ASSESSMENT OF WOOD LAMINATED MATERIAL FOR HOUSING PRODUCTION

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ABSTRACT

ASSESSMENT OF WOOD LAMINATED MATERIAL FOR HOUSING PRODUCTION

Today, laminated wood material is used in different types of structures. In many countries such as our country, as well as countries where this usage is intense, laminated wood material is not preferred in housing production yet. Although it seems that reinforced concrete structures have replaced wooden structures today, environmentally sensitive approaches expressed with concepts such as sustainability, ecological balance and repeatability have enabled the reuse of wood material.

In this study, the properties of laminated wood technology, which is predicted to be an alternative technology to conventional construction technologies, are evaluated. With this assessment, laminated wood technology could be an alternative structure production technology in our country.

At the beginning of the study, wood materials, wood damaging factors, composite wood materials, the use of wood in residential production and the use of laminated wood in residential production were examined under four main headings. The properties of wood materials and laminated wood materials were examined in detail and the methods, advantages and disadvantages of these materials were determined. This study is detailed on the structure of JZ House which was designed and built by architect Serhat AKBAY in Antalya with laminated wood technology.

The laminated wooden parts produced for the building were examined based on scientific data on the design process, static resistance of the building, fire resistance, sustainability, environmental and human health contributions. With the evaluation, it is aimed to increase the preference of wooden structures constructed with developing wood technology.

Keywords: Housing Construction Technology, Wood, Composite Wood Material, Laminated Wood, JZ House

ÖZET

AHŞAP LAMİNE MALZEMENİN KONUT ÜRETİMİ İÇİN DEĞERLENDİRİLMESİ

Günümüzde lamine edilmiş ahşap malzeme, farklı tip yapılarda kullanılmaktadır. Bu kullanımın yoğun olduğu ülkeler olduğu gibi ülkemiz gibi birçok ülkede henüz konut üretiminde lamine ahşap malzeme tercih edilmemektedir. Günümüzde ahşap yapıların yerini betonarme yapılar almış gibi görünse de sürdürülebilirlik, ekolojik denge ve yinelenebilirlik gibi kavramlar ile ifadelendirilen çevreye duyarlı yaklaşımlar ahşap malzemenin ahşap malzemenin yeniden kullanımını sağlamıştır.

Bu çalışmada lamine ahşap teknolojisinin yapı üretiminde konvansiyonel yapı teknolojilerine alternatif bir teknoloji olabilmesini sağlayacağı öngörülen özellikleri değerlendirilmiştir. Bu değerlendirme ile lamine ahşap teknolojisinin ülkemizde alternatif bir yapı üretim teknolojisi olabileceği düşüncedi bilimsel veriler ışığında ortaya konulmuştur.

Çalışmanın başlangıcında ahşap malzeme, ahşaba zarar veren etkenler, kompozit ahşap malzeme, ahşabın konut üretiminde kullanımı ve lamine ahşabın konut üretiminde kullanımı dört ana başlık altında incelenmiştir. Ahşap malzeme ve lamine ahşap malzeme özellikleri de detaylı olarak incelenerek yapılarda kullanımı yöntemleri, avantaj ve dezavantajları tespit edilmiştir. Bu inceleme lamine ahşap teknolojisi ile Antalya'da mimar Serhat Akbay tarafından tasarlanan ve inşa edilen JZ Evi yapısı üzerinde detaylandırılmıştır.

Yapı için üretilen lamine ahşap parçalar, tasarım süreci, yapının statik direnci, yangın dayanımı, sürdürülebilirliğe, çevreye ve insan sağlığına olan katkıları bilimsel verilere dayanarak incelenmiştir. Yapılan değerlendirmeler ile gelişmekte olan ahşap teknolojisi kullanılarak inşa edilen ahşap yapıların tercih edilmesini artırmak amaçlanmıştır.

Anahtar kelimeler: Konut Yapım Teknolojisi, Ahşap, Kompozit Ahşap Malzeme, Lamine Ahşap, JZ Evi

TABLE OF CONTENT

LIST OF FIGURES

Figure **Page**

Figure **Page**

Figure **Page**

LIST OF TABLES

Table **Page**

CHAPTER 1

INTRODUCTION

1.1. Problem Definition

The building materials produced by the developing technology in construction applications have passed ahead of the wooden material. According to the TürkStat, Buildings Permit Statistics (January - June 2017), reinforced concrete is the leading product. Rapidly produced concrete materials instead of wood material for many years, rapidly triggered global warming, and the main problem of our age. Due to the carbon dioxide emission, it negatively affects the environmental pollution and human health. It also causes climate change. In addition, synthetic insulation materials used in reinforced concrete structures also increase the damage caused by concrete. Concrete which has a structure, which cannot breathe negatively, affects user comfort. By destroying the green areas, instead of constantly releasing carbon dioxide, structures that threaten human health are being constructed. These structures, which cause air and noise pollution, affect people physiologically and psychologically. Many structures have been designed to improve the comfort of life of different properties, but the designs made do not provide the intended comfort of life due to the material properties used.

In recent years, the concepts of sustainability, ecological balance and repeatability have been a discussion area in architecture in order to increase the comfort of life. The positive effects of wood materials on human and environmental health, being sustainable and reproducible materials, energy efficiency, and wood in this context prevent the materials used in building production. Natural wood material can be damaged by environmental factors due to its structural properties. For this reason, the production of natural wood material is limited. However, composite wood material and laminated wood material obtained by processing natural wood can be used in building production, indoor and outdoor applications, ceiling and floor applications, stairs, door-window joinery applications. Drying of wood parts, grouping according to material properties, laminated wood products obtained by applying high pressure with the help of various protective chemicals and glues are the structural elements that can be used

without the need of any covering elements. Wood material can be used as beam, column, arch, joinery ladder elements in building applications. Being a dense and homogeneous material, it provides high fire resistance and high earthquake resistance compared to other wooden materials. Wood material can be produced in desired sizes according to the applications to be used, but the dimensions and shapes of the elements to be used in the structures produced with solid wood are limited (Karayılmazlar, Çabuk, Tümen, & Atmaca, 2008).

The technology of laminated wood material began in 1906 by Otto Hetzer with the bonding of wooden parts. Wood products produced by laminating process can be produced in desired shapes and dimensions can reach up to 40 m. The construction cost is lower than steel or reinforced concrete structures (Zmijewki & Wojtowicz-Jankowska, 2017). Laminated process is applied on wooden parts free from defects. Therefore, the laminated product obtained is of higher quality than natural wood material and can be produced with different aesthetic properties (Karayılmazlar, Çabuk, Atmaca, & Aşkın, 2007). In the studies on laminated wood material, it is seen that laminated wood parts have higher water repellency, higher distortion resistance, lower equilibrium moisture content and higher thermal insulation capacity than natural wood material (Kwon, Shin, Separated, & Han, 2014).

In our daily life, we spend many activities such as working, socializing and resting in closed spaces. This shows that most of the energy consumed is residential applications. The concepts such as sustainability, ecological living and living comfort, which are frequently encountered today, shape the housing designs where we spend most of our time. Environmental pollution, which poses a great threat to the future, is as important as building design as the material to be used in building applications. When the construction materials such as steel, reinforced concrete and wood are examined in this context, the wood material stands out thanks to its properties. In the studies on laminated wood material which has superior properties to natural wood material, the production process of laminated wood, materials used for the production of laminated wood, the effect of the preferred material on the quality of laminated wood, the properties of laminated wood and the static calculations related to the strength of the laminated wood are examined.

Today, housing production with wooden materials is not frequently encountered. The first reason behind the timber material is that according to the forest regulations, tree cutting is restricted in our country. Restricted wood cutting reduces the source of

raw materials. The lack of raw material supply leads to a lack of production continuity. In addition, the number of factories with special equipment for the production of laminated wood material to be used in the construction of housing in our country is few. There are carpenters mostly producing locally. The fact that the number of qualified personnel is also low is a major disadvantage for the development and use of laminated wood technology in our country. Therefore, the production of laminated wood is quite limited in our country. In addition to these reasons, there is not enough information on wood static calculations in undergraduate courses. This situation causes the number of people who can make the static calculations of the structure to be built is small. The fact that the number of people who specialize in wood static calculations in the environment is low reduces the preference of wood materials in housing production.

The aim of this thesis is to examine the design and construction of the house in Antalya by examining the example of JZ House by Serhat Akbay in order to expand the use of laminated wood in residential production.

1.2. Objectives and Scope of the Study

This study demonstrates the potential of laminated wood material, which has superior properties to natural wood material in residential applications. It claims that laminated wood, which has the positive effects on human and environmental health, supports the concepts of sustainability, ecological balance and repeatability, provides ease of application to the person, and can be produced in the desired dimensions of high quality, has an important place in housing production. This claim is supported by the design and construction of Serhat Akbay in Antalya with the example of JZ House in order to increase the use of laminated wood in residential production, its advantages, and increase the use of laminated wood in residential production. The aim of the study is to find answers to the following questions.

- What are the properties of materials used in the production of laminated wood?
- What is the production process of laminated wood used in residential production?
- What are the production methods of laminated wood used in residential production?
- What are the types of laminated wood?

- What are the physical, chemical, mechanical and ecological properties of the wood material produced?
- What are the laminated wood structure production technologies?
- What are the applications in which laminated wood is used in residential production?

With the answers given to the above questions, it is aimed to achieve the following objectives.

- Housing production methods,
- Material selection and importance in housing production,
- The effects of laminated wood used for residential production on human and environmental health,
- Laminated wood used for residential production

In this context, the similarities and differences between natural wood material and housing production and treated wood material and housing production were examined. The fact that laminated wood is more advantageous in residential production leaves natural wood used in various construction applications from the past to the present. There is a size limit in the production of building elements with natural wood material. However, the wooden parts produced by lamination technique can be in desired dimensions according to the applications. The curvilinear forms can easily be produced in a durable manner. Small parts of the final laminated wood are combined with glues and chemicals under high pressure to produce a homogeneous product. These properties and the other features included in the thesis make laminated wood material important for housing production.

In this research, JZ House features, design stage, regional climate, and harmony of laminated wood with nature and human life were investigated. The production methods and techniques used in the production of houses are evaluated by considering the necessary properties of wood and laminated wood. The properties of JZ House, which is examined for the thesis, were evaluated together with the cost evaluation, static strength, fire resistance and research data.

1.3. Methodology and the Outline of the Thesis

This study was carried out with the aim of ensuring the widespread use of environmentally friendly laminated wood material in housing production. In accordance with the aim of the study, wood materials, composite wood materials, the use of wood materials in housing production, laminated wood materials' properties, production methods, the use of laminated wood materials in housing production and the advantages of laminated wood materials were investigated. With the help of the researches, the target was determined by examining the JZ House sample project. In other words, this thesis presents a case study as research methods.

Inspection of the JZ House made it possible to see the properties of laminated wood on a sample. The information supported by the literature studies were evaluated in detail with the JZ House project, which is a sample residence. JZ House has been an example of the advantages and disadvantages of using laminated timber from the design process to the completion of its construction. For this reason, it is evaluated as an example that will enable the thesis to reach its aim and examined within the scope of the thesis. In the study, a literature study on the subject was made. Based on previously obtained thesis studies, articles, information obtained from different construction companies and sources of wood materials in the library, data have been arranged within the scope of the determined purpose.

This study consists of three different stages. In the first stage, wood material and composite materials were examined. In the second stage, laminated wood with more advanced properties than wood was examined. In the third stage, the JZ House construction was analyzed for the usage of laminated timber.

The thesis consists of six different sections. In the first part, the aim of the thesis, the scope and boundaries of the thesis and the methods used to create the thesis are explained in detail. In the second chapter, the general information about the material properties and the factors that damage the wood material under the main title of wood material are examined and general information was given. The visual, physical, mechanical, chemical and ecological properties of wood materials are given. The factors that damage the wooden material used as building material from the past to the present are summarized in the light of the studies examined. In addition to the wood materials, the properties and types of wood composite materials used in different applications are

also included. In the third chapter, the use of wood materials in housing production, its importance and the benefits of the material in housing production were evaluated. In the fourth chapter, the properties of laminated wood, its use in house production, lamination techniques and usage areas are investigated in detail. In the fifth chapter, the JZ House sample was investigated. In the sixth chapter, the results were evaluated together with JZ House.

In this thesis, attention is paid to the advantages of laminated wood material produced by the technology developed with the new materials and wood materials used in building production for years. The advantages of this developing technology are examined on a sample and the effects of laminated wood materials on the environment and human health are explained.

The production methods and techniques used in the production of houses are evaluated by considering the necessary properties of wood and laminated wood. The properties of JZ House, which is examined for the thesis, were evaluated together with the cost evaluation, static strength, fire resistance and research data.

Within the scope of the thesis, Naswood Company that provides laminated wood material to many applications in Turkey and abroad, Serhat AKBAY, who is specialized in the construction of wood, has benefited from the experience and information provided by Susuzlu Wood Company, which provides the production of laminated wood for the JZ House. With the help of the data provided from the written sources and from the people working in this industry; the status of the wooden structure, the production methods of laminated wood structures, the properties of the building materials, their usage areas and the methods of use have been investigated and examined.

CHAPTER 2

WOOD MATERIAL IN CONSTRUCTION PRODUCTION

2.1. Natural Wood Material

Wood is a material that can be used without changing its structural and physical properties. Wood is an organic, sustainable and environmentally friendly material makes wood valuable. Besides, wood is breathing, living and healthy material. It does not cause environmental pollution during its production and use in applications and does not pose any threat to human health. In addition, the property can be rotting in the soil and does not harm the environment in this process it distinguishes wood from other materials. Wood is the only building material that can be renewed (Winandy, October 1994).

Wood is a natural, easy-to-use material used for many years in heating, protection, sheltering, bridge, industrial design, landscape and similar applications. It can be easily processed and easily shaped. Some wood materials can even be shaped by hand. The forming process may vary depending on the fiber structure of the wood and the hardness - softness degree. The cellulose contained in the structure gives flexibility to the tree and lignin gives the tree hardness and resistance (Figure 2.1). Wood pieces can be easily combined with connection materials such as nails, screws, g.lue or other materials made of wood (Yaman, Ocak 2007). This feature provides design flexibility and efficiency, and offers practical solutions. Wood material, which can be produced according to many different standards, can also be produced in different sizes suitable for the desired purpose. Error share is low in applications. Wooden pieces used in applications can be removed and reused in a different application (Usta, 2017).

Much less energy is required for production and processing compared to other building materials. The lightness of the wood material makes it easier for many aspects in the production, transportation and connection process.

Today, the increase in interest in natural life, wood takes an active role as one of the more valuable and indispensable materials. In most of our living areas, goods, carriers or complementary materials can be used as insulation materials. The best understanding of the physical and chemical properties of the wood is of great

importance in terms of life and performance of the wood materials used in the applications. The type of wood should be determined according to the purpose of use of the wood element to be used. For easier processing of wood and for more trouble-free use, it is more accurate to cut the fattening water in its structure at least during the cutting period (Winter and Kehl 2002).

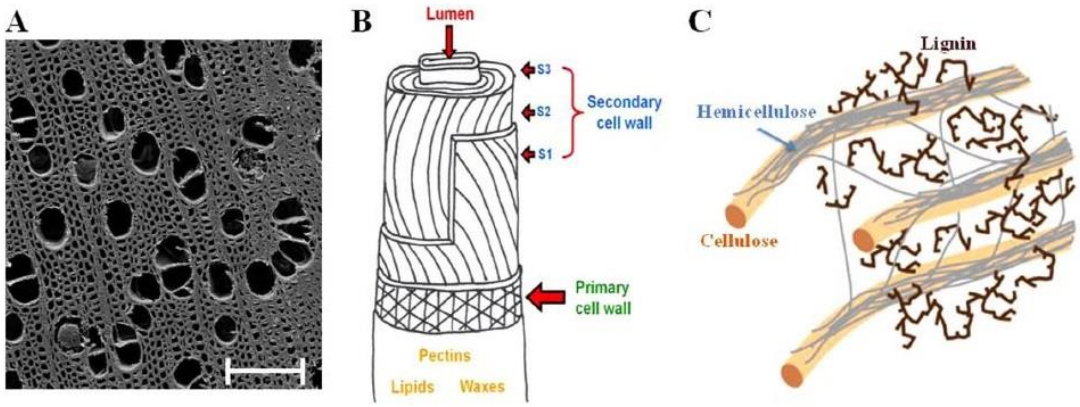


Figure 2. 1. A: cellulose, B, C: Lignin[1]

Wood material is not deformed if necessary precautions are taken during processing and application. It can be protected by applying impregnation against both living and inanimate pests which damage the wooden material structure which is used in its natural form without any process being applied. Thus it can be used for many years.

Figure 2. 2. View of Temple[2]

[1] Ramage et al., 2017b
[2] Michael, Turtle. "Oldest Wooden Building." Oldest Wooden Building.

The world's oldest surviving wooden building is an ancient Japanese temple built in Japan, in Kansai region, in 700 AD (Figure 2.2). The five-storey pagoda and the main hall of the temple are 1300 years old and called as the masterpieces of wooden architecture[3]. It was selected as a unique storehouse of world Buddhist culture by UNESCO as a part of World Heritage[4]. The structural system of the temple was designed to transport the heavy load of the exposed roofs, which is a characteristic of Japanese and Chinese architecture, with a complex bracket system to the outer columns (Figure 2.3).

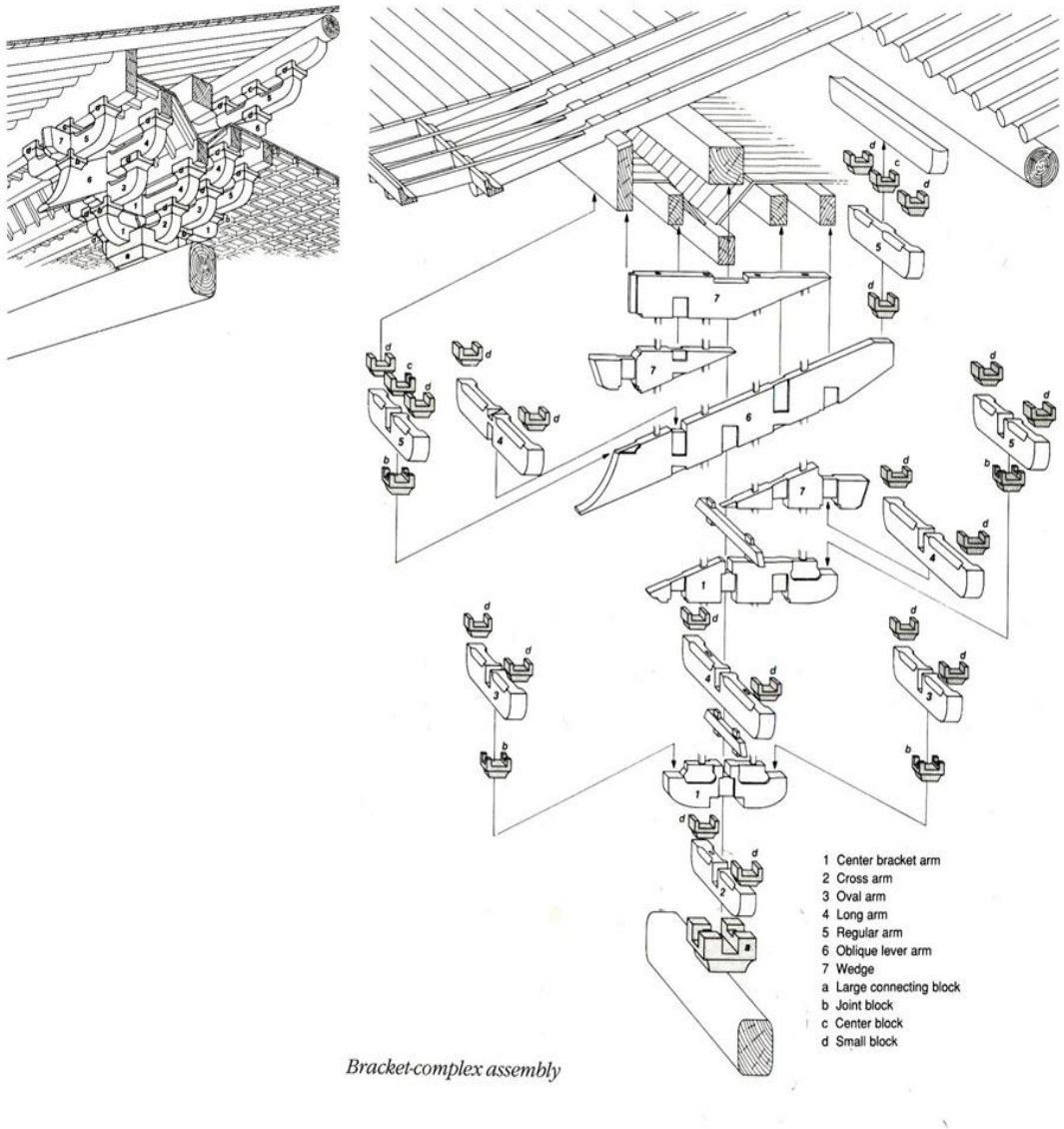


Figure 2. 3. Bracket-complex assembly[5]

[3] Unesco. Accessed 20 April, 2019. https://whc.unesco.org/en/list/660
[4] Horyuji. Accessed 20 April, 2019. http://www.horyuji.or.jp/en/garan/
[5] Graubner, Wolfram. "Exposed Roofs in Japanese and Chinese Structures." Exposed Roofs in Japanese and Chinese Structures. October 13, 2011. Accessed July 7, 2018.

2.1.1. General Features of Wood Material

Wood material is used in different applications such as construction, furniture and veneer which are obtained from the tree which has a living structure. As a living material, each wooden material has different visual, physical, mechanical, chemical and ecological properties.

2.1.1.1. Visual Properties of Wood

Wood is a preferred material for many different applications. Apart from the applications where visual aesthetics is not very important such as structural systems, wall systems and similar applications; wood material is preferred in different façade systems, wall coverings, furniture production, industrial design products and coatings. It is possible to find wood in many different colors, textures and brightness in nature. A large number of options achieving the desired appearance makes it easier to find than other materials (Dinwoodie, 1996b). It is possible to examine the visual properties of wood in terms of color, brightness and texture and macro structure.

The color of wood varies according to the type of wood used, the cutting technique of the tree, the time in contact with the air and the difference in the reflection of the beam due to the density difference in the structure (Hıraoğlu, 2007). The resin and pigments, which is in the structure of the wood, cause it to be more colorful. Depending on the variety of tree species, it is possible to obtain many colors and textures. In addition, some chemical processes applied to wood are among the factors that change the color of wood.

The size, density, and the location of the medullary rays reflecting the light affect the brightness of the wood. Wood has a matt surface due to the narrow medullary radiations and the thin cell wall. The expansion of the medullary rays and the thickening of the cell wall increase the brightness of the wood (Figure 2.4). Transparent protective or decorative coatings can be used to preserve the brightness of the wooden surface and make it stronger. The different size medulose beams in the structure of wood, fiber structure, annual rings, the type of tree, section direction, the size and layout of the cells cause tissue differences between wood materials (Figure 2.4) (Dinwoodie, 1996a).

The annual ring width in the trees constitutes the macro structure. This feature allows us to examine the wood in two different categories according to the degree of

hardness and softness (Figure 2.4).

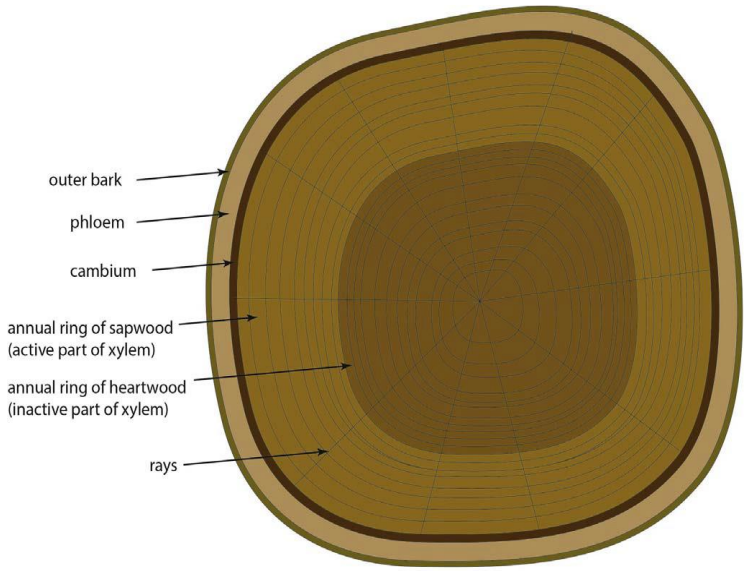


Figure 2. 4. Macro Structure of Wood[6]

2.1.1.2. Physical Properties of Wood

Nowadays, many new studies are being carried out and new products are being produced in order to control the noise that occurs both inside and outside. Wood material is a preferred material with its various insulation materials in many applications thanks to its properties. Due to the contrast in the sound transmission feature, wood is a preferred material in the construction of musical instruments because it transmits of the sound well. On the other hand, there are many examples in the interior acoustics as a sound-absorbing material. It emulates the sound and prevents the echo from occurring (Godshall & Davis, May, 1969). The flawless combination of elements in applications, the gaps between some elements, the order of the elements used and the choice of the right wood product increase the acoustic performance of the application. Good selection of materials to be used for work places, schools or wooden furniture selected in apartments may reduce the noise that may occur in the environment (Smardzewski et al., 2015). However, the wood alone is not enough to provide a good acoustic performance.

[6] Ramage et al., 2017a

The electrical conductivity of wood is inversely proportional to the dryness of the tree. As the wood is dried, the electrical conductivity decreases and disappears. However, the opposite cases are greater if the amount of moisture in the electrical conductivity increases. The direction of the fibers in the structure of the wood also plays an important role in the electrical conductivity. It can be used as dried wood insulation material (Şenkal, 1996).

It has high heat storage properties due to its porous structure and lightness due to its density. Heat conductivity and retention vary according to the type and fibre structure of wood. When wood is evaluated together with different building materials, it performs better by using thinner section than other building materials. The change in the amount of water in the wood cells causes the wood to shrink and swell. The deformation that will occur in the wood material is directly proportional to the tissue density. The higher the density of the tissue, the more water it can get into the wood, or the water is lost rapidly. This situation can significantly affect the deformation.

The moisture content of the wood is calculated by the ratio of the moisture content of the wood to the dry wood weight. The moisture content of a cut tree is approximately 60%. For effective use, the drying process must be applied to reduce the moisture content of the tree. Drying is initiated by wetting the cell membrane and evaporating water in the spaces between the capillary cells and the cells in the wood structure. The drying process can be carried out in specially prepared ovens or can be carried out in open air.

If the wood does not reach the required moisture content, it may cause rotting due to fungi and insects. Thanks to its hygroscopic feature, it gets moisture from the surrounding environment. Depending on the humidity in the structure of the wood, the humidity in the environment and the amount of moisture in the structure varies over time. This change can cause changes in the performance of wood. The excess water that incorporates into the wood causes the wood to expand and the water spread to its environment causes the wood to narrow. However, any lengthening or shortening is not observed. This indicates that wood is a working material. There is no effect of heat on the wood material size of wood and there is no softening and hardening within the structure. Thanks to the lack of change in size, it allows perfect opening of large openings (Wiedenhoeft, 2009). Design of the wood by taking into consideration the swelling and shrinkage of the wood prevents the damage that may occur later. If wood material is to be used in an open-air application, it should have a humidity rate of about

15-18%; if it is to be used in an indoor area application it should have a humidity rate of 9-12% (Pfeifer et al. 1998).

Contraction and deterioration of the structure occurs by affecting the direction of the wooden growth rings. These distortions are in the form of arcs, twists, crooks and cups (Figure 2.5).

The fibers in the structure of the wood cause water to deform the cells by giving water. This deformation is caused by internal stresses on the surface and internal cracks. In order to prevent cracks on the wood material, the moisture ratio should not be different from the optimum values during drying and must be protected against moisture during storage and use. Wood density is low but resistance is quite high material. The density of wood material is directly related to moisture. Knowing the density of wood allows us to estimate the strength of wood to be used in applications and its susceptibility to decay.

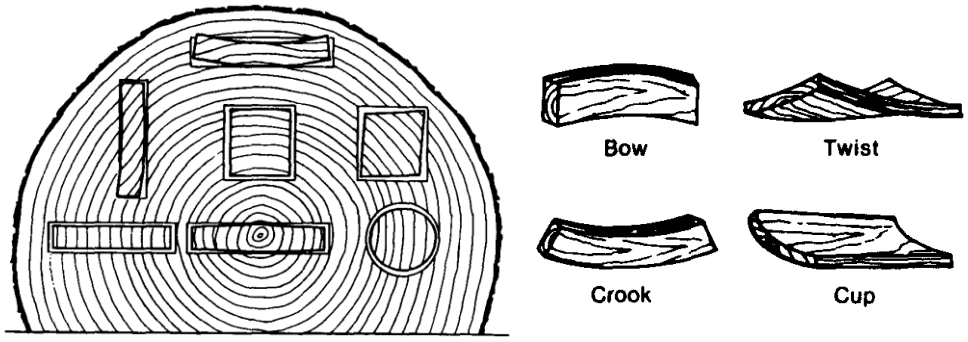


Figure 2. 5. Shrinkage Deformation[7]

2.1.1.3. Mechanical Properties of Wood

Due to the fact that wood is a living material, various microorganisms, fungi, insects, worms and bacteria can be found in it. These creatures are fed with cellulose and lignin contained in the wood and cause deterioration of the tree structure. For this reason, damage to wood may vary depending on where the tree grows. Chemical measures to be taken against these creatures will directly affect the life of the wood material positively. It can be used as supporter elements in wooden applications with high bearing capacity having high resistance to earthquake. Even if it is damaged, it can

[7] Arntzen, Charles J., ed. Encyclopedia of Agricultural Science. Orlando, FL: Academic Press: 553. Vol. 4.October 1994

be continued to be used by performing the maintenance that is required before it is completely destroyed. This feature of wood puts it ahead of other building materials.

2.1.1.4. Chemical Properties of Wood

Nowadays, the physical properties of raw wood can be changed by processing wood with water-soluble polymers, synthetic resins, certain chemicals, heat and similar variables or substances. The processes not only change the physical properties of the wood, but also produce more powerful, robust and more durable water and fire resistant products. It differs according to the usage process of raw wood. Due to the fact thatwood is a natural substance, the physical and chemical properties of each part may vary depending on the environmental conditions (moisture, soil, air and biological factors). The possibilities for the use of wood material are very high. It can be suitable for any building style. Knowing the characteristics of the wood material to be used, the designs can be made by taking into consideration the positive contribution to human life and can be transferred for generations (Pettersen, 1984).

2.1.1.5. Ecological Properties of Wood

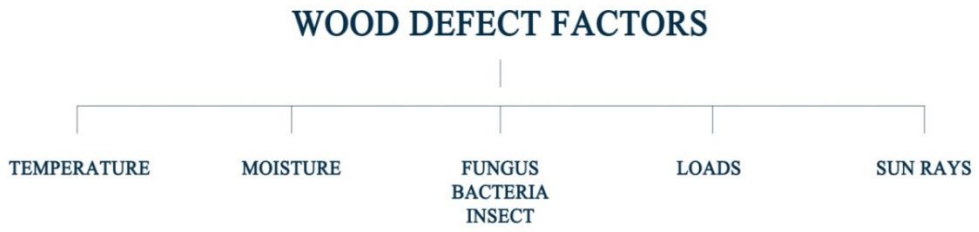
Wood is a versatile material that has been known and used around the world since it has aesthetic properties and an environmentally friendly material. Building materials produced by various technological developments emit greenhouse gas during production and during use. This causes environmental problems in the long term.

Wood is the only renewable resource among materials. As in other materials, it does not release harmful gases to the environment during its production and waste generation is very low. This makes wood an environmentally friendly material. Increasing environmental problems that pose a threat to the future increases the interest in the use of wood. However, composite chemicals produced by using various chemicals are dangerous due to the volatile chemicals used in the structure. For this reason, wood materials that are not cut from the wood or wood that is produced by using less hazardous chemicals should be preferred (Koca, November 2018).

2.1.2. Wood Damaging Factors

Wood material is a living material used in building applications and in other applications. Wood is degraded by physical, chemical and mechanical effects by environmental factors. In addition to environmental factors, biological factors also damage wood. Factors that damage wood are described below (Table 2.1).

Table 2. 1. Wood Defect Factors



2.1.2.1. Decay

Many defects can occur on the wood during its life. Since it is a living material, it can house bacteria, fungi, insects, worms and many other living things (Figure 2.6). These creatures adversely affect the static resistance, service life and aesthetic appearance of wood.

Bacteria and fungi cause stains on the colorand surface of the wood (Figure 2.7). This does not affect the static strength of wood but it causes decay. Humid conditions are suitable for the growth of fungi. The protection of the cut wood and the wood used in the applications in dry conditions is the main precaution that can be taken for the formation and reproduction of fungi. It should also be noted that air must be consumed while preserving the wood. Insects eat the wood unlike mushrooms and insect larvae cause the digestion of cellulose. As a result, it affects the aesthetic appearance and decreases the static strength of the wood. The worms that make the wood into sawdust are mostly found in the interior of the wood, they cannot climb to the surface (Madison, 1999). Unlike bacteria, fungi and worms, birds form holes in the wood surface. Another factor that damages the tree is that the remaining branches of broken or cut tree branches continue to feed from the tree for a certain period, causing the formation of dark rings called knot.

Figure 2.6. Decay of Wood[8]

Termites live in a tree and cause serious damage to wood. They enter the wood from the cracks or parts of the joints formed in the wooden material and lay their eggs. As they break the material from the inside, they can cause great damage to the applications (Figure 2.8).

Figure 2.7. Wood Decay Because of Fungi[9]

Unlike bacteria, fungi and worms, birds form holes in the wood surface. Another factor that damages the tree is that the remaining branches of broken or cut tree branches continue to feed from the tree for a certain period of time, causing the formation of dark rings called knot.

The change in the amount of moisture in the environment and the structure of

[8] "Decay." Factsheet - Decay. Accessed April 09, 2019.
[9] Zmijewki, T., and D. Wojtowicz-Jankowska. "Timber - Material of the Future - Examples of Small Wooden Architectural Structures." 2017 / 11 / 04 / 2017.

the tree may cause deformation of the wood material. Because of its hygroscopic structure, it takes over moisture in the environment or leaves excess water in the environment. Depending on the increase and decrease of the amount of water in the structure of wood shrinkage and swelling occurs. This causes different problems to arise.

Figure 2.8. Termite Damage[10]

Variable climatic conditions can cause opening of wood joints. It also causes crack formation and color differences on the surface. Thus, the aesthetic appearance of the wood will be damaged.

As one can see, some environmental factors and living things can cause various damages within the body. This damage in the wood structure makes it difficult to obtain a solid wood product to be used in applications. The less the damage on the cut wood, the lower the process required for the designed product, and this directly affects the generated waste, the cost and the time (Sawata, Sasaki, Doi, & Iijima, 2008).

2.1.2.2. Drying the Wood

The wood has a large amount of water in its structure immediately after the cutting. In order to use the cut wood in applications, it should be ensured that the moisture content in the structure is optimized according to the place where it will be used which will gain strength and resistance. Applied drying process directly affects the

[10] "Are These Termites or Carpenter Ants?" Yes Pest Control. April 30, 2019. Accessed May 03, 2019.

electrical and thermal conductivity of wood (Madison,1999). Besides, transportation and transportation costs will be positively affected as the weight of the wood decreases.

Since wood is a natural material, it is affected from environmental factors and living things throughout its life. Optimal conditions must be ensured in order not to affect the wood. For example; if the amount of moisture in the environment is below 20%, this does not pose a threat to the wood material (Ramage et al., 2017b).

If the amount of moisture in the environment is more than in the wood material and no precautions are taken, the volume of wood will increase by taking moisture. If the wood is not sufficiently dried and used in a dry environment, the amount of water in its structure decreases and the wood undergoes shrinkage. However, when the humidity is above 20%, deformation occurs in the wooden material if no action is taken. If the moisture performance of the wood is in between 15-19%, than the environmental resistance will be high. Among these values, the wood would have reached its moisture balance and will not exchange water with the environment. Therefore, drying of wood is important which can be used in various applications. However, in applications such as parquet, furniture, woodwork, humidity must be in the range of 6 - 8% (Madison, 1999).

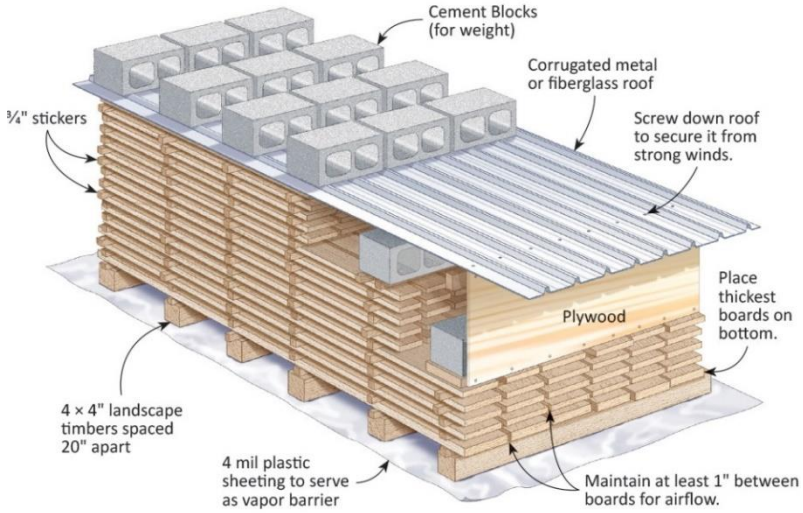


Figure 2.9. Air Drying Stack[11]

Air drying stack is drying of wood under natural environmental conditions. As it depends on natural environmental conditions, drying speed cannot be interfered with.

[11] "How To Air-Dry Lumber: Turn Freshly Cut Stock Into A Cash Crop Of Woodworking Woods." Woodworking Plans & Tools. April 10, 2015. Accessed June 18, 2019.

Drying speed depends on wind, temperature and humidity. It is an efficient drying process, but the drying time of the wood can be long (Figure 2.9).

The drying process can be carried out in furnaces, by natural means and by different processes. The type of wood in the drying process, cell structure, and amount of moisture in the structure, ambient temperature, absolute humidity, relative humidity and the air movement are important factors. If these factors are not taken into account during the drying process that wood breakage and cracking may occur. The drying process should be fast. The slow drying process can cause staining of wood material (Figure 2.10).

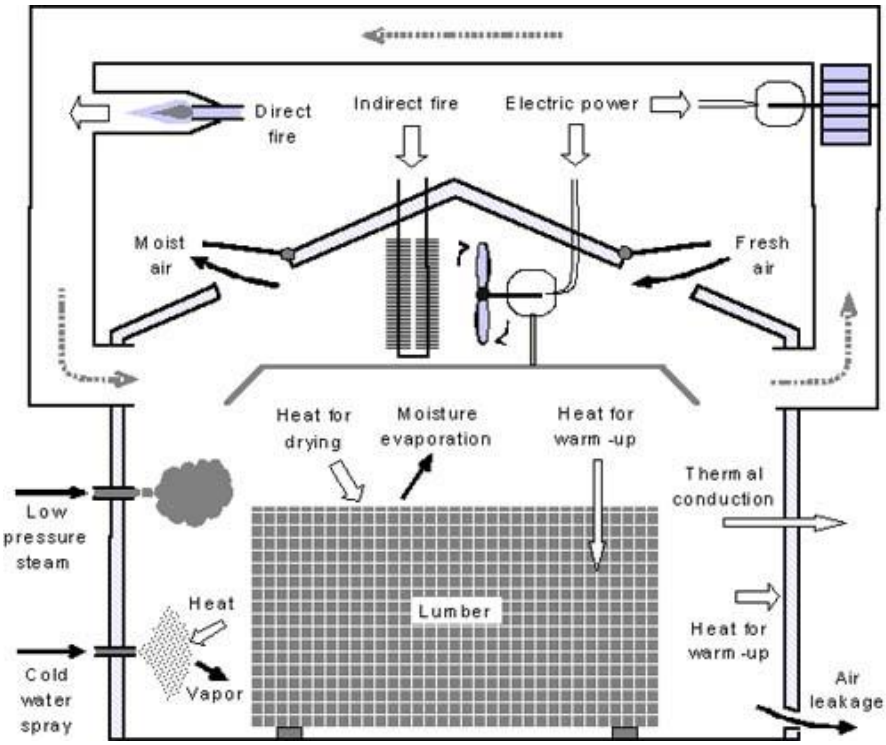


Figure 2.10. All components of the kiln energy model[12]

The wood that is dried in suitable conditions can be efficiently made available in applications. The desired shape can be given easily, joining process can be done; paint and varnish can be applied.

If wood drying process is not sustained sufficiently, there can be bacteria formation such as living things rapidly reproducing within the wood can cause wood color change, mold growth, static resistance decline and reduction of material problems.

[12] "Types Of Commercial Humidification Systems." Construction Home Design and Decoration Ideas - Best Home Improvement and Build. Accessed June 18, 2019.

2.1.2.3. Fire

Wood is a flammable substance. However, the structure of the cellulose and lignin has long resistance during the fire because of high self-ignition property which shows a partial resistance. Low thermal conductivity ensures high fire resistance. Due to its thermal conductivity, it burns slowly and regularly. The carbonization on the surface of the burning wood prevents the passage of inward oxygen and provides a later damage to the inner surfaces of the section (Figure 2.11) (Bilici, 2006).

Figure 2.11. Fired Wood Example[13]

Wood's resistance to fire is higher than concrete and steel. Due to the high coefficient of expansion, the steel melts in a short time and loses its bearing strength. For this reason, the steel connections used in many places to accommodate a large crowd are covered with wood, which has a higher fire resistance. In the course of fire, expansion and collapse do not occur in the wood. Fire resistance can be increased by applying chemical protection processes on wood. This time can be between 30 and 120 minutes. The cross section of the wood is important to increase the durability of the wood from any chemical application. The increase in surface area adversely affects the fire resistance of wood. For this reason, the use of multi-piece wood in applications has more fire resistance than the use of massive and large sectioned wood. In addition, it is possible to increase the fire resistance by covering the surface of the used wooden elements with limy, plaster and clayey fluids (Yaman, Ocak 2007) .

[13] "AWC Fire-Resistance Design Primer for Mass Timber Construction." Think Wood. June 25, 2019. Accessed June 18, 2019.

2.1.2.4. UV Rays

The lignin that connects the cells in the structure of wood material is damaged when exposed to ultra violet rays. When damage to the lignin occurs the tree structure leads to the formation of breakage. This deterioration in the structure of wood material reduces the resistance of wood to environmental conditions. Wooden parts that lose their durability become more permeable and therefore deterioration will ocur in a short time. In order to prevent short-term deterioration, the use of protective paints, varnishes, chemical products that do not pose a threat to human health or environmental pollution should be used on wooden parts for the outdoor applications. It is also necessary to adjust the maintenance and repair times correctly. If necessary precautions are taken for the wooden parts and regular maintenance is provided, the degradation in the structure of the wooden material can be minimized (Cogulet, 2016).

2.1.2.5. Water and Humidity

Due to changing weather conditions and temperatures, changes in the amount of water in the structure of the wood material emanates. The loss of the water causes the wood material to dry and crack. The cracks that occur rapidly cause water and moisture to enter the body of the wood by the increasing amount of moisture in the air. Sudden changes in the structure of wood, accelerates the decomposition of wood. Therefore, the aesthetic appearance of the applications begins to deteriorate.

To increase the resistance of wood against water and moisture, water repellent products should be applied to close pores on the material. At the beginning of these products are specially produced candles. The materials need to be ordered correctly so that the wooden parts can last for a long time; otherwise, they are easily affected by water and moisture changes (Madison, 1999).

2.1.2.6. Heat

If the necessary precautions are not taken, changes in the air temperature will cause moisture changes in the wood material structure used in the applications. In addition, the temperature causes the wood material to burn and become damaged. The

sudden increase in moisture causes swelling of the cells. The loss of moisture causes the cells to shrink and cause the wood to crack. These changes in wood reduce the resistance of the material. It also causes deterioration of the binding property in the structure of the material and increases the leakage of wood from cracks. In the end, this causes rotting of the wood material.

Wood parts should be dried according to the ambient conditions in which they will be used in order to prevent the damage caused by the temperature change in the wood. Regular maintenance should be provided to prevent damage that may occur over time (Kettunen, 2006).

2.2. Wood Composite Material

Composite wood can be produced from different materials. Wood pieces are put together to make it stronger. Various sources such as plastic and wood can be used to create composite wood material. The independent parts are connected to each other by means of adhesives. Composite wood is a product that is frequently used in building applications, furniture production, floor applications, indoor and outdoor coating applications (Maloney, 1996). However, it is necessary to pay attention to the chemicals and adhesives to be used in the production. Care should be taken not to use products that affect human health.

Composite wood material is used in many different types of buildings. As the design properties differ, the type of composite wood used varies. Composite wood material is preferred because of its features in different applications such as designs with large openings, designs with visual appearance and environmentally sensitive designs.

Glulam wood applications were used on the facade and roof trusses of the main auditorium of the building. The use of glulam contributed to the sustainability of the structure. To improve acoustic performance, the gap between the cages planned on both sides is filled with ¾ to 1½-inch wooden strips. The 215-tonne roof, which is grafted using steel in the auditorium, is supported by wooden parts covering a 30-meter-wide area (Figure 2.12).

Barents House Kirkenes is a building located in the region between Norway and Russia. Wood and timber were used for this structure, which was designed to reflect the various changes taking place between the two countries and to symbolize innovation

and new possibilities. This structure is the longest wooden building in the world. Glulam was used for post and beam and CLT was used for floor system (Figure 2.13).

Figure 2. 12. University of Queensland Advanced Engineering Building—GHD Auditorium[14]

Figure 2. 13. Barents House[15]

Nest We Grow is a building in Hokkaido, Japan, designed to store and prepare local fod for people in the community. In this building, the glulam column is fixed to the concrete legs, providing basic structural support. Sections of glulam beams are held by nine steel plates, four small end sections and by 40 bolts (Figure 2.14).

[14] "University of Queensland Advanced Engineering Building." GHD Auditorium. Accessed November 26, 2018.
[15] Reiulf, Ramstad. "Barents House." Accessed November 28, 2018.

Figure 2. 14. Nest We Grow / Kengo Kuma & Associates + College of Environmental Design UC Berkeley[16]

Fontanals Golf Club was constructed with laminated wood in Girona, Spain, in 2006. In some of the parts, iron columns and beams were added as supportive elements. The most impressing part of the building is the pool section, which is carried with laminated wooden beams exceeding ~20 m (Figure 2.15).

Figure 2. 15. Fontanals Golf Club (Casa del Club Golf de Fontanals), MIAS Architects, 2006[17]

Mayr-Melnhof Holz Holding Building was designed to reflect the company's expertise on wooden structures (Figure 2.16). Two 80 m length wooden framed volumes were connected with a glass transparent cube and the whole building was

[16] "Nest We Grow / Kengo Kuma & Associates + College of Environmental Design UC Berkeley " 29 Jan 2015. ArchDaily. Accessed 7 Aug 2019.
[17] https://www.plataformaarquitectura.cl/cl/02-94071/casa-del-club-golf-de-fontanals-mias-arquitectes

elevated with M-shaped supports. Due to the low cost and the easy construction of the wood, the building was constructed within 10 months. Laminated wood was used as structural element with the steel supportive elements[18].

Figure 2. 16. Mayr-Melnhof Holz Holding AG Headquarters Building, Nussmüller Architecture ZT GmbH, Graz[19]

2.2.1. General Properties of Wood Composite Material

Wood composite is a material which is produced by removing the defects of solid smaller wood pieces and making them more powerful and subjecting them to various processes of solid woods with different properties in order to increase their capacity. Wood composites become more advantageous with science and technology from natural wood.

The main step in the production of wood composite materials is the use of different applications for cutting of solid wood material. However, the cut strips are combined with glue and different pressing methods. Wood composite material produced By curing and impregnation processes is made ready for use in applications (Yılmaz, 2011).

Wood composite material having the desired size variety, color diversity and esthetic appearance is also more advantageous than the solid wood with its carrying

[18] Burçin Yılmaz. 2009 Agust. "Mayr-Melnhof Holz Holding AG Genel Merkez Binası." *Yapı* p. 62-65.
[19] "Mayr Melnhof." Accessed September 27, 2018.

capacity. It is used in different applications including both indoor and outdoor areas. Wood composite material compared to solid wood is lighter, more economical, easy to work with and is a functional and aesthetic product from which defects have been eliminated. In the case of solid wood, which has been cut in different ways, the defects are removed and combined with different types of adhesives, resulting in thinner yet more robust products, making the application lighter. The first reason for being an economic product is that the composit material does not generate much waste during both the application and production. The second reason is that it is obtained by using smaller parts for the production of larger parts.

As the size of the parts used in production becomes smaller, the wood composite material becomes more homogeneous and more useful (Aguilera, 2017). Wood composite material also can be produced in the desired size and shape allows the parts to be mounted without any processing in the application area. Damage and incorrect cut parts can easily be removed during the application. This gives workers and application owners many advantages. In addition, environmental impact is the one of the main advantages of wood composite. Adhesive materials, which are used in production of wood composites effect sustainability of the composites.

Depending on the type of glue used in the structure of the composite material, the amount of use and the properties of the solid wood strips used in the structure, the resistance of the product against fire and environmental conditions are increased. The resistance of wood composite materials to different environmental conditions is quite high. It is not affected by water and moisture for many years. Changing ambient conditions do not cause any decay on the wood composite material. Composite wood material is preferred because of its properties. The temperature, pressure, humidity, the amount and type of adhesive used in obtaining the composite material varies according to the purpose of the wood composite material. It is possible to classify the composite wood material according to the type of wooden strip sheets in different sizes and shapes used in the production and the methods used for the joining of these strips (Madison, 1999).

2.2.2. Wood Composite Material Types

Wood composite materials are classified in four different ways: panel products, molded products, inorganic-bonded products, lumber and timber products (Table 2.2)

(Maloney, 1996).

Table 2. 2. Wood Composite Materials

2.2.2.1. Panel Product

Wood panel product is produced by gathering flat or different shaped wood-based sheets together with various adhesives. Both sheets and adhesives bonded in high pressure and temperature with aditives. Properties of wood panel products changes with the character of the wood based sheet, additives and adhesives. Wood panel product may be examined in two different categories, which are structural, and non-structural panel products. The difference between structural and non-structural panel is structural panels are produced resistant to load. They used in building and construction applications. Non-structural panel products are qualified according to both durability and rigidity. Non-structural panel woods are generally important for interior design applications; like furniture, door, window and flooring. Plywood, OSB, blockboard, particleboard, fiberboard, waferboard and COM-PLY panels are the main types of wood panel products (Yu, 2017).

2.2.2.1.1. Plywood

Plywood is a type of panel product manufactured with many thin panel sheets by gluing with high pressure. Many layers are laminated and glued together with 90°C to get high strength performance. The moisture content of all thin sheets used in

production of plywood has been optimized. Appropriation in terms of moisture is a necessary step to achieve high performance of plywood. The sheet layer's placing with the grain direction identfy the thickness and properties of plywood. Heat and pressure conditions give direction of the stability of plywood more than the preferred adhesive.

Figure 2.17. Structural Plywood and Cladding Example[20]

The characteristic of face and back veneers determines the qualifications of plywood product (Maloney, 1996). The sheets placing may differ according to usage goals such as furniture design, building sheeting, engineered wood products, etc. The stability of playwood panels do not change along its width and length.

Plywood can be used as external cladding, doors, flooring, framing, joinery, interior panelling, stairs in structural applications (Figure 2.17, 2.18).

Figure 2.18. Flooring and Stair Example[21,22]

[20] Rowney, Mike. "Plywood Guide: Grades and Uses." Austim. January 15, 2018. Accessed June 18, 2019.

Softwood plywood face and back veneers are produced with softwood unlike hardwood. These products are used for structural sheeting applications and interior decoration. Hardwood plywood is generally produced for decorative applications. Both softwood and hardwood plywood products are environmentally friendy because they are reusable and renewable material. In addition, when it is compared with static stability of steel and plywood products, plywood is more powerful. This product offers many inherent qualified options with its versatility to the architects. It also protects its properties for many years (Maloney, 1996).

2.2.2.1.2. OSB

Figure 2.19. OSB Panel and Uses Example[23,24]

Oriented strand lumber (OSB) is produced by bringing wood strands together in longitudinal direction by combining them in certain directions with chemicals such as glue and wax. OSB is baked and refined timber with size of 122x244 cm. Its strength and properties are superior the other timber products (Wang, 2019). The reason is that OSB is produced in special facilities is that the need for use in electronic humidity controlled environment and in harmony with the size of self-controlled machines.

OSB panels are concordant material to humidity and water. In addition, these panels have flexible properties for decoration purposes due to their wood appearance. OSB panel is a compatible material with gluing, cuttung and nailing. Nailing process

[21] AU, Selector. "Structural Plywood – Ecoply Structural Square Edge." Selector Australia. Accessed June 18, 2019.
[22] "Plywood with Concealed Stringer." Plywood with Concealed Stringer | Just Stairs. Accessed June 18, 2019.
[23] Admin. "OSB Nedir? OSB Levha Nerelerde Kullanılır?" INSAPEDIA. December 21, 2018.
[24] "The Basics of OSB Construction." ECHOtape. May 03, 2019. Accessed April 18, 2019.

can easily done because the wood chips are arranged parallel to each other and each layer is arranged in different directions. However, the final layer and first layer should be in the same direction (Hodoušek, 2018).

The wood can be used in the form of OSB in all kinds of carpentry activities such as in many process of decoration, flooring, wall covering; in order to provide flat surface, in the production of decorations in the performing arts (due to its easy and fast machinability) and to raise or correct the flooring (Figure 2.16) (Tasdemir, 2019).

Properties of OSB can vary according to the preferring different kind of adhesives, production techniques, different shaped strands, and different conditions. Before using OSB, it should be brought to the application area and kept for two days to provide moisture balance in between the area and OSB panel. OSB panel is the most preferred product of the building sector compared to alternative materials due to its being economic property. Besides, when compared to alternative materials, wood is well ahead because of the easa of use, fast application, storage and ease of transportation. In addition to all, its color can be changed with paint and varnish (Wang, 2019).

2.2.2.1.3. Blockboard

Figure 2.20. Blockboard[25]

Blockboard is an engineered wood, which glued softwood strips are put together edge to edge among two-plywood layers under high pressure with little gaps, whichcan not be seen easily. Blockboard can be produced in different size and thickness (Figure 2.17). Blockboard is a suitable material for interior design such as doors, panels,

[25] "Wooden Block Board." Joy Bhavya Plyboard Pvt. Ltd. Accessed May 7, 2019.

shelves, tables and furniture, because interior adhesives used during the production of blockboard. Blockboard can be easily built in many applications. They can be joined with screws and nails. It is easy to carry and work due to its light weight. It is ligther than plywood product. Blockboards show high resistance to warping and breaking during its lifetime. Blockboard pieces are rigid and flexural therefore they are used in applications requiring long pieces (Nazerian, 2018).

2.2.2.1.4. Particleboard

Figure 2.21. Particleboard[26]

Particleboard is produced with product manufactured with many wood chips, which is smaller than 2 mm by gluing with urea formaldehyde. Little wood chips provide homogeous material to the particleboard. Particleboard can be produce in various thiknesses and quality but it has no fire and water resistance (Figure 2.18).In addition, its impact resistance depens on qualiy of particleboard production standarts. If the bonding process is not performed at sufficient pressure, the product becomes unstable. Particleboard, produced as an alternative to wood timber, is also economic and easy to cut and assemble. Besides, particleboard is used instead of high cost plywood (Marsavina, 2019).

2.2.2.1.5. Fiberboard

Fiberboard is a kind of wood product produced especially from wood fibers. Plywood is often mixed with chipboard but is actually composed of thin wood layers

[26] "Partical Board." Partical Board - Plywood - Products. Accessed June 28, 2019.

rather than wood particles or fibers. It is coated with a coating material to obtain an aesthetic appearance.

Fiberboard is an engineered wood product, which is produced with softwood and hardwood fibers by using resins or some organic materials. Medium density fiberboard, insulating board and hardboard are the types of fiberboard. All these types of fiberboard have different properties and production process (Tisserat, 2018).

2.2.2.1.5.1. Medium Density Fiberboard

Figure 2. 22. Medium Density Fiberboard[27]

Medium density fiberboard (MDF) is a wood-based material produced as softwood sheets by fusing wood fibers with hot-curing synthetic resin. The uniform distribution of the fibers at each point of the MDF and its very dense presence allow both sides of the plates to be machined as well as their edges without any gaps between the material particles. MDF, which has an extremely smooth and homogeneous surface, provides a very good base for either painting and decorative foil or wood coating (Figure 2.19). The same features are observed all over the MDF plates. MDF is a heavier engineered wood product due to its density compared with plywood and lumber. During cutting MDF product large amount of dust comes out. Therefore, a different area should be chosen from the application area for the cutting process (Ashori, 2009).

MDF materials, which are mainly used in bathrooms and kitchens, are also preferred in bedrooms and lounge furniture. MDF products have a long lifetime.

[27] "Yiğiter Orman Ürünleri: Kategori." Yiğiter Orman Ürünleri | Kategori. Accessed June 28, 2019.

2.2.2.1.5.2. Insulating Board- Non-Compressed Fiberboard

Figure 2. 23. Insulatıing-board[28]

Wet-process system is used during the production of insulating board. Insulating boards produced for insulation, sound deadening. There is no binder in insulating boards. Hydrogen bonds are used to keep the wood pieces of insulating board. A cold pressing procedure is applied to remove excess water within the board. Drying process is done from 120°C to 190°C to make insulating board ready for use with suitable moisture content (Figure 2.20) (Maloney, 1996).

2.2.2.1.5.3. Hardboard – Compressed Fiberboard

Figure 2. 24. Hardboard[29]

Hardboard is produced by using wood fibres, sawdust and wood chips under pressure (Figure 2.21). Wood fibres are divided with high steam and heat. During wet-

[28] "Softboard." Kattan Group. August 10, 2017. Accessed June 28, 2019.
[29] "Panel Duro." Global Sources. Accessed July 28, 2019.

process, the water is removed from the pulp under high pressure. Final process for product hardboard is dry-forming process, which dried fibers are mixed with adhesives and pressed. Hardboard is a suitable material for interior furniture design, packaging, panelling, automotive industries but it is not suitable for outside uses because it takes on water easily (Maloney, 1996). Standard, medium and oil-tempered are three different varieties of hardboard.

2.2.2.1.6. Waferboard

Waferboard has same properties with plywood but waferboard is produced with very small pieces unlike plywood has regular wood layers (Figure 2.22). Therefore, plywood has different patern and waferboard surface is blended because wood pieces are placed ramdomly with glue. Waferboard has little resistance to moisture due to being fragmented product (Maloney, 1996).

Figure 2.25. Waferboard[30]

2.2.2.2. Molded Product

Wood fiber materials and plastic fiber materials are used for production of molded product. The integration of plastic and wood fiber products provides a perfect material and high strength for automobile industry and displacing plastic products and also structural parts of buildings such as roof applications, floor applications, plate applications (Maloney, 1996).

[30] "Waferboard/OSB." M & M Lumber. Accessed May 14, 2019.

2.2.2.3. Inorganic-Bonded Product

Flakes, wood wool, small pieces, fibers mixed with gypsum, portland cement which are inorganic materials and allow production of inorganic bonded product (Maloney, 1996).

2.2.2.4. Lumber and Timber Product

Lumber and timber both are wood-based product. Their names can be used interchangeably, but there are some differences between lumber and timber. Timber is used for untreated wood pieces. Lumber is preferred to be used in treated wood pieces. Also drying process is applied on lumber product, which is usually used for furniture product (Maloney, 1996).

2.2.2.4.1. Laminated Veneer Lumber

In Laminated Veneer Lumber (LVL) production, long and flat wood parts are preferred. It is possible to obtain products of the desired size. However, in the production of large parts, the amount of waste product is high as flat and long pieces are preferred. Further information on LVL production is available in part 4.3.4.

2.2.2.4.2. Parallel Strand Lumber

In order to obtain Parallel Strand Lumber (PSL), wooden pieces are used as strips. Almost all of the tree can be used for PSL production. Therefore, the amount of waste material released is very low. Compared to timber or glulam, it has a perfect appearance. Because the parts used are in the form of thin strips, the defects on the tree are not reflected in the PSL product. Striped wood parts are pressed under high pressure. It can be preferred for applications with wide openings. More information is included in 4.3.3.

2.2.2.4.3. Oriented Strand Lumber

Oriented Strand Lumber (OSL) products are obtained by combining the long pieces of wood in parallel with high temperature and pressure. It is a solid product, which can be used in furniture applications in residential applications, indoor and outdoor applications. In OSL production, fast growing trees are preferred. It is a product with high carrying capacity .

CHAPTER 3

USE OF WOODEN MATERIALS IN HOUSING PRODUCTION

Today, the construction sector is developing rapidly. Developing technology offers various material options such as metal, aluminum and concrete for the construction industry. However, the development of production technology has negative consequences for the development of the environment as well as its positive aspects. Wood is always preferred because of its easy applicability, ease of procurement, availability in different applications, applicability of desired designs, which is also a durable material. It is used as an efficient material in many areas such as carrier, joinery, facade cladding and insulation.

Wood material, a renewable material, has a high degree of thermal, acoustic, mechanical, static and aesthetic performance. This allows wood to be an alternative to emerging technologies because of its potential for environmental problems (Madison, 1999).

Wood material contributes positively to comfortable living, ecological solutions and to the environment. It establishes a healthy relationship between human and nature. In this way, it has become a preferred modern material in the wooden housing production sector which has been used in many areas from past to present.

Figure 3. 1. Strickland-Ferris Residence, USA, 2008[31].

[31] Gaete, Javier. "Strickland-Ferris Residence / Frank Harmon Architect." ArchDaily. June 17, 2013. Accessed August 07, 2019.

Strickland-Ferris Residence was constructed in Raleigh, N.C., United States in 2008 by the architect Frank Harmon. The owner of the house wanted to feel as if she is living in the trees. So that, the architect had created wide openings with a butterfly-shaped roof to meet the northern view. Laminated wood, parallel strand lumber, was used in both columns and beams as the structure of the house[32] (Figure 3.1).

Figure 3. 2. Streeter House, Deephaven, Minnesota, David Salmela, 2006[33].

In Streeter House, laminated wood, black concrete block, SIP panels, slatted wood screens and recycled cypress combination was used in to create a unique structure, which was designed by architect David Salmela and Carly Coulson[34] (Figure 3.2).

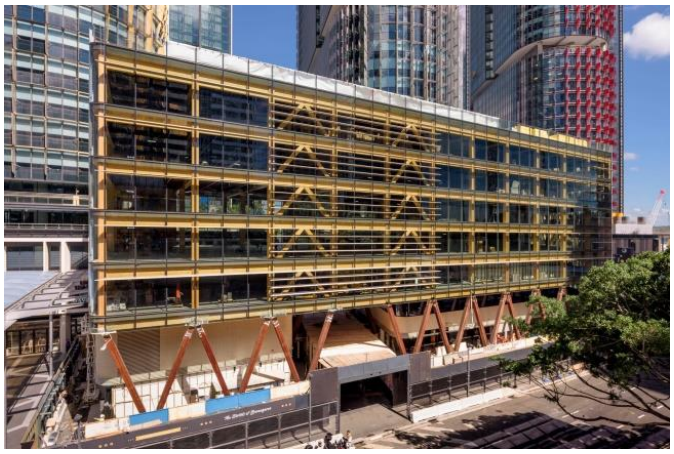


Figure 3. 3. International House Sydney[35]

[32] Archdaily. Accessed May 19, 2019. https://www.archdaily.com/387708/strickland-ferris-residence-frank-harmon-architect-pa
[33] "25 Iconic Minnesota Homes." Midwest Home. July 10, 2018. Accessed December 27, 2018.
[34] Burçin Yılmaz. 2007 April. “Streeter Evi.” *Yapı* p.62-67.
[35] "International House Sydney Wins Two Major International Design Awards." Make It Wood. Accessed April 04, 2019.

The project is completely constructed using CLT panels and glulam, including floors, pillars, walls, roof, elevator cavities, exit stairs and support slots (Figure 3.3).

Figure 3. 4. Livinhome / Woodview Mews, London, UK, 2015[36].

The building was designed by the architect Geraghty Taylor in London to meet the needs of different kinds of habitants; from one-bedroom house up to a six-bedroomed house. While the interior space is flexible in plan layout, the outer space signifies versions of similar facades. The façade was covered with high-density laminate timber panels, which are highly resistant to UV radiation and atmospheric conditions[37] (Figure 3.4).

3.1. Importance of Housing Production with Wooden Building Material

Wood is the only renewable material among building materials. Thanks to its static and thermal properties, it is the building material of the present and future in housing production. Easy manufacturing and production techniques, ease of transportation and installation, light and harmonious material production of wood in the production of housing increases the choice. Being a renewable material provides a great advantage in its use. Damage caused during application can be easily removed without waste of material or the damaged part can be used in different applications by removing the defects (Madison, 1999).

[36] "Livinhome / Woodview Mews." Geraghty Taylor. Accessed December 17, 2018.
[37] Archdaily. Accessed May 20, 2019. https://www.archdaily.com/catalog/us/products/6999/wood-cladding-facade-parklex.

Wood material can be used in high performance in various climates. The wood material used in the housing production provides the user with very healthy environmental conditions due to the acoustic performance and mechanical performance of the thermal performance. It prevents the greenhouse effect that may occur in the wooden housing, which has the ability to absorb harmful substances in the environment (Aguilera & Davim, 2017).

Even wood material that is strengthened with protective chemicals has a long-term durability life. In addition to its features in terms of human and environmental health, wood materials used in housing production show high fire resistance. It maintains its static strength even at high temperatures for a long time (Aguilera & Davim, 2017).

3.1.1. Contribution to Sustainability of Nature's Ecological Balance

Nowadays, with the increase in the population, the need for housing has emerged. The rapidly growing population has led to the development and increase in the construction sector. However, the construction sector is one of the main reasons for the increase of ecological problems. Increasing environmental problems are being produced in the construction sector worldwide. In addition to developing technology, the use of natural materials and recyclable materials against environmental problems are also important.

Wood is a non-recyclable material that can unclear without damaging the nature. Wood, which is the only renewable material, is one of the most positive steps for the environment.

Wood is a material that can grow and sustain itself in nature. A small amount of energy is consumed to make the wood usable in applications, and its production is simpler compared to other building materials. In addition, the waste material produced during production is both small and can be used in different applications (Winandy, 1994).

The high heat insulation provided by the wood material used in the construction of housing minimizes the amount of energy to be spent for heating. Low energy consumption provides a positive effect on environmental pollution. In addition to low energy consumption, it is an environmentally friendly material that does not cause air

pollution and water pollution. Wood is a material that can be used without being processed by any chemical (Kettunen, 2006).

3.1.2. Contribution to the Protection of Human Health

Most of our time is spent in closed areas during the day. For this reason, the materials that are used in our environment directly affect our health. When different structural materials are evaluated, wood material that makes positive contributions to human health comes forward. Wooden materials to be used in the production of modern houses are combined with chemical materials in a controlled manner. This prevents a threat to human health. Wood material does not attract dust particles in the area where it is used, but also absorbs the moisture in the environment and ensures the regulation of the humidity in the environment. With its heat conductivity and breathability, wood provides optimum comfort for human health (Dinwoodie, 1996b).

Changes in climatic conditions do not damage the wood protected by different methods. This is necessary for the continuity of a comfortable life. In addition, wood materials used in indoors provide improvement for human psychology. Researches in different countries has shown that wood reduces stress and thus human health is positively affected (Melo, Stangerlin, Santana, & Pedrosa, 2014) .

The wooden material used in the production of contemporary housing not only provides comfort in the interior, but also creates an environmentally compatible material and does not create harmful waste in its production. In this way, the quality of life is increasing both in inside and outside.

3.1.3. Economic Importance

Wood is a lightweight construction material that is easy to transport and install. Ease of installation reduces the number of workers required for applications and the working time of workers. The number of workers, the low working hours and the ease of transport considerably reduce the total construction cost. In addition, the thin parts in the application, provide the required comfort and makes the application lightweight. The lightness of the houses positively affects the basic size, the amount of openings and the direct costs (Maloney, 1996).

The amount of energy required to make wood material usable in housing production is less than other building materials. Since the wood used in housing production has the necessary insulation properties, it does not consume much energy during the usage period of the space. This saves a great deal of energy.

The fact that the wood is not affected by climate conditions and can be applied quickly is very important for the production of housing under any circumstances. Produced housing is more resistant to fire and earthquake compared to other building materials. In addition, the lifetime of the wood is quite long. The time and cost required for maintenance and repair are quite low.

3.2. The Benefits of Wood Material in Housing Production

Wood is one of the most preferred materials for residential use because of its features. Natural and warm material has been preferred from past to present. In addition to being healthy in its applications, it offers an aesthetic appearance and workability, reusability, speed and reverse probability during the application, cost advantage, earthquake safety and high life expectancy.

3.2.1. Workability

Wood material is a building material that can be produced in many different textures. Since ancient times, wood materials are preferred to meet the needs of people, especially for housing. The fact that it is a light material makes it easy to assemble, even with old methods. With the contribution of today's technology, raw trees are cut easily and ready for use in a short period. The dimensions and the number to be produced are determined according to the dimensions of the parts designed for the applications. Produced parts are easily combined in the application area. Due to easy connection details, lightweight materials and easy repair of the damages that occur during application, applications are completed with a small number of workers and in a short time (Kettunen, 2006).

3.2.2. Reusability

The pieces of waste wood produced during the production of wooden construction materials, which are a natural building material, can be converted into new products and used in different applications. Waste pieces can be converted into a product in new applications or can be used in any project and damaged wooden parts can be used for maintenance. This ensures that the life of the wood is prolonged, which allows many trees to live. The fact that the wood is a reusable material provides energy savings. Repeated cost formation is prevented. Reuse of the wood material, which prevents the damage to the environment, prevents the environmental pollution (Ramage et al., 2017b).

3.2.3. Speed and Recycling in Construction Process

Wood is a natural and lightweight building material. The parts to be used in the applications are produced according to previously designed details and dimensions. Due to the fact that it is easy to apply, it provides easy installation for workers. Errors that can occur during the manufacturing process can be easily removed. It is installed in a short time with a small number of workers (Madison, 1999) .

3.2.4. Cost

Thanks to the superior material properties of the wood, it has a cost advantage compared to other building elements. The cost of labor is low because the pieces were prepared ready for installation in the factory, which enables to complete construction in a short time on site. A feature that reduces the cost of workers of the wood material is that it is lightweight character. Besides, lightweight material reduces transport costs and provides easy installation and transportation without the need for large scaffolding and cranes. Wood material not only provides cost advantages during application, but also superior insulation properties reduce the amount of energy consumed for heating and cooling during use. Repair and reuse of damaged wooden parts keeps the maintenance cost low (Dinwoodie, 1996b).

3.2.5. Earthquake Reliability

Structures constructed with wooden materials are lighter than those built using reinforced concrete and steel materials. Considering the earthquake load to be applied to the building during the earthquake, the structure becomes lighter. In addition to being light, wood is a material with high tensile and pressure resistance. However, in order to prevent major damage to the structure during an earthquake, the connection points must be constructed carefully and intentively. Any damage to be caused by lightweight parts does not cause great damage. In addition, the damage can be easily removed after the earthquake (Karayilmazlar, Çabuk, Tümen, & Atmaca, 2008).

3.2.6. Lifetime

Wood material is resistant to environmental conditions. By using different chemical products, the durability of the compound can be increased. Besides, its resistance to fire and earthquakes makes the wood more durable and outlasting than other materials. The only material that can be renewed is the damage to the wood and the aesthetic appearance can be restored. However, the wood material has many enemies such as fungi and bacteria. If the necessary precautions are not taken before the application and the maintenance of the wooden material is not done periodically than the enemies will give harm to the wood. For this reason, the amount of drying is important to prevent damage of the wood. The drying process, which is adjusted according to the humidity and temperature of the environment, ensures the long life of the wood material. Only the drying process is not enough. In addition to the drying process, protective paints, varnishes or some chemicals that do not threaten human health should be used (Winandy, 1994).

CHAPTER 4

USE OF LAMINATED WOOD IN HOUSING PRODUCTION

Laminated wood material has many uses in architecture. The ease of use, service life and the possibility of production of small details provide many different possibilities for architecture.

The wood material laminated with advanced technology performs better than natural wood. Laminated wood performs better, as well as longer. It is more resistant to humidity and microorganisms, and it is more resistant to fire thanks to the adhesives and different methods used in its production. In this way, it has new usage areas. During the process of production of laminated timber and during its use, human, environmental health and comfort conditions are prioritized. Its physical properties support the comfort needs, sensitivity to human health and environmental health.

Laminated wood offers the possibility to design in desired dimensions.

Figure 4. 1. Irmak High School, Caddebostan, İstanbul[38]

Irmak High School Building is an education building placed near a primary school. The building was designed to be constructed in two summer holidays, as it is right next to an existing primary school and cannot be built during school year. The

[38] Nsmh. NSMH. Accessed December 17, 2018.

construction methods were evaluated according to this assumption. It was designed in 1998 and it was built up in between 1998 and 1999 over an area of 7,270 m^2 (Figure 4.1). This building is a composition of wood, steel and concrete, which used the site as a production place in order to complete the building in a short time. Thus, the separation of macrostructure and fine structure has disappeared. In addition, the architect of the building, Nevzat Sayın, had mentioned that they were able to industrialize traditional building methods, and they have turned the construction site to an installation site[39].

4.1. Material Properties

Structural elements are laminated to make them stronger than the properties of natural wood. Solid, durable and aesthetically structured laminated wood products carry the improved properties of natural wood materials. The properties of laminated wood, which is a homogeneous material, were examined in detail under four subheadings.

4.1.1. Energy Efficiency

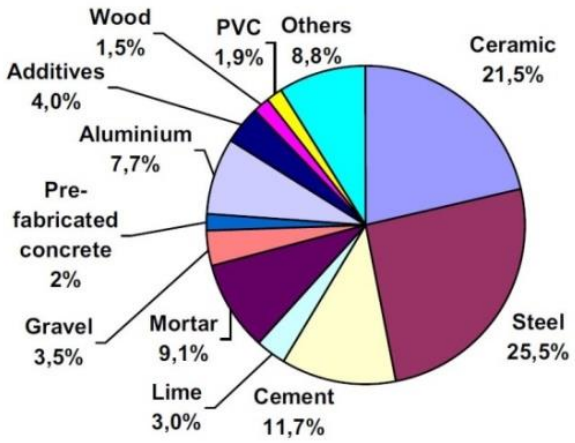


Figure 4. 2.Contribution of primary energy demand for the manufacture of the materials needed in the construction of 1 m^2[,40]

Energy efficiency depends not only on the use of natural resources during application, but also on the regularity of the amount of energy used to ensure that the material used works correctly throughout the lifetime of the structure. In order to

[39] Accessed 19, May 2019. http://www.nsmh.com/proje_detay.asp?lang=tr&ID=18
[40] Zabalza Bribián etal., 2011

increase energy efficiency, it is necessary to consume less energy during production and use. Besides, to produce energy with the use of renewable materials is as important as the amount of energy produced and consumed.

Raw materials, which cause high-energy consumption, are used in the construction sector. Choosing materials with high-energy efficiency is very important during and after building production. In addition to material selection, heating, ventilation and the amount of energy required to fill the air are also very important (Zabalza Bribián, Valero Capilla, & Aranda Usón, 2011).

According to the researches, the amount of energy required for the production of materials needed for 1 m^2 construction area is shown in Figure 4.2. When the graph is examined, wood is the material that requires minimum energy consumption from all the materials used for construction applications. This graph also shows that the use of wood is the most efficient option.

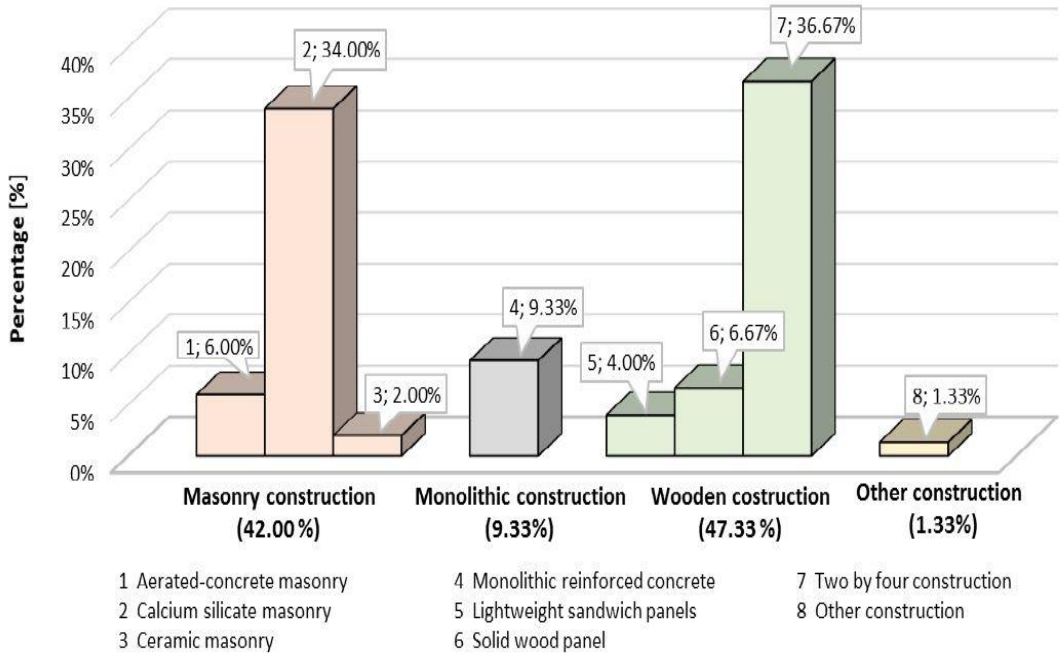


Figure 4. 3. Percentage of Building Materials in Energy Efficient Buildings[41]

Figure 4.3 shows the energy efficiency percentages of the materials used as the outer cladding element. According to the figure, it is seen that the veneer elements using wood material have a higher percentage in construction.

[41] Kraus, 2014.

The structures produced with laminated wood materials are thus superior in their energy efficiency. The amount of energy used for heating in residential areas covers the majority of energy consumption. There is a need for qualified designs to ensure the efficiency of the structures and to eliminate the heat loss that may occur during the usage period of the structure and to regulate the air flow.

4.1.2. Earthquake Safety

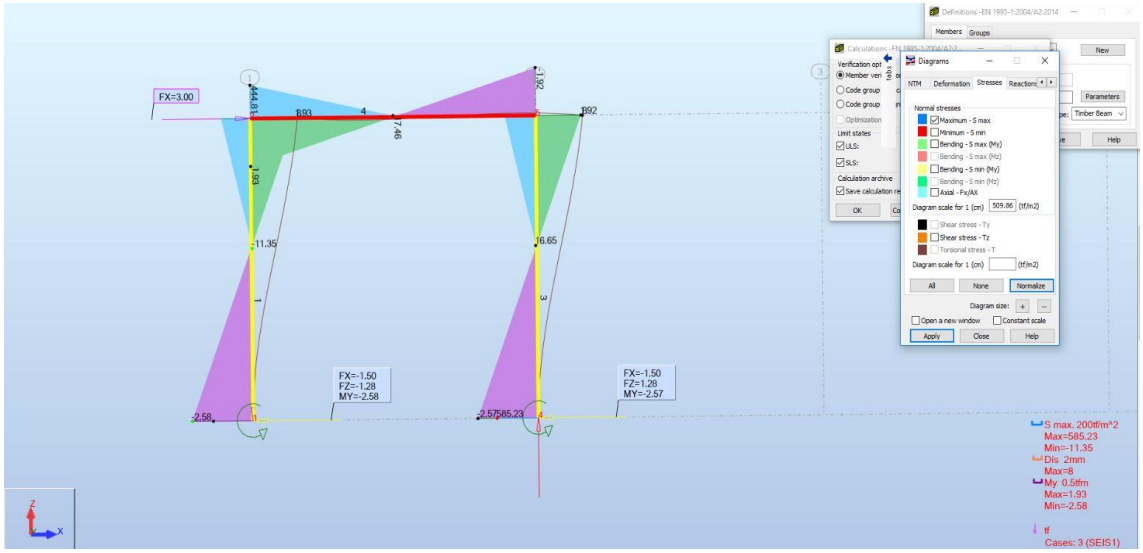


Figure 4. 4. Structural Analysis of Wood

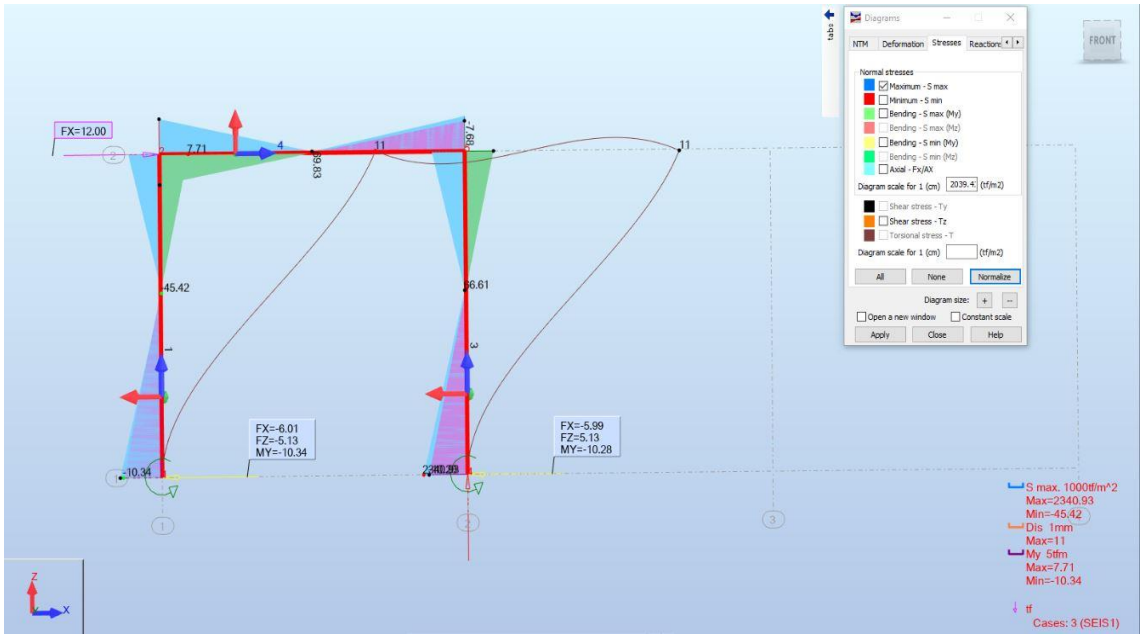


Figure 4. 5. Structural Analysis of C25 Concrete

Static behavior was observed by applying seismic load on 30x30 wood, C25 concrete and 30x30 5 mm steel. The models are shaped as two columns and one beam. 3 tons of seismic load was applied to wood and steel. 12 tons of seismic load was applied to the concrete model in proportion to its weight. According to the results, it was observed that the tensile strength of the wood material in the cross section was M_{max} = 583.23 tone/m^2, the tensile strength of the concrete was M_{max} = 2340.93 tone/m^2, the tensile strength of the steel was M_{max} = 4716.05 tone/m^2. In other words, the durability of the wood material is higher than other materials (Figure 4.4, 4.5, 4.6).

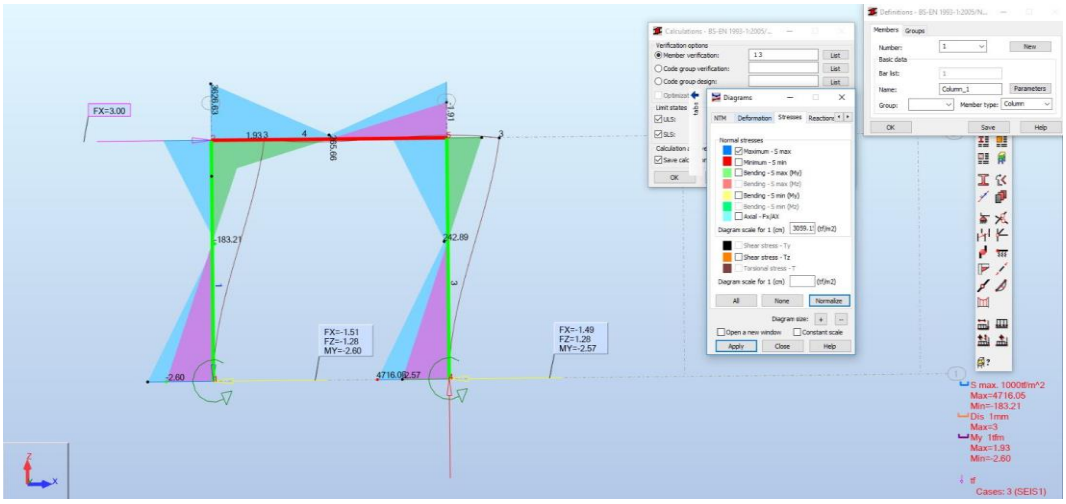


Figure 4. 6. Structural Analysis of Steel

Wood is more durable and advantageous against earthquakes due to its flexible, durable and lightweight material character compared to other building materials. The weight of the building will cause the sections to thicken, and the earthquake force will have more impact on the building. The fact that the building is made of wood makes the building light. Therefore, the loads circulating within the building are also small. Thanks to the connection elements that provide the combination of applications used in the wooden skeleton system, the earthquake load is easily distributed and absorbed. Horizontal and vertical elements bearing the structure must be connected to each other correctly. Moreover, due to the flexibility of the wood material, it moves in the same direction of the tidal waves during an earthquake. This ensures that wood is a more durable material at the time of the earthquake (Bayülke, 2001).

The construction of the building from lightweight materials does not ensure that the building is completely reliable against an earthquake. At the same time, the material must also be robust and durable. Since laminated wood is made by combining

different or same wood pieces with various adhesives under high pressure, wood type selected for the lamination of wood pieces that are obtained by combining small parts free of defects, glue properties used and pressure applied on them is very important for the end product strength (Perçin, Özbay, & Ordu, 2009).

In this case, the wood material used is becoming more durable and long lasting. When the solid wood and laminated wood were evaluated together, it was observed that the laminated wood parts were more resistant to earthquakes (Efe & Kasal, 2007). If there is no mistake in the joints, the wooden building will not turn into a ruined building, even if it is damaged during the earthquake.

4.1.3. Time Advantage

As a result of the static calculations for wooden structures, the sections of the parts to be used in the construction, the details of the joints and how many pieces are to be used are determined. The pieces to be used are produced in accordance with the determined features and shapes before the construction application starts. These elements produced during construction are combined in different methods like a toy blocks. Problems that occur during the construction or transportation phase can be easily solved (Zmijewki & Wojtowicz-Jankowska, 2017). Since wood is a light material, it is easy to transport the laminated parts to the site, which are produced before construction. More pieces can be transported at one time. This helps to reduce transportation time. In addition, a light material allows easy handling and installation without the need for large cranes during construction. The elements that were produced previously for the construction of the house creates time advantage for the construction. With a small number of workers, it is impossible to construct a concrete structure in a shorter time (Zmijewki & Wojtowicz-Jankowska, 2017).

4.1.4. Fire Safety

Fire resistance is an important feature for all buildings. Therefore, various precautions are taken in buildings to increase fire resistance. Material selection is one of the measures to be taken, and wood materials are the leading materials. Wood, which is a flammable material, provides resistance against fire while burning. It provides resistance to fire as it begins to burn from the wood surface, which is a combustible

material. Cellulose and lignin in the structure of wood are not flammable substances (Ramage et al., 2017b). The low thermal conductivity of the wood material causes the wood to burn slowly in case of any fire.

Wood protects its shape for a long time during the fire. Wood material that starts to burn from the surface creates carbonation on the surface during the burning period. This carbonization creates carbon layer which prevents the passage of oxygen from the wood surface. This also retards the burning of the inner surface of the wood. The fire resistance of the wooden structures designed today is regulated between 90-120 min (Zmijewki & Wojtowicz-Jankowska, 2017). Late crossing of the inner section allows the wood to maintain its strength for a long time. Since steel material has high thermal conductivity and expansion coefficient compared to wood, it easily loses its shape in a short time and causes the building to collapse. For this reason, in the applications where steel is used to pass large openings, the steel material is covered with wood material in order to show the long-term strength of the structural system (Denizli-Tankut, Smith, Smith, & Tankut, 2004).

Laminated timber material retards the ignition of the internal parts of the laminated timber due to the properties of adhesives used in bonding. In addition, the fire resistance of the wood material increases as the cross-sectional size used increases.

4.1.5. Environment

There are many environmental problems, such as global warming, greenhouse gas and sustainability, that have become important in our daily lives, and the people are looking for solutions to these problems. When these problems are examined, the main suggestions that can be produced are concentrated on the material. Building materials are developed with the support of technology should be used for a healthier future and environment. The construction sector, which uses approximately 40% of energy consumption, increases the importance of this situation (Escrivá-Escrivá, Santamaria-Orts, & Mugarra-Llopis, 2012).

Wood absorbs carbon dioxide during tree growth and continues when the carbon dioxide absorption process becomes lumber and laminated material. It prevents greenhouse gas from getting into the atmosphere. However, it is necessary to be careful when selecting chemicals and adhesives to be used in laminated timber (Karaaslan,

Abar, & Çamkaya, 2017). Materials that cause minimal harm to nature and human health should be used.

The emissions generated during the production and use of construction materials are given in the Table 4.1. This table shows that the wood material has less CO_2 emission than the concrete and steel (Pacheco-Torres et al., 2014). This means that wood is less harmful to the environment. Wood is a material that can be renewed and blended in nature, and also has the ability to retain greenhouse gas.

The amount of energy used during the use and production of wood materials is less than that of other materials. Lower energy consumption results in less environmental pollution. Waste materials produced during the production of laminated wood do not cause any harm to the nature and can be reused or used as fuel at any time (Markström, Sandberg, Fredriksson, Kuzman, & Bystedt, 2018). Today, the increase in the use of laminated wood materials reduces the consumption of current energy resources, and therefore decreases the damage to the environment by energy consumption.

Table 4. 1. Emissions Produced by Construction Materials Used in Work Units[42]

Materials	**Density (kg/m^3)**	**Embodied energy (MJ/kg)**	**Carbon data (kg CO_2/kg)**	**Unit**	**Carbon data (kg CO_2/unit)**
Steel	7850.00	3,81	2,82	kg	2,82
Concrete	2340.00	1,06	0,1	m^3	231,83
Mortar (M5)	1650.00	1,58	0,15	m^3	242,91
Cement	1880.00	7,34	0,68	m^3	1284,04
Wood (beech)	510.00	3,04	0,09	m^3	46,04
Baked clay	850.00	4,29	0,32	m.u.	528,27
Sand	1800.00	0,12	0,01	m^3	11,91
Plaster	1200.00	3,34	0,3	m^3	356,38
PVC	1380.00	80,34	11,86	ml	16,05
Expanded polystyrene	24.00	101,08	14,92	m^2	3,58
Aluminum	2700.00	160,34	23,55	m^2	317,86
Glass	2490.00	19,34	1,15	m^2	11,41
Bitumen	2400.00	10,07	1,47	m^2	3,54

[42] Pacheco-Torres, Jadraque, Roldán-Fontana, & Ordóñez, 2014

4.1.6. Health

Nearly all of our time is spent in closed areas such as our home and work place. For this reason, the selection of materials is very important in the construction of the structures that we live in. The requirements of the users should be determined by the designer, and in this respect, structures should be designed to provide optimum life comfort for the users. It is also important that the structure, designed for the life comfort of the user, should be in harmony with nature. This can only be possible with a correct material selection. In the selection of materials, waste materials that are released during the production period of the material and the toxic substances released should be considered.Wood, which is a natural material, has a positive effect on human health, both physiologically and psychologically. In order to ensure the comfort of the place, fresh air must be constantly present in the environment (Editörden, 2004). The amount of carbon dioxide produced by wood is low and does not generate solid waste. The use of wood as a warm, breathing and living material provides many benefits for the health of people. Wood material can be used as furniture element, as a covering element and as a carrier element. Laminated products obtained without using synthetic products and without exceeding formaldehyde emission limit values provide indoor air comfort, thanks to the breathability of wood. It is important that the heat exchange made with the external environment is balanced, as well as the presence of oxygen in the air, to ensure the comfort of life.

Thermal conductivity varies depending on the humidity in the environment, temperature difference between them and air movement(Zmijewki & Wojtowicz-Jankowska, 2017) . Laminated wood material is in great harmony with the environment. In this way, it does not harm the environment and living creatures. Laminated wood is not only in the field of use, but also in the production phase and during maintenance. It protects human health without disturbing the ecological balance and damaging the relationship between human and nature.

4.2. Laminated Construction Technology

The use of single and large parts due to many defects in the structure of solid wood material such as decay, cracks, cavities created by insects, environmental

conditions and defects occurring on the wood is not suitable in terms of both economics and robustness (Karayilmazlar et al., 2008). It is difficult to find a raw product with few defects and the cost is quite high. In addition, the use of solid material as a single piece causes more waste in the production of curved elements and in this curved form, the cutting process causes the cutting of fibers diagonally to decrease the resistance of wood.

The environmental effects of solid wood material and its negative properties can be eliminated, and better performance products can be obtained when they are available. The emergence of new technologies in woodworking and wood-based material production has turned lumber into a high-tech material. With the emerging technologies eliminating the existing restrictions, timber has become as important as important as steel and concrete (Kwon, Shin, Ayrilmis, & Han, 2014).

The design features of the new wood-based products allow the wood structures to be higher, pass larger openings and take more forms than ever before. Solid wood and coatings are not suitable for construction applications because of their lower quality. Different types of water-resistant and strong adhesives are made of laminated wood elements and sheets, making them more durable as a result. The lamination technique is one of the technologies that provide ease in eliminating the existing defects and in processing and shaping the wood. This technology consists of combining two or more timbers with a waterproof adhesive, which results in a stronger product than the timber itself; thus the wood used becomes a more powerful element in construction applications.The application of the laminated method allows the efficient use of the wood material, the elimination of the defects in the structure and the production of the desired shapes and sizes. This creates different potentials for designers. Thanks to the laminated application, it is possible to produce the desired forms with higher quality. The final product can reach up to 40 meters in length while it can have a long, straight or desired curve (Zmijewki & Wojtowicz-Jankowska, 2017).

The high pressure and tensile strength of laminated wood allows structures to be higher than usual and reach more than six floors. Nowadays, such buildings have been built in many parts of the world and currently the University of British Columbia in Vancouver, Canada, has the highest elevation of eighteen floors with a height of 53 meters (Zmijewki & Wojtowicz-Jankowska, 2017).

In recent years, traditional wooden structures using solid timber with the use of wooden materials have also been developed dynamically. Engineered wood performs

better than steel and reinforced concrete with its insulation performance and fire resistance performance.

Lamination method allows obtaining longer and larger products than short and small parts, thereby reducing the waste rate. Reduction of the fire rate and the obtaining of the desired size product from small parts directly affects the cost positively (Altınok, Özalp, Kızılırmak, & Yeşil, 2009). Products with different strengths, high aesthetic appearance, and desired shape and size are obtained, and there are many methods for this. Finger joint process and lamination techniques, consisting of many sub-units, allow us to obtain these products.

4.2.1. Finger Jointed Wood Products

When laminated wooden parts are used parallel to each other, they show high strength. However, it is not always easy to combine laminated wood parts together with adhesives to be used in applications. In such cases, finger joint process is applied. This process is applied in various structural forms. The geometries at the end of the wood vary depending on the intended use of the end product and the capacity to transmit the load. If the strength of the applications is not significant; that is, a non-structural connection, then the finger joints are short, which is intended to eliminate natural defects. Flooring elements, finishing applications, furniture production, window and door frames are some of usage applications. The beam can be used in applications as a carrier element (Jokerst & Laboratory, 1981).

The design of the finger components determines the intended purpose. As a result of many studies, the elements forming the geometry must be very thin to achieve maximum strength (Figure 4.7). An increase in thickness causes a decrease in strength. At the same time, the slope between the ends is one of the factors affecting the strength. Decrease in gradient results in strength. The finger components must be firmly seated without any gaps. In the finger joint procedure, the vertical joints are more powerful than the horizontal joints, and their performance against stress is stronger. The process of joining the joints starts with material selection and preparation, forming a common profile, application of glue, mounting of joints and ends with curing of the adhesive. This sorting may vary according to the product to be used, but all stages are important for all quality products (Jokerst & Laboratory, 1981).

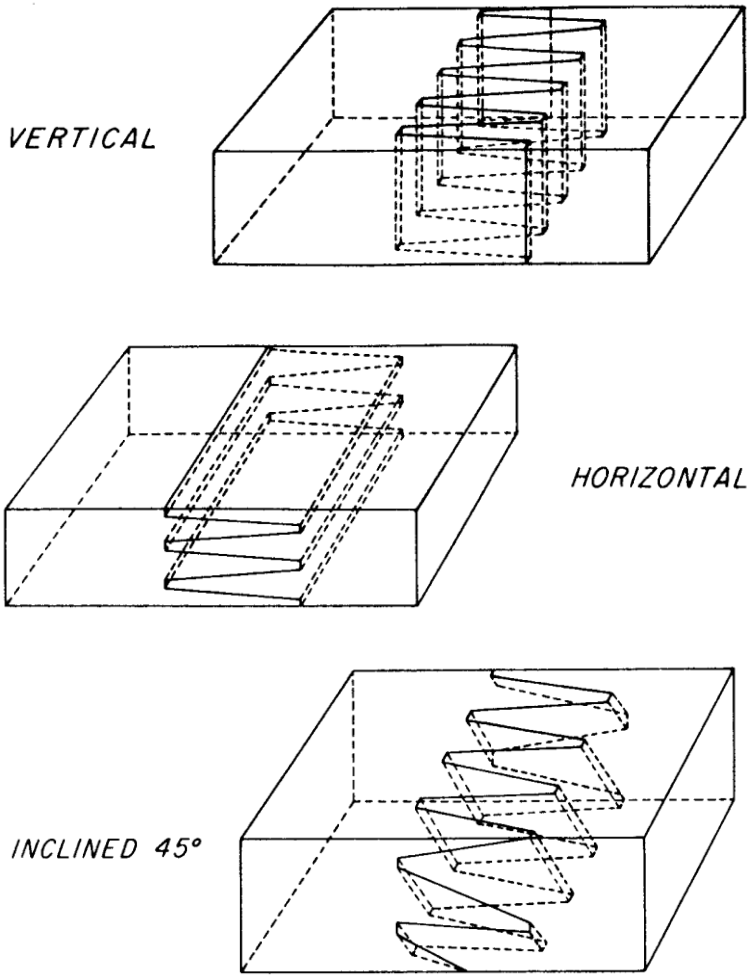


Figure 4.7. Finger Joints Orientations[43]

4.2.2. Laminating Process

The laminating process is the process of making two or more wood elements into a single element by means of heat and pressure with the help of chemicals or various glues in parallel or perpendicular to each other. It is a process that is applied in order to make the wooden material more solid and to reshape the desired shape (Altınok et al., 2009). Laminated wood material is used in many different applications. The laminating process can be made with many different types of wood by using different numbers and sizes, and can be obtained with the desired thickness. About 30% of solid wood is wasted during the laminating process. However, the resulting waste can be used for different laminations or as fuel. Also, in applications where solid wood is used, the sections will be thicker than laminated wood, and it will be difficult to obtain perfect

[43] Jokerst & Laboratory, 1981

solid wood, so there is more wasting of trees in applications. For building applications, structural elements such as columns, beams, arches, scissors, as well as coating elements, furniture and parquet, which provide aesthetic appereance, are used. The fact that the product can be produced with the desired shape and size by the laminating process ensures the emergence of original designs. Parts and details to be used in the designs can be produced one by one.

The selected tree species is important in obtaining laminated products. The selected type of tree should be lightweight in applications so that there is no overload on the structural elements in the applications, and it will be easy to assemble and easy to transport. At the same time, the mechanical strength of the tree selected for the laminated elements, which are used as structural elements, should be high. The glue used in the applications should not be multi-grained and should be resin-free. The surface to be glued must be clean and smooth. In order for the parts to stick together properly, the applied glue thickness must be sufficient. The resistance of laminated product affects the wood parts used in the structure. If the wood parts have few cracks, rotting and flaws, the resulting laminated product is very strong. In addition, as the knot diameter of the wooden part increases, the resistance of the laminated product decreases. The laminated product must be obtained by combining an odd number of parts, such as 3 or 5, in order to be efficient. The lower and upper layers balance each other in the tensile and bending resistance while the remaining part is responsible for neutralizing both sides.

The moisture content of the wood material to be laminated is very important. If the product is to be used outdoors, this ratio should not exceed 16-19% and if the product is to be used indoors (dry), it should not exceed 16% (Çelik & Yazgan, 2007). The humidity difference between the elements to form the laminated product should not be more than 5% according to ANSI A 190.1 and 4% according to Pr EN 386. If the humidity difference between the pieces is above these ratios, a decrease in the humidity ratios occurs (Perçin et al., 2009). This results in cracks on the laminated product when the stresses on the parts exceed the tensile strength in the fibers. The natural drying method for drying the wooden parts is to be used, and the technical drying method is applied to ensure the desired moisture content. The dried pieces must be stored in a storage equivalent to the ambient conditions in which the laminated wood will be produced.

The temperature of the space to be used during the laminate process should not be less than 15°C and ambient humidity should not be less than 30%. The wood pieces, which are combined with the help of phenolic-based adhesives, should be kept under pressure for about at least 24 hours. If the laminate is to be made with aminoplastic-based adhesives, the parts should be kept under pressure for approximately 72 hours. Cracks, detachments and deteriorations may occur in laminated products that are cut before the expiry of the period. For this reason, the time during which wood pieces are kept under pressure is important. During use and during the cutting process of the laminated product, the pieces of wood should be placed in a staggered manner so that the parts are not separated. In addition, it is necessary to pay attention to the annual ring arrangement of the wooden parts that is used to prevent damage to the laminated product and to avoid damage during use (Perçin, 2009).

4.3. Lamination Techniques

Laminated process is used for the purpose of obtaining a final stronger product and without any defects. The final laminated product, which can be obtained by various techniques, has the desired size, color and aesthetic image.

The common feature of the techniques used is the moisture content of the laminated wood material to be produced. The moisture difference between the layers that form the laminate product is also common. This difference should not exceed 4% according to TS EN 386 and DIN 68140 (Perçin et al., 2009). The moisture content of the layers to be used in the production is determined according to the environment in which the final product will be used. In a closed dry environment, the moisture content of the material should not exceed 16%, and the humidity of the material should not exceed 16-19% in the open air. In the humid air, the moisture content of the material is calculated by the correction factor. When lamination is done outside of these standards, cracking may occur within the laminated product due to the tensile strength between the fibers depending on the space and gluing method used (Çelik & Yazgan, 2007).

The position of the annual rings is important in the regulation of the layers to be laminated. The structure, pressing time and pressure of the wood to be used in this process, the technical properties of the selected glue significantly affect the adhesion strength of the layers. Different wood types, variable number of layers, different sizes,

shapes and thicknesses can be applied in the laminated process. The obtained laminated wood material can be formed from different thickness and color layers and has high aesthetic value. If the laminated wood element to be obtained consists of different structure layers, the press pressure is determined according to the soft layer (Sullivan, Miller, & Gupta, 2018).

The obtained laminated products can be used in building applications, bridge applications and industrial applications. Thanks to its resistance to fire, to its heat insulation, sound insulation properties and to its ecological character, wood materials are preferred for construction applications. The installation time of laminated products is faster than reinforced concrete and the number of personnel working during the manufacturing period is also low. The amount of energy required for the application is less than 40% of the concrete and 50% of the steel. It is also 14 times durable from steel and 4 times lighter than concrete. This means that the shipping cost is lower (Zmijewki & Wojtowicz-Jankowska, 2017).

The laminated elements are named in different ways according to the self-forming layer thicknesses, the types of wood used and the adhesive products. The most widely used types of laminated wood are: laminated veneer lumber (LVL), glued laminated timber (glulam), cross laminated timber (CLT) and parallel strand timber (PSL).

4.3.1. Cross Laminated Timber

CLT is a structural wood product which is obtained by gluing three, five or seven different wood layers in a symmetrical manner (usually at a 90 degree angle). The thickness of the layers varies between 6-45 mm. It is possible to produce CLT in desired sizes. Wood is a hard, light, high strength construction material that can be used as a floor application. It is a material that is resistant to both vertical and lateral loads. It can be used in a building's roof, wall or for floor applications. This light material is preferred for medium and high-rise buildings. Besides, many designers prefer to use CLT due to its cost, environmental performance and for its aesthetics value. This feature of CLT, which is a material with high thermal performance and energy efficient feature, is directly proportional to the panel thickness used. Thermal insulation is stronger in applications where thicker panel is used and therefore less insulation material is

necessary. In addition, it has been observed that it performs very well especially in multi-layer applications after various seismic experiments. The availability of the product in desired shapes offers design flexibility and can be compatible with different materials. Structures designed with long openings can be applied in combination with CLT floors and box beams. Thanks to the applicability of the CLT panel source in different ways and with the capacity to be specially produced for each project, the installation and modification works can be easily done and virtually no construction site waste is generated during the application process. The waste parts can be used as different application elements or as biofuel. All of these features, as well as rapid installation and efficiency increases the CLT preference in specific applications (Weissensteiner & Barbu, 2013).

Cross-laminated timber (CLT) has both cross-shaped lamination as well as good shape stability and possible bidirectional force transfer. However, the transverse layers in CLT tend to a round-cutting error under an out-of-plane load. The innovative multi-layer composite laminated panel (CLP) was developed by combining different sizes of timber to overcome structural composite lumber (SCL) and rolling shifts, while maintaining high mechanical performance and aesthetic appearance of natural wood (Weissensteiner & Barbu, 2013). CLT panel example and building application example are shown in Figure 4.4.

Figure 4. 8. (Left) Five-Layer CLT Element; (middle to right) Impressions From Project Wittenbauerstraße/Graz/Austria: Two Three-Storey Residential Buildings[44]

Mass timber is a developing building material, which has gained popularity worldwide with the development of mass timber construction in recent years. Mass

[44] Brandner, Flatscher, Ringhofer, Schickhofer, & Thiel, 2016

timber panels (MTP) are often referred to as large and sectioned paneled wood products. MTPs cover large-scale wood products of known conventional, parallel laminated elements, such as glued laminated timber (GLT), nail-laminated wood (NLT) and dowel laminated timber (DLT) (Brandner et al., 2016).

4.3.2. Laminated Strand Lumber (LSL)

Laminated Strand Lumber (LSL) is a type of laminated wood, which is formed under water with heat strength by combining the waterproof adhesives. LSL can be obtained using each section of the tree (Figure 4.9). Therefore, the amount of waste products is very low. The homogeneity of the material obtained by the random placement of the thin parts provides the user a high strength and a flexible product. The material properties of the LSL are dependent on the density of the panel, the type of wood layer used and the orientation of the strip layers. By changing the direction of the strip, the bending stiffness and strength properties of the final product of LSL can be changed. Five different panel layout can be applied in production. These are (A) fully oriented; (B) randomly oriented; (C) surfaces oriented, core randomly oriented; (D) surfaces randomly oriented, core fully oriented; and (E) eight fully oriented layers aligned at angles 0 and ± 45 (Moses, Prion, Li, & Boehner, 2003).

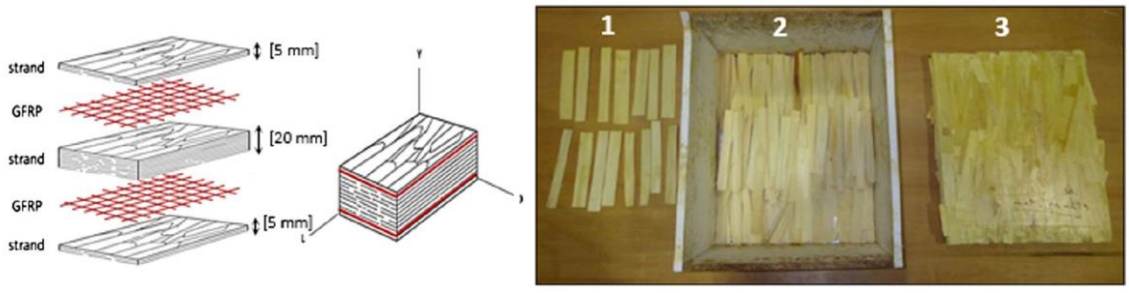


Figure 4. 9. Laminated Strand Lumber Schematic and Laboratory Procedure[45]

The panel density and the selected tree type, obtained from the LSL are directly related to the hardness and strength of the product. Product of different lengths, widths and thicknesses can be obtained. Due to the adhesive coating of the wood layers used and the homogenous structure of the resulting product, LSL is resistant to most of the

[45] Moradpour, Pirayesh, Gerami, & Rashidi Jouybari, 2018

environmental conditions. However, it should not be left in direct interaction with environmental conditions. LSL is widely used in industrial field, furniture manufacturing, window and door construction, sill plates, windowsills, floor beams and frameworks for support beams. They are easily machined, sanded and drilled. During these operations, there is no bending and separation. LSL is also an environmentally friendly material. The disadvantage of LSL is that it is expensive from most alternative products (Denizli-Tankut et al., 2004).

4.3.3. Parallel Strand Lumber (PSL)

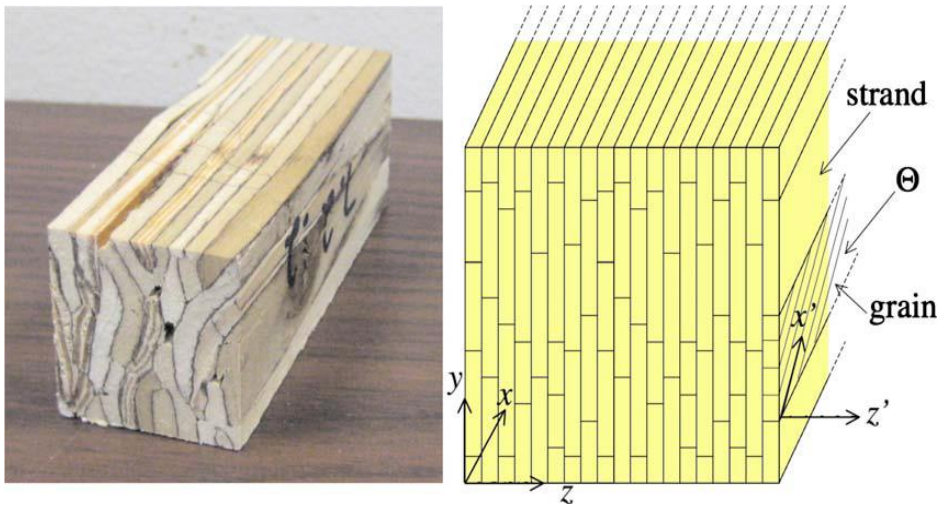


Figure 4. 10. Actual and Idealized PSL[46]

Parallel Strand Lumber (PSL) is often used in the production of hardwoods, mostly of Douglas fir, western hemlock, yellow poplar, and Southern Scotchwood PSL, which are less expensive than stand-alone. The use of hybrid poplar trees, which grow up faster are cheaper for PSL production (Figure 4.10). The resulting PSL product is waxed with phenol formaldehyde adhesive mixed with wax; this adhesive mixture is heated to a certain temperature and applied under pressure to the hardened parts. The resulting PSL product is cut into a billet shape and then into the desired dimensions (R. Kurt et al., 2012). This results in a small amount of waste, which can be obtained by adhering to the desired length . PSL is more widely used as column, lintel and high bending strength beam. It is smoother than timber and glulam. This feature is preferred in wood applications where finished appearance is important.

[46] Arwade, Winans, & Clouston, 2010

4.3.4. Laminated Veneer Lumber

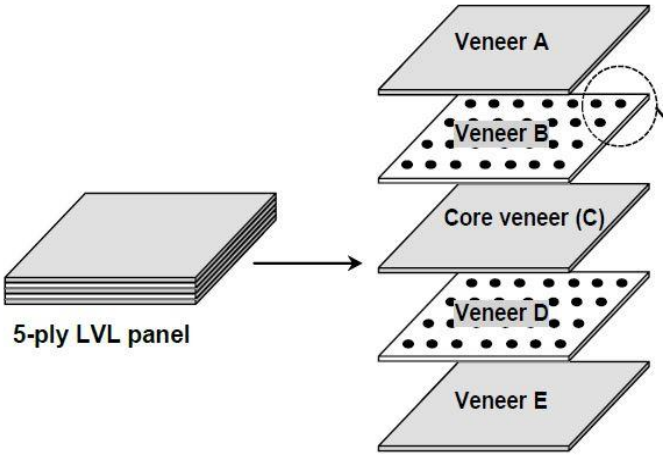


Figure 4. 11. Laminated Veneer Lumber[47]

The Laminated Veneer Lumber (LVL) consists of parallel interlocking coatings with a thickness of about 3.2 mm. Only flat and long plates are used in the production of LVL (Crossman & Simm, 2014). For this reason, although the desired form can be obtained in LVL production, the amount of waste product is higher than flat sheet production. Pine trees and Douglas fir (radiata pine, larch, eucalyptus and poplar) trees are used in LVL production due to their physical and mechanical properties. The logs to be used in LVL production are kept in hot water for 24 hours. Two meter wide and 3-4 mm thick layers are separated from the softened logs by a rotary peeling method. The drying layers in 6-8% moisture are combined in parallel with the phenol formaldehyde adhesive to form the desired product. Laying of the sheets parallel to each other makes LVL a more robust and more productive product. The elements must be placed perpendicular to each other in order to reduce the load effects (Figure 4.11). The resulting product is pressed under high temperature and pressure and cut diagonally in desired sizes. The maximum width is 2.5 m and its length can be up to 25 m depending on usage (Zmijewki & Wojtowicz-Jankowska, 2017). The length of the laminated product is limited as long parts are difficult to transport. Its advantages can be compared to glulam. For example, it can be used as main beam in many applications for load bearing. It can also be used in applications of flooring, lattice, frame, roof, wall, floor, concrete mold and scaffolding board. In addition to conventional wood materials, LVL

[47] Pangh & Doosthoseini, 2017

is a homogeneous product that does not change its performance during all environmental conditions. It has great resistance to moisture. In this way, neither the structure of decay, nor no crushing occurs. Its structural stability makes a swelling and buckling resistant and makes it a long lasting product. The low porosity between the layers used and the oxidation neutrality of the phenol formaldehyde adhesive used for combining increases the fire resistance. It is easy to apply and its lightweight structure makes the application progress faster.

4.3.5. Nail-Laminated Timber

Figure 4. 12. Nail Laminated Timber (left) and Ceiling Application Example (right)[48]

A large production plant is not required for Nail-Laminated Timber (NLT) production. It can be easily produced with ready-to-use wood for use in various applications, and all kinds of wood can be used in its production. It is performed by mechanical compression of the parts with nails or screws (Figure 4.12). Plywood or strip plate cover is added to one side of the panel. This provides the in-plane cutting capacity of the NLT. Mechanical technique is applied to obtain a structural NLT element. Product surfaces obtained by combining timber of different sizes of NLT may differ (Newswire, 2017). This application changes the acoustic performance of NLT. Besides, it is an economic product. Damage to NLT during transport and installation can be eliminated by means of patching or by sanding. However, this may cause

[48] Parajuli, Rajan, and Frederik Laleicke. "Mass Timber Products: Innovative Wood-Based Building Materials." NC State Extension Publications. Accessed April 16, 2019.

distortion in the grooved appearance of NLT. If the ceiling and the floor are mounted in line with the top of the beams during the application process, the installation thickness is reduced. It can be mounted with elevated flooring system that hides the appearance of the beam to obtain an aesthetic view. When using the raised floor system, the space between the NLT panel and the surface must be carefully considered because the space between the surfaces affects the sound movement, which is important for the acoustics of the space. CLT and NLT perform in a similar manner acoustically. However, in NLT, unlike CLT, there are small gaps for the transport of sound. If a durable protective product is not used in NLT production, the sun's rays cause the wood to discolour. After the manufacturing process, film coatings can be applied but this application may form cracks on the laminated elements. When using NLT elements, the shrinkage and swelling tolerance should be considered. They are used in flooring, floor, roof, wall, elevator and stairwell applications. It is an old method used to obtain a nice look (Newswire, 2017).

4.3.6. Dowel Laminated Timber

The nails, screws, dowels and bolts that carry the load perpendicular to their longitudinal axes form the dowel type connections. The connectors of Dowel Laminated Timber (DLT) can also be used diagonally. DLT material is easier and safer to process due to its system that works without the use of nails or screws. DLT is similar to NLT, but the similarity is separated by the used wooden dowels instead of screws to join the laminated wood. Glue, chemical products and volatile organic compounds (VOC) are not used in the production of DLT except the glue used for finger joints within the system. This situation accelerates the production and provides air quality to the room. There are two important criterias for DLT system designs: local design criteria and global design criteria. With the local design criteria developed by K. W. Johansen the capacity of the wood where the binding element is buried is evaluated (Pedersen, 2002). The design and position of the fasteners are not important when evaluating. The global design criterion evaluates the spacing and distance criteria between the binding elements. The connections used in the system can be used by applying small and large forces and can be produced easily. Dowels provide a combination of sheets and provide stability to them (Chen, Lee, & Jeng, 2003). The number of hinges used, the distance

between them, the diameter of the dowel, the density of the wood used, the friction between the dowel and the wood, the smoothness of the dowel surface are the main characteristics affecting the character of the DLT system (Sawata, Sasaki, & Kanetaka, 2006). It is more convenient to use for roofing and flooring because of the parts that make the system work in one direction. It is more economical than CLT and other laminated products and production speed is high. Strips can be placed on the bottom surface of the DLT panel to provide acoustic performance. DLT can withstand fire for about 2 hours (Chen et al., 2003).

Joints are usually one of the weakest points in the wooden structure. The loss of perfect continuity in the structure resulting from the presence of joints will result in a decrease in the global strength of the structure. This means an increase in the size of the assembled elements.

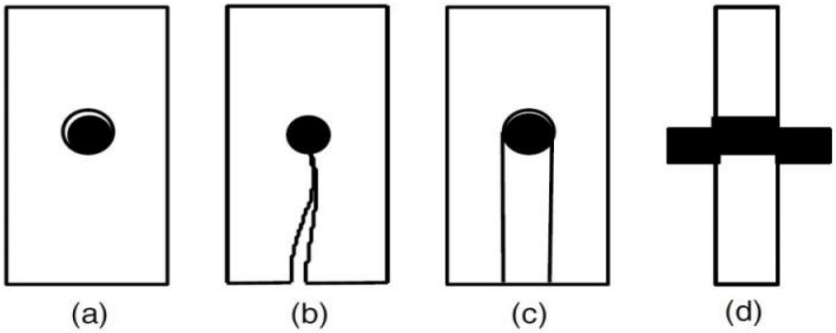


Figure 4. 13. Dowel laminated timber possible failures
(a)bearing, (b) splitting, (c) shearing out, (d) fastener[49]

Figure 4. 14. Dowel Laminated Timber Roof Application Examples[50]

[49] Chen et al., 2003

Depending on the arrangement of the wood and the force to be applied to the element, some deterioration may occur on the wood parts (Figure 4.13). Dowel connections are used to provide esthetical appearance, heat insulation and acoustic performance in many applications such as roof, wall, interior and exterior applications (Figure 4.14, 4.15).

Figure 4. 15. Dowel Laminated Timber Wall and Stair Application Examples[51]

4.3.7. Glue Laminated Timber

Glue Laminated Timber (Glulam) is a wood product obtained by gluing small pieces of wood together (Figure 4.16). These small parts are available in standard widths and lengths. However, it can be produced in desired shapes and sizes for various design applications at any time. The coverslips are dried in 7-15% humidity and sanded to obtain a smooth surface (Jokerst & Laboratory, 1981). The lamella panels are joined together under pressure by finger joints to obtain longer glulam products. The finger joints should have a thin tip and a straight and narrow slope. The length of the joints provides high strength to the glulam product. This joining process produces a small amount of waste product (shorter joints save more waste than long joints) but after this process, the product must undergo a quality control process. Phenol-resorcinol and melamine-based resins are used as adhesives. Glue spreading rate, assembly time, ambient conditions and laminated conditions are effective on the quality of the final product. Douglass is the preferred tree species for the production of fir, larch, spruce, Norwegian spruce, southern pine, yellow poplar glulam. It has a wide range of

[50] Dowel Laminated Timber Design Guide & Profile Handbook pg.20
[51] Dowel Laminated Timber Design Guide & Profile Handbook pg.22, 31

applications. However, its aesthetic appearance is not satisfactory compared to other elements. Beams, columns, cages and headers are some of the applications of Glulam. In addition to long straight beams, it is also used for the construction of curved arches. Damage to the surface during installation can be eliminated by using fabric hangers. The elements should be kept as vertical as possible and care should be taken not to be affected by weather conditions. Glulam is stronger and more robust than steel. It shows longer lasting performance than steel beams under fire conditions (Jokerst & Laboratory, 1981).

Figure 4. 16. Glue Laminated Timber[52]

4.3.8. Oriented Strand Lumber

Figure 4. 17. Oriented Strand Lumber[53]

[52] "Hyne Timber Expands Glue Laminated Timber Capacity in Queensland." Timber Industry News. October 22, 2018. Accessed April 14, 2019.

Oriented Strand Lumber (OSL) is formed by combining cut wood parts with high length and thickness ratio parallel to each other (Figure 4.18). These parts are obtained from less-used and fast-growing trees. The parts are combined with adhesives and then compressed to give OSL logs. It is used in many applications such as beams, edge plates, headboard, furniture production and industrial applications. OSL is similar to LSL but shorter parts are used in OSL production. It is a consistent product and has the capacity to carry large loads (Veerapong, Buhnnum, & Winai, 2008).

4.4. Using Laminated Wood Material

Laminated wood is a product that facilitates the use of small size elements by making them large and curved. Defects in wood are removed and the wood is made suitable for use. Laminated wood material can be used as both supporter and complementary element in various applications. It is used in wall, roof and floor systems as supporter and complementary.

4.4.1. Use as a Structural System Element

The structural elements such as foundation, curtain, column, beam, flooring, which are formed to carry and transfer loads in order to resist the external factors of the structure, constitute the carrier system. Wood is a natural material which is robust, easy to shape and can be produced in desired dimensions. Laminated wood is suitable for all construction applications such as bridges, buildings, sports halls as it is produced specially according to the usage purpose and dimensions.

4.4.1.1. Wall Systems

The wooden wall system consists of elements such as soil beam, post, brace, prop, column capital. Floor beams are built on basement wall or on ground concrete. The floor beam ensures the durability of the flooring, and the hard and smooth standing. In addition, heat contributes to the maximum level of sound insulation. Wood beams reduce the load on walls and foundation due to its low weight. Therefore, it can be

[53] "Oriented Strand Lumber." Natural Resources Canada. April 29, 2019. Accessed April 14, 2019.

preferred in applications in earthquake zones. The transport process and the installation process are also easily done. There is no need for large scaffolding and cranes in applications that have a light material.

Wooden walls need to be used in the corners of the application areas and in the dividing of the walls to be used as vertical elements. Vertical elements are referred as posts. These posts are connected to each other by the brace located horizontally on top of them. The elements called the braces are not only used for connecting the post elements but also for the roof elements. The horizontal elements, called column capital, are laid to the top of the floor beams placed on the brace elements. Wooden posts are supported by cross prop (Figure 4.19) (Köysüren, 2002).

There are two different structural systems used as structural elements. One of them is solid wood structure system and the other is skeleton construction system.

Figure 4. 18. JZ House Wall

In the masonry solid wood construction system, the laminated or non-laminated wood material must be stacked on top of each other. Column and beam elements are not used in the solid wood masonry systems. Structural system is provided by walls. Laminated pieces of laminated wooden wall system are combined with finger joint system by glue. Different connection profiles are created for each application and the profiles produced for convenience during installation are numbered and packaged. Toy block-shaped parts are easily assembled in the application area (Figure 4.19). The thickness of the wood to be used for the solid wood masonry system may vary between

8-24 cm. The thickness of the part to be used varies according to the application purpose and the tree type selected. Good thermal insulation performance makes it easier to achieve the desired performance with less thickness. The thickness of the wood material used prevents the need for different insulation elements.

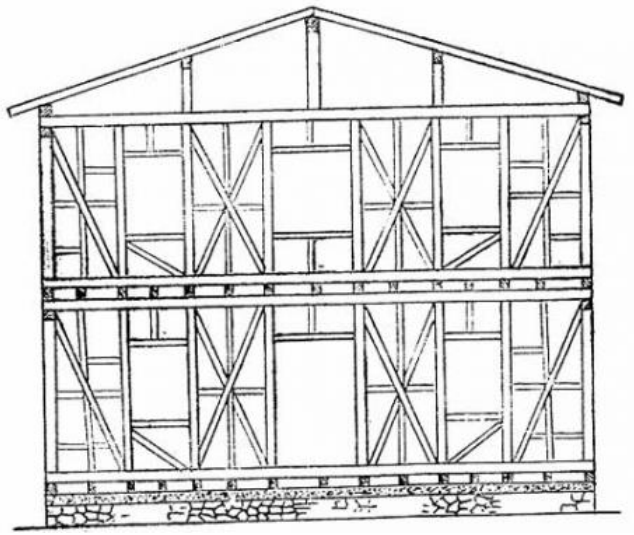


Figure 4. 19. Skeleton Construction System[54]

Framework construction system is a system consisting of wooden columns and beams as supporting elements (Figure 4.20, 4.21). Vertical and horizontal cross joint systems are used for the connections used in applications. After the skeleton construction system installation, various coating materials can be chosen by using CLT wall panels or insulating materials.

Cross-laminated panel system is a system that is formed by overlapping wood pieces arranged side by side. This system is not only used in wall applications but also in many different applications such as floor and ceiling material, stairs and wind turbine. The cross laminated panel system is a frequently preferred building system due to its positive contribution to environmental problems. It offers designers the flexibility and high-quality environmental performance. The water absorbing properties of the wood prevents the sweating and dripping on the walls in difficult environmental conditions. The double-sided walls used in wooden structures ensure that the sound insulation is kept at the desired level. Moreover, wooden walls, as natural material, provide a high degree of thermal insulation and comfort in all climates.

[54] "Fotoğraf Albümü." SimpleSite.com.tr. Accessed May 4, 2019.

Figure 4. 20. Example from JZ House

4.4.1.2. Roof Systems

The roof is a structural element used to protect the structure from external factors. Roof system consists of structural, coating and covering elements. High quality, high performance and long life wood materials should be selected for woods used in roof systems in order to provide high comfort in places. The span to be crossed, environmental conditions, the quality of the tree used and the design criteria play an important role in the form of the wooden roof. Different types of roof designs can be used in applications such as gabled, mansard, gambrel, saltbox, hip or flat (Figure 4.22) (Koca & As, 2016).

Wood is a material with different visual characteristics, resistant to environmental conditions, easy to install, light and has a long life.

Changing temperatures and decreasing rainfall can cause changes in the amount of moisture in the structure of the wood and may cause deterioration of the structure. In order to increase the life of the material used in the roof, which is directly in interaction with the environmental conditions and to prevent decay, structural designs should be made according to the environmental conditions of the region by using different chemicals. When selecting the chemicals to be used, it is necessary to consider the place of use, the damage it can cause to the environment, human health, and the conditions of indoor comfort.

In the traditional wooden architecture, hip roofs and roofs with eaves were used.

Today, they are called hot and cold roofs. In contrast to cold roofs, hot roofs do not have a gap between the roofs (Koca & As, 2016).

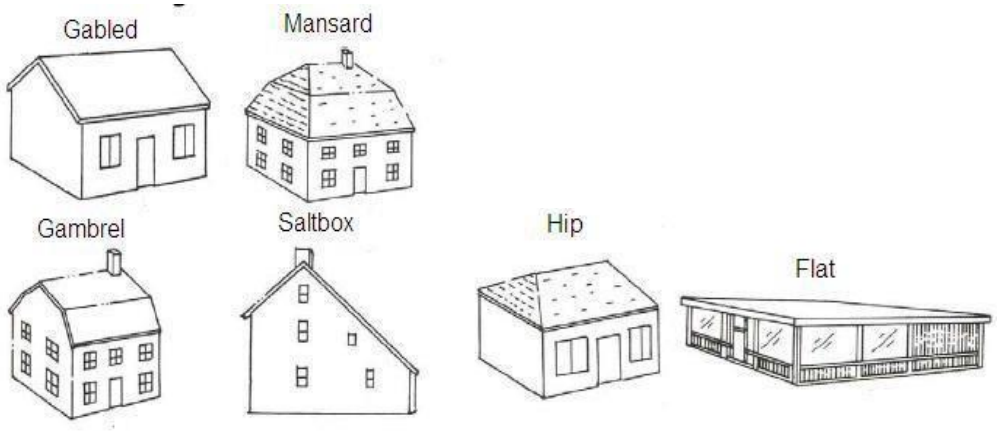


Figure 4. 21. Roof Types[55]

Different materials such as PVC, metal, tile, wood can be used as the cover element of cold roof applications. In such roofs, the structural system separates the structure and the roof, and the remaining gap prevents the structure from being affected from the environmental conditions.

The roof systems differ depending on the elements such as wooden lattice systems, box beams, putreel beams with wood filling, I section beams with plywood filling, laminated wooden roofs, mounting roofs and suspended roofs that can be placed in the roof system.

4.4.1.3. Flooring Systems

Floors are the building elements that separate the storeys from each other in applications and provide the loads to be conveyed to the structural system on which they sit. Flooring applications can be made with different materials such as reinforced concrete, steel and wood. It consists of two different sections: the structural section and the coatings. Wood plating elements are placed on the beams determined according to the span to be passed. According to the load on the beam, the dimensions will change proportionately. Since wood is a light material, it is preferred not only in wood structures but also in reinforced concrete and masonry structures. In addition to being a

[55] Koca& As, 2016

light material, it is durable, long lasting and abrasion resistant material. Insulation material is placed between the floor and the wooden flooring to provide heat and sound insulation.

Flooring is applied by using round, chipped or sawn timber elements in accordance with the masonry methods used in masonry wooden structures.

Flat wood veneer is applied on the timber applications in the use of round wood. Wood veneer materials can be used under the floor (ceiling) and flooring. Upholstery coverings were used more as ornamentation elements in old buildings.

Studs, sill plate, foundation, joist, floor boards, baseboard are the elements that make up the flooring system (Figure 4.23). Studs are one of the smaller uprights in the partitioning of the walls of a building for paneling. For sill plate walls, 2 x 6 cm and larger dimensions are preferred. That are applied along the base length and also properly designed and assembled in accordance with the details. Durable foundations can be produced using laminated wood and corrosion-resistant fasteners. Joist is a building element, which can be made with wood or different materials parallel to the wall on the floor and ceiling applications. Baseboard runs along the base of an interior wall, which is made with small and tight wooden pieces.

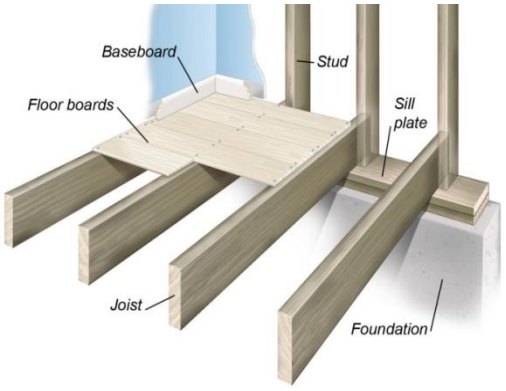


Figure 4. 22. Flooring System[56]

4.4.2. Use as an Architectural Element

Wooden building elements are frequently used from past to present. The reason for the use of wood in the construction is that wood is a local material, easy to find, use

[56] Elektromain.xyz. "Wood Floor Frame Construction." Elektromain Image. Accessed April 5, 2019.

and produce. It is possible to obtain elements of any size with high bearing capacity and durability. It is used in the production of doors, window joineries, stairs as well as structural elements in buildings.

4.4.2.1. Windows

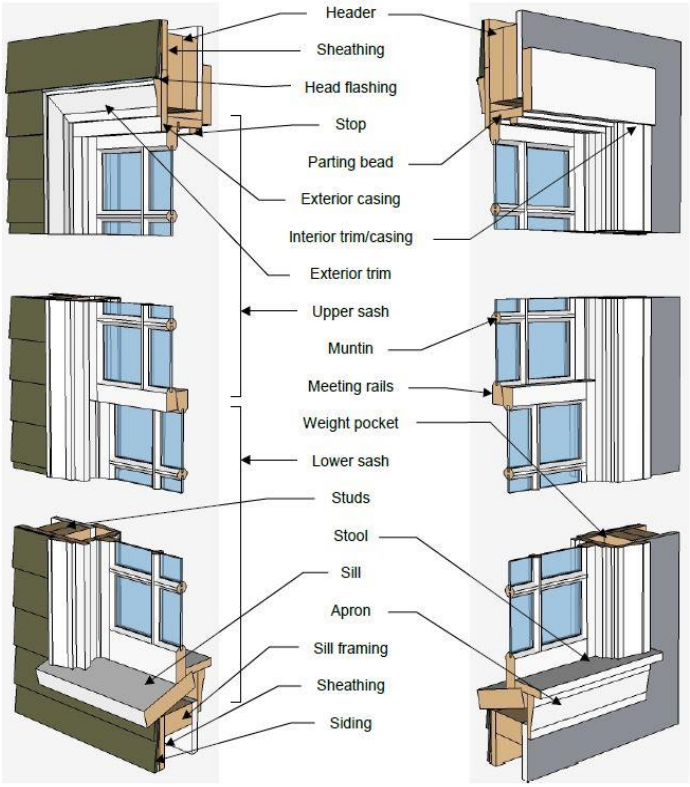


Figure 4.23. Window Components[57]

When heat losses of the buildings are analyzed, 15% of the total heat loss is from the windows. Heat conduction coefficient of wood is very low. The windows used in the production of laminated wood reduce the heat loss due to the air-filled cells that prevent the heat exchange in the structure. The laminated timber material has superior performance in sound insulation as well as heat insulation. It prevents absorption of noise from the environment. Thanks to this feature, it is an ideal material for concert halls. In the laminated timber windows, there is no change in the form when temperature changes. Unlike other materials, it becomes more powerful with drying. Due to wood's economic, long lasting, easily applicable and good aesthetic appearance

[57] Measure Guideline: Wood Window Repair, Rehabilitation, and Replacement, pg. 10

features laminated timber windows are preferred. It does not harm the nature during the production process and during the usage process and makes a positive contribution to the comfort of life. The wood material is dried according to the usage area. It is possible to produce wooden pieces with finger joints and laminated surfaces according to the application, color, size and specifications.

The laminated products are painted with water-based protective paints to ensure protection against external environmental conditions and these are polished and made ready for installation. Contrary to what is believed, it is not a material that requires frequent maintenance. The period of maintenance ranges from 8-12 years for laminated products made of durable wood (Baker, 2012).

It is possible to produce windows of different sizes. In order to maintain and improve the quality of the produced window, it is necessary to understand the window components, the wall connections of the system and the location to be placed (Figure 4.24).

4.4.2.2. Doors

Doors can also be manufactured using solid wood materials by using laminated fiberboard, MDF or plywood. In order to prevent any changes in the size of the wooden doors used in the applications, it should have a maximum humidity of 12% -14%. MDF product options consisting of hard fiberboards that are resistant to environmental conditions are used for the production of doors that can be used for outdoor applications. The non-formaldehyde-free adhesives that are used for MDF panels are not harmful to human health. Doors with laminated products prevent noise pollution. Doors produced under high pressure are very robust and fire resistant that for these reasons they are preferable. Besides, the wooden doors that can be produced in any desired colors, sizes and details give an aesthetic appearance to the applications (Knight, 2005).

4.4.2.3. Stairs

Wood elements can be used as beams, steps, risers, landings, railing and covering elements. Beams used in the construction of stairs can be single or multi-part.

Compared to other materials, the ladder produced with wooden materials has a more aesthetic appearance. It is a long lasting and robust building element. Depending on the construction techniques used and the ladder elements, stairs can be designed in many different ways. In addition to all design, for the production of wood staircase, fire prevention precautions must be taken.

Earthquake load, movable and constant loads should be taken into consideration in shaping the stair structure (Lam, 2004).

CHAPTER 5

JZ HOUSE

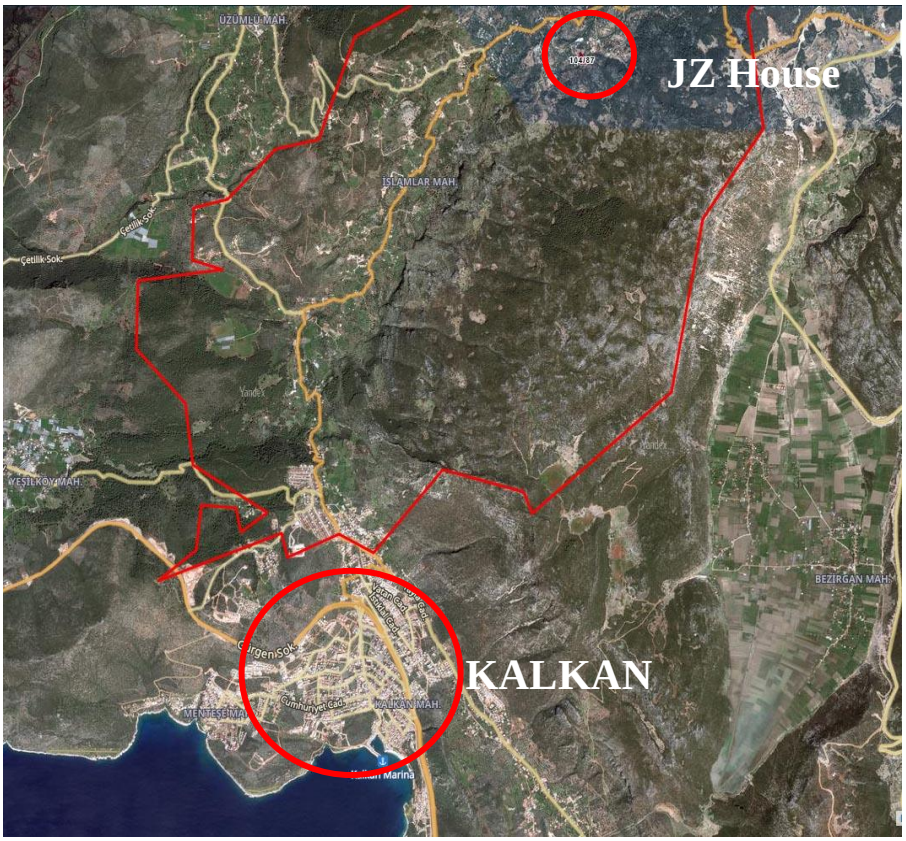


Figure 5. 1. JZ House Location on Map[58]

The JZ house, located in the Southeast of the İslamlar Village in Kaş / Kalkan, Antalya, was built in 2009 on a land of 1876 m² (Figure 5.1, 5.2). It has a construction area of 76 m^2. The JZ House is located on a sunny area having an average of 300 days of sunshine per year. The building was placed on two retaining walls at different levels obtained from limestone found on the site. JZ House was produced by using laminated wooden pieces obtained from cedar trees found in the Kalkan, Antalya. The region has warm summers and mild winters. Precipitation rate is higher in winter than summer months. The annual average temperature is 18.2 °C and the annual average rainfall is 926 mm[59].

[58] Parselsorgu.tkgm.gov.tr. Accessed March 14, 2019.
[59] Climate data. Accessed April 12, 2019. https://tr.climate-data.org/asya/tuerkiye/antalya/kalkan-187348/

Figure 5. 2. JZ House Location on Map[60]

5.1. JZ House Design Process

Figure 5.3. General View of JZ House

JZ House was started to be designed in 2008 and its design was completed in the same year and construction started. The construction of JZ House was completed in 2009 located on a land of 1876 m² (Figure 5.3). The design process of JZ House is given under two subheadings in the continuation of the thesis.

[60] Parselsorgu.tkgm.gov.tr. Accessed March 14, 2019.

5.1.1. Architectural Design

Serhat Akbay, the architect of the building, has designed a comfortable life for the user by keeping the green and the landscape in the center of the design. The JZ House design process, which started in line with the needs of the user, took its final form by shaping the natural parameters around the design process. Today, concepts such as ecological life and sustainability lead the design approach. The concept of ecological design prioritizes the efficient use of resources available in the environment while the concept of sustainable design prioritizes the continuous use of natural resources. The design criteria of the study is determined according to the choice of materials. The preferred material must ensure the comfort of the space, a sustainable material and a long-term use. Trees provide oxygen to the environment by keeping carbondioxide in it. This contributes positively to the nature and human health. Wood material is a sustainable material, which is soluble in nature and suitable for the use in different ways after years.

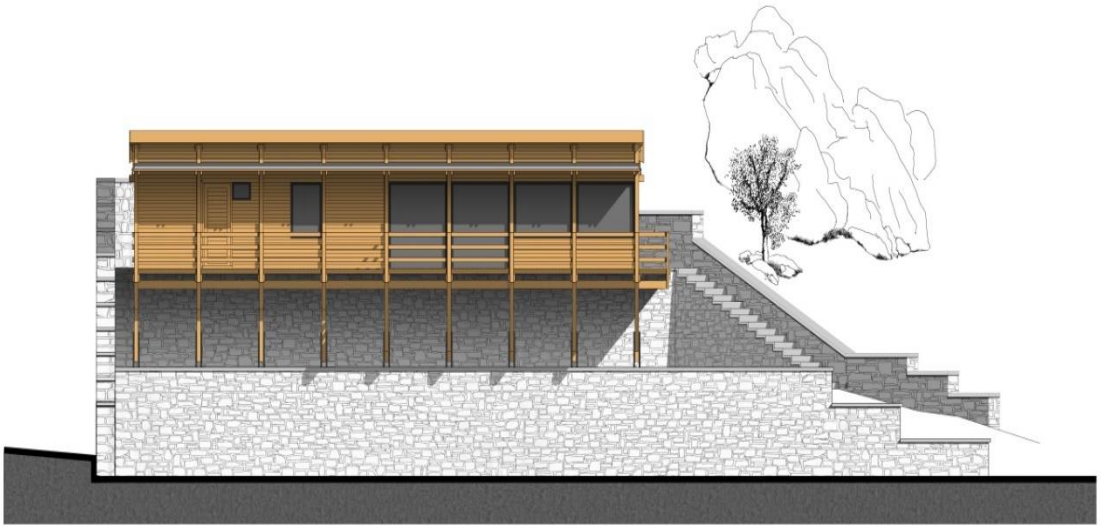


Figure 5.4. Front Elevation

JZ house uses the choice of materials for laminated wood by prioritizing the concepts of ecological, sustainability, interior comfort and durability. Laminated wood is a good example for design criteria such as environmental health, human health, fire resistance, time advantage, earthquake safety and energy efficiency. The trees used as timbers in JZ House land were cut and laminated from its land.

In order to reach the structure, the land on which it is located has a minimum level of intervention. The structure rests on retaining walls consisting of limestone on the field. The building elements are designed, prepared and transported to the land in the application area. No advanced technology is needed for the construction of the building which is designed in accordance with the traditional construction features.

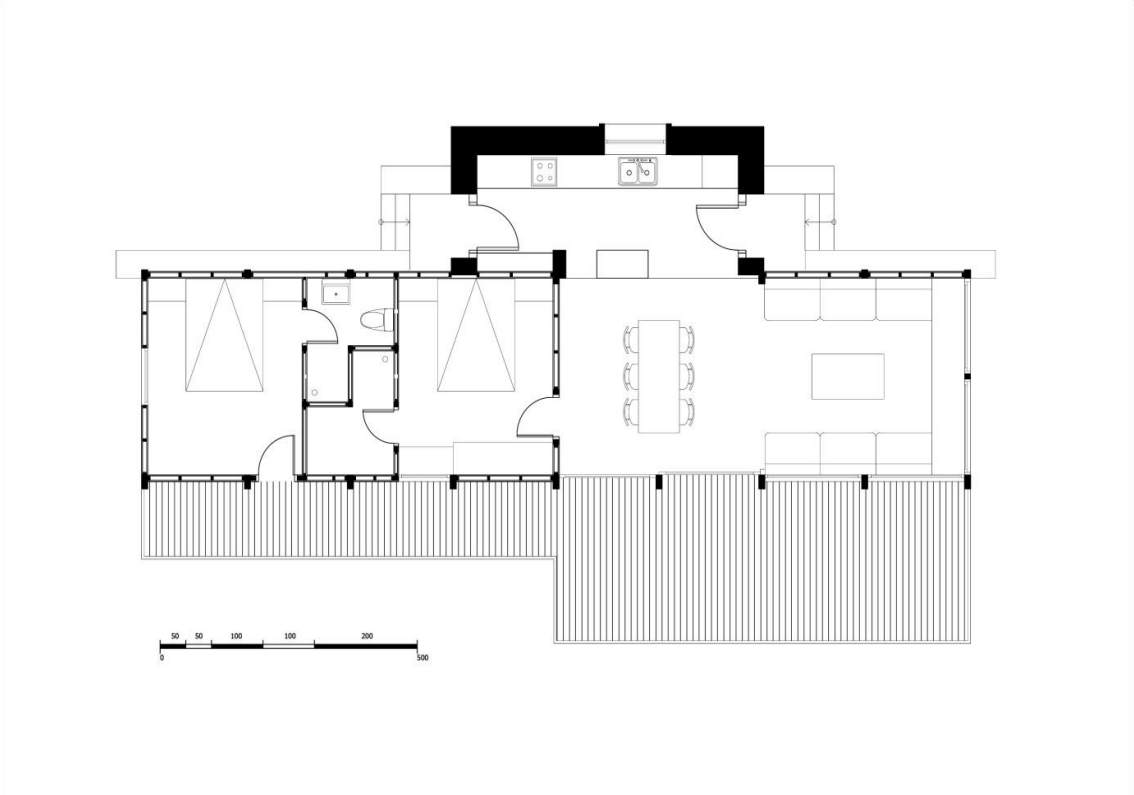


Figure 5.5. JZ House Groundfloor Plan

There are two bedrooms, one kitchen and one living area in the building. The part between the retaining walls and the basement floor area of the building is used as storage area. There is an entrance door to welcome the guests coming from the southeast of the field and an entrance on the southwest welcoming the users from a -3.0 m level with concrete stairs. These entrances are positioned opposite each other which open to the kitchen area (Figure 5.5). To the south of the building, there is a mountainous and forested area and a unique landscape (Figure 5.6). The mass is positioned to dominate the landscape. In the mass design, wide openings are positioned in the landscape direction to fully see the landscape from inside (Figure 5.4).

JZ House has not only selected laminated timber material for the structural construction of the building, but also all the furniture used in the bedroom, kitchen, hall,

and cellar are made up of laminated timber and solid wood (Figure 5.7, 5.8). The needs of the users are prioritized. Designs are made of laminated wood or solid wood according to the function definitions of the furniture. Appropriate material production methods have been determined for the purpose of usage. The produced materials are cut to fit the designs and combined in a suitable environment. During the design and the production of the material, the features of the product were kept permanent, natural and aesthetic. Since the installation of the furniture was produced according to the design's dimensions, it was very easy to install the pieces in the application area.

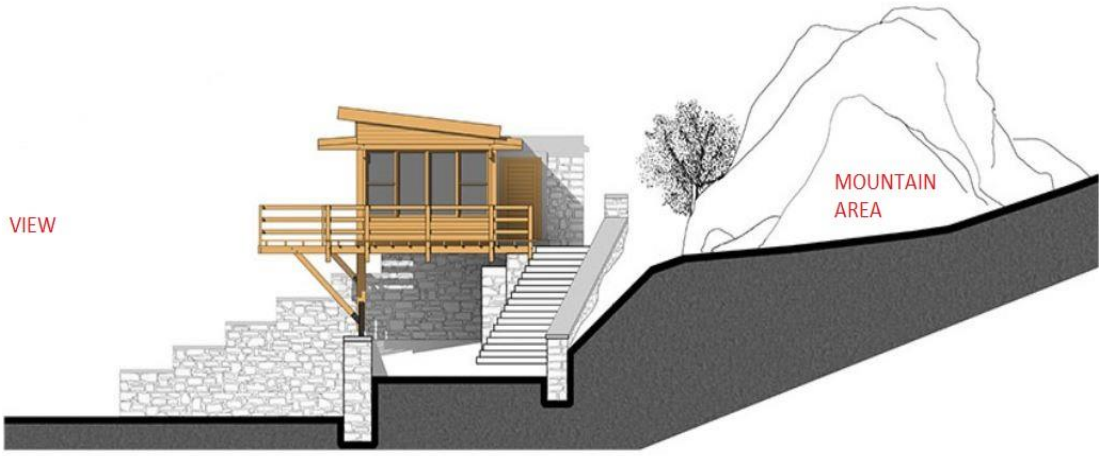


Figure 5.6. Location of JZ House

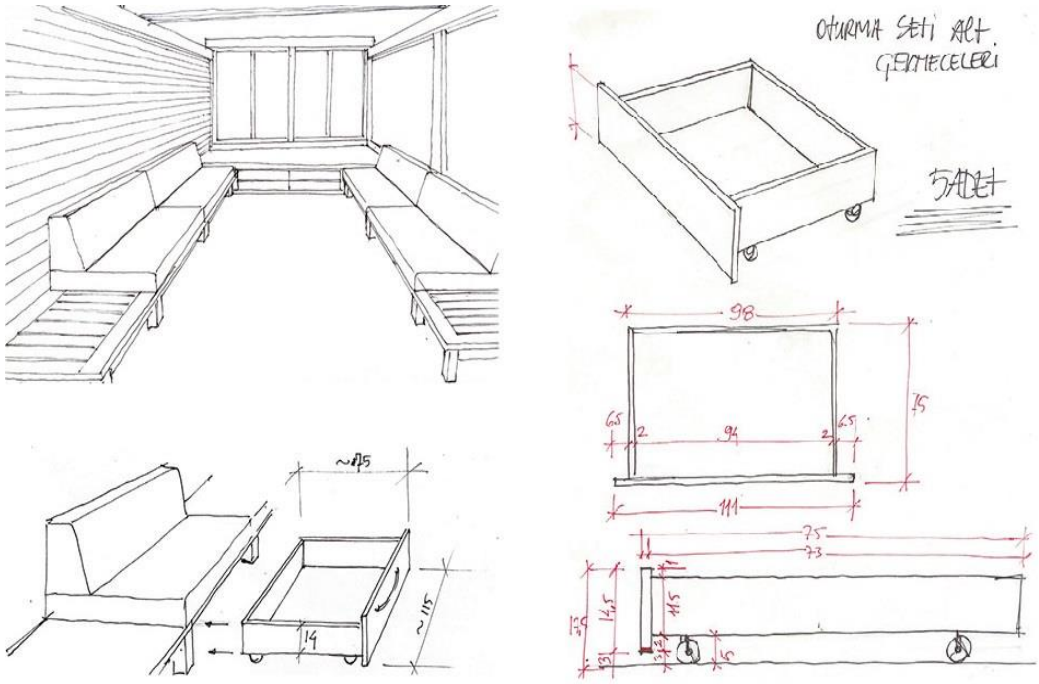


Figure 5. 7. Details of Living Area Furniture

JZ House is a design example that meets the owner's needs; it is compatible with nature, can protect itself in changing climatic conditions, is sensitive to human health and does not harm the environment.

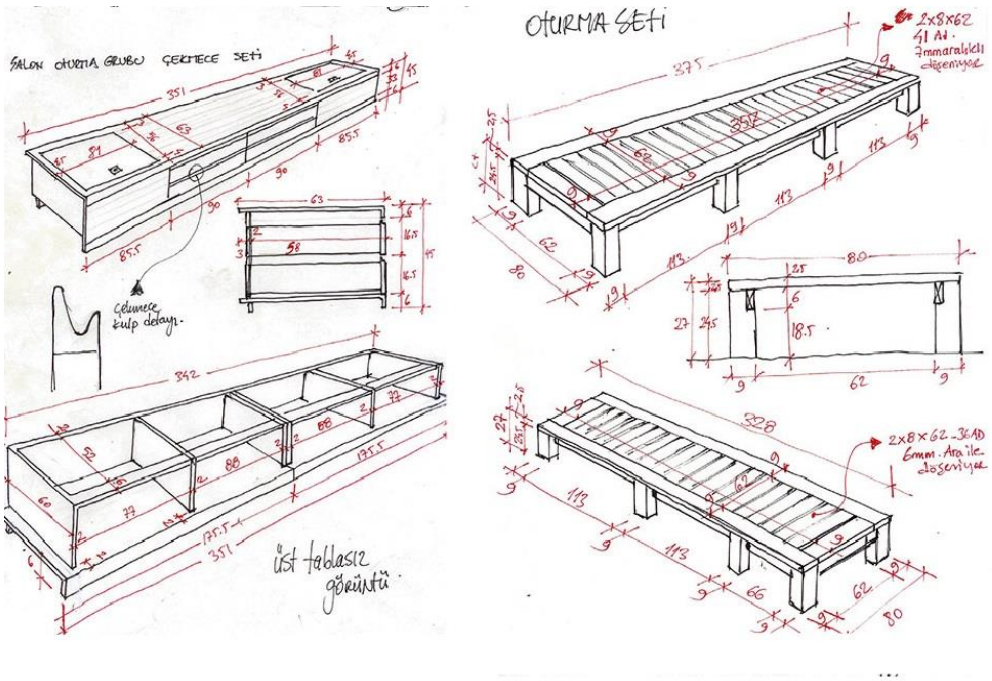


Figure 5.8. Details of Living Area Furniture

5.1.2. Structural Design

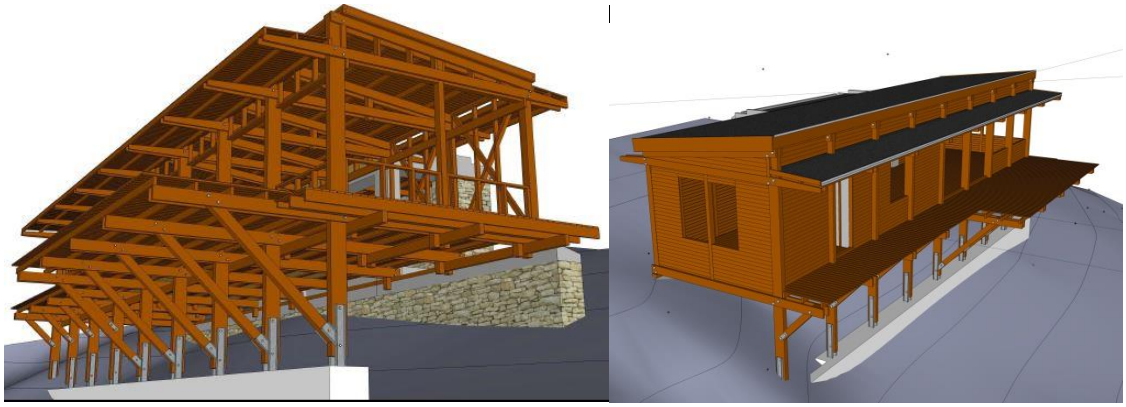


Figure 5.9. 3D view of JZ House Structure

After the static calculations of the JZ House, the skeleton system of the building was modeled with all the joint details in accordance with the determined element

dimensions (Figure 5.9). The 3D skeleton model, which contains all the details, is the solution for the production of laminated wood parts and it will prevent the errors that may occur during the application.

While static calculations of JZ House were carried out, fixed load of the structure, particle loads used in coating materials, movable loads, earthquake load and wind load were evaluated (Figure 5.10, 5.11). Due to the regional climate, the snow load is not taken into consideration.

The main elements of the wood flooring and paneling, which are sewing elements, base and head girders, intermediate beams and cross members are modeled with two dimensional finite elements. The wood cladding was modeled with two-dimensional finite elements and in simple systems with the equivalent cross-elements of wood veneer. Here, the wood veneer system is not applied and the loads are transmitted directly from the roof through the intermediate beams.

The modulus of elasticity and the shear modulus of the wood vary according to the type of wood, but do not vary according to the class quality. Elasticity modules and shear modules of the wood types used in building materials are given by TS 647[61] (Turkish Calculations and Construction Rules of Wooden Structures). According to this, firstly the stresses of the operating loads acting on the structure are determined. After that, the material stress is divided by a safety factor and the safety stresses are determined. Finally, the cross-sectional dimensions are determined such that the operating stress is less than or equal to the safety stress.

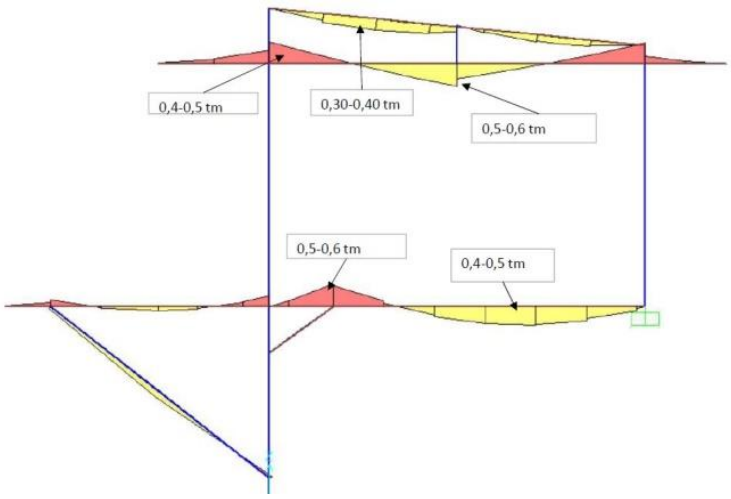


Figure 5.10. Moment Diagram

[61] Türk Standardı. Accessed March 26, 2019.

In static calculations, max moment of roof and ceiling beams was calculated at a level of 0.6 tm (Figure 5.10). Since the calculated value is less than σeem = 100 kg / cm², it is considered to be a safe structure in terms of bending moment. If the same diagram is to be obtained for a reinforced concrete structure, the cross-section of the structural system to be used must be increased. The growth in the cross-section creates an extra load for the structure. This may cause the damage to occur during the earthquake. Wood material is a low density material. Its elastic structure provides high resistance. The elastic deformation ability of the wood material is quite high. Thus, it is suitable for use in earthquake zones since it can absorb destructive power immediately (Karayilmazlar et al., 2008).

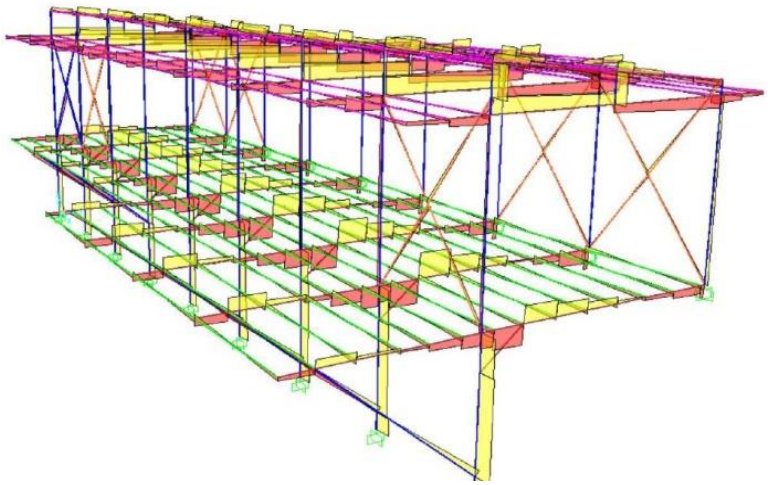


Figure 5.11. Cutting Force Diagram

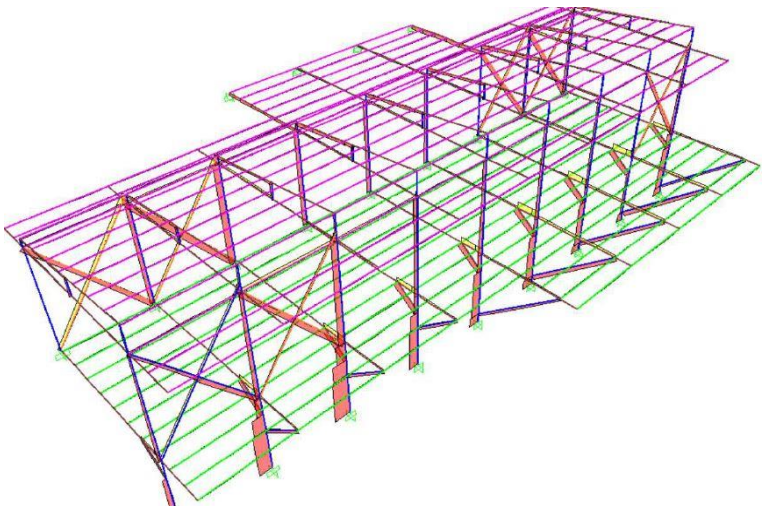


Figure 5.12. Axial Force Diagram of Pressure Elements

According to the calculations, the shear force value of the wooden elements are less than the required value of Tem = 9 kg/cm2. These results show that the structure is safe. JZ House shear force diagram is shown in Figure 5.11, 5.12.

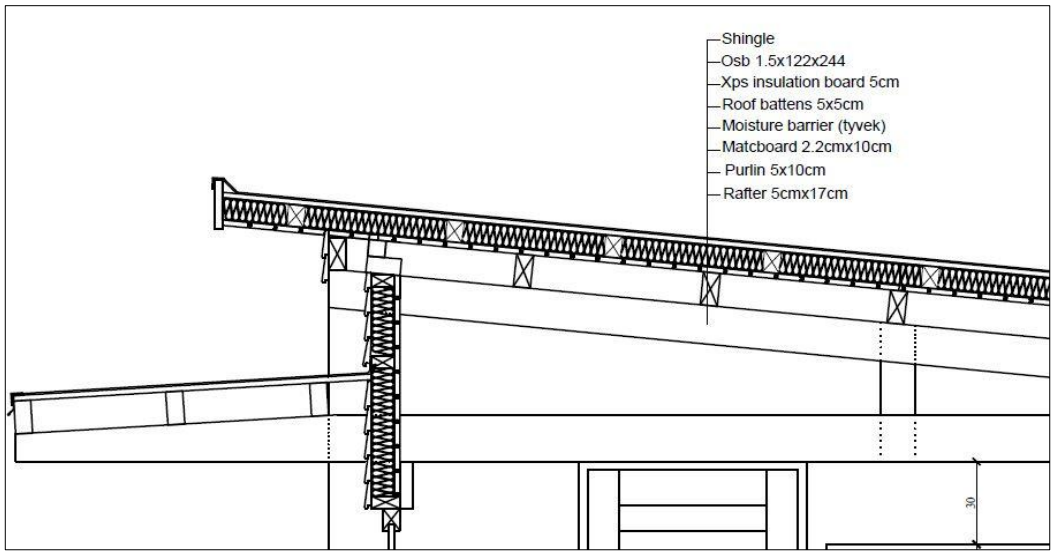


Figure 5.13. Roof Details of JZ House

One-way sloping roof is designed for JZ House. 5x17 cm rafter, 5x10 cm purlin, 2.2x10 cm matchboard, moisture barrier (tyvek), 5x5 cm roof battens, 5 cm xps insulation board, 1.5x122x244 cm OSB and shingle elements are used in roof application (Figure 5.13).

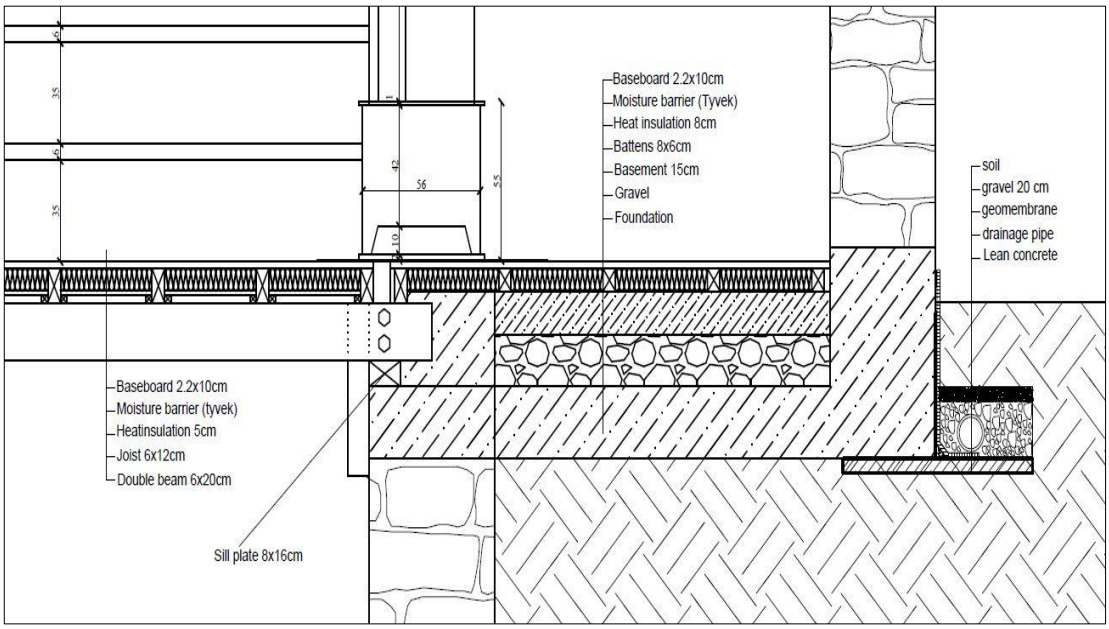


Figure 5.14. Floor, Water Drainage Details of JZ House

Tyvek moisture barrier and 5 cm heat insulation were used in interior flooring. Beams in the size of 6x20 cm were placed on the 8x16 cm sill plate. Foundation, gravel, 15 cm basement concrete, 8x6 cm battens, 8 cm heat insulation and geotextile tyvek elements were used on the ground. Drainage details include lean concrete, drainage pipe, geomembrane, 20 cm gravel and soil (Figure 5.14).

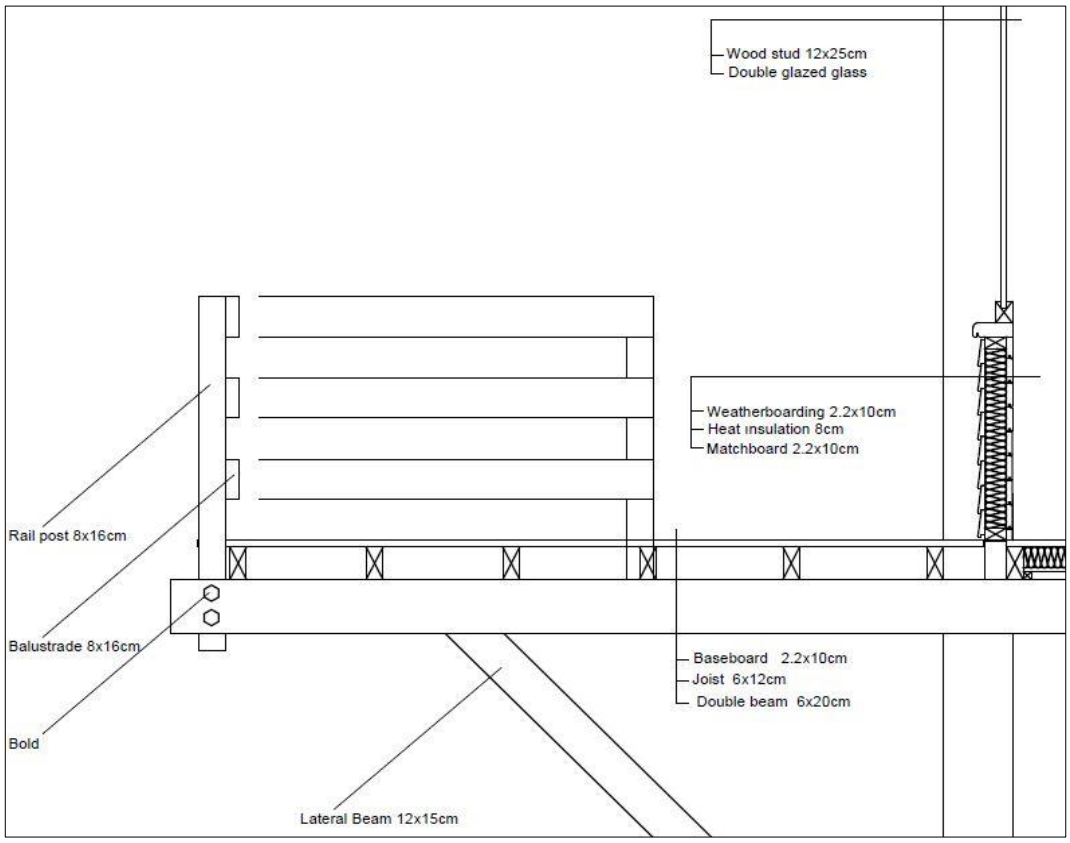


Figure 5.15. Wall, Floor, Railing Details of JZ House

2.2x10 cm weatherboard, 8 cm heat insulation, 2.2x10 cm matchboard elements were used in the wall application designed for JZ House. 2.2x10 cm baseboard, 6x12 cm joist and 6x20 cm double beam were used for the construction of the terrace. For railing, 8x16 cm rail post and 8x16 cm balustrade were used. Rail posts are mounted on the beam with the help of bolt (Figure 5.15).

5.2. JZ House Manufacturing Process

The manufacturing process consists of three stages; design process, material production process and construction process. The design process is designed according

to the wishes and needs of the user; two bedrooms, a lounge and a kitchen. The second design criteria for JZ House, was the climatic characteristics of the land and the region. In the design process, JZ House is positioned according to landscape and wind direction. The choice of materials is made of laminated wood considering sustainability, ecological balance and renewability concepts besides regional characteristics. In the material production process, cedar trees cut from Kalkan, Antalya which were subjected to laminating process and produced in accordance with the determined sizes based on static calculations. During the construction period, laminated wooden pieces produced in accordance with the desired dimensions and the pieces were combined to complete JZ House production.

Figure 5.16. Retaining Wall Manufacturing

Worms and insects do not attack the tree due to the structure of the resin found in cedar trees cut for JZ house construction. In this way, decay and defects on the tree do not occur. In addition, insects do not harm the tree so that its life span can last for thousand of years. The cedar tree is resistant to crack formation and scratches compared to other trees. Like other trees, it is not affected by the surrounding water and moisture. In this way, the structure does not swell and shrink. This feature of cedar wood makes it suitable for many applications such as exterior claddings, scaffolding floors, furniture productions. Its high grain structure and low density provide high insulation. The structure of the cedar tree provides vibration relief. This feature also improves acoustic performance. The cut trees were selected from old trees. Transported trees were cleared

of logs. Trees to be used for construction were free from cracks and defects. The structure of cedar wood is suitable for painting and varnish application. In addition, the structure of the cedar tree can be processed easily.

After the JZ House design was completed, the floor was made more durable with the retaining wall that was built without interfering with the existing elevation differences (Figure 5.17). For the construction of retaining wall, all the stones were obtained from the land. Procurement of stones from the land prevented extra construction costs.

Figure 5.17. Preparation Stage for Foundation

JZ House is made of reinforced concrete foundation to strengthen the contact of the mass with the ground so that the columns it rests on are not affected by any vibration. The columns that provide contact with the ground are embedded in the concrete foundation (Figure 5.17).

Figure 5.18. Column and Beam Laying

The ground floor slab element helps to transmit the mass load to the wooden studs. The first task of the flooring system is to carry the structural system of house. The size of the span varies according to the mass load affecting the pavement. It transfers the load on the floor to vertical elements with the help of beams. There are no large openings for JZ House. For this reason, simpler systems have been used (Figure 5.18).

Figure 5.19. Structure of JZ House

The architectural and static designs of JZ House were considered according to the traditional wood load bearing system. Columns were combined with the appropriate connection elements (Figure 5.19). For JZ House building system, laminated wooden parts produced with glulam technique was used.

Figure 5.20. Wall System of JZ House

Wall systems consisting of base beam, post, brace, prop and columun capital elements were prepared in the factory and brought to the application area (Figure 5.20).

In the construction area, only metal joining elements were used to keep these assembled elements intact for a long time. By placing laminated wooden pieces stacked on top of each other together with xps bellows, the insulation properties of JZ House were increased. Overlapping laminated wood pieces have an aesthetic appearance without the need for a covering element (Figure 5.21).

Figure 5.21. Wall System of JZ House

Figure 5.22. Roof System of JZ House

For the roof structure of JZ House, cedar wood was laminated. The wooden roof is highly resistant to environmental conditions. Laminated timber, which is a long-lasting material, provides long-term resistance. The parts produced according to the designed dimensions were added to each other end-to-end and vertically-horizontally to form a lattice system to support the roof (Figure 5.22). The purlin elements are

connected with rafters in accordance with the determined slope. The cage system is covered with insulation materials.

5.2.1. Material Production Methods

Laminated wood material can be produced in the desired size and form for both interior decoration and architecture. In addition, laminated wood, which can be obtained in different thicknesses and colors, provides an aesthetic appearance. When compared with solid wood materials, there is almost no change in the dimensions of laminated wood. However, the preparation of the laminated product and the gluing process create an additional cost compared to the solid wood. The type of glue used influences its durability. The quality of the glue used to obtain a durable laminate is also an extra cost compared to the solid wood. The production area should be appropriate and the worker should be a qualified person.

The transported trees were primarily free of defects. Defects-free wood material was subjected to a natural drying process for about two weeks. The moisture difference between the wood pieces used in drying process is determined not to exceed 5%. This ratio is important in order to prevent the stresses occurring during the cutting process, application process and usage process and the tensile force should be perpendicular to the fibers. In addition, differences that are more than this ratio can cause variations in humidity between the parts. Thus, the wood can not keep its shape. In order to achieve a proper drying process, the ambient temperature should not be less than 15 ° C and the humidity should not be less than 30%. After the drying process, an odd number of parts, such as 3, 5, are combined with the help of glue. The glue layer must penetrate along the joint surfaces of the joined wood parts. There are animal, vegetable and synthetic adhesives in the markets. Kleiberite 303.0 adhesive product was used for JZ House. The materials adhered are dust and oil-free and air-conditioned. The best working temperature for the adhesive is 18 - 20 ° C, the best moisture content of the wood is 10-14%. The kleiberit adhesive used does not harm human health.

After the pieces were glued and joined to each other, they were kept for a period of time before the pressure was applied. This period affects the production conditions, the density of the glue, and the surface structure of the timber parts. If this period is kept longer than necessary, it causes a non-homogeneous surface due to the freezing of the glue. When placing the parts, attention was paid to the joints. It was also necessary to

pay attention to the positioning of the annual rings. The fact that the joints were in a staggered manner increased the resistance of the laminated product. The products which were compressed under high pressure by a hydraulic and pneumatic system were kept waiting 24 hours and then become ready for cutting. The pressure was applied in two directions so that high pressure did not damage the wooden parts. In order to prevent the laminated product from being affected by environmental conditions, impregnation was applied to the parts. This process can be applied before or after gluing of wood pieces. All these proceses are manufactured in the area of Susuzlu Wood Company in Güzelbahçe (Figure 5.23).

Figure 5.23. Manufacture of Laminated Wood Pieces

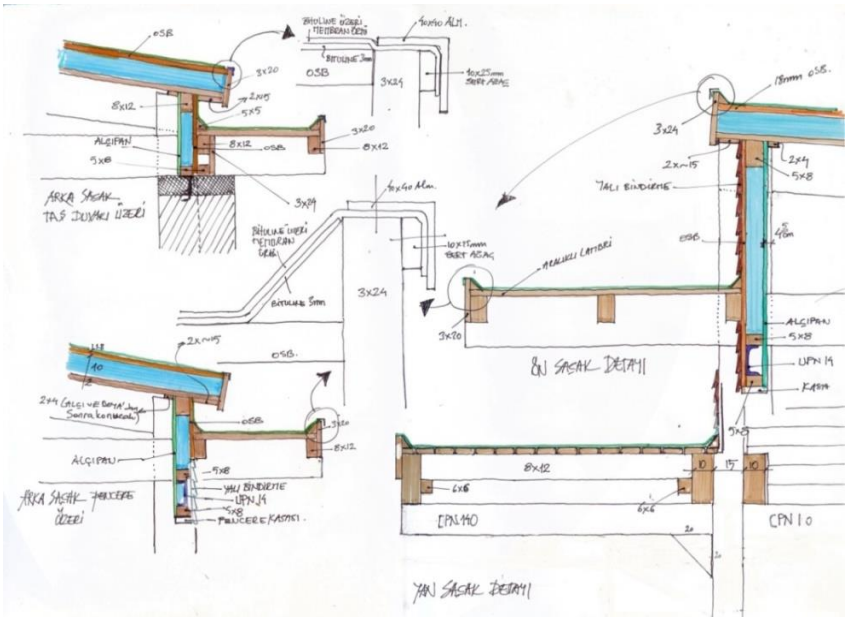


Figure 5.24. Details of JZ House's Roof

According to calculations made for JZ House manufacturing, 12cm x 15cm and 12cm x 25cm pieces were used for the studs. Lime and flooring applications 5 cm x 20 cm and 6cm x 12cm wood parts were used. Breast and cross member dimensions were also determined as 10cm x 10cm and 5cm x 20cm. The details shown in Figure 5.24 are designed according to the wind load calculation results determined according to TS498 load standard.

5.2.2. Applications of Laminated Wood in JZ House Production

Bonded laminated wood materials were used throughout the entire JZ House construction (Figure 5.25). The reason why it was used throughout the building is easy processing of laminated wood, ease of transportation, ease of maintenance for the user, aesthetic appearance, positive contribution to human health and environment and completion of the assembly process in a short time.

Figure 5.25. JZ House

The laminated wood parts used in wall applications are produced separately as floor girder, pillar, yoke, pillar and head elements. The beams and columns produced in different sizes allow the structure to carry itself. The light weight of the wood pieces reduces the load applied to the foundation. Pieces that are easily transported make it easy for workers to install. Wood pieces which in accordance with the calculations of the pieces determined in the factory to be produced in the application area is mounted without any extra treatment. Wood frame structure system was selected for JZ House.

The walls placed between the column and the beams are shaped with knobs, xps foam and waterproofing.

The roof is a construction element used to protect human from external factors and to it provides comfort. For this reason, the materials to be used for the roof should have high moisture proof and should be long lasting material with high insulation performance. JZ House roofing is designed for one-way sloped roof. Shekels, panelling, OSB, tyvek and shingle elements were used from laminated elements. In order to increase the insulation, xps foam was selected.

Laminated wood is used for both flooring system and as a structural and coating element. Laminated flooring materials are placed on laminated beams. The beam dimensions are calculated according to the building load. Insulating materials are placed between laminated flooring and laminated beams to keep heat and sound insulation at a high level.

5.2.3. Insulation Applications

Wood material is a material with high insulation properties, even without any processing. In order to increase the insulation properties, impregnation process can be applied to wood material with various chemicals. In addition, the laminating process adds extra insulation to the wood.

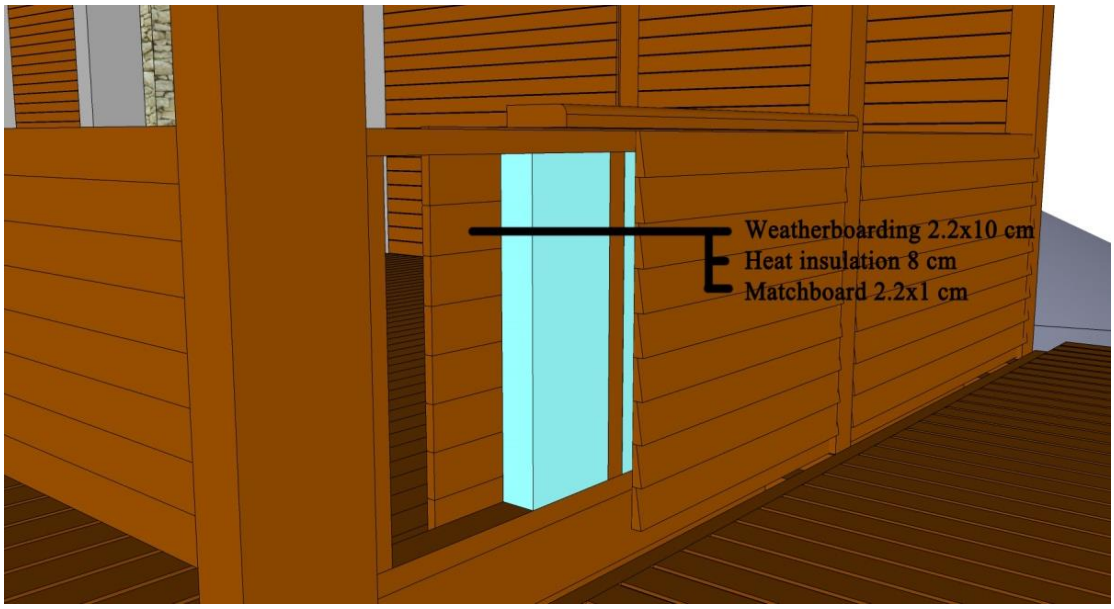


Figure 5.26. Heat Insulain of Wall

The cedar tree used in the JZ House application has high insulation properties due to its large grains and low density. In addition, the structure of the cedar tree provides vibration relief. This allows high acoustic performance. The high insulation performance of wood provides comfort to the users. Some insulation measures have been taken to protect the JZ House from outdoor weather and condensation from the indoor climate. At the beginning of these measures, the airtight weber 20-deitermann product, which provides waterproofing, was used in the retaining walls built from limestone found in the area, which is the connection between the structure and the ground. It was mixed with 3% of the limestone dust. By this way the retaining wall became resistant to chemical products and water. This ensures that the structure is protected against rainwater. It also gives the wall an elasticity. 8 cm heat insulation element is used on exterior walls. The wall consists of 2.2x10 cm weatherboarding, 8 cm heat insulation and 2.2x10 cm matchboard (Figure 5.26).

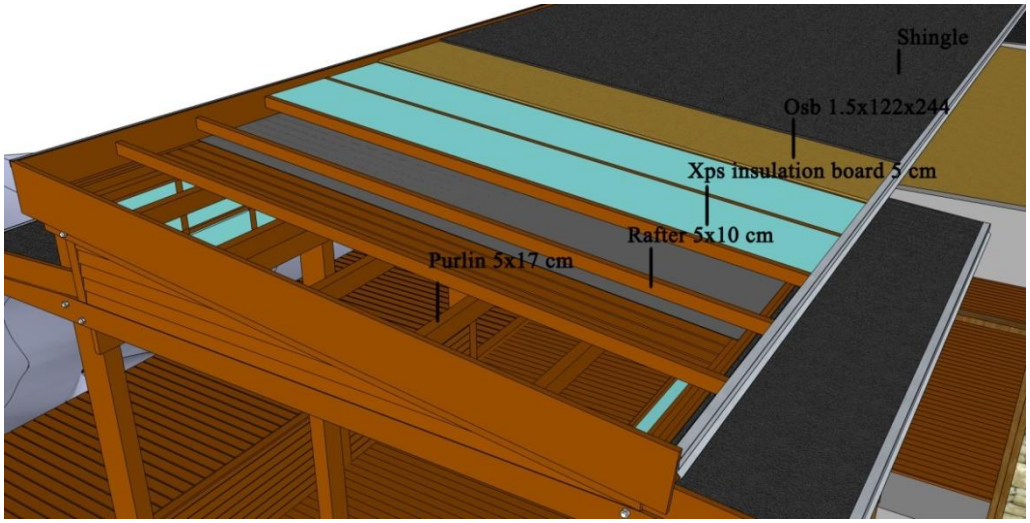


Figure 5.27. Insulation Detail of Roof

In order to prevent heat exchange due to temperature differences between indoor and outdoor, to reduce the energy spent and to keep the user comfort at maximum level, it was necessary to take some protective measures on the façades, door and window joineries and roof systems. Thermal insulation is important not only to protect from the cold, but also to protect from heat in Antalya, which is in a hot climate. For that reason the energy used to cool the space is more than the energy spent to heat among the year. On the floor, xps foam was applied having 50% density between laminated beams and laminated flooring. In the walls, inside and outside, xps foam and waterproofing

materials were used which provided insulation between the exterior and interior. In the roof application of JZ House, xps foam tyvek insulation element was used to protect the structure from sun, rain and many adverse environmental conditions. Xps foam is placed between OSB and paneling. It was covered with shingle material by using tyvek on OSB elements (Figure 5.27). The xps foam used in wall systems, roofing and flooring reduces the thermal conductivity of the structure (Figure 5.26, 5.27). Xps foam material is waterproof. In this way, no change in thermal conductivity value occurs. Thanks to its bending and pressing force, the thickness and size of the xps material used does not change. During application, the desired size can be cut and xps foams are not broken during cutting process. The tyvek waterproofing product used in roof systems limits the heat loss that will occur in the structure through convection. Besides, it reduces the energy consumption cost of the building. It prevents the condensation, water and air leakage in the building. It allows water vapor to be expelled. In addition to all, it provides user comfort while protecting the building structure from the environmental factor.

5.2.4. Fire Precautions

Wood material is a fire-resistant building material because of the estimated burning duration according to the waterproof materials that were applied. Depending on the thickness used, adhesives, chemical materials, the duration of fire resistance may vary. The wood material forms a carbon layer during the burning. The resulting carbon layer inhibits the ingress of oxygen and delays combustion. This time can reach 30, 60, 90, 120 minutes. The burning wood resistance will not get lost easily. It is not a flammable material due to its low thermal conductivity, it is regular and slow burning material, and it has non-flammable cellulose and lignin materials. The fire resistance of the wood can be extended by applying protective materials on the wood element. Wall and ceiling elements are important elements for fire. The materials used in walls and on the ceiling affect the fire resistance time. The gaps between the walls, the insulation materials used and the use of fire-resistant paints affect the resistance time. The roof element is also a section that could increase the burning speed of the structure. The laminated elements used in the roof and the materials selected for thermal insulation should be selected from materials with high fire resistance and non-flammable

materials. For this reason, the materials of the household goods are also important. The products laminated for JZ House use tyvek protective material (Figure 5.29). Besides, laminated wood and solid wood are both used in furniture production. Thus, the amount of poisonous gas that can occur during the fire is small.

Figure 5.28. Tyvek Membrane and Kleiberit 303.0

In addition to the insulation feature of Tyvek material, there is also a feature that prevents the fire from progressing. In this way, the precautions have been taken to prevent the JZ House from catching fire or to delay its period. In addition, the Kleiberit 303.0 adhesive product used when laminating the wood elements to contribute to the fire precautions (Figure 5.28). The laminated product sections used ensures that the structure is resistant approximately up to 60 minutes.

5.3. Advantages of Using Laminated Wood in JZ House Application

Glulam was used for JZ House application. Glued laminated timber shows high resistance to deformation. Glulam technology enables the production of laminated products with high performance properties. For JZ House, cedar wood was selected for laminated wood. Thanks to its structural features, the cedar wood enables the production of high-performance parts with glulam technology.

The wood used actively in the past is now developing itself with laminated wood technology. The buildings constructed using laminated wood show different performance characteristics according to the type of wood used and the laminated wood

technology applied. The advantages and disadvantages of JZ House with its performance characteristics are examined under seven sub-headings.

5.3.1. Energy Efficiency

Wood material is a preferred material over the use of concrete and steel. The wood material, which also harmonizes with the developing technology, has many advantages, especially energy efficiency. Heating and cooling systems constitute a large amount of the energy consumption in a structure. Reinforced concrete and steel used in buildings are materials with high heat permeability. Therefore, energy consumption costs are quite high. Thermal insulation measures can be used to reduce this cost. However, wooden material reduces high insulation performance of concrete and steel structures (Winandy, 1994).

The wood material selected for the applications is an important material that provides the comfort of life when it is used in the right thickness and supported by the correct insulation materials. Wood material, which is an environmentally friendly material, has been laminated for JZ House to make it more durable.

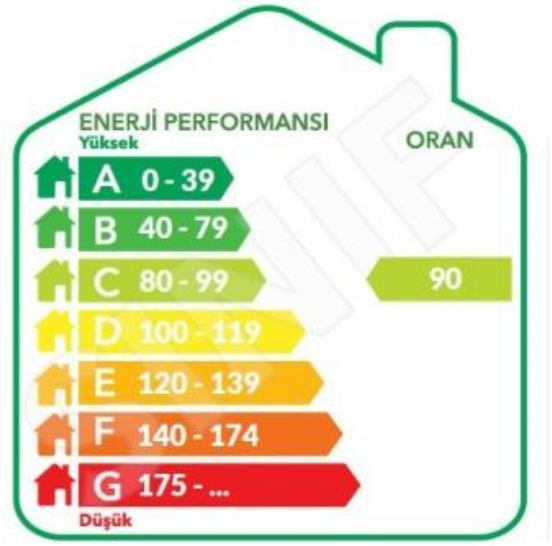


Figure 5.29. Energy Performance of JZ House

The EKB certificate, which was prepared based on the characteristics of the energy systems and building details used in JZ House, was reported with numerical data on the amount of energy consumed to meet the heating, cooling, hot water, ventilation

and lighting needs. The energy performance certificate (EKB) classifies the structures between A, B, C, D, E, F and G using the BepTR program developed by Ministry of Environment and Urban Planning.

Air conditioning was not used for JZ House heating system. Electric water heater is used for hot water system. The split system selected for the reference building was used for the cooling system when entering the data for the energy identity certificate. JZ House has an air conditioning area of 78 square meters and has an annual energy consumption of 11249,47 kWh/year which some part of this energy consumption is used for cooling energy. Approximately one third of the energy used for the cooling system is used for the heating system. Hot water consumption accounts for a year 1729,17 kWh/year is used. Lighting system consumption accounts for a year 267,76 kWh/year is used. When the climatic conditions of Antalya are evaluated, the energy used for the cooling system is more than the energy used for the heating system. According to the EKB report, energy consumption class of JZ house is class C (80-99) (Figure 5.29). Class C is a classification in which all required standards for energy identification certificate are met. Therefore, it is considered a subclass of the good performance. JZ House is a structure that meets these standards with its performance.

5.3.2. CO_2 Emission

CO_2 is a pollutant that affects the quality of life and is directly related to human and environmental health. CO_2 emission is the release of carbon into the atmosphere. CO_2 emissions are rapidly increasing with developing technology. The increase in CO_2 emissions causes global warming and climate changes. The use of fossil fuels, gases from industrial enterprises, toxic gases from vehicles, and excessive energy consumption trigger this increase. If no measures are taken serious problems may occur in the future. High levels of CO_2 release lead to an increase in acidic formations. Acid rains cause great harm to living things. The global warming process accelerates. Changes in climatic conditions glaciers melt and water level changes will occur.

Renewable energy sources are the most important precautions against CO_2 emission to combat the danger that may occur in the world. Renewable energy sources play an active role in environmental protection by preventing carbon emissions (Karaaslan et al., 2017).

CO_2 is stored throughout the life of the tree. The storage of CO_2 continues after the tree has been cut. In order to stop the CO_2 storage of the wood, it is necessary to burn the cut wood pieces. Thanks to its ability to store CO_2, wood is one of the most important and effective materials that can be used against global warming, which is an important problem today.

During the production and application of laminated wood materials, compared to other materials in the manufacturing process, CO_2 emissions are observed at a minimum level (Table 4.1).

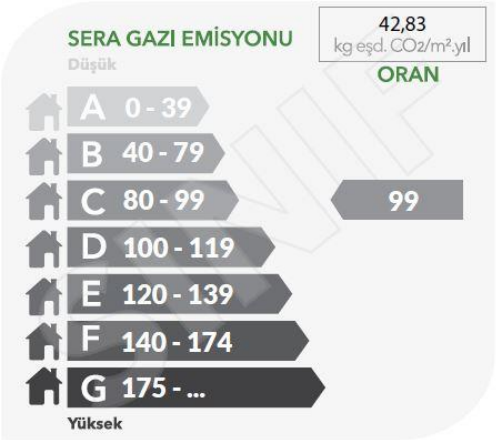


Figure 5.30. CO_2 Emission of the JZ House

As a result of the EKB calculation, the annual heating, cooling, hot water, lighting and ventilation consumption of the building is determined as the primary energy. CO_2 emission is calculated based on these consumption values. The use of renewable energy sources is taken into account. The calculated energy consumption and CO_2 emission of the building are compared with the values of the reference building. When greenhouse gas emission is evaluated, it is seen that this ratio is 42.83 kg eq.CO_2/m^2 year (Figure 5.30).

5.3.3. Effects on Human Health

The fact that the majority of our time is spent in indoor places increases the importance of materials used in space designs. It is important to choose materials that will affect human health physiologically and physically. Wood material is one of the

best examples (Editörden, 2004). In the design of the JZ House, the selection of wood materials was made by keeping human health in the forefront. The wood material is laminated to ensure that the material used is long lasting and more durable. Kleiberit 303.0 adhesive used for laminating is an expensive product but it is completely harmless product for human health. It can be used easily even in the presence of asthma patients. Wood provides indoor comfort thanks to its breathable structure. Besides, superior thermal insulation performance reduces the amount of energy used. While the amount of energy reduces, there occurs less environmental damage, so that fresh air in the atmosphere positively affects human health. The furniture designed for JZ House also provides a healthy environment by increasing the comfort of the interior.

5.3.4. Cost Assessment of JZ House

When calculating the construction cost of JZ House, two different cost amounts, rough construction and finishing construction, were taken into consideration. Architectural, static, electrical, mechanical and landscape design projects have been prepared for JZ House, which were planned first. Subsequently, the materials to be used in construction were determined based on the projects. The architectural, static, electrical, mechanical and landscape design projects have been calculated in accordance with the project outcomes. Unit prices and items were determined according to the selected quantity calculations. The cost table was prepared by evaluating the unit prices, quantities and items together.

Cost assesment of the building is calculated with two different cost calculations in order to evaluate the cost of reinforced concrete and wooden building. Wooden and reinforced concrete building cost calculation is similar to each other for both building materials, land leveling works, wiring, mechanical operations and joinery work items. The items that will determine the cost difference between wood and reinforced concrete structure are the material difference to be used in rough construction (load-bearing system and foundation) and finishing construction.

The cost calculation for JZ House production according to 2019 value for wooden framed building structure and reinforced concrete structure are shown in the Table 5.1 and 5.2. When the cost calculations are evaluated, it is seen that the cost of using wooden materials is lower than reinforced concrete. Total construction cost of

wood framed building is 335.815,0 TL and the cost of the reinforced concrete structure is 368.496,0 TL.

Table 5. 1. Cost Assesment of Wood Framing Buildings

Wood Framed Building				
RAIL DESCRIPTION	UNIT	UNIT PRICE	TOTAL QUANTITY	TOTAL COST
Cedar Tree	m³	4000	14	56.000,0 ₺
Outer side printing	m²	120	110	13.200,0 ₺
Panelling	m²	80	150	12.000,
Floor and Ceiling	m²	80	215	17.200,0 ₺
Impregnated	m³	760	14	10.640,0 ₺
Panelling/İmpregnated Paint	m³	35	485	16.975,0 ₺
Isolation	m²			2.400,0 ₺
Shingle	m²			2.500,0 ₺
Tyvek/geotextile	m³			1.000,0 ₺
OSB	m²			3.000,0 ₺
Excavation				5.000,0 ₺
Transportation				10.000,0 ₺
Workmanship	m²	2250	14	31.500,0 ₺
Covering	m²	485	40	19.400,0 ₺
			TOTAL =	190.815,0 ₺

Table 5. 2. Cost Assesment of Reinforced Concrete Buildings

Reinforced Concrete Building				
RAIL DESCRIPTION	UNIT	UNIT PRICE	TOTAL QUANTITY	TOTAL COST
Concrete	m³	217	138	29.946,0 ₺
Iron	t	3360	12,5	42.000,0 ₺
Workmanship	m²	115	280	32.200,0 ₺
Plaster	mt	50	650	32.500,0 ₺
Hollow-tile floor slab	number	3	1700	5.100,0 ₺
Ceramic	m²	100	210	21.000,0 ₺
Isolation	m²			10.000,0 ₺
Cement Finish	m²			7.500,0 ₺
Painting	m²	25	650	16.250,0 ₺
Auxiliary Materials				12.000,0 ₺
Excavation				5.000,0 ₺
Transportation				10.000,0 ₺
			TOTAL =	223.496,0 ₺

5.3.5. Earthquake Resistance

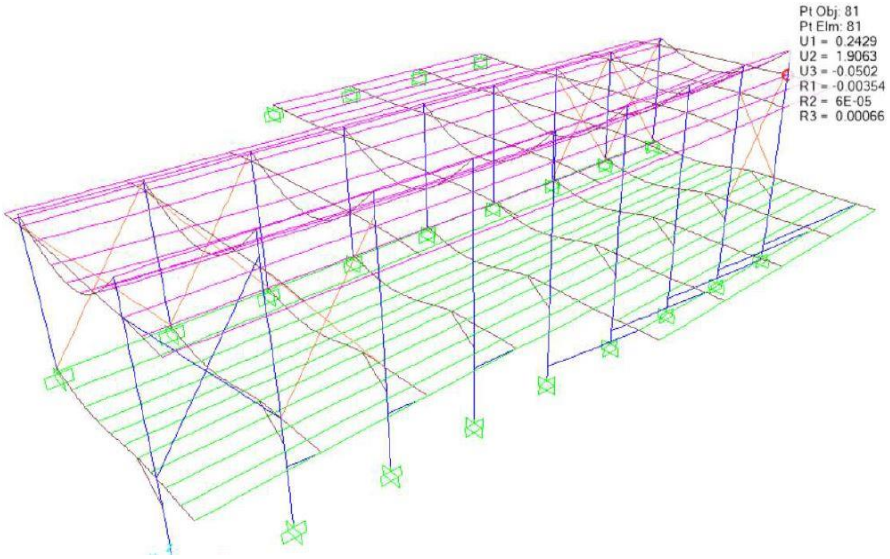


Figure 5.31. Building's Performance Under Increased Earthquake Impact

Wood is a strong, flexible and lightweight construction material. As in the other wooden structures, the wooden post and beam connections used in the JZ House provide the absorption of the stresses and forces that will occur during the earthquake. Excess load that will occur at any joint point is dissipated by dispersing to other posts and beams used in the application. Screws, nails, bolts and similar fasteners used at joint points to absorb and disperse the energy generated during an earthquake, giving flexibility to the members (Karayılmazlar et al., 2008).

According to the static calculations made for JZ House, the system was tested for long-term durability during the earthquake when the structural elements given in the system are used and the detail combinations are made without errors (Figure 5.31).

5.3.6. Material Maintenance and Renewal

Wood materials that can be used in different functions in outdoor and indoor areas are worn out due to changing environmental conditions (rain, wind, sunrays). Cracks and abrasions may occur on the material surface. There may also be some damage during construction. This wear will depend on the quality of the wood used. The maintenance period decreases as the quality of the protective element used for

wood and surface increases. To regenerate the worn wood, the surface was sanded to remove dust. Water-based and environmentally friendly protective varnish or paint was applied. Parts that cannot be reused were replaced with new ones. The damaged part can be used in different applications. However, the characteristics of the new piece of wood to be used must be in harmony with the structure. The same type of tree should be selected in order to adapt the selected piece of wood to the structure.

The cedar wood of JZ House keeps insects away, thanks to its resin. Thus, wooden parts are obtained, which are durable and without stains. It is a tree, which is resistant to cracks and splits. Due to the durable structure of the cedar tree, the maintenance period of JZ House is very long. In addition, the adhesive product used during the laminating process and the water-based product used as a preservative supporter to extend this time.

5.3.7. Sustainability

Sustainable design targets a cleaner environment in the future that does not harm the nature. It aims to design comfortable spaces by using natural resources in the most efficient way. The material must be recyclable and suitable for to long-term use. Wood is a material that carries these properties.

The choice of wood materials in buildings provides positive contributions to human health and environmental health. Trees keep carbon and contributes oxygen to the atmosphere. Wood is a material that provides high insulation. It has high solar energy in its structure. The amount of energy consumed during the life of the structure and during the production of the material to be used is very low. Thus, the damage to the environment is very low. The choice of the chemical product to be used during construction or maintenance of the building is important. Otherwise, chemical products will damage the environment (Pettersen, 1984).

Wood is a renewable and a recyclable material, which has low carbon dioxide emissions, which can be mixed with nature and a material that is sustainable. Waste products produced during cutting and production can be used in different applications or as fuel.

The wood material used in the construction of the building ensures a low waste. In this way, material consumption and the costs are low. The small amount of waste

material reduces the amount of energy consumed. In addition, structures that contribute to the natural cycle are constructed and energy-efficient structures are created (Madison, 1999).

Laminated wood materials used in the construction of the JZ House are also produced from cedar trees in the Kalkan, Antalya. Trees from the field contribute to the natural life cycle. It has superior structural and insulating properties due to its cedar tree structure. Wood material provides an energy efficient structure by providing the insulation required for the building in the best way. Providing the materials used in the near vicinity, being compatible with nature, and low energy consumption ensure that JZ House is an example of sustainable construction.

CHAPTER 6

CONCLUSION

In this study, the usage of laminated wood in residential production was analyzed with the help of JZ House.

Wood material has been an alternative material for building production from past to present. In recent years, with its renewable, ecological and sustainable properties, it has been used in various applications in our country as in the whole world. Today, the effective use of wood material in building production is achieved by working the wood through different procedure. In this thesis, laminated process, which is one of these methods, is investigated. Laminated wood technology helps to strengthen the properties of the wood material, ensure that non-passable openings are easily crossed and applications last longer. Today, laminated wood technology is used especially in building applications and special solutions. The use of reinforced concrete in residential production, which covers approximately 85% (Turkish Statistical Institute-TÜİK) of the total building production in Turkey, plays an active role in reducing environmental pollution by reducing CO2 emissions, which is the main cause of ecological problems. Within the scope of this thesis, advantages of laminated wood have been evaluated with JZ House example in the light of the researches. The properties of laminated wood used in residential production, production methods, production process, types and properties of laminated wood, laminated wood structure production technologies were investigated in accordance with the researches. With the help of investigations and analysis, it is aimed to increase the use of laminated wood in residential production by emphasizing the importance of using laminated wood in residential production.

The aim of the thesis was achieved by the examination of JZ House. JZ House architectural and static project stages, the use of laminated wood materials and the advantages and disadvantages of the use of laminated wood materials to the building, insulation applications used in the building, building resistance to environmental conditions, such as the parameters were evaluated together with the research. As a result of the analysis, the performance of JZ House, the importance of laminated wood for building use, its resistance to earthquake and fire, annual energy consumption and

annual CO_2 emission results were obtained.

In particular, it has been found that laminated wood is effective in terms of superior insulation properties, lightweight and easy application. Since wood is a natural material, it can be affected by environmental conditions, insects and fungi. Depending on the type of wood used in applications, the type of damage and the size of the damage varies. Drying of the wood should be done with great care in order to prevent any damage. According to the place to be used, the amount of damage against wood materials is small and the duration of the damage is quite long. The shape and structure of the wood material can be easily degraded by changing environmental conditions and can be turned into an advantage for the user by strengthening it with the glue applied to the wooden parts and the chemical materials used during the laminating process and providing it to last for years without damaging the environment. In addition, the fact that the defective wood parts are used for the production of laminated wood makes the structure more durable. These properties make laminated wood an alternative material in residential production. In order to ensure the widespread use of laminated wood materials, it is important to carry out and continue research on such topics as energy efficiency, ease of use and production, earthquake, fire resistance, and solutions to the ecological problems.

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