lime into a range of forms and colors (Wigginton, 1997).

This revolutionary technique led to the development in the 6th century of transparent glass window which replaced the thin nearly opaque stone like sheets of alabaster or marble used in buildings. The Romans often credited with being the first to make glass large enough for windows used colored glass sheets set in a frame of wood or bronze for a more translucent pane (Kolarevic, 2003).

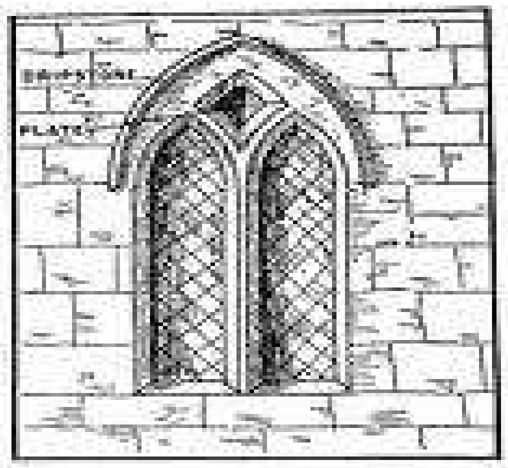


Figure 22: The Roman`s glass window [http://karennswhimsy.com/gothic-architecture.shtm]

Glass did not take on a significant structural work until many centuries later. Nonetheless in the mid 19th century the French artisan Gustave Falconnier mass-produced had-blow glass bricks in oval and hexagonal forms which extremely popular however it is expensive material on the time. Le Corbusier and August Perret enjoyed using them despite their limited load-bearing capacity and problems due to condensation development (Bell & Rand, 2006).

Picture 47: Gustave Falconnier`s mass-produced had-blow glass bricks [http://www.mediatinker.com/blog/images/red-glass-tiles.jpg]

The French architect Joachim built the first structural dome of concrete and glass in 1904. In 1907 Friedrich Keppler a German engineer has been invented and patented interlocking solid glass blocks that could be placed into reinforced concrete structures, allowing for load-bearing capacity as well as light transmission. In 1930s the Owen Illinois glass cooperation produced the hollow glass blocks which is commonly used today. Keppler`s stone blocks were heavy it is better to use hollowed glass brick. With the technology these inventions has been made through the years (Bell & Rand, 2006).

Picture 48: Hollow glass brick and its usages in the building
[http://www.malzemem.com/custom/odesismc/1000043562.jpg]

In 1950s, the British inventor Alastair Pilkington completely transformed the way in which glass was used in architecture through his development of float glass. The process used to produce is similar 90% of architectural glass today. Mies Var der Rohe`s use of glass and steel at the Illinois Institute of Technology in Chicago in 1940 represents an early forms of the example, as does his Seagram Building in New York in 1958. In Seagram building glass curtain walls has been used to cover building facades as such this application on the building`s facades decreased the structural loads of the building because glass is an lighter material than steel or concrete.

Picture 49: Mies Van Der Rohe`s the illinois Institute of Technology in Chicago at 1940 [http://architecturerevied.blogspot.com]

Picture 50: The Seagram Building exterior all glass facade
[http://www.wikipedia.com]

In the 1960s and 70s advancement in reflective, tinted, coated, and insulating glass exploded. Then in 1980s and 90s photochromic, electochromic, thermochromic (low emissivity glazing) and holographic has been invented. These inventions giving designers the ability to control the amount of heat and solar gain in curtain wall buildings. Still sculptural forms are not constructed with glass because of the problem of its elasticity property in fact it is not elastic material.

In the 20th century ushered further advancements of the glass into three district area: environmental control, structural uses and a vast array of surfaces and color treatments. Nowadays it is using as a structural members in the constructions but still there is another material which is helping glass for carrying of the load. There is no whole glass structure in the world. It is desire to have whole glass structural systems in the future. With the development of technology it seems that it will be happen.

5.1.4 Concrete

Concrete is a plain and unpretentious material, already some 2,000 years old. On the other hand, Reinforced concrete has a relatively short history and is quite a different sort of material. Concrete is widely used material in building construction, it is used to build variety of elements of a building like foundations, footings, columns, beams, slabs, walls, bridges, roads, etc (Wigginton, 1997).

During the Roman Empire, Roman concrete (or Opus caementicium) was made from quicklime, pozzolanic ash/pozzolana, and an aggregate of pumice. Its widespread use in many Roman structures, a key event in the history of architecture termed the Concrete Revolution, freed Roman construction from the restrictions of stone and brick material and allowed for revolutionarily new designs designs both in terms of structural complexity and dimension (Lancaster, 2005).

Concrete, as the Romans knew it, was in effect a new and revolutionary material. Laid in the shape of arches, vaults and domes, it quickly hardened into a rigid mass, free from many of the internal thrusts and strains which trouble the builders of similar structures in stone or brick (Lancaster, 2005).

The widespread use of concrete in many Roman structures has ensured that many survive to the present day. The Baths of Caracalla in Rome built in Rome between AD 212 and 216, during the reign of the Emperor Caracalla. It is just one example of the longevity of concrete, which allowed the Romans to build this and similar structures across the Roman Empire (Gokbayrak, 2005).

Picture 51: The exterior view of Baths of Caracalla, Italy
[http://www.wikipedia.com]

Many Roman aqueducts and Roman bridges have masonry cladding to a concrete core, a technique they used in structures such as the Pantheon, the dome of which is concrete.

Picture 52: The outher view of the Parthenon [http://www.wikipedia.com]

Outer view of the Roman Pantheon building has shown in Picture 5.15 above Parthenon still the largest unreinforced solid concrete dome to this day.

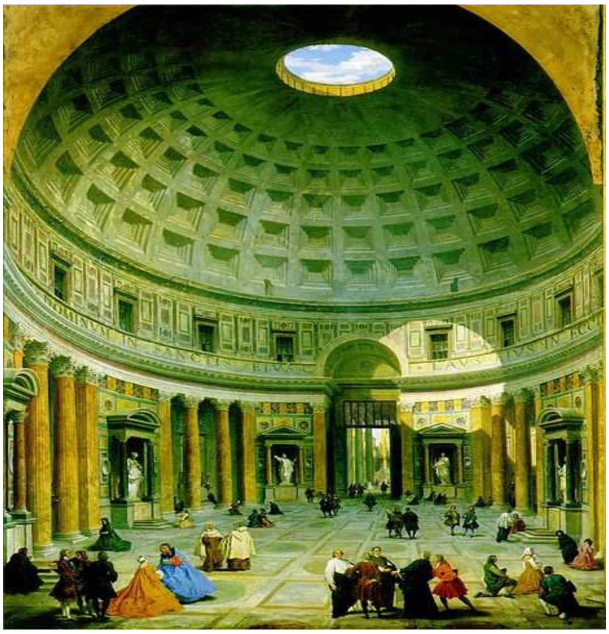


Figure 23: The interior view of the Parthenon by Giovanni Paolo Panini [http://www.wikipedia.com]

According to Oz the secret of concrete was lost for 13th centuries until 1756, when the British engineer John Smeaton pioneered the use of hydraulic lime in concrete, using pebbles and powdered brick as aggregate. This version of history has been challenged however, as the Canal du Midi was constructed using concrete in 1670 (Oz, 2002). Therefore with the industrial revolution concrete has been developed by the additives. As such big spans and loads has been passed and carried by the developed concrete.

Picture 53: Canal du Midi in France
[http://www.concretetech.org.canal/du/midi.html]

Portland cement was first used in concrete in the early 1840s. Subsequently with the development of reinforce concrete in late 19^{th} century has been allowed the extension of the maximum span which was possible with the form-active types of structure. Reinforce concrete has many advantages over masonry such as it is resist tension as well as compression and also it has ability to resist bending and shears tresses. (Macdonald, 2001).

Therefore concrete can resist both tensile and bending stress in the system of section-active, surface –active and in height-active structures. Also this can help the building to lose their heavy weights. It is obvious that the development in material industry can help us to constitute a structural form of the buildings.

The example of Fairbairn Textile mill in Manchester at 1845 is a good example for innovation of materials and their effects on structural form. This building was made practically possible by the discovery of Portland Cement in the 1820`s and was used in a primitive form in the thin and large floor construction of the building in the system of section-active structure, in fact Portland concrete can resist all compressive, tensile, shear and bending stress in the system (Dooley, 2004).

Picture 54: The example of Fairbairn Textile mill in Manchester at 1845
[http://www.manchester2002-uk.com/history/victorian/mills.html]

Concrete was a more versatile material however capable of assuming any shape according to the framework in which it was cast. Rectangular, repetitive formworks continued to be used where economy was important but it was ability to constitute forms like sculpture. The words of Macdonald has been verified the objection “The additional factor which favored the use of simple forms was that the design and construction of very complex forms was laborious and costly, thus inhibiting the full exploitation of the potential offered by these new materials.”(Macdonald, p.109, 2001). It is expensive to built complex forms rather than simple geometric forms with concrete however it is desired to build complex, formless form. This is desired because it somehow a show of power and ability of the technology in the existing time of the project.

The Vitra design Museum in Basel, Switzerland at 1989 by architect Frank O. Gehry who is the master architects of sculptural forms. The form of a building presents a challenge. Their construction made possible by the excellent structural properties of present day materials which is reinforced concrete. However the scale of this project is small.

Picture 55: The Vitra design Museum in Basel, Switzerland at 1989 by architect Frank O. Gehry [http://wikipedia.com]

Macdonald said that “Great ingenuity was often required of the engineers who devised the structural solutions for buildings whose forms had been devised in a purely sculptural way” (Macdonald, p.110, 2001). In this context engineers and architects must have togetherness for best structural form and material usages in the design projects.

The big scale amazing project`s of stone made for Valencia Opera house in Spain made by Santiago Calatrava is a masterpiece of concrete architecture with its materiality and design relationship. Building structural form made by concrete.

Picture 56: Valencia Opera House, Santiago Calatrava, 2005
[http://www.wikipedia.com]

With the development of formwork industry it is possible to built formless forms. The Vitra Museum and Valencia Opera House buildings are the best examples of this development.

Consequently under the light of all mentioned examples in this section it is not wrong to say that simple forms has been build with concrete material from invention of it for economical, structural reasons however with the development of technology complex forms has been made with concrete still it is expensive but desired.

5.1.5 Steel, Aluminum and Other Metals

Metals are one of the oldest materials to be manipulated by man and has been used for its strenght and versality reasons. For centuries metals have been shaped into tools, weapons and different practical object. Metals have been used as decorative facing materials in the oldest times (Sebestyen, 2003).

The first known metals that used in buildings are; iron, bronze, copper, zinc, lead and brass. However at the present day different alloy`s of steel, aluminum and titanium has been found. In this context with the innovation in the material industry, know structural forms has been weekened through the substitution of heavy materials to lightweight materials (Baktir, 2006).

Ironbridge, built in England in 1779 by Abraham Darby, Jr., the iron founder who built the bridge, it is a good example of what could be interpreted as a case of substitution of materials. Ironbridge has a semi-circular form characteristic of a stone arch and connections that are wedged and pinned like timber construction. The connections have to be seen in the context of processing technology and in experience of structures in this kind of building. The wedged connections are actually distribute the stress more evenly over the components being connected than a bolt would. Such a connection is good for cast iron because cast iron has a low resistance to fracture. A bolted or pinned connection would require putting a hole in the component that creates a high stress concentration. This is cast iron, not wrought iron or steel. The material has a relatively high compressive strength compared to its tensile strength. Furthermore, the dimensions of the arch ribs have no correlation to the heaviness of stone construction (Dooley, 2004). The heavy materials change its structural place with lighter materials such as steel.

Nonetheless Abraham Darby, Jr., did express knowledge of the fact that the semi-circle is not the most efficient form of an arch. The slenderness of the ribs is allowable because, unlike a stone arch, the cast iron can resist a certain magnitude of tensile stress materially and structurally because the iron arch segments are mechanically connected. (Dooley, 2004). When anlayzed the project at his context it is obvious that Ironbridge is both used appropriate structural form with appropriate material. At that point it is not logical to use stone instead of iron because the new material which is iron was invented, therefore it is the time to design and construct lightweight, up to date, technologicaly developed buildings. Also this substitution shows that there is an attempt to find new materials which are having more ability and freedom to form desired structural forms then traditional materials such as stone. Development of steel argued that is one of the pivotal moments in the history of architecture, giving a freedom of design and space and opening up structural possibilities in countless new ways. Steel that it has contains more than 10 % of chrome, to be denominate as a stainless steel. At the same time stainless steel alloys may contains manganese, chrome, nickel, carbon, silicon, nitrogen. Stainless steel was found in 19. Century and it was used in the architectural works at the beginning of the 20. Century. Normal steel production can be same as the stainless steel production but stainless steel may differ from the normal steel with its thickness and last procedures that applied on the surfaces (Sebestyen, 2003).

With the construction of Joseph Paxton`s Crystal Palace in London in 1851, cast iron and wrought iron later refined to what it is used as steel today has been developed through the technology.

Also, the Crystal Palace project in London, UK, at 1851 by Josepth Paxton is an good example for material and structural form relationship. In the structural sytem of the building steel and timber were used. In this context it was at the forefront of what was technically possible at the time. “The major desicions affecting the structural form of the building were taken for technical reasons and were not compromised for visual or stylistic effects” (Macdonald, p. 97, 2001). In this way with the word of “technical” relatively it is meant that the material ability and technics of construction.

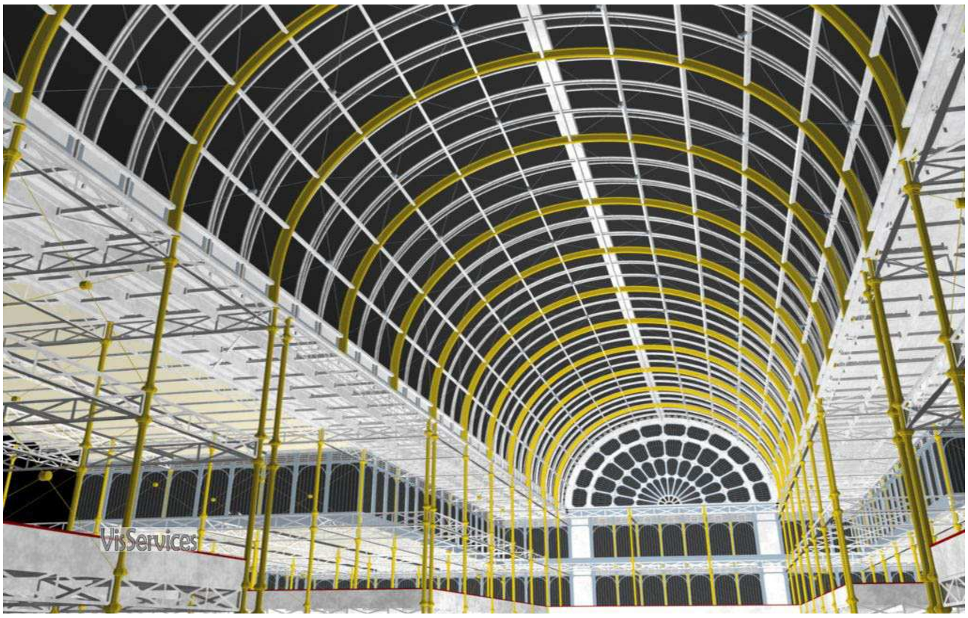


Figure 24: The Crystal Palace project in London, UK, at 1851 by Joseph Paxton [http://www.sdc.edu/us/]

Then the use of steel as a primary structural material in the constructions in the late nineteenth century is because the cheap methods used for manufacturing it on a large scale were developed as such this idea has been proved by the Paxton`s work. Today it is using as a structural members and as a covering element in the architectural works.

Frank O. Gehry which is Guggenheim Museum in Bilbao, Spain is a masterpiece design of steel architecture. According to the words of the Macdonald for Gehry`s projects they are fascinating. The curves on the building were designed to appear random. The architect has been quoted as saying that "the randomness of the curves are designed to catch the light" (Macdonald, p.110, 2001). When it was opened to the public in 1997, it was immediately hailed as one of the world's most spectacular buildings in the style of deconstructivism, although Gehry does not associate himself with that architectural movement (Zanchi, 2000).

Picture 57: Guggenheim museum, by Frank O. Gehry, 1997
[http://www.wikipedia.com]

The museum's design and construction serve as an object lesson in Gehry's style and method. Like many of Gehry's other works, it has a structure that consists of radically sculpted, organic contours. Sited as it is in a port town, it is intended to resemble a ship. Its brilliantly reflective titanium panels resemble fish scales, echoing the other organic life (and, in particular, fish-like) forms that recur commonly in Gehry's designs, as well as the river Nervión upon which the museum sits. Also in typical Gehry fashion, the building is uniquely a product of the period's technology. Computer Aided Three Dimensional Interactive Application (CATIA) and visualizations were used heavily in the structural form design. Nonetheless, computer simulations of the building's structure made it feasible to build forms that architects of earlier eras would have found nearly impossible to construct. Therefore there are unanswerable relationship between structural form organization and material selection. Absolutely it is impossible to build that kind of formless forms with the material of stone, because it is heavy and not flexible under the bending forces (Macdonald, 2001).

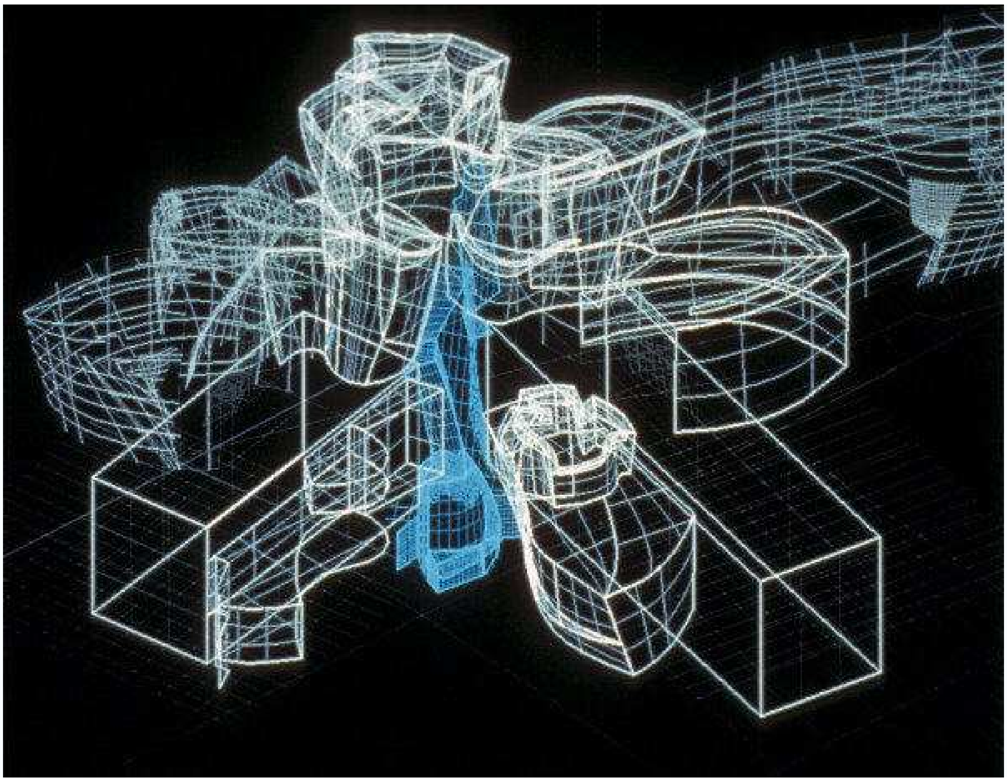


Figure 25: Guggenheim museum, 1997, CATIA program architectural drawing [http://host.uniroma3.it/.../programma/programma]

Thus architects desires more freedom in their project`s designs. The words of Wolf Prix verified that architects pressing the boundaries of existing technologies to freely realizing their designs "…..we want to keep the design moment free of all material constraints…..in the initial stages structural planning is never an immediate priority…"(Macdonald, p.110, 2001).

With the glory of material industry these forms structurally carry the loads as such materials helping to realizing the impossible sculptural forms. Furthermore it is not possible to construct these structural forms with the material`s stone. So with the development of new materials, new forms have been constituted. Probably these structural forms may designed many years ago but because of time disability in material industry, they were not constructed. In this way it is obvious that the material may effects structural form desicions in the design process, somehow the designs were change according to the ability of the existing materials behaviours in structural form.

Another fascinating project of steel is Springtecture H. In the project of Springtecture H which is designed by the architect of Shuhei Endo the material effects on structural form decisions has been seen apparently. The building are giving facilities of men`s and women`s lavatories and park-keepers apartments. With economy of means, this structure forms a sculptural landmark in the middle of recreational park in Osaka, Japan. Obviously the structure has no defined roof, wall or column, appearing instead as a single flowing entity.

Picture 58: Springtecture H which is designed by architect Shuhei Endo [Bell & Rand, p.170, 2006]

A single versatile material does almost everything in this building; spirals of steel sheets make up the structural form, define the space and providing enclosure using a simple language of one continuous ribbon like material. The form is made possible with the curving and flowing of steel sheets to form the walls, column and roof. The use of galvanized corrugated steel sheets to form this structure efficiently exploits all of the material`s properties such as counteracting compressive, tensile and shear forces. Bell and Rand said that "in this project properties associated with a particular form are juxtaposed with the properties of a different material and scale."(Bell & Rand, p. 170, 2006). Obviously the poetry of form and material is successfully worked up and realized, also the relationship between material and structural form were lying out.

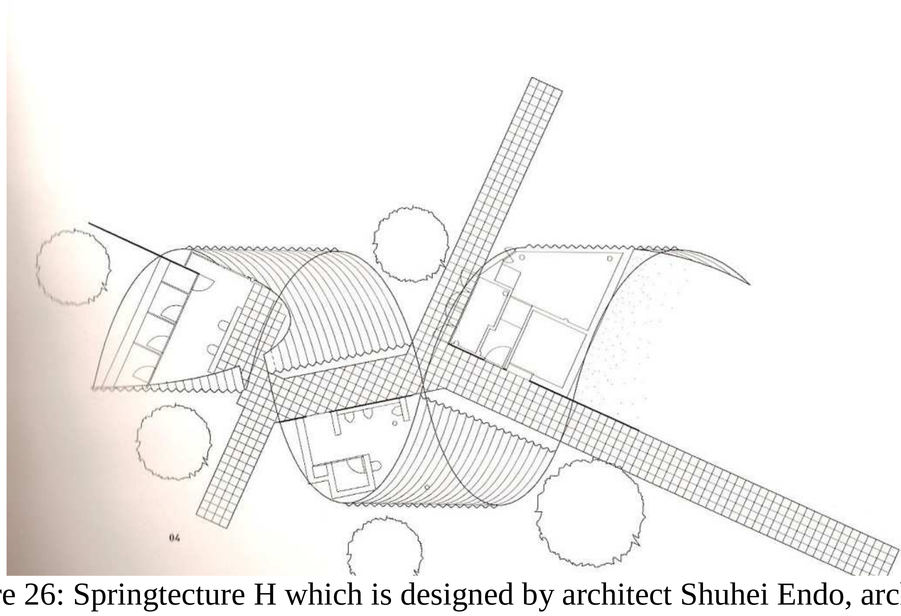


Figure 26: Springtecture H which is designed by architect Shuhei Endo, architectural plan drawing [Bell & Rand, p.170, 2006]

In the book of "Materials for architectural designs" architect has been described the structure of the building through these words "as "half-tecture" which means half architecture since it is characterized by equal parts openness and enclosure." (Bell and Rand, p.170, 2006). In this context obviously with the word half-tecture architect has been meant that the half the amount of the project were realized by the development in the material industry and other half were developed by the art knowledge.

5.1.6 Plastic

Plastics were first formulated in the 19th century although significant advancement did not occur until well into the 20th (Bell & Rand, 2006).

Plastics are synthetic materials, which are not found on the earth naturally. They are chemical combinations of various ingredients, most derived from petroleum. The ingredients are liquid in the manufacturing state but when its put together under heat and pressure they are capable of formed into various shapes. The end product is solid and it has resistance to pressure, moisture and corrosion. Despite this features they are not environment sensitive materials because of its ingredient petroleum also they are frangible under the pressure and flammable against the fire (Macdonald, 2002).

The development of technology in material industry provides plastic, which has been lost its flammable, permanent features to shows different performance of property to increase the material quality. Today, plastic and its derivative, which is composite properties gained membranes, are used especially in pneumatic, tensile structures as in panel or film layer shapes (Sebestyen, 2003).

As technology grew plastics became even more significant, becoming commonplace as the growth of fiber optic cables and telephone cables were made. 1950s has brought new and unheralded advances to the plastics industry, making it one of the most ubiquitous materials in the world. Technology is the imperative factor on the invention of plastics also technology will be imperative on the developments of it through the next years.

Films, with its develop production technology are the materials which has been produced by synthetics and are presenting new façade technologies to construction industry. These films are produced by PVC, Polyurethane and ETFE (Ethylene Tetra Fluoro Ethylene) and also they can be transparent, can be shaped in variety of forms, and they can be applied as in pneumatic or mechanic structures.

Eden project which is designed by Nicholas Grimshaw were used three layers of ETFE films in its structure. Also it is the masterpieces project which has been used ETFE layer. The films are produced by production companies in determined dimensions. In interior spaces PVC films were used (Zanchi, 2000).

Picture 59: Eden project, Nicholas Grimshaw, 2001 [http://www.wikipedia.com]

In Munich Stadium projects Herzong de Meuron was used two layers of ETFE which is changing its colors. In this project ETFE film has been used in pneumatic structure as a covering material.

Figure 27: Munih Stadium, by Herzog de Meuron, 2005
[http://www.greatbuildings.com]

With all these gained knowledge, it has high elasticity which helps to cover on the surfaces of the sculptural forms. It is not using as a structural element in the buildings because it is mild as such it become flexible and elastic under the applied loads on. Under the highest capacity of load it is deform so it is not used as a structural member in the constructions. May be in the future with the development of the technology plastics can be using as a structural element in the constructions.

5.2 General Conclusion of the Chapter

The relationship between material and structural form had been fairly innovating straightforward after industrial revolution, has intensified with new emphasis of science and engineering in architecture. In the 20th century a new breed of innovated materials and structures have played a dominant role in the evolution of new architectural forms. According to Frampton, “a logical and reasoned approach is necessary for the appropriate use of new materials and structural systems which reveals the inherent character of the built-form as a proper reflection of its time and place.” (Frampton, p36, 1994).

From the past to the present material may effects the structural form decisions in architecture as such it has been attested with the mentioned argument in the previous parts of the chapter. Usually materials are playing an important role in the constitution of architectural forms for instance some form has not been realized up to present’s days because of the insufficiency of existing materials property.

As it is mentioned before in the chapter three to practically realizing a design projects which can stand on the ground it is conceived that the improvement, development, discoveries and newness in material industry must be considered from starting point of the design process till the end. Without development in the materials industry it is impossible to rich that much long spans and high. Also without development of the technology in materials industry it is impossible to design sculpturally formed structural forms.

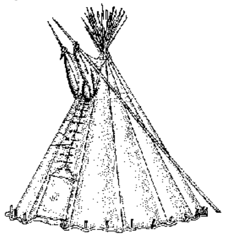
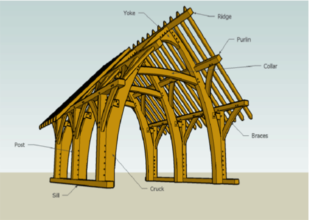
As it has been said in introduction part of the thesis the starting point of this research is planning to throw a light for dilemma between of technology and architecture. All these collections and works shows that building material and technology together with each other may influence an all architectural design process from starting point of the design till the finishing point of the construction. In this context nowadays technology holds architecture in its body.

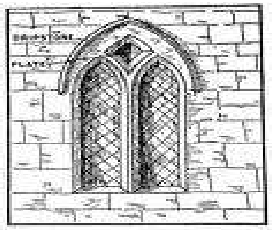
These examples shows that the material and structural form has a direct relationship. With the development in material industry new materials has been discovered or existing materials resistanceses were increased to perform a impossible structural forms possible. That means it is not wrong to say that new materials can give chance to design new forms which are structurally appropriate to support the loads and easthetically impressive.

In this section the relationships of building materials with structural form in the architectural design projects has been discussed through the years for six selected material. For better understanding of the idea of the thesis it is suggested to take a look on the table 9 which is stated below as a summary of the whole chapter’s idea. With this table it is aimed to bring out all the claims accuracy which has been argued in this section.

Table 8: Shows selected materials development through the years

#	Before Industrial Revolution	After Industrial Revolution	The Contemporary Architecture	Structural System	Future Direction
Stone	• In early times stone has been used as a one piece to constitute a form • Afterward stone has been used in many pieces to shape the forms such as dome, vault.  Dolmen Lanyon Quoits at Cornwall, England. [http://www.stonepages.wordpress.com]	• Afterward stone has been used in many pieces to shape the forms such as dome, vault. • Also usage of stone as a covering material has been seen rarely on the builings.  Stone usages in Gothic Church [http://www1.cs.columbia.edu]	• At the present day stone relinquished its position as a structural material. New materials supersede the structural work of the stone such as steel, concrete. • Nowadays most commonly it is using as a covering material on the building surfaces  Botta`s Chapel of Santa Maria degli Angele [http://www.botta.ch.]	• Form-active • Surface-Active • Hybrid	• In the future it seems that stone will be use as a covering or decorative element instead of its structural applications or with the invention of technology may be the disadvantages of the stone will be solved.

Wood	• The crude structures of the pit dwelling, simple earth structures covered with wood members for shelter. • Other early wood structures include yurts, teepees. • In the Middle Ages braced wood frames began to be used for walls. Then some small houses build by wood.  Shows structural wood elements of the teepee from ancient times. [http://www.wikipedia.com]	• Afterward around 1830s in Chicago, a new methods of wood system which is called balloon framing has been evolved which requires less skill to construct and less time to build than timber framing.  The timber framing structural system [www.timberstructures.net/timber-framing.html]	• Afterward with the development of technology new inventions made such as glue technology in wood industry has been used to produce more durable wood with adding some chemical additives  Olympic Stadium, Niels Torp, 1992 [http://www.wikipedia.com]	• Vector-active • Section-active • Hybrid	• It seems that in the future most light structure of the buildings will be made with wood with the improvement of its properties by technology.

Glass	• Around 1700-1600 BC, artisans developed the skill to creating translucent bottles, jars and the first window panes for buildings. • In the 6th century of transparent glass window has been invented to used • Glass did not take on a significant structural work until many centuries later.  The Romans glass windows [http://karwhimsy.com]	• In the mid 19th century Falconnier mass-produced had-blow glass bricks in oval and hexagonal forms • In 1907 Keppler has been invented interlocking solid glass blocks that could be placed into R.C. structures. • In 1930s the O. Illinois glass coorperation produced the hollow glass blocks  Hollow Glass brick [http://www.malzeme.com]	• In 1950s, Pilkington development of float glass • In the 1960s and 70s advancement in reflective, tinted, coated, and insulating glass exploded. • Then in 1980s and 90s photochromic, electochromic, thermochromic and holographic glass has been invented.  The Seagram Building all glass facade [http://www.wikipedia.com]	Glass can be using as a vertical surface covering material commonly. Still it is not possible to construct whole glass structered sytems.	• There is no whole glass structure in the world. It is desire to have whole glass structural systems in the future. With the development of technology it seems that it will be happen.

Concrete	• Firstly normal concrete invented • During the Roman Empire, Roman concrete (or Opus caementicium) was made from quicklime, pozzolanic ash/pozzolana, and an aggregate of pumice  The exterior view of Baths of Caracalla, Italy (http://wikipedia.com)	• In 1750s John Smeaton pioneered the use of hydraulic lime in concrete, using pebbles and powdered brick as aggregate. • Portland cement was first used in concrete in the early 1840s.  Fairbairn Textile mill in Manchester at 1845 [http://www.manchester2002-uk.com]	• Reinforced concrete, precast and prestressed concrete has been invented in the sequence of its order. • In 1990s litracon, bendable concretes has been invented • With the development of formwork industry it is possible to built formless forms.  Valencia Opera House, Santiago Calatrava, 2005, [http://wikipedia.com]	• Form-active • Section-active • Surface-active • Height-active • Hybrid	• In the future the disadvantages of the concrete will be solved by adding additives in with the technology.

Steel, Aluminum, Other Metals	• In early times first metals have been used in making of crock, pottery elements, and dishes in the ancient times. • Then metals have been used as decorative facing materials • The first known metals that used in buildings in are; iron, bronze, copper, zinc, lead and brass.	• Steel and then stainless steel has been invented after the industrial revolution • It is using as a structural members and rarely used as a covering element in the architectural works.İt is hard to used as cladding element beacuse CATIA technology has not been invented yet.  The Crystal Palace project [http://www.sdsc.edu]	• It is using as a structural members and as a covering element in the architectural works.Many metals such as steel, titanium panel have been prefabricated by the CIATIA technology to cover on the surfaces. • Last point that has been reached in steel development is carbon nanotubes idea  Gugenheim museum, [http://www.wikipedia.org]	• Form-active • Vector-active • Section-active • Surface-active • Height-active • Hybrid	• It becomes more durable for many environmental factors which affect it badly. In the future all problems of metals will be solved by the technology.

Plastics	• Plastic has no such pedigree like other materials	• Plastics were first formulated in the 19th century although significant advancement did not occur until well into the 20th.	• Films technology on to cover building surfaces has been developed. • These films has been made by PVC, Polyurethane and ETFE (Ethylene Tetra Fluoro Ethylene) and also they can be transparent, can be shaped in variety of forms, and they can be applied as in pneumatic or mechanic structures  Eden Project, [http://wikipedia.com]	• Plastic can be using as a vertical surface covering material commonly.	• May be in the future with the development of the technology plastics can be using as a structural element in the constructions by improving it properties.

CHAPTER 6

CONCLUSION

Human has been used building materials to create shelter or restricted boundaries to protect themselves from environment thus this is a continuously developing effort of humanities through the history.

Technological development is forcing us to search for a “new”. The developments that affect these innovations are relatively physic and chemistry sciences and development of nanotechnologies.

With the development of technology the meaning that has been loaded to the existing material were changed. For instance, glass has always been know with its transparency however today it is possible to see opaque and semi permeable glasses. With glass it is possible to have massive volumetric expressions.

The development in the physics and chemistry sciences has been opened a way to improve the properties of the existing materials and production of new materials. All these developments has been presented a newness into the architecture field however has been brought up a debate of material`s “original or fake”. Also materials materiality properties have been changed. In this reseach the abstract concepts “dematerialization” and “immaterialization” are emerged in the process of building material`s development.

The literature survey shows that building materials, structural form, and technological development and architecture subjects has not been examined all in one of the research yet. As it has been said before the aim of this study was integrated to fill the gap of this deficiency in architectural world. This study has been prepared for those architects and architecture students who try to get a better grasp of the idea of building materials, structural form and technological development in architectural world.

In this context building materials and structural form has been examined and it has been showed that the effects on them within the development of technology cannot be ignored, during the development processes of the first civilization`s on the earth. Therefore, the relationship between building materials and structural form interactions within the influences of technological development in architectural design projects has been recognized within this thesis. In chapter three building materials and in chapter four structural form has been examined.

Afterwards to rich the aim of the dissertation which is stated as the influences of technological developments of building materials and their interactions with structural form in architectural design projects; as such the structural form and its contexts in the architectural world has been examined for brief understanding of the idea.

And finally this thesis subject of the issues has been examined in the chapter five. The relationship of building materials and structural forms has been discussed. From the past to the present material may effects the structural form decisions in architecture as such it has been attested with the mentioned argument in the chapter 5. This will be done by deep investigation of six selected materials with respect to technology factors in their existing time through the years to show building material and structural from relation modification respect to time; in fact those materials has been examined in chapter 3 in more detail. Therefore the influences of technological developments of building materials and their interactions with structural form in architectural design projects have been brought out apparently. Also with the innovation of new material and improvement of the existing materials properties it is argued about what was happened to the structural forms and building material relationship in the context of architectural design projects. Therefore materials are playing an important role in the constitution of architectural forms for instance some form has not been realized up to present's days because of the insufficiency of existing materials property.

Consequently to practically realizing a design projects which can stand on the ground it is conceived that the improvement, development, discoveries and newness in material industry must be considered from starting point of the design process till the end. Without development in the materials industry it is impossible to rich that much long spans, high and it is impossible to design sculpturally formed structural forms. This thesis has been shown that the material and structural form has a direct relationship. With the development in material industry new materials has been discovered or existing materials resistanceses were increased to perform a impossible structural forms possible. That means it is not wrong to say that new materials can give chance to design new forms which are structurally appropriate to support the loads and easthetically impressive.

Technology is the most effective factor which affects this process of development. As it has been said in introduction part of the thesis the starting point of this research has been planned to throw a light for dilemma between of technology and architecture. All these collections and works shows that building material and technology together with each other may influence an all architectural design process from starting point of the design till the finishing point of the construction. In this context nowadays technology holds architecture in its body.

Consequently this thesis has been filled the gap of deficiencies in the architecture field and has been draw an attention of the architect's and architecture student`s to the influences of technology and building materials on architectural design projects.
For further study the author suggest that to have a research about one selected building materials with considering all the mentioned tools in this thesis. In this context about the selected material there will be a complete, useful and informative guide about the influences of technological developments of building materials and their interactions with structural form in architectural design projects.

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APPENDIX

APPENDIX A: The Properties of Building Materials

According to CIB Master List the checklist for headings about properties of building materials are given below.

CIB MASTER LIST

CHECKLIST FOR HEADINGS

- 0 Document
  - 1 Identification, brief description
  - 1.1 Manufacturer of product; supplier of service
  - 1.2 Date of publication
  - 1.3 Generic name
  - 1.4 Commercial name
  - 1.5 Brief description
  - 1.6 Authority for technical claims
- 2 Requirement
- 3 Technical description
  - 3.1 Composition
  - 3.2 Methods of assembly and connection
  - 3.3 Accessories
  - 3.4 Shape, size
  - 3.5 Weight, density
  - 3.6 Surface and sensory characteristics
- 4 Performance
  - 4.1 Active, capacity, output, consumption
  - 4.2 Structural, mechanical

4.3 Fire

4.4 Gaseous, liquid, solid

4.5 Biological

4.6 Thermal

4.7 Optical

4.8 Acoustic

4.9 Electric, magnetic, electro-magnetic radiation

4.10 Resistance to attack

4.11 Service life, durability, reliability

5 Design work

5.1 Technical and economic implication

5.2 Side effect, precaution in use

5.3 Design aids

6 Sitework

6.1 Planning sitework

6.2 Resource requirement

6.3 Handling storage

6.4 Erection, installation and fixing

6.5 Supervision, quality control

6.6 Commissioning

6.7 Security, safety, welfare on site

7 Operation and use

7.1 Methods of operation

7.2 Safety, security

8 Maintenance, repair, replacement, disposal

8.1 Cleaning, servicing

8.2 Resources, requirement

8.3 Labour requirement

8.4 Access

8.5 Repairs and replacement

8.6 Precautions during maintenance and repairs

8.7 Safety and security

8.8 Disposal

9 Supply

9.1 Ordering

9.2 Conditions of sale

9.3 Delivery, special service

10 Manufacturer, supplier

10.1 Commercial and administrative

10.2 Technical and advisory organization

10.3 Manufacturing and warehouse organization

10.4 Quality assurance arrangements