/ U-Chair

Aalto University
School of Arts, Design and Architecture
Department of Design
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Contents/

Abstract/

This thesis demonstrates the occupation knowledge and skills about I have learned for ten years as a design student. The experience in two different design fields, industrial design and furniture design, helps me to discover more potential possibilities during designing. There is no doubt that the industrial development has become more advanced nowadays. Designers can apply variety of technologies and materials; however, some principle still should be followed. For example, The structure of product should be sturdy, and the aesthetics are kept at the same time. Hence, my graduation thesis will study and test different possibilities based on those principles above.

The main elements of design are composed of material and structure. Classic design has innovative elements and meets its material character so that it can present its natural essence and beauty. For instance, wood and stone are all pure material. Designers use their creativity and modern technology to innovate an extraordinary design.

The research establishes from the literature review: the history and usage of structure and the function of structure to furniture. The goal is to find the inspiration and motivation from the different points of view. The conclusion of the literature review will be the basic knowledge for this design project, and later on, the material will be selected and applied to the structure.

My thesis researches different kinds of Information related to structure. After considerations, the shell structure is selected as the main element for this project because it can reduce the weight and also makes the furniture sturdy. Besides, the plywood is chosen as the material because it is a flexible material. The characteristic of plywood provides more feasibility to play with the shell structure. In a variety of furniture, the chair is the best topic to show a designer's ability because the structure of the chair plays an important role during design process since users' safety is the top priority.

All practical works have been carried out by a trial and error method. This thesis writing depends on the experience during the process. The limit of plywood is challenged for several times and the production problems are also considered, so the final prototype displays an armchair with the innovation and unique U-form legs. The special feature of this chair is the legs with only R 65 mm U-form. Thus, the chair is named as U-chair, which can show the concept for the user directly.

Ackbowledgments/

First of all, I would like to thank Aalto University, which give an opportunity to study and finish several projects in Finland. These experiences are going to become the nutrient for the future design. This thesis lets me research unexpected knowledge and technic. All challenges are completed by several helps.

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Introduction/

It is every design students' dream to be an independent designer; I am no exception. Looking back these ten years, I finished my bachelor degree in product design, went to the military and the United States, and changed the field into furniture design in Finland. Those excellent experiences become the nutrient and inspiration of my design. Before into the workplace, I want to challenge everything I have learned so far. The chair is chosen as the topic of this thesis because it has already existed for 5000 years, and the function of the chair is simple. Designers should use their talent to create the new style to attract people attention.

My college professor once told me, "The best way to solve the problems during the design process is using the structure." I have been influenced until now by what she said and spent much time seeking any possibility of structure.

Even though many materials have been invented, the wood, metal, glass and plastic are still mostly used. It is an important class for designer how to use the material and structure appropriately. Construction does not only offer the strength but also related to the product's detail. A small and simple structure element can creative rigid shape, and the innovation usage of these elements can create many masterpieces.

My interest in the furniture has always been to test and challenge the limit of structure and material. I am also fascinated by the light-weight items. In my thesis, I want to study how to apply material and structure together to bring out a light-weight and sturdy furniture. The component of structure can create the visual detail. A study of how the strength of thin material can be enhanced by using structures. A small adjustment can make extremely sturdy shape. The inspiration for the project is from how people have used the structure in a simple way during the history. Triangle and shell structure give many potential possibilities to change the unstable status into structurally stable. A common challenge for a designer is how a to overcome the unexpected problems during the design process. Many questions have been answered in this thesis. How can I play within variety information? What can be altered to improved the final result? How to design furniture that can be manufactured?

1.What is the Structure? Definition/

The research theme was directed by some reason. The main reason is that I am always attracted by the beauty of the structure because it builds our living environment, such as building, furniture, and house ware. People have known how to use structure to solve the problems for a long time. I have also understood that the structure not only offers the strength the things need but also many other benefits during my study. Therefore, I would like to use this project to re-learn all knowledge about structure.

At first, it is important to know what is structure. According to Oxford Dictionaries, the definition of the structure is “the way in which the parts of something are connected together, arranged or organized; a particular arrangement of parts” However there are many different types of structure like biological structure, chemical structure, and so on, the physical structure is the main one I am going to focus [1].

From engineering and architecture view, a system which is formed by a body or assembly of bodies in space can support weight is the structure. Moreover, the structure can be classified into two classes:

- Man made: Building, aircraft, skeletons, and so on.
- Nature arrangement: Anthills, beaver dams, and so on.

Man made structures are a subset of the physical structure. These are divided into the building and non-building structure, and make up the infrastructure of our society. Different structure elements can compose many kinds of build structure, such as columns, beams, and trusses. Designers apply the structures well to approach their purposes. Architecture, furniture, and product designers, need to learn how to use structures appropriately to have the benefit from the structure[2].

[1] Oxford (2016) ‘Oxford dictionaries’, in Oxford Dictionary. Available at: http://www.oxforddictionaries.com (Accessed: 12 April 2016).

[2] Carpinteri, A. (1997) Structural mechanics: A unified approach. United Kingdom: Taylor & Francis.

Fig .1 Man made structure: Hoover Dam
(http://www.history.com, retrieved 12.4.2016)

Fig. 2 Nature arrangement:: honeycomb
(http://tophdimgs.com, retrieved 12.4.2016)

2.History of Structure/

2.1 Outline/

Most structures had been invented for architecture usage, so it is essential to observe the records about the architecture structural engineering as the first step.

Imhotep, the primary engineer, become recorded within the history at the least 2700 BC earlier than, built Step Pyramid for Pharaoh Djoser. The pyramid was also used generally for historical civilization due to the fact the shape of the pyramid is extraordinarily solid and may be nearly infinitely scaled. This benefit is opposed to maximum other structural forms, which cannot be improved in size in sharing to multiplied weight [3].

The concept of structures did not exist and the understanding how structures stood up also lacked at the same point of medieval. Therefore, most architectural and production became completed through artisans, which include stonemasons and carpenters. The artisans built the construction in accordance their experiences. The expertise from cumulative experience retained through guilds.

No report indicates while the first calculation of power and behavior of structural material had been carried out, however the profession of structural engineer came about in the Industrial Revolution and when the discovery of concrete. Moreover, the physical science of structural engineer started to be understood and have been developing in advance since the Renaissance [3].

Fig. 3 Step-Pyramid by oritkaye (https://oritkaye.wordpress.com,retrieved 12.4.2016)

[3] Saouma, V.E. (2004) Structural engineering. Available at: http://ceae.colorado.edu/~saouma/Lecture-Notes/se.pdf (Accessed: 14 April 2016).

2.2 Early Structural Engineering Developments/

Fig. 4

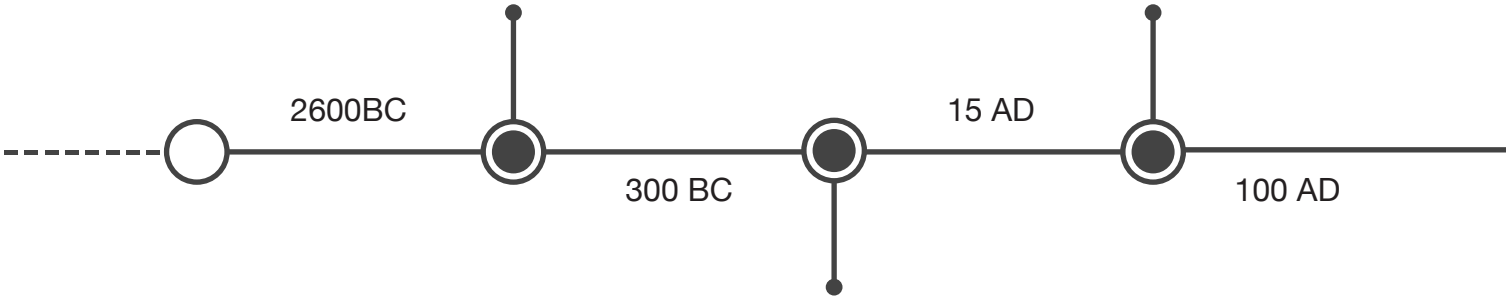
Great Pyramid of Giza

The largest man-made structure untill 19th C

Fig. 6

De architectura

A thesis on architecture written by the Roman architect Marcus Vitruvius Pollio



Archimedes

A pioneer scientist in mechanics

Fig. 5

As the mention before, the largest man-made shape till the 19th BC is Pyramid, and the first time the structure engineer was recorded. The historical Romans additionally made notable bounds in structure engineering, and plenty of huge shapes which were built with the masonry and concrete still stand nowadays which includes columns, shielding wall, and harbours. The methods about how they used the materials and machines in the production had been written by Vitruvius in De Architectura. The reason they have been successful on the building is due to the fact the use of the accurate tools well and also doing the sizable surveying.

Archimedes, a pioneer scientist in 3rd BC, used a few concepts to calculate the area and the centre of gravity of diverse geometric figures, which includes triangles, and hemispheres. Modern structural engineers have the benefit of mathematics and knowledge of structure from Archimedes' work. It's also the beginning of the knowledge of physical laws inside the western l[4].

At the end of middle ages, Leonardo da Vinci additionally produced many engineering designs primarily based on observation and from the point of view nowadays it still contains the possible and structurally valid, such as a bridge across the Golden Horn[5].

Fig. 8

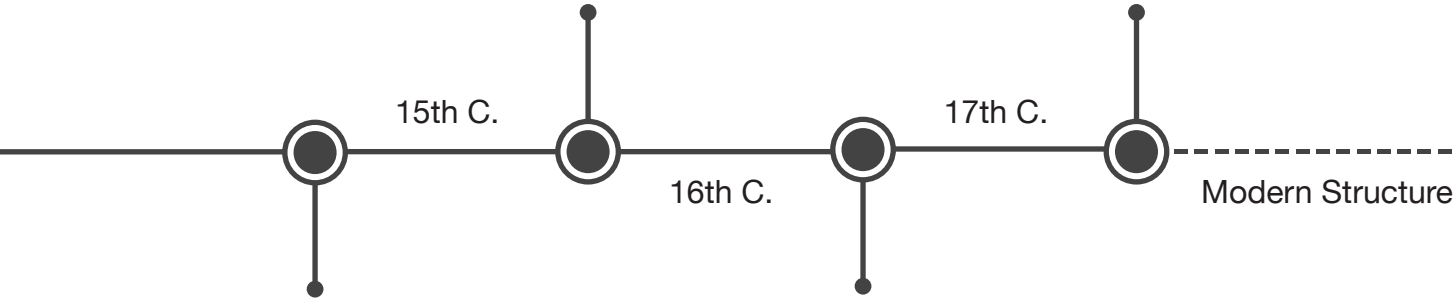
Leonardo da Vinci

Father of paleontology, ichnology, and architecture.

Fig. 10/11

Robert Hooke Isaac Newton

Both of them published many scientific works which is the inspiration of modern structural engineering.



Pont du Gard

Ancient Roman aqueduct that crosses the Gardon River.

Fig. 7

Galileo Galilei

A important role in the scientific revolution during the Renaissance.

Fig. 9

Within the 17th Century, three scientists, Galileo Galilei, Robert Hooke, and Isaac Newton, published many scientific works which grow to be the inspiration of modern structural engineering. Their contributions are indexed as below.

- Galileo Galilei

He outlined the mechanics of material and the motion of gadgets and made the contribution on approaching to structural engineering. The structural analysis, the mathematical, and layout of construction additionally were completed the first time.

- Robert Hooke

He gave a systematic information about elasticity of materials and the change of the object under the load in 1676

- Isaac Newton

Newton published the laws of movement which offers the foundational knowledge about controlling the structure[6].

Many math and theory about the construction have further advances all through 18th C.. Scientists published the understanding of structure basic on three pioneers' works, Galileo, Hooke, and Newton. Leonhard Euler developed many strategies which permit structure engineers to investigate and model the structure and also created Euler-Bernoulli beam equation with Daniel Bernoulli[7].

2.3 Modern Structural Engineering Developments/

Fig. 13

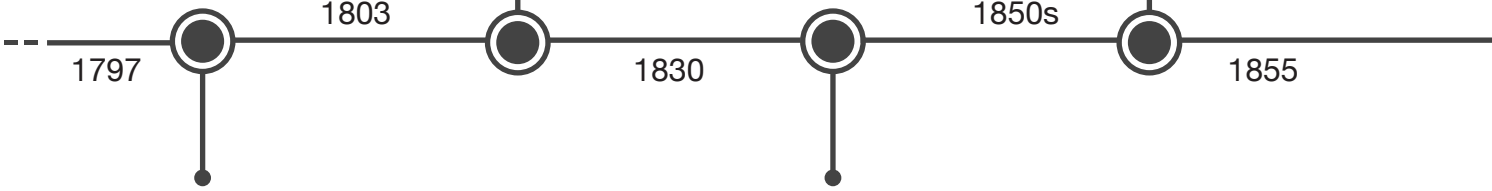
Belper North Mill

the first fireproof building, using a full cast iron frame,designed by William Strutt

Fig. 15

Bessemer method

Henry Bessemer developed the Bessemer method to supply steel



Ditherington Flax Mill

the first building with interior iron frame, designed by Charles Bage

Fig. 12

Claude-Louis Navier

General theory of elasticity in a mathematically usable form

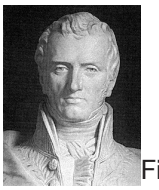


Fig. 14

For the duration of the late 19th and early 20th centuries, material technological and the structural analysis experienced development at a terrific pace.

Claude-Louis Navier developed the general theory of elasticity and is the primary one to outline the function of a structure engineer who should recognize the final and failed condition of the structure, and also prevent the failure earlier. He also created the elastic modulus to help engineers understand the structure and the material behavior at the start point[8].

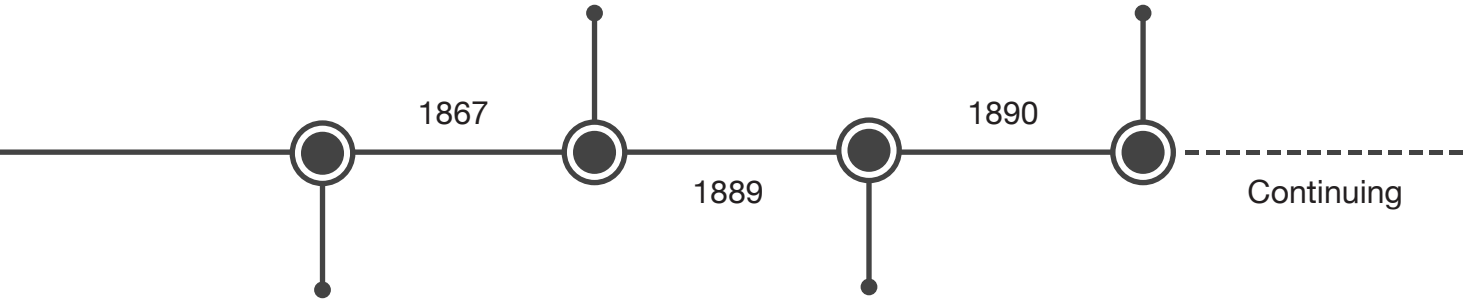
The concrete structure was nonetheless in development. A rowing boat was built by ferrocement that is the forerunner of reinforced concrete via Joseph-Louis Lambot in 1855. This manner became inspired for Joseph Monier and was used to create concrete planting tub in 1867. Monier becomes the primary one to apply metal reinforcement bars positioned in areas of tension in the structure.

Robert Maillart made further advanced on reinforced concrete structure. He noticed that many concrete bridges were cracked, and the cracked area is no contribution in supporting. Maillart studied and had more information about concrete characteristic. The result turned into on Salginatobel Bridge, designed in 1930; that is the most beautiful bridge and also exist these days.

Henry Bessemer developed the Bessemer method to supply steel, which means that

Fig. 17

Fig. 19



Joseph Monier

Create Iron-reinforced troughs for horticulture

Forth Bridge

The first major uses of steel, and a landmark in bridge design.

Joseph-Louis Lambot

Design a rowing boat which was built by ferrocement

Eiffel Tower

built by wrought-iron Show the potential of construction using iron

Fig. 16

Fig. 18

the steel structure turned into possible in the 1850s. He gained the patents for converting solid iron into cast steel in 1858. Ultimately, mild steel has replaced both wrought iron and cast iron because the desired of steel for structure[9].

Cast iron become used and is substituted wrought iron gradually at some stage in the later 19th. Ditherington Flax Mill in Shrewsbury, designed by the engineer Charles Bage, became the first construction with an interior iron body. Belper West Mill, designed by William Strutt in 1792, was the first building which attempted to frame up the fireproof building and the first example of fireproof engineering. The concept of Belper West Mill additionally changed into advanced by Strutt and Bage. They construct Belper North Mill, which used a complete cast iron body and also the primary fireproofed building of the world at that time[10].

Two buildings, Forth Bridge and Eiffel Tower, show the capability of constructions using iron, despite the fact that the steel is already used extensively. The material of wrought-iron completed the Eiffel Tower in 1889. Forth Bridge is the first landmark which major uses the metal inside the bridge design in the next year.

During the late 19th, Russian structural engineer Vladimir Shukhov also had different contributions on growing analysis methods for tensile structures, thin-shell systems, lattice shell systems and new structural geometries along with hyperboloid structures.

Modern Structural Chronology/

Fig. 21

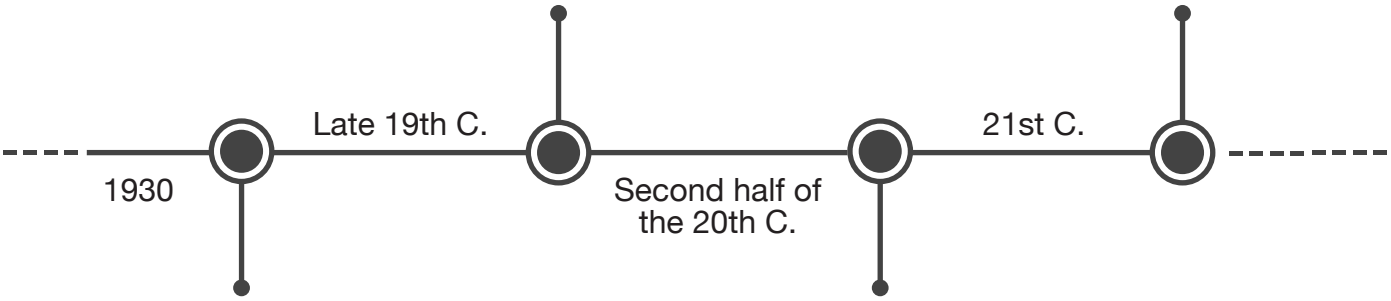
Vladimir Shukhov

developed analysis methods for tensile structures, thin-shell structures

Fig. 23

Computer

Engineers can analyze and expect the force of complicated systems



Salginatobel Bridge

The most beautiful bridge and also exist these days, designed by Robert Maillart

Fig. 20

John Hancock centre

Designed by Fazlur Khan who give the large contribution on High-rise construction

Fig. 22

High-rise construction started the improvement from the late nineteenth century, and in the second half of the 20th C., the greatly advanced occurs. Fazlur Khan had large contribution at the fundamental of the high-rise structures. Khan had improvements in skyscraper layout and construction. One is the tube structure system, and the other one is X-bracing. He had many masterpieces with skyscraper(e.g., John Hancock centre in 1969 and Sears Tower in 1973).

The development of computer had led the structure engineering into a new generation in 21st C.. Engineers have been allowed to analyze and expect the force of complicated systems, and also had the benefit on designing something related to systems, inclusive of structure and furniture.

The understanding of the properties of the material is also vital for structure engineering at the end of twentieth C.. Engineers can recognize the reaction between different materials under various situations which includes temperature and earthquake. The strong knowledge is available now, and plenty of complicated structure were created. The technologies will offer more opportunities to innovative beautiful and solid systems.

[4] The works of Archimedes: Heath, T.L.: Free Download & streaming: Internet archive (2006) Available at: https://archive.org/details/worksofarchimede029517mbp (Accessed: 13 April 2016).

[5] Leonardo da Vinci (no date) Available at: http://legacy.mos.org/leonardo/inventor.html (Accessed: 13 April 2016).

[6] TWO NEW SCIENCESBY GALILEO (no date) Available at: http://files.libertyfund.org/files/753/0416_Bk.pdf (Accessed: 13 April 2016).

[7] Heyman, J. (1999) The science of structural engineering. United Kingdom: Imperial College Press.

[8] Hosford, W.F. (2005) Mechanical behavior of materials. United Kingdom: Cambridge University Press.

[9] Swank, J.M. (2007) History of the manufacture of iron in all ages. Kessinger Publishing.

[10] Stainless steel in construction (no date) Available at: http://www.designingbuildings.co.uk/wiki/Stainless_steel_in_construction (Accessed: 13 April 2016).

3. Analyzation of Structural Elements and Exteriors/

Structures are composed by different elements. Those elements are created for the various purpose to support the load from any directions and engage the shape being stable and safe. The goal which wants to achieve from the history study is to find the impressive and inspired structure elements for the future use.

In this chapter, some impressive elements are selected for depth study. These elements were chosen according to certain criteria.

1. It is a basic structure element.
2. Many extended usage under this basic structure element.

3.1 Triangle/

The triangle may be a humble structure component. People don't notice. However, the triangle is omnipresent in our life. Several structures expected to be a sturdy and rigid rely upon triangles to succeed the goal. It's not simply giving strength however additionally creative various of geometrics type in several buildings. Analyzation and understanding of the triangle structures are the basic steps for structural engineering.

Modern structures might not use the triangle as exterior structure. However, some parts are. The rationale why the triangle is common to be used is as a result of triangles should support its weight and additionally stand up to resist the external force.

The triangle is a two-dimensional figure which is built of rigid members with hinged corners. It is completely fixed in form as a result of the every member is the restriction on the compressive and tensile. On the other hand, a square may be malformed into a parallelogram.

Any polygons can be reinforced through the use of triangles. Rectangular is not the only one being misshapen without difficulty. Different polygons have the equal problem about being flexed by force. The triangle which is used to strengthen the polygons is frequently referred to as "gussets". The gussets efficiently make the two connecting participants into an inflexible component. The polygon turns into several triangles and additionally are solid while enough internal triangle is added[11].

The strength of triangles even is applied into the three-dimensional. A pyramid that consists of four triangles in 3 dimensional may be an example. Any 3-dimensional object that can also be cut back to various triangles by adding the gusset, and it'll become rigid.

The reason the triangle is used so often is because of some reasons

- The strength is strong
- Any polygon is composed by the triangle so that it can be applied widely.
- It can reduce the material, so the cost is cheaper when using in the structure [12].

Fig. 24 Epcot Spaceship Earth Walt Disney World Orlando: Various triangles shape a strong structure in 3-dimension, By chensiyuan - chensiyuan

[11] Posted (2012) The strength and mystery of triangles - CTG technical Blog. Available at: http://www.ctgclean.com/tech-blog/2012/10/the-strength-and-mystery-of-triangles/ (Accessed: 13 April 2016).

[12] the, R. of (2013) Lesson: Triangles & trusses. Available at: https://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_trusses/cub_trusses_lesson01.xml (Accessed: 13 April 2016).

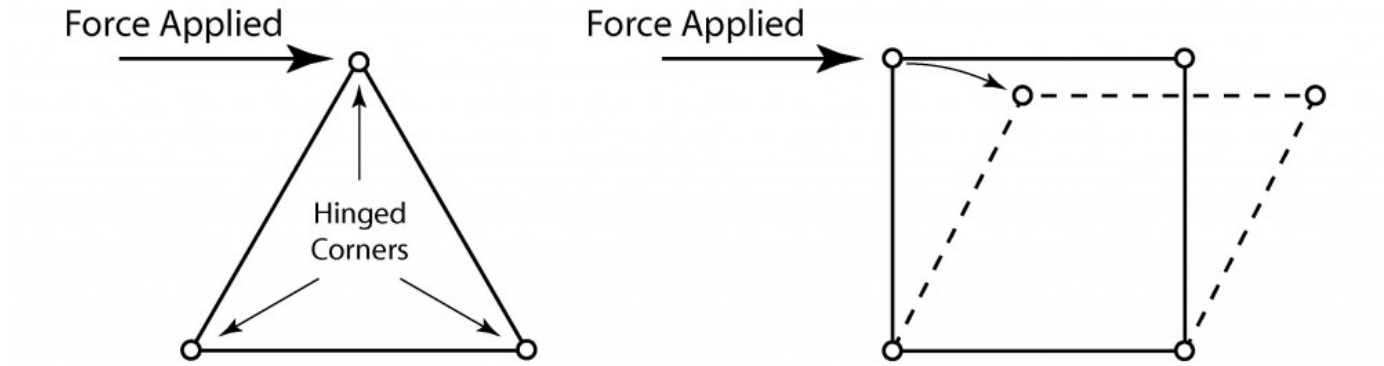


Fig. 25 The triangle is stiff when it is composed by three member and hinged corner, but the square is in the opposite way, it is easy moved(http://www.ctgclean.com/tech-blog/, retrieved14.4.2016).

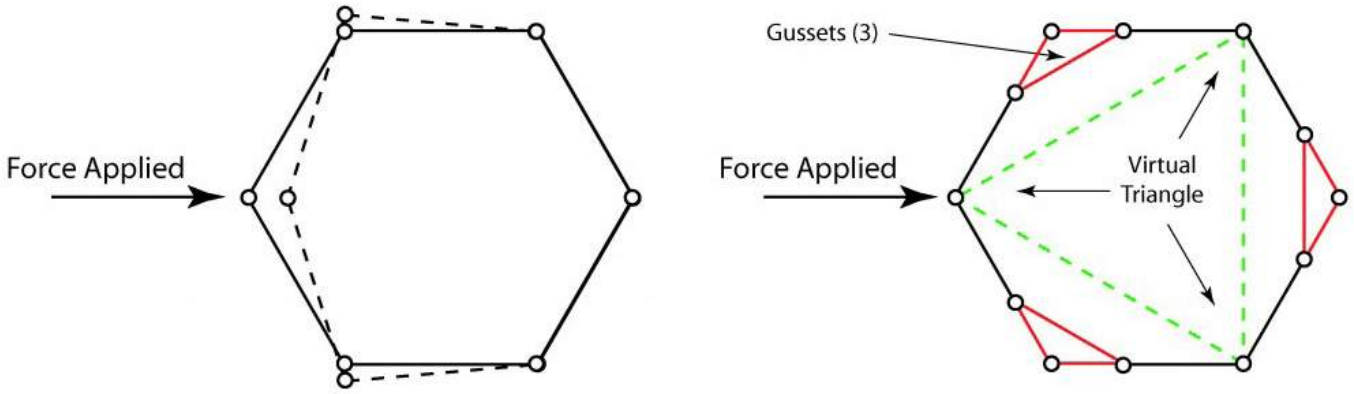


Fig. 26 The hexagon is stiff when the triangular gussets added in the three corner because it becomes a internal triangle shape (http://www.ctgclean.com/tech-blog/, retrieved14.4.2016).

3.2 Steel Structure/

When thinking about the construction, it is necessary to choose the right item for the different purpose. Steel beams and components are used commonly in construction because it comes in a variety of shape and size, each designed for the different usage. Designers should always consider the capacity of loading-bearing of steel before applied it to a supporting element. There are some steel structures which is easy seen in our life, and the physical strength also has been calculated and proved by scientists for a long time.

- **I-beam**

I-beams have a central bar and four horizontal flanges, and the profile of I-beam resembles the letter I. I-beams additionally are labelled by an “A” number in step with their load-bearing potential, such as with A992, which could load 65,000 lbs. Per square inch. I-beams are also called S-beams. They’re used as a primary structural aspect in lots of special challenge, from garden sheds to skyscrapers.

- **Wide-Flange Beams**

A wide-flange beam has longer flanged than S-Beams so that the beams in profile resembles the letter H. In American, standard wide-flange beams has flanges which are not parallel. H-beams are commonly used as foundation beams or vertical piles[13].

- **T-Beams**

The characteristic of T-Beams is with a short horizontal flange and long vertical element and also called stem. The beams' profile is like the letter T. The beam is classified by flange width, and depth, thickness and weight of stem[14].

Fig. 27 I-Beam (http://http://www.hungnguyentradico.com, retrieved14.4.2016).

- **Channels**

Channels are the shape of a U with flat, shallow beams. One side of the beam is set with two short flanges which are parallel. The channel can be used as the basic of the roof or the foundation of concrete[15].

Fig. 28 Wide-Flange Beams (http://www.discountsteel.com, retrieved14.4.2016).

- **Flats and Rails**

The steel beams without flanges are called flats, which is up to 7.6 cm in the thickness and up to 20.3 cm wide. The price is depend on different dimension.

The steel beams of rail is a short vertical stem with thick and wide best. The rounded and horizontal section is on the other side. It is like the railroad.

Fig. 29 T-Beams (http://www.gunungsteel.com, retrieved14.4.2016).

- **Z-Shape**

The Z-shape is the opposite direction which has a half flange.

- **Angle**

Angle is the L-shape as the profile.

- **HSS-Shape**

The hollow structural section is also named as SHS (structural hollow section), and the cross-sections including square, rectangular, circular (pipe) and elliptical.

Fig. 30 Channels (http://www.nithyasteels.com, retrieved14.4.2016).

Many types of steel beams are made by hot or cold rolling; others are made by welding together flat or bent plates. Some sections can be produced in very long length, and it will be cut and sold in 20-foot lengths normally.

Fig. 31 Rails (http://dianestewart4us.org, retrieved14.4.2016).

There are many factors which can be considered when choosing a construction material. Cost is commonly the controlling element; however, other considerations such as weight, strength, constructibility, availability, and sustainability will be taken into account before a final decision is made. Designers should know what benefits we can have when choosing the steel structure.

- Cost
  Steel is cheaper than other metals like aluminum or titanium. Moreover, it is the responsibility of the designers to specify the lightest members possible while still maintaining a safe structural. The other way to reduce the cost in design is to use many of same size steel member as opposed to many unique members.

- Strength/Weight Ratio
  Steel has a very high strength-to-weight ratio which means the strength of the material over its density. The benefits of the steel structure can give the designers an information about how useful the material is in comparison to its weight.

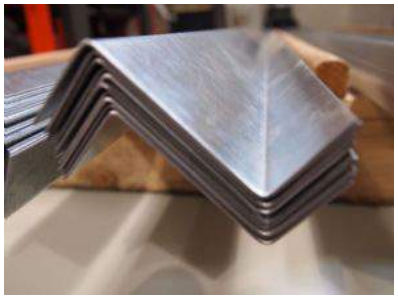


Fig. 32 Z-Shape (http://www.roofing-store.co.uk, retrieved14.4.2016).

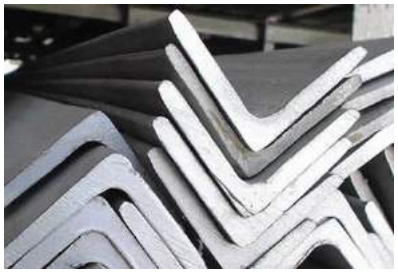


Fig. 33 Angle (http://blog.steelfromchina.com/#sthash.zF3NsYsV.dpbs, retrieved14.4.2016).

Fig. 34 HSS-Shape (http://www.farweststeel.com, retrieved14.4.2016).

[13] BNBC2 (2013) STEEL STRUCTURES 10.1 general provisions for structural steel buildings and structures. Available at: https://law.resource.org/pub/bd/bnbc.2012/gov.bd.bnbc.2012.06.10.1.pdf (Accessed: 14 April 2016).

[14] [14]Cheng, H.T., Mohammed, B.S. and Mustapha, K.N. (2009) 'Experimental and analytical analysis of pretensioned inverted t-beam with circular web openings', International Journal of Mechanics and Materials in Design, 5(2), pp. 203–215. doi: 10.1007/s10999-009-9096-4

[15] Manual of Steel Construction, 8th Edition, 2nd revised printing, American Institute of Steel Construction, 1987

3.2 Shell Structures/

The definition of the shell is a shell with a thickness that is small compared to its different dimensions and the deformations are not massive in the comparison of thickness. The distinct among shell structure and a plate structure are that, in the unstressed condition, the shell shape has curvature, but the plate structure, the other hand, is flat. Membrane status in a shell structure is essentially resulted by in-plane forces, although the secondary forces might be as a result of flexural deformations. In which a flat plate acts just like a beam with bending and shear stresses, shells are analogous to a cable which resists hundreds through tensile stresses. Although the proper skinny shell ought to be capable of growing both tension and compression. There are many nature and curved shape, which includes shell eggs, a nut, human skull, and shell of a tortoise. The methods of the way scientists classify shell systems may be defined as below.

- **Cylindrical Barrel Vaults**

Barrel vaults are possibly the most functional shell systems due to the fact they could span as much as 150feet with at the least material. They are effective structures because the use of arch form can reduce stresses and thicknesses in the transverse direction. A circle is usually used for the cross-section of the barrel. However, many different kinds of elements also can be applied. For instance, the ellipse, a parabola, or a funicular curve, all of them can ensure the strength requirement, and specific structural and esthetic characteristics can be gained from the different form.

Many terms had been created to describe cylindrical shells. If the span is big in comparison to the width, the shape is known as a long shell. The short shell is used for the short length of the shell structure. An arbitrary proportion for long shells is a span/radius proportion of five. A short shell has a span/radius proportion much less than 1, and shells between those limits are called intermediate shells. Short shells are a specific structural kind and are described in a later category.

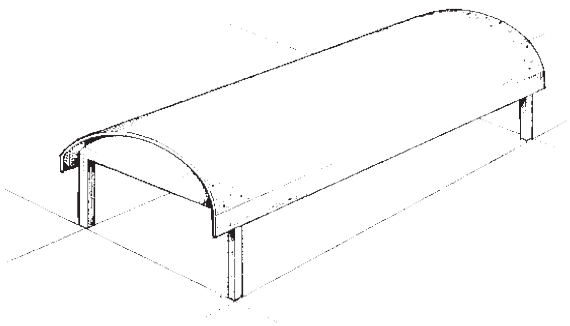


Fig. 35 Cylindrical Barrel Vaults

- **Folded Plates**

Fold plate is an appropriate start to introduce the shape and form of shell system because it is the origin knowledge of shell structure.

The distinguishing function of the folded plate is the convenience in forming flat surfaces. Therefore, they are adaptable to the smaller place than surfaces which require multiple uses of shape for optimum financial investment. For the same spans, the cost might be the same between the folded plate and horizontal slab, but the folded plate uses less steel and concert. Folded plates are not adapted to as wide curved spacing(e.g., barrel vaults). A few benefit may be won via increasing the thickness of the slab simply at valleys, so it act as hundreds of beams and as an I section plate girder.

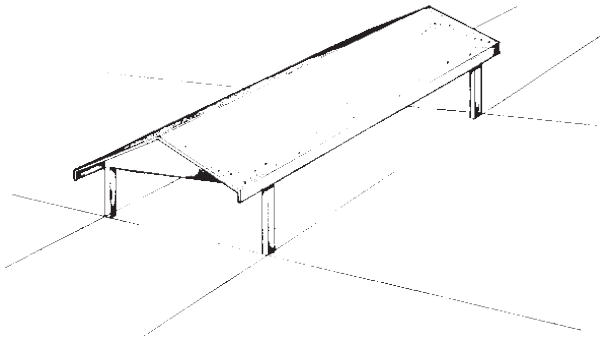


Fig. 36 Folded plates

- **Short Shells**

In the previous type, barrel vaults had been defined as having a long of the barrel that is in comparison to the width, and the short shells are going to be defined here: The cylindrical shell has a large radius in the comparison to the length. The application of these two type is totally different and the architectural and engineering problems require a one of a kind technique.

Many structures (e.g., huge hangars and auditoriums) which are built into short shell could also be built by using different structure or material to reach the same purpose. The architecture, therefore, should be primarily based on the exploitation of the shape of the arch instead of the shell itself.

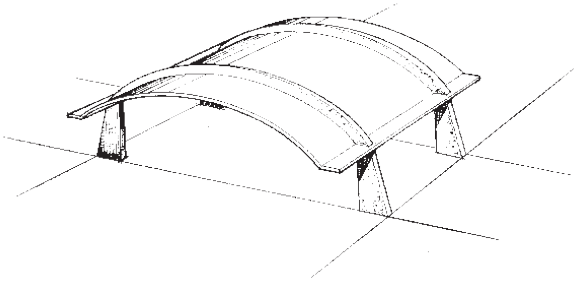


Fig. 37 Short Shells

- **Folded Plate Domes**

In this class includes all domes which are made with plane slabs and plates is included. There are only some of them may be shown here in numerous versions. Domes can be built with small angles among the plates or with large angles between plates and the structural form can be extensively unique for each type.

The apparent gain of the folded plate dome is that the surfaces are less complicated to shape due to the fact they are flat. However, for slab spans over sixteen feet, the shell wall is thicker than a curved surface due to the fact bending problem has to be considered. Another benefit is about acoustical properties. It is difficult to focus the sound ray if the structure is with a plane surface. This feature can be sufficient to make the folded plate dome advanced to the curved dome to be used in an auditorium.

The structural layout of folded plate domes follows that of folded plate barrels. Slab members are made first and the function of the folded lines is to support the loads. Those forces are then carried by direct compressive stresses with the aid of the fold strains appearing.

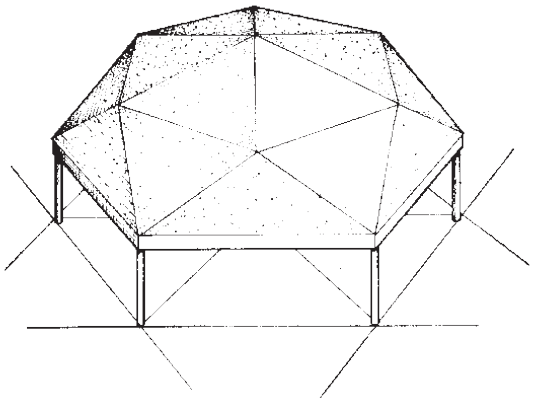


Fig. 38 Folded plate Domes

- **Domes Of Revolution**

The deification of the domes is a structure which covers a square or circular area. Some remarkable examples are still existence which were built in Ancient Rome. They might also be the earliest shell structure. They were built by a surface generated through a curve of any form revolving approximately a vertical line. Because the surface is a double curve, the double curve is stiffer and stronger than a single curve. The simplest dome of revolution is a part of a sphere. But different curves are also suitable, inclusive of the ellipse, the parabola, different conic sections, or random curves.

There is an infinite form of feasible shapes, each appropriate for a specific motive. Elements of domes of revolution, square or polygonal in plan with part of the shell eliminated, are also considered as domes of revolution. Their structural condition is more complicated than a dome around in a plan.

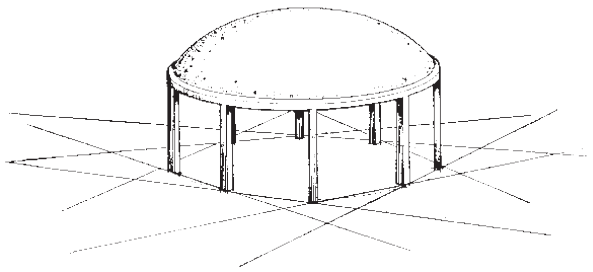


Fig. 39 Domes Of Revolution

- **Warped Surface**

The shell structure can gain a great advantage from the warped surface because they can be made from boards even though the surfaces are double curvature. There are two types mostly used.

- The conoid: The conoid, as its name, is a part of a cone
- Hyperbolic paraboloid: A particular mathematical surface is named as Hyperbolic paraboloid. This kind of shell structure can be constructed to an ultimate light production, minimum reinforcing and ease of transferring shape.

Stresses within the hyperbolic paraboloid shell are almost absolutely membrane (direct tension and compression), and all forces are brought as shear parallel to the stiffening ribs. The shell thickness in structures built by Candela in Mexico is on and one-half inches except for slight greater thickness on the intersection of the surfaces. This dimension is based totally on a cover of one centimetre on every side of two layers of bars and no longer any structural requirement for force.

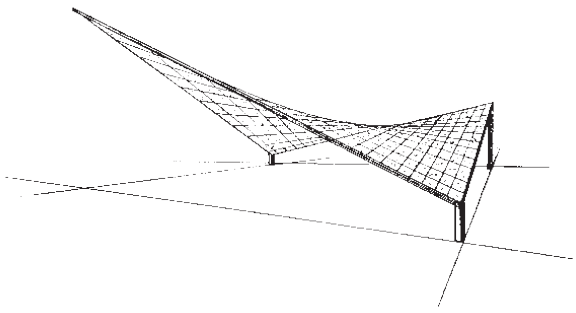


Fig. 40 Hyperbolic paraboloid

- **Shell Arches**

The basically beams of shell arches are from Folded plates and cylindrical barrel shells. The identical move sectional shapes can be used for arches and a new set of form, having a specific structural function, is obtained. It became a concept worthwhile to display them separately. Hyperbolic paraboloidal surfaces can also be used to form those arches, the virtue being that they may be shaped with straight lines.

Shell arches are a bit inside the same category as brief shells in that the shell motion is subservient to the arch motion. All the thicknesses may be made pretty small of an arch is used due to the fact the stresses can be compressed. It is common that the curve of the arch is a funicular form. It has to earn the thrust line to support loads. As in the folds plates rigid frame, the shell arched becomes inefficient if the bending action is high.

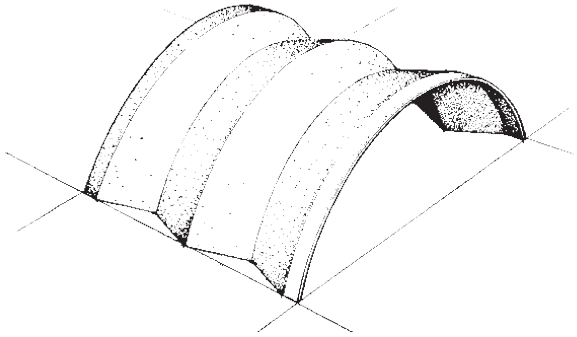


Fig. 41 Shell Archs

The Advantage:

- The use of different material on shell shape can also reduce the price of material and production.
- The different supporting system of shell can also reduce the load
- The light form of structure.
- The arch shapes can be span longer, which is another advantage.

Fig. 35 ~ Fig 41
(http://www.ketchum.org/ShellTandF/index.html, retrieved14.4.2016).

3.3 Finding with Structural Elements/

After the survey of the previous chapter, there are some findings between different structures.

1. Relationship between materials and structures

Two things are important to be concerned with applying structure for different purposes. One is what kind of structure is suitable for the design, and the other one is the materials choice. Both of them interact with each other. The same structure can be used with the different material because a good structure can increase the material strength. The designer can expect that the structure can create extra strength for the different goals, such as holding people's body, or against the force from variety directions.

An example is going to provide to explain the finding from the previous study. Both, Z-shape in steel structure and folded plates in shell structure, use the same structure with different materials, steel and concrete, to achieve the purpose they are required. Steel and concrete are the strong material, but we can also use the shell structure with a sheet of paper. A flat paper cannot hold a coin. However, if we fold a paper several times, it will have the ability to support weight from several coins.

Designers or engineers have more opportunities to create a remarkable design when they can understand different structures because a simple structure can be applied to many materials and still keep the strength which the Item is supported to be.

2. Cost

Cost should always be considered during designing, and It is the best way to reduce the cost by using appropriate structures. According to preview study, we can find that there is the same advantage between different structure types which is reducing cost. There is not influence when producing a mock-up or a small prototype, but the cost will be a big issue when manufacturing products or building architecture. It is also the reason why structure is always discussed and applied while starting new projects. For instance, there are several ways to make a box. The first way is using six thick boards and connecting them together, and the second way is making a frame with twelve sticks, and six thin board are attached from outside. The second one is saving more materials. Costumes can buy the designed product with affordable price if designers understand how the structure can contribute.

3. Stiff

Many people think that the structure, assuredly, should be stiff. However, it is not as simple as imagination. The thing is always going to be more complicated because the material in different structure has different behavior. Hence, Designers should notice whether the structure is still stiff when they choose the materials and structure. That is also why designer always makes several mock-ups or use the computer to analyze the strength before making the final decision. A master designer can solve the cost problems with material and structure and still guarantee the safety of the product or building.

It seems that the structure makes many contributions to our society. However, in the next chapter is going to focus on analyzing how the furniture designer can gain benefits from applying structure appropriately.

4 Furniture's Structure/ Definition/

The structure is really important. Almost everything in our life is built by structure, such as building, product, and furniture. The furniture is the topic of this study. It will be helpful to know what is furniture. The definition of furniture

1. Movable objects intended to support various human activities, such as chairs and beds.
2. To hold objects at a convenient height for work, or to store things, such as tables and shelves

The definition of furniture is similar to structure. Both of them should support the weight, but the furniture is added more limitation. In other words, furniture seems like a narrow sense of structure. Hence, the structure is an appropriate start point. It is a method to know how structure makes the contribution by analyzing the structure of classic or modern furniture. Seven chairs are chosen because of its beautiful structure.

4.1 Analyze the Furniture Structure/

Chair One

Chair ONE is built a bit like football: the variety of flat planes assembled at angles to every alternative, making the three-dimensional type. Designer Konstantin Grcic wished to use the smallest amount material to make the foremost product[16].

Structure Analyzation: Triangle structure, Steel structure, Shell Structure

Fig. 42 Chair One
(http://http://www.magisdesign.com, retrieved14.4.2016).

Fig. 43 Butterfly Stool
(https://www.vitra.com, retrieved14.4.2016).

Butterfly Stool

A pioneer of Japanese industrial styler, Sori Yanagi prefers light and rounded forms as a result of they “radiate human warmth”. The Butterfly Stool makes the use of a connective metal section that against the divergent forces of the two rounded panels by using the shell principles of compression and tension. The veneer-cutting technique is used to ensure that every 1/2 the stool’s surface mirrors the grain of the opposite side. The result: a stool is an easy assembly with the style of elegant and soaring[17].

Structure Analyzation: Shell Structure, Triangle structure

Panton Chair

Verner Panton was one amongst the foremost authoritative figures within the development of style throughout the 1960s and 1970s. In conjunction with his experimental approach to forms and colours, he was attracted by the potential of plastic, a unique material at the time. His aim was to make a cushy chair which can be created in one piece that might be used in any place. When finding out a manufacturer for many years, Panton came into contact with Vitra in 1963.,and Vitra developed the Panton Chair in 1967.

Serial production of the Panton Chair began in 1967. It was hailed as a sensation and received various prizes. MOMA Design Museum now collects the first mould. Nowadays the Panton Chair is considered a classic of contemporary furniture design. The initial version of the chair made of polyurethane foam with a shiny lacquer end is marketed with the name Panton Chair Classic[18].

Structure Analyzation: Triangle structure, Shell structure

Fig. 44 Panton Chair (https://www.vitra.com, retrieved 14.4.2016).

Little Nobody

It is a clear figure of speech for a chair is protected by the fabric. Little Nobody shows the shadow side of the lifetime of a chair when it is not used. The shape is blurred by a cover. Little Nobody is seen as a cover without a chair beneath. The fabric remembers the form of the chair even though the chair has been taken away.

NOBODY is created by thermo-pressing with the material the polymer fibre - PET felt mat, and there is no any frame inside. The PET felt is an ECO-friendly material which is produced by recycling the soda or water bottle. Moreover, no additives, screws, or reinforcements are added during the production process.

Little Nobody is light and stackable and can be used in both public and interior space. The PET felt is also fro easy cleaning[19].

Structure Analyzation: Shell structure

Fig. 45 Hyperbolic paraboloid (https://www.hay.dk, retrieved14.4.2016).

Molded plastic chair

The Molded Fiberglass Chair is made as the first single-shell form in 1950 by Charles and Ray Eames. However, while the environmental risks related to fibreglass manufacturing became extra broadly understood, the manufacturing process of fibreglass shell is decided to discontinue until better material is found. In 2001, Molded Plastic Chair was reintroduced with the material of polypropylene by Herman Miller. Molded plastic chair is not only 100 percent recyclable but durability. The matter texture creates a soft touch. Both arm and dining chair are designed with five colors[20].

Structure Analyzation: Triangle structure, Shell structure

Fig. 46 Molded Plastic Chair (http://www.hermanmiller.com, retrieved 14.4.2016).

Fig. 47 GJ Chair (http://www.langeproduction.com, retrieved 14.4.2016).

GJ Chair

Two folded plywood pieces construct the GJ Chair. The deceptively simple production was accomplished via a complex process of plywood technology skill. Hence, only about 300 were produced in 1960, and it was reissued in 2009. Surprisingly for a lady, Jalk had apprenticed as a cabinetmaker and studied furniture at the Copenhagen Royal Academy of Fine Arts with Kaare Klint before organizing her studio. A considerate method to customers' desires and her exploratory manipulation of materials and industrial manufacturing made her project especially widespread[21].

Structure Analyzation: Shell structure, Triangle structure

Pressed Chair

Only one single metal sheet made this chair, and its stable structure is built by the way of its shape and the circumferential pressure detail. The Pressed Chair may be stacked and suitable for interior or outdoor space.

A simple material 2.5 mm aluminum sheet is used to design an innovation chair. The value of the design is the intent to use a piece of material without any joint and connection. Furthermore, the producing produces no waste of material and also 100% recyclable[22].

Structure Analyzation: Shell structure

Fig. 48 Pressed Chair (https://www.moormann.de, retrieved 14.4.2016).

4.2 Conclusion/

After the analyzation, there are some characteristics which all these chairs have. The detail description will be listed as below.

• Light

Movable object is a definition of furniture. The designer successfully reduces the weight by using suitable structure.

• Material saving

Material saving can achieve the goal which is not just reducing the weight but saving the cost. Hence, people can buy these masterpieces with affordable price.

• Realizable

Every chair looks strong because applying the structure which can be trusted in our life. Another advantage to show the general structure on furniture is that people get used to trusting the common items which appear from surrounding. Hence, from the psychological level, the familiar structure can give the safety for the user.

• One main structure

All chair have one main structure, and the auxiliary structure will help to increase the strength of the chair. For instance, Chair one is mainly used triangular structure, and the T-beam is used on the detail to ensure that the chair is strong enough.

According to the conclusion, this project is heading to design a chair from one main structure. Besides, the goal which wants to be achieved is a chair which can be manufactured, realizable and also light-weight.

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[16] Spa, M. (2004) Chair_One. Available at: http://www.magisdesign.com/elenco_prodotti/family_one/chair_one/ (Accessed: 14 April 2016).

[17] AG, V. (2016) Products: Butterfly stool. Available at: https://www.vitra.com/en-ch/product/butterfly-stool (Accessed: 14 April 2016).

[18] AG, V. (2016) Products: Panton chair classic. Available at: https://www.vitra.com/en-as/product/panton-chair-classic (Accessed: 14 April 2016).

[19] (no date) Available at: http://www.hay.dk/m/product.php?top=furniture&mid=chairs&pid=little-nobody&path=furniture&max=7&img=1 (Accessed: 14 April 2016).

[20] Miller, H. (2016) Eames molded plastic - guest chair. Available at: http://www.hermanmiller.com/products/seating/multi-use-guest-chairs/eames-molded-plastic-chairs.html (Accessed: 14 April 2016).

[21] GJ chair (no date) Available at: http://www.langeproduction.com/Default.aspx?ID=235&M=Shop&PID=516&ProductID=41&pagetitle=GJ%20Chair (Accessed: 14 April 2016).

[22] Harry Thaler: (no date) Available at: http://www.harrythaler.it/pressed-chair/ (Accessed: 14 April 2016).

5. Learning by Doing/

5.1 The Structure and Material choice/

Because as the mentioned earlier, the structure and materials choice is always vital oat the start poit because they have interaction with each other. For this project, the shell shape is chosen as the principle element because the aim is to design a light-weight chair. Also, other structure can be applied all through the design process if it is essential.

The cause why the shell structure is selected is due to its function: the strength may be increased via folding the piece of sheet, and the weight of the object will be dramatically reduced. Many materials can be chosen to create the shell shape, including steel, timber, and plastic. However, the plywood is selected as the material for this design project due to the fact it is natural, warm, and flexible material.

Why Plywood

For the beginning, the study for moulded plywood goes to take at the primary place. Plywood consists of numerous thin veneer layers that are organized with crosswise at the angle of 90 degrees, and each veneer is glued together via the heat and pressures to shape two or three dimensionally formed merchandise. The advantage of using plywood is as below.

- Strength

The plywood is stronger than the solid wooden due to the fact the grain of every ply degrees into an opposing direction with each new layer. For this reason, the plywood can against the force from various direction. On the opposite way, the solid wood can only resist the pressure from few way because all grain is going in the same way.

- Environmentally friendly

Plywood is the most efficient method to apply the fast-growing soft wooden, such as birch. The entire tree can be sliced into the piece of sheet, and the strength will be ensured by using its internal structure. Consequently, there is little or no waste throughout manufacturing.

- Versatility and durability

The various of veneers developments improve the way to apply the plywood. The 3D veneers can make it possible to produce small curve product, and UPM Grada reduces the manufacturing time. Moreover, specific adhesives can increase the sturdiness of plywood.

The plywood has many advantages but also has its limitation. All things can be taken into consideration and challenged all through the design process with a purpose: a chair which can be seen the beauty of structure and also delicate.

Fig. 49 Molded Plywood (https://itp.nyu.edu/fab/, retrieved 15.4.2016).

5.2 Concept/

From preview study, many kinds of shell structure have its feasibility for use in the furniture, and thus, the material application will become more significant. The plywood has already selected as the material for this design. Therefore, the limitation of plywood has to be thought while choosing what sort of shell structure is suitable for further development. The vital challenge for plywood is the bending issues. Too small radius is hard to be bent for plywood due to the fact the ductility of the wooden is not fine as metal. The split on plywood commonly occurs while producing, and the yield rate also dramatically drops. This kind of result departs from the intention which was set up before: a chair can be manufactured.

The cylindrical barrel vaults are selected as the main structure after thinking over any possibility. The shape of cylindrical barrel vaults has the bigger radius which compares with the folded plates, and the curve is straightforward as compared with the warped surface. Therefore, the cylindrical barrel vaults turn into the final decision from several shell structure types.

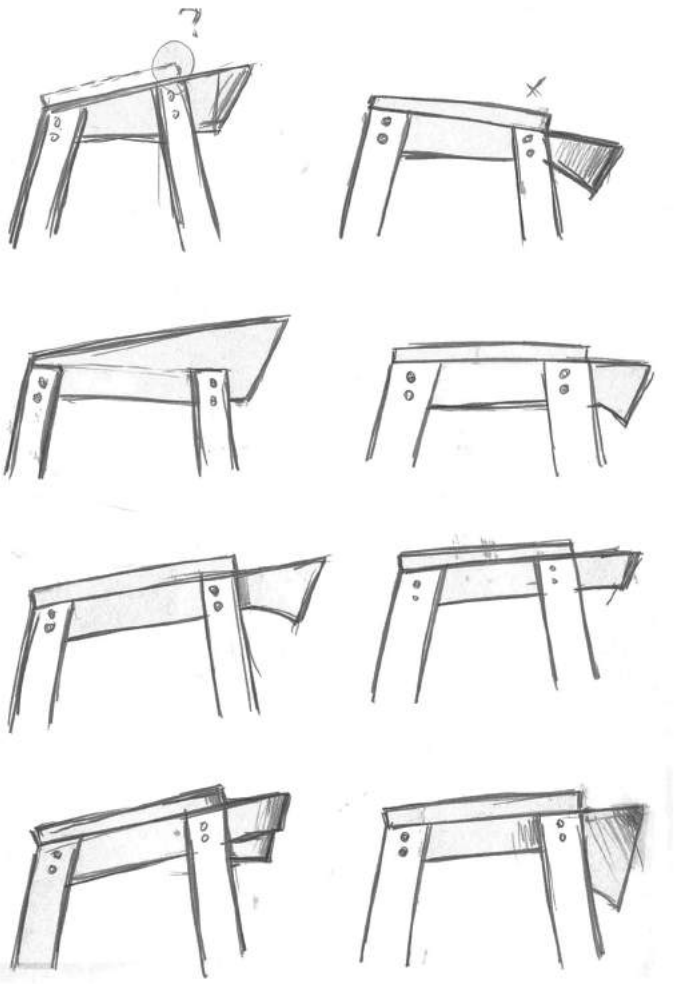
The cylindrical barrel vaults is a great structure family, which includes multiple barrels, the lazy S, and so on. Every of them has its capability to become part of the furniture. For instance, multiple barrels can be used as the skeleton for a table. The British product designer, Benjamin Hubert, designs the Ripple desk which has consisted through Corelam panel. The Ripple table shows the potential capacity from the structure of cylindrical barrel vaults.

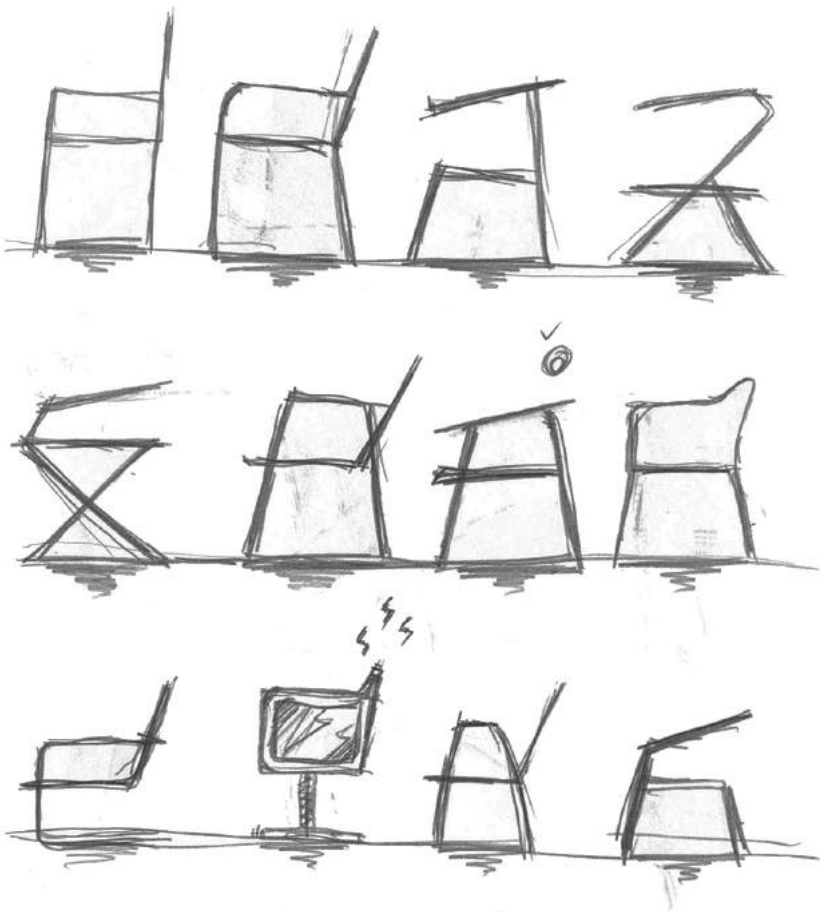
For this design project, single barrel vault is selected because the single barrel vaults have several advantage for design: the curve is simple which could reduce the manufacturing issues specifically while the material is plywood. Moreover, more variations can be tried when the form is simple, and therefore varieties of possibilities have been tested all through the sketch step.

After deliberation, The primary feature of chair focuses on the legs for the last draught. When the chair is expected with simple style, the issue how to join each part of the chair together needs to be treated carefully. This chair in the latest draught is with four U-form legs and a seat with the plywood, and every leg connected with four solid wooden beams. Similarly, the big U-shape is also used as the backrest. The arm of the backrest is used to connect with legs.

Besides aesthetics, two things have to be considered for a furniture designer. One is how to produce, and the other one is whether it is stable. Inside the mock-up step should answer both questions.

Fig. 50 Ripple (http://layerdesign.com, retrieved 15.4.2016).





5.3 Legs Production Testing/

The task for this project is the primary element - U-form legs. The dimension of legs are 300mm×400mm: the inner radius of U-form is R75 mm and the thickness of the plywood is 75 mm. The task is whether the plywood can be bent with the small radius. The ductility of plywood is doubted while the beginning of design process, especially on the U-form legs. The limitation for the plywood production still exists although it is a superb material for furniture. The plywood often splits when the radius is too small, and the effect is the reduction of yield rate.

The first thing needed to do is to test the limit of plywood, which means whether the plywood will split under the small radius-75 mm. The two side mould was chosen at the beginning point because it is how manufacturing facility to produce the plywood furniture. The short mould was made to form the small test piece. For the result of the first test, the plywood is bent well and no split on the surface. However, a new problem was found: the plywood will shrink after the glue gets dry. Hence, the data of the second mould is regulated: length of the mould is extended into 900 mm as same as the chair's legs, and the angle turned into 93 degrees to one side. This adjustment aims to measure how many degrees should be reserved for shrinking in the final mould, and it's also an opportunity to observe whether the surface of plywood is still perfect for the long piece.

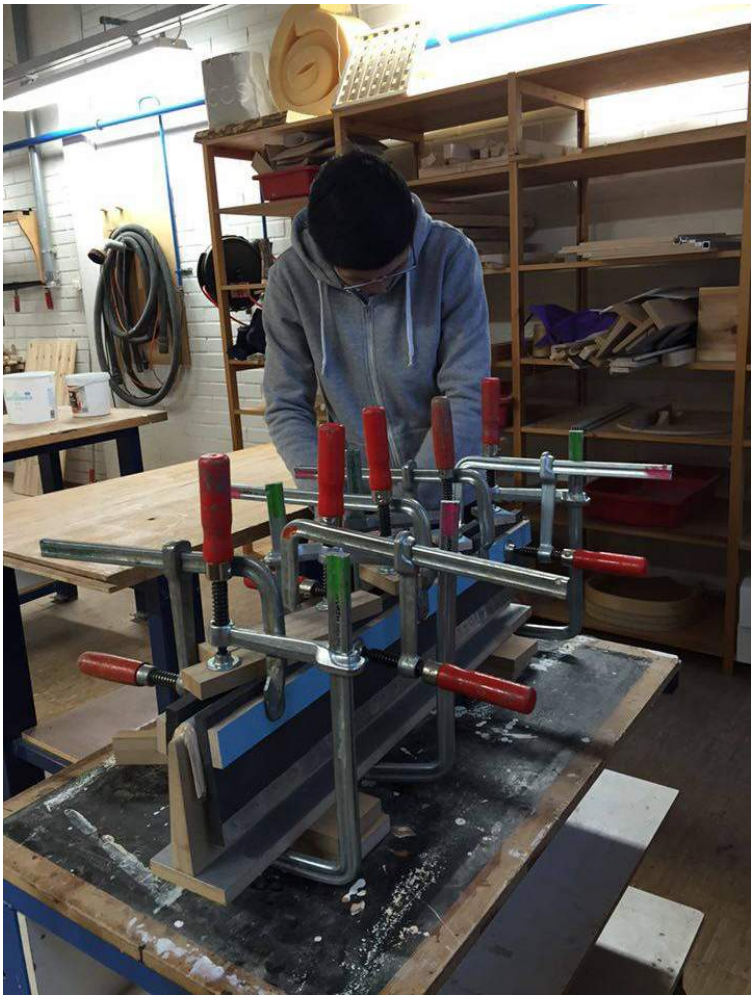
The second mould is changed to a one side mould. Due to the fact it is considered as a mock-up step, many dimension might be adjusted throughout the developing process. The benefit of the one side mould is that the thickness of the leg can be altered consistent with different requirement without problems.

The result for the test is amazed. No split appears on the long piece leg even though the veneer is also added on the top at this time, but the shrinkage is stronger than the anticipation. Plywood shrank inward by 5 degrees, so for the last mould, the angle for the U-form is 98 degree. Ultimately, all questions for the leg production is answered. It is possible to be made, and the quality is also excellent.

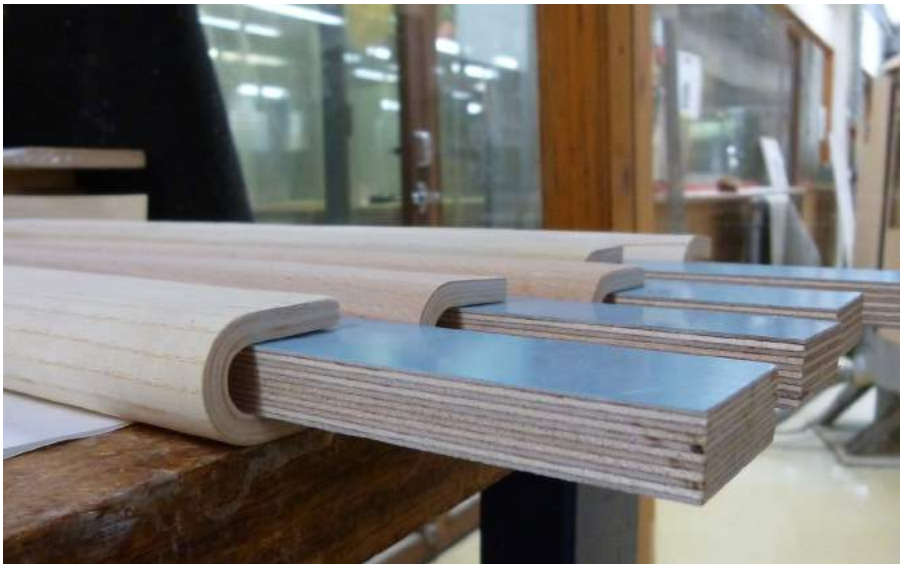
5.3.1 Limit and shrinkage/

The small plywood limit test piece for the U-form legs.

The shrinkage measurement




test - ⑤ 7.00 mm
test - ④ 7.00 mm
test - ③ 6.4 mm
test - ② 9.5mm
test - ① 9 mm



5.4 The Whole Structure Test/

5.4.1 The First Structur Test Muck-up/

It is hard to assert whether the chair is stable or not before the test. Hence, the structure test model should be made especially in this project because there are many materials is taken away from the legs. No one knows the effect of losing material.

The simple and rapid manner is applied to understand the stability of the chair for the first model. The measurement of legs is similar to the draught, but the form is a square frame made of solid wood. However, the outcome is dissatisfied. This version shakes severely. Many possibilities may cause this shaking problem, along with the material usage, or the rough structure. After the first experience, the exquisite version is decided to be made to remove any potential effect.

The first rought muck-up.

5.4.2 The Second Structur Test Muck-up/

The new exquisite model is expected to solve the problem, so it follows all requirement and measurement on the draught: 4 plywood legs, and the structure frame follow precise dimension. But, the result is still disappointed. The shaking situation is that the chair tilts towards both sides by 8.5 degrees. If the 8.5 degrees is extended to the armrest, the armrest will move 100 mm from the middle line towards each side. This amplitude of shaking is not acceptable for a chair despite the fact that the structure is strong.

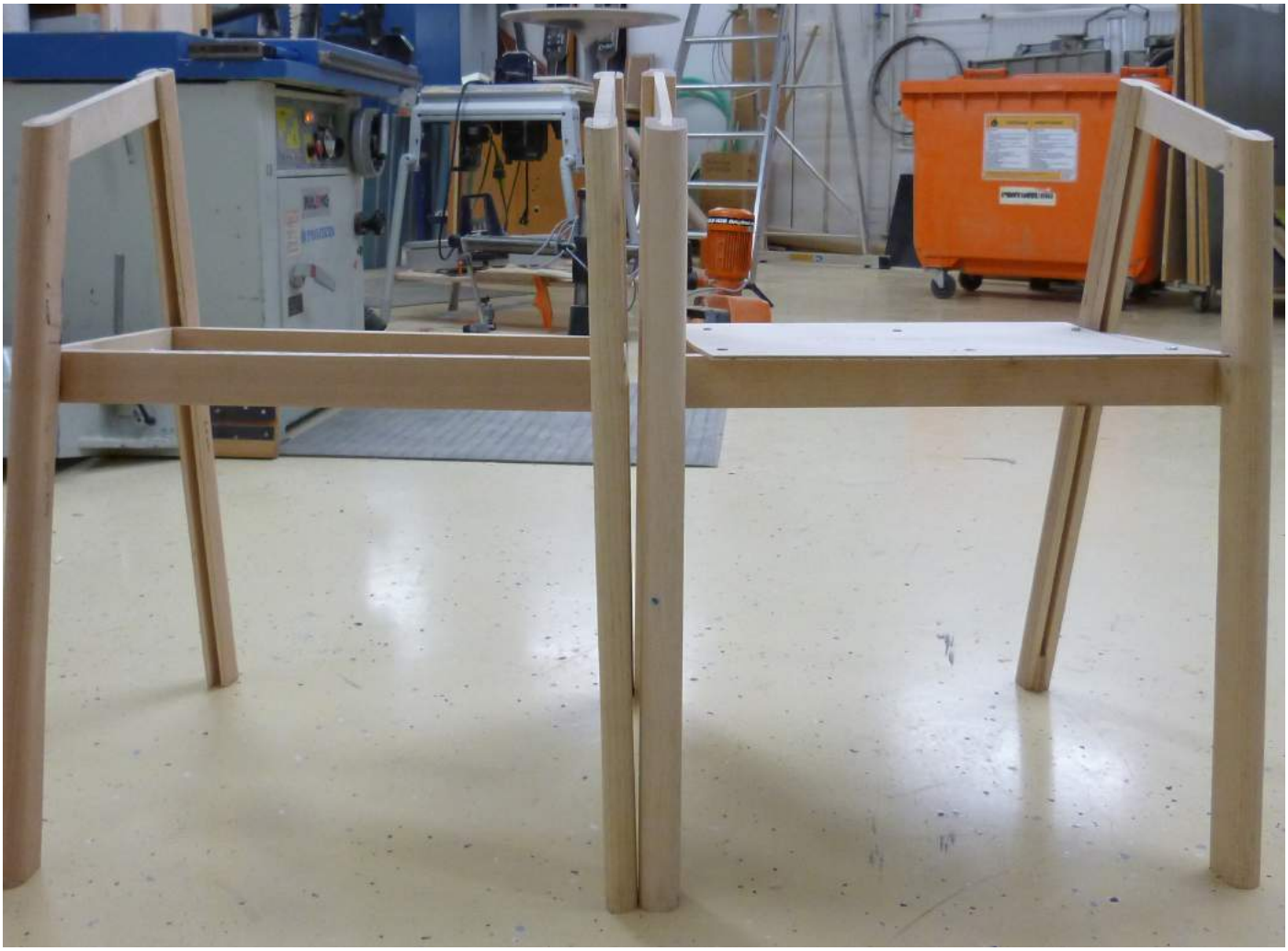
The second precice muck-up.

The amplitude of shaking is too large for a chair (The chair tilts 8.5 degrees toward both side)

5.4.3 The Third Structur Test Muck-up/

The structure stability can be enhanced by numerous ways. The first method is to increase the thickness of legs due to the fact the less material is probably the reason which causes the unstable state. This factor needs to be observed while designing a light-weight furniture. When more materials are taken away, furniture might also lose more support at the same time. However, the stability is constantly the priority for lots items. Subsequently, the size of legs is changed into 350 mm×350mm with the R5 mm of the U-form legs, and the thickness of plywood is increased to 125 mm. However, the state is not improved. The chair shakes as the first mock-up. The more severe issue for the second mock-up is neither light nor elegant.

The Thick Legs 120mm anf Detail

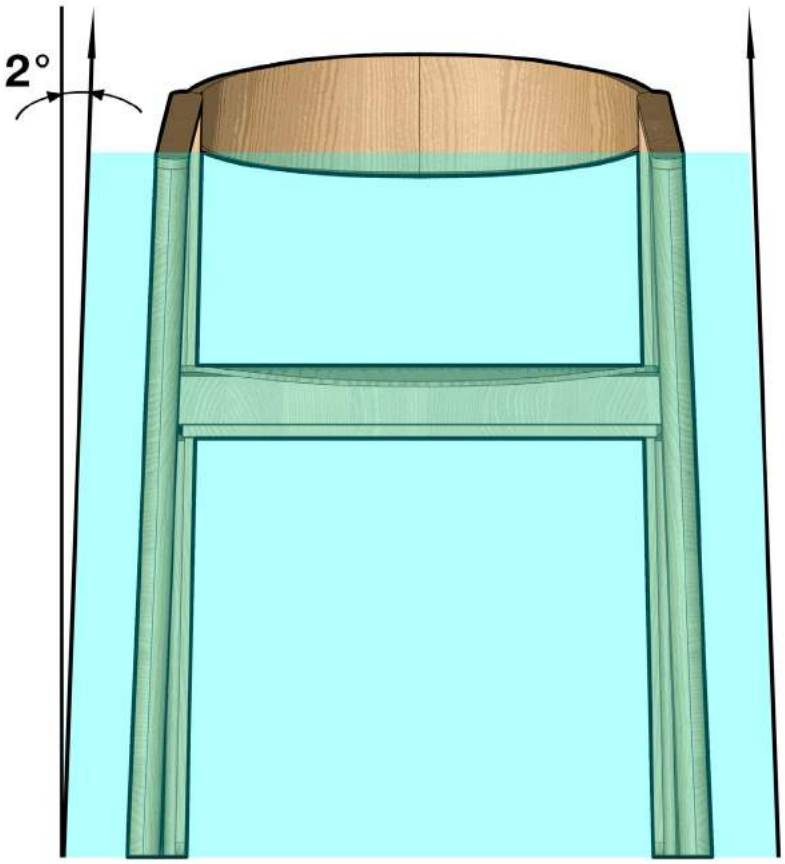


Comparison Between Thin and Thick Version

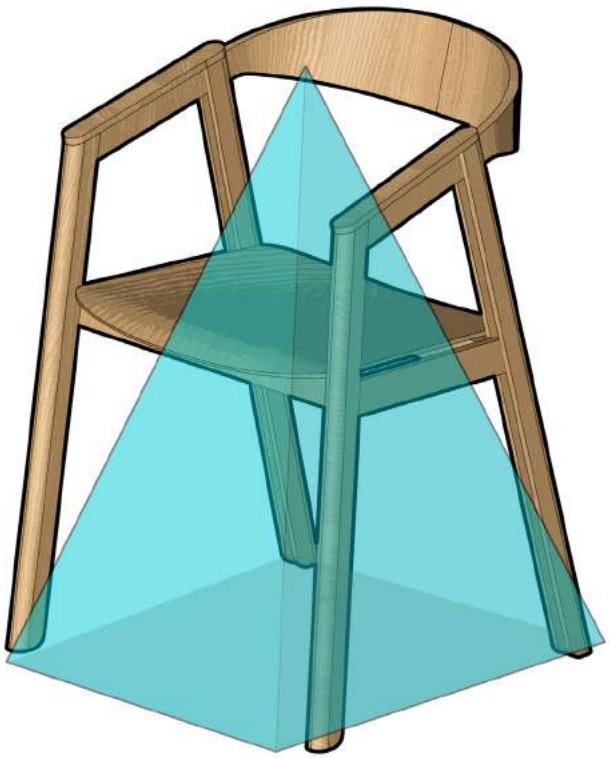
5.4.3 The Fourth Structur Test Muck-up/

After the failure of the first and second mock-up test. The structure is considered as the potential solution again. After analyzing the structure of the chair, It does not shake back and forth due to the fact the front and back legs compose a sturdy triangle shape. Therefore, the structural strength is probably additionally increased if triangle shape is likewise shaped by using the right and left legs. In order to prove this hypothesis, the both side legs are tilted inward two degrees. The outcome is four legs will consist a pyramid for the entire structure.

It is a small adjustment. However, the final result is satisfied. The amplitude of shaking is reduced to 2.5 degrees, and the armrest moves 30 mm from middle line towards the both side. The structure makes the contribution again, and the goals about a light and elegant chair are also achieved.



Both side legs are tilted inward two degrees



Four legs compose a pyramid as the inner structure of the chair

A substantial reduction in the amplitude of shaking

5.5 The Seat production

The seat production will be tested in this chapter. This chair is assembled by using three elements: legs, seat, and backrest. The problems about the production of legs and the whole structure are dealt as the priority. The U-form legs are the main concept of this design, and the stability is the basic requirement for a chair. Consequently, this design cannot be finished if both issues cannot be proved. But, the design process is not ended after two foremost feature are successful because seat and backrest also have to be tested.

Seat Mould Production by CNC Machine

5.5.1 The first Seat Muck-Up

The seat design is related to the chair's comfort, so the seat is designed as a warped surface in an effort to healthy with the thighs and buttocks at the beginning. The two side mould is selected for the seat manufacturing because the warped surface needs extra pressure. The CNC machine assists to mill the precise mould, and clamps are used to fix two moulds together. However, The outcome is not perfect; a big split comes on the top veneer.

One possibility for the fail bending is the incorrect direction of veneer. The wood grain of the primary test piece comes with horizontal, but the veneer would possibly extend better while the grain is vertical. Therefore, the vertical grain veneer is applied to the second version. However, The split still happens on the second test piece despite the split becomes smaller. One issue begins to be taken into consideration whether the ductility of the plywood is not good enough for the warped surface. If there is a restriction among the plywood and warped surface, the form of the seat have to be changed.

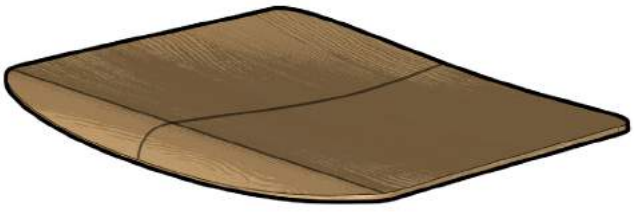
The cracks appear on different veneer direction

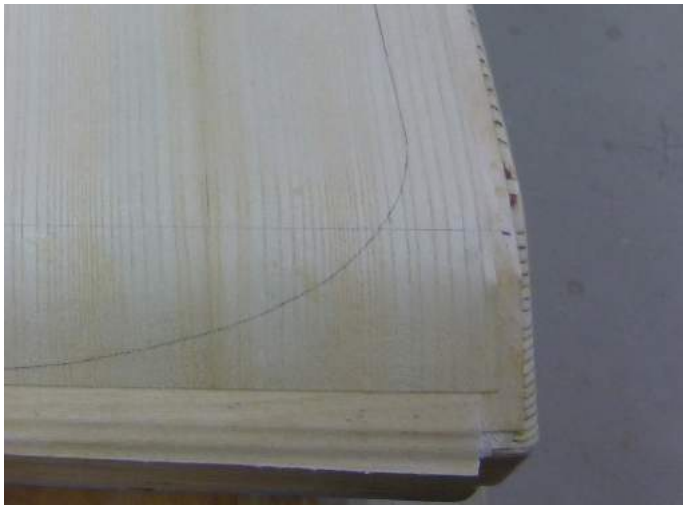
5.5.2 The Second Seat Muck-Up

One point about the seat's comfort is demanded to be observed in the process of re-design. The relation between the seat and body ought to be analyzed. One curve supplies a place for thighs, and the other curve is needed to cover the buttocks. As a result, the warped surface is separated into two curves, and two curves do not cross each other. Moreover, people still have good experience with the chair. Because of the adjustment, the third test piece is bent successfully, and it is still comfortable after testing.

Before

After





The perfect seat top surface

5.6 The backrest production

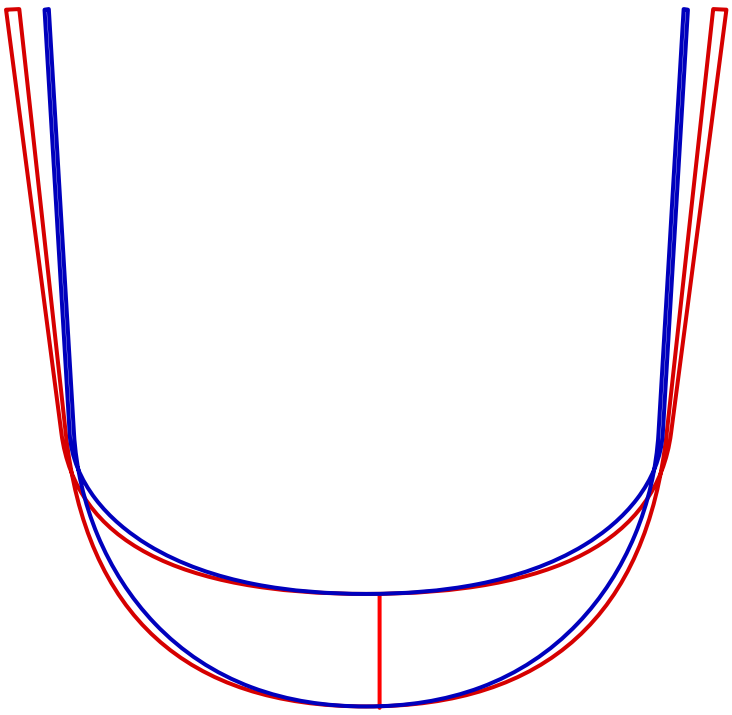
The shape of the backrest is a gradual change curve as it needs to comply with the legs perspective. The main problem surface which connects the legs and backrest is a warped floor, so the mould of the backrest should be milled by five-axis CNC machine to have the precise final piece. The same issue is also considered before making backrest mould: the shrinkage of the plywood. The shrinkage is different while the form and thickness of plywood are different, so the measurement of the shrinkage has to be done again.

Backrest Mould Production by 5-axis CNC Machine

5.6.1 The Shrinkage Measurement

The small test mould is made, and the measurement is done after the shrinking is complete. For the result, the test piece shrinks inward by 6 degrees. Hence, the mould of the backrest's angle is increased outward by 3 degrees on both sides. The different can be seen on the picture in the below.

The Shrinkagn Measurement



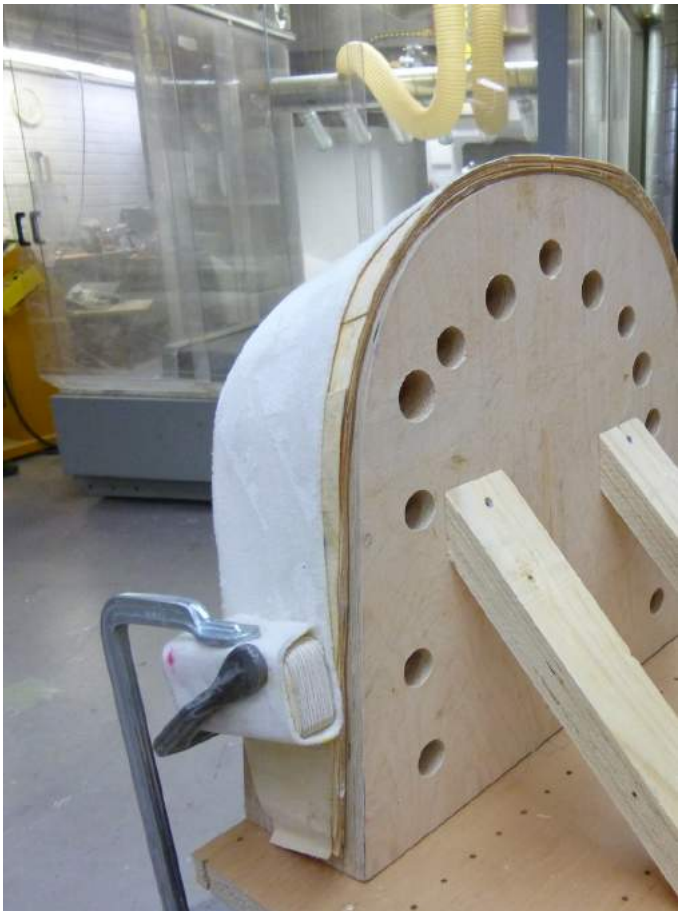
The original beckrest

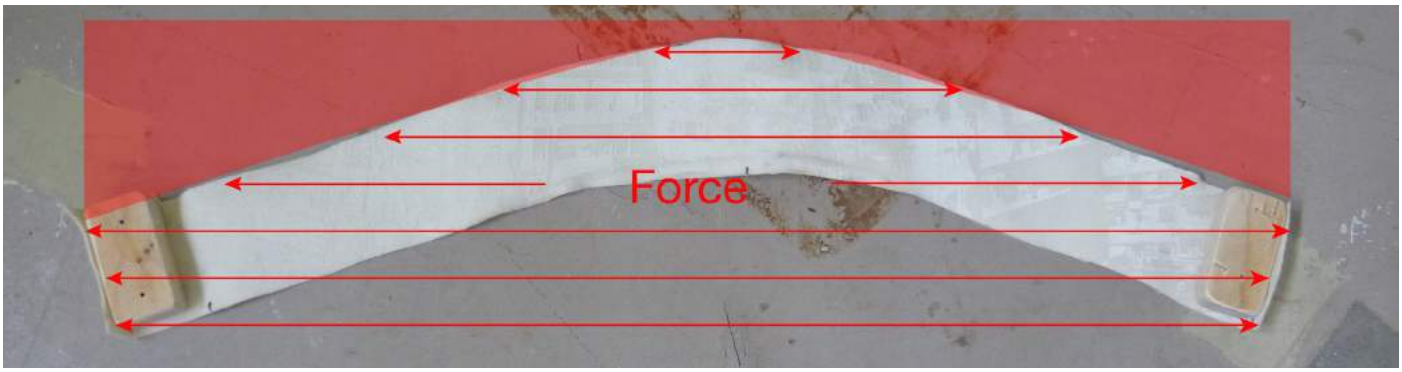
The mould backrest

5.6.2 The Soluction for Backrest Production

The serious trouble for the backrest production is unexpected. The backrest is a gradual change curve, so the pressure cannot be evenly distributed on the mould. Each layer of the plywood cannot be glued together perfectly, and the gap may be seen on the corner. Although it is not the method how factory produces the backrest, the solution still has to be found out.

The solution focuses on how to add the pressure for the specific place: the corner. The force from clamps is transferred from fabric, so it is probably a very good point to study the shape of the fabric. The first fabric is an arc-shape. If several horizontal lines which can be treated as the force are drawn from the middle of the fabric, one thing can be noticed: there is no line to cross through the corner area. Because of lacking pressure, the corner of the backrest cannot be formed well. According to the result from the analyzation, extra fabric is added into the area where is required to transfer the force for the corner place. After many trials, the beautiful gradual change curve is finally made successfully.





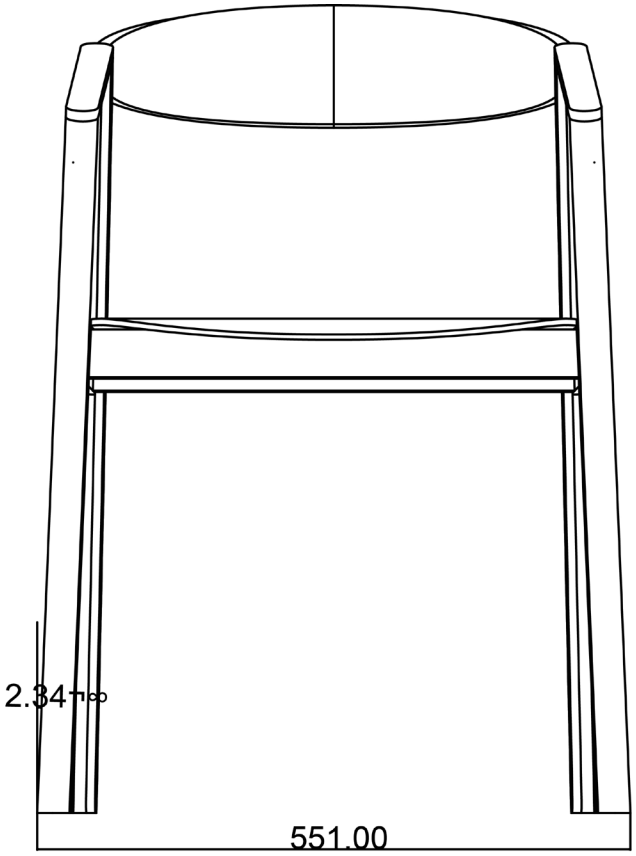
Lack the fabric to transfer the pressure from the clamps

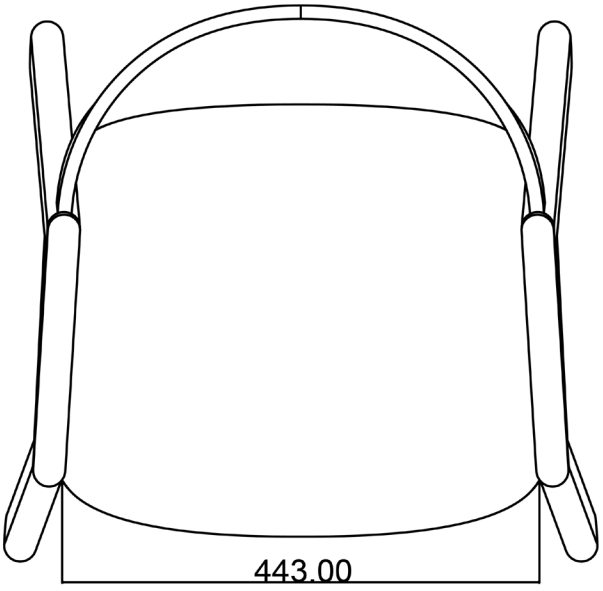
More fabrics are added to transfer the pressure from the clamps

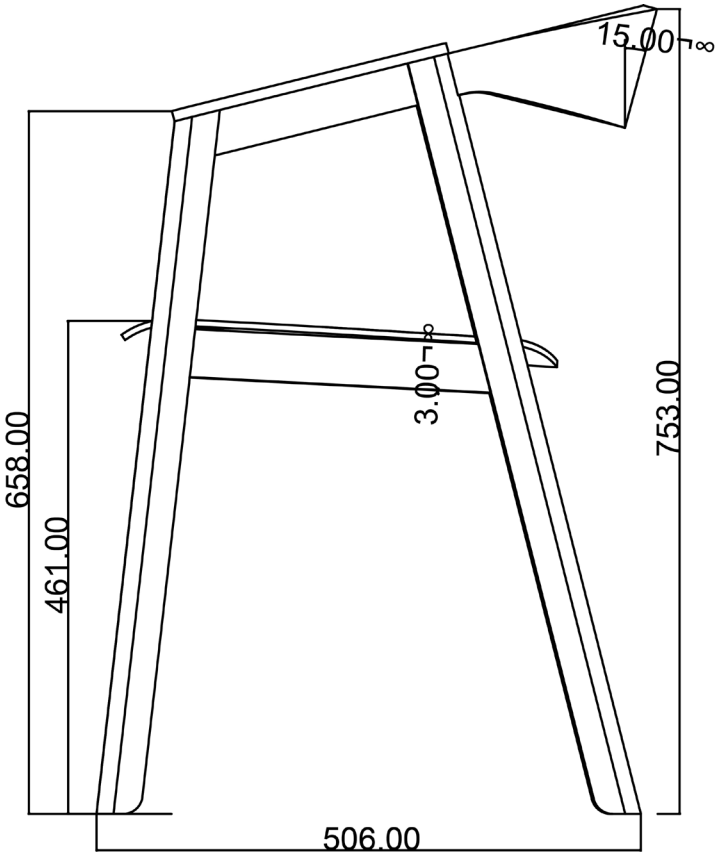
6. The Final Prototype/

Many experiments have been done. Also, the problems about structure and production of legs, seat, and backrest are solved in three months. However, the design process has not ended yet. The last design process should focus on the detail and the proportion of the chair. The radius of the U-form legs is reduced to R65 mm to make the chair more elegant visually. Moreover, The button of legs has a smooth radius because this radius can make the chair more smoothly, and the size of dowel are also considered. Two small dowels can show the craft-skill and also ensure the strength of chair. The designed chair is finished after all details have been done. The chair is named as U-chair because U-chair can tell users about the concept of the chair directly.

7. Size/






15.00
8°
3.00
8°
658.00
461.00
753.00
506.00

8. Final Though/

The requirement for a chair is simple: a place is stiff enough to hold the people weight. The goal a stiff chair can be achieved by applying different structure, which is also the reason why the structure become the main topic for this thesis. Moreover, structure indeed make the contribution in the design process.

During my research, I have accomplished the commitment what is made before the project starts: a light-weight, elegant chair which also can be manufactured. It is harder than what I though to develop a new design through the trial and error method. Many situation is unexpected. However, the mission for a designer is to overcome the difficulty, and bring new and useful items to the world. This mission is why I am always attracted to be a designer.

The technology is improved continuously. New materials and production methods lead to many striking and remarkable chairs. However, every chair still cannot escape from some simple physical law no matter how outstanding they are. I am interesting in the structure because the structure can be seen as the crystal of the physical law. It might have more chance to give what people really need if the design starts from the essence of the world: structure.

Too many chair want to give strong impression by using new technology and material nowadays. Though it is not the only way to create modern chair. The chair should be like our best friends to accompany us everyday. Hence, the most important and basic things should be considered at the beginning is the structure. I always remind myself while designing “Every masterpiece is composed by the humble and basic elements, I should have patience to play with them, and enjoy the challenge”. U-Chair concludes all my knowledge these ten years, and also give me the confidence to face the further challenge in the future.

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