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USING PREFABRICATION SYSTEMS IN BUILDING CONSTRUCTION

Master's Thesis

ALIREZA BAGHCHESARAEI

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THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES M.S. ARCHITECTURE

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ALIREZA BAGHCHESARAEI

Supervisor: Assist. Prof. MELTEM VATAN

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Name/Last Name of the Student: Alirzea Baghchesaraei

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Assoc. Prof. BURAK KÜNTAY

Graduate School Director

Signature

I certify that this thesis meets all requirements as a thesis for degree of Master of Arts.

Assoc. Prof. EMINE ÖZEN EYÜCE

Program Coordinator

Signature

This is to certify that we have read this thesis and we find it fully adequate in scope, quality and content, as a thesis for the degree of Master of Arts.

Examining Committee Members Signature____

Thesis Supervisor

Assist. Prof. MELTEM VATAN ----------------------------------

Member

Assist. Prof. FATIH YAZICIOĞLU ----------------------------------

Member

Assist. Prof. ALI DEVRIM ISIKKAYA ----------------------------------

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ABSTRACT

USING PREFABRICATION SYSTEMS IN BUILDING CONSTRUCTION

ALIREZA BAGHCHESARAEI

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Prefabrication is a development industry term used to depict assemblies that are fabricated under processing factory conditions and afterward transported to the construction site.

The work with this thesis was initiated with a general literature study to get an overview of construction methodologies of prefabrication systems. Prefabrication systems could be divided according to materials, methods, structural configuration etc. In this thesis, prefabrication systems are divided according to their configuration.

Today the world is facing huge crisis due to regular increase in population rate. The awareness of methods such as prefabrication with a higher density would be a key for solving the problem. Prefabrication will keep on growing in many countries as the interest for quick reasonable building increments. It could be stated that prefabrication systems in building construction have the most effect on time and cost reduction.

Although there are numerous advantages connected with developing and assembling buildings utilizing prefabrication construction frameworks, a few constraints might likewise exist. The goal of prefabrication systems is to offer a way to get a well-designed building that is at least roughly tailored to resident's needs. It could be stated that prefabrication systems in building construction have the most effect on time and cost reduction.

It is understood that, prefabrication systems could be used more in building construction if the disadvantages of prefabrication are solved and It is possible to say that further improvement of prefabrication systems will prompt a closer joining between building construction and future potential of prefabrication.

Key words: Prefabrication, Standardization, Assembling, Construction.

OZET

BİNA İNŞAATLARINDA PREFABRİKASYON SİSTEMLERİN KULLANIMI

Alireza Baghchesaraei

Mimar

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Prefabrikasyon bir gelişmiş endüstri terimi olup, fabrika koşulları altında işlenmiş, üretilmiş ve daha sonra şantiyeye sevk edilmiş malzeme anlamını ifade etmektedir. Bu tez altında gerçekleştirilen çalışma prefabrikasyon sistemlerinin yapım yöntemlerine genel bir bakış imkanı sağlamaktadır. Prefabrikasyon sistemleri malzeme, yöntem, yapısal konfigürasyonlarına göre bölümlere ayrılabilir.

Bu tez çalışmasında, prefabrikasyon sistemleri yapısal konfigürasyonlarına göre bölünmektedir. Bu gün dünya nüfus oranında düzenli artış nedeniyle büyük bir krizle yaşamaktadır. Yüksek yoğunlukta prefabrikasyon gibi yöntemlerde yaratılacak farkındalık bu problemin çözümünde önemli bir anahtar olacaktır. Bir çok ülkede çabuk bina inşaatına ilgi artarken, buna paralel olarak prefabrikasyonda büyümeye devam edecektir. Prefabrikasyon sistemlerinin bina inşaatlarının maliyet ve inşa sürelerinde en önemli etken oldukları söylenebilir.

Gerçi prefabrikasyon inşaat malzemelerinin binalarda kullanımının geliştirilmesi ve montajında büyük faydalar vardır, ama ayni şekilde kısıtlayıcı birkaç hususta vardır. Prefabrikasyon sistemlerinin amacı iyi, tasarlanmış, en azından içinde yaşayacak insanların –gereksinimlerine kabaca da olsa imkan sağlayacak bir çare sunmaktır. . Prefabrikasyon sistemlerinin bina inşaatlarının maliyet ve inşa sürelerinde en önemli etken oldukları söylenebilir. Prefabrikasyon sistemlerinin dezavantajları ortadan kaldırılsa bina inşaatlarında daha fazla kullanılacakları anlaşılmaktadır. Prefabrikasyonlarının daha fazla geliştirilmesi gelecekte üretilecek potansiyel prefabrikasyon malzemeleriyle bina inşaatlarının daha fazla yakınlaşması sağlanabilecektir. Prefabrikasyon sistemlerinin bina inşaatlarının maliyet ve inşa sürelerinde en önemli etken oldukları söylenebilir

Anahtar kelimeler: Prefabrikasyon, standardizasyon, montaj, inşaat.

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1. INTRODUCTION

Prefabrication is the act of collecting segments of a structure in a manufacturing process or other assembling site, and transporting complete congregations or sub-gatherings to the development site where the structure is to be constructed. The term is utilized to recognize this procedure from the more ordinary development routine of transporting the essential materials to the construction site where all get together is completed (Limthongtang, 2005).

The quickly developing populace triggers the requirement for another, cost-cognizant building system to fulfill the enormous interest on ease construction. to be satis (Limthongtang, 2005):

1. Fast and easy erection with unskilled laborers

2. Economical use of local materials

3. Structurally stable construction

4. Good thermal and sound insulation

5. Great variety of design features

6. Minimum installation work on site (no cranes)

Conventional building systems, for example, block, solid, steel and prefab consent just halfway with these necessities. The Conventional system for constructing a building in prefabrication is to transport structural elements and structural materials and so forth to the site, and to construct the building on site. In prefabricated construction, only the establishments are developed thusly, while segments of dividers, floors and rooftop are assembled in a processing factory (conceivably with window and door jambs included), transported to the site, lifted into spot by a crane and blasted together.

There are various technologies available worldwide for using prefabricated construction methods, almost all technologies try to reduce costs and time, prefabrication method gives possibility to the designers for assembling their structures in a short period of time.

Although designers are allowed to use different kinds of materials, they mostly prefer to choose light weight ones. Wood and steel are the most practical materials in prefabrication construction. Designers should carry out prefabricated buildings by the usage of different technologies and systems, however these technologies need high level of knowledge and experience and high quality of application on site, so prefabricated construction technologies are preferred in many developed countries.

Lack of knowledge and experience has caused decreasing in prefabrication construction technologies in many developing countries. In the other hand many countries encounter earthquake risk and it is one of the important reasons which prefabrication is not such an appropriate choice for countries in disaster prone areas. However, several developing countries start using prefabrication by importing its knowledge and techniques. Nowadays prefabrication technologies play an important role in multiple developing countries and its usage has been increasing every day (Fetters, 2002). Prefabrication process is the association and administration of the arrangements, gear, materials and work included in the construction of buildings or components.

Prefabrication is a development industry term used to depict assemblies that are fabricated under processing factory conditions and afterward transported to development destinations for joining into building and structural designing works. The segments of prefabricated structures are fabricated of different materials, for instance, steel, concrete, reinforced concrete, wood, aluminum composites, and plastics, in specific plants of the development business or in on site yards (Best, 2002).

The work with this thesis was initiated with a general literature study to get an overview of construction methodologies of prefabrication systems to acquire some background knowledge of these kinds of constructions. The first step was to look into how prefabrication systems have been constructed historically. The focus of the literature review was to study the various methods that are used today when constructing prefabricated buildings. The aim of this research is to examine various prefabrication systems according to their structural elements. Additionally, to discuss the way of using prefabrication systems in architectural design such as: sustainability and project management. This thesis will discuss the future market of prefabrication. Besides, the study will show the possibility of decrease the time and costs of construction projects by prefabrication.

1.1 DEFINITION OF THE PROBLEM

There are two techniques for people to get a new way for construction. One way is to use traditional ways that offers a handful of models and the other way, for those with a strong desire for customization, are to design a system from scratch, and have it built from basic components.

The goal of prefabrication is to offer a third way, a way to get a well-designed building that is at least roughly tailored to resident's needs.

There are multiple ways for architects to build their ideas and in nowadays construction, time, cost, energy, management and etc. play striking role in construction process. Prefabrication systems have this potential to cover all these potentials and definitions. Additionally, most of methods and ways are not appropriate for using in different regions but prefabrication is a method which has this potential to use in several countries with several features. Prefabrication plays an important role in the modern world in field of construction. It refers to the making of parts in an offsite workshop or factory prior to the installation at the site. "The primary purpose of prefabrication is to produce building components in an efficient work environment with accesses to specialized skills and equipment in order to reduce cost and time expenditures on the site while enhancing quality and consistency" (Anderson and Jensen, 2007).

There are several systems which can be used among architects and designers, this research will try to detect all these systems (according to the structural behaviors) and find some appropriate ways for many countries (Especially developing countries) to use prefabrication systems in their construction more.

Nowadays, in many countries people need an approach to fabricate building faster and more modestly. Unless they are a gifted building wright many people are not able to cut the intricate joinery needed for a timber casing building.

Prefabrication plays an important role in the modern world in field of construction today, it refers to the making of parts in an offsite workshop or factory prior to the installation at the site. Anderson and Jensen "The primary purpose of prefabrication is to produce building components in an efficient work environment with accesses to specialized skills and equipment in order to reduce cost and time expenditures on the site while enhancing quality and consistency" (Anderson and Jensen, 2007). It is clear that using prefabricated systems have many advantages, and it may enlarge its usage around the world, from primary structures to small architectural ornaments.

Although prefabrication is a common method of construction in many developed countries, several developing countries still do not use this method widely. Due to the fact that those countries have different social and economic systems conditions, such as: seismic risk, lack of knowledge and expertise and transportation problems and low quality of infrastructure. Additionally they tend to use more actual personals for constructions rather than prefabrication methods. Construction methods that require a lot of physical labor such as masonry, hand paint or cast-in-place concrete are common in these countries.

Developing countries have been trying to transform from an agricultural society to an industrial society. For decades, they have invested a lot of money in education to develop its people in fields that would make its transition to an industrial nation much easier. As a result, labor costs have risen exponentially (William, 1997). Many developers and contractors in those countries also see this problem and respond by using more prefabrication; this attracts many investors from all over the world to invest more in the prefabricated residential construction methods in some of them. Currently, there are several building developers there that use prefabrication for their projects. In the near future, prefabrication is expected to play a major role in developing countries construction, like in many European countries and the USA.

The theory behind the prefabricated construction is that time and costs is spared if comparable development assignments could be assembled, and mechanical production systems could be utilized in construction at an area where expert work is accessible, while blockage at the gathering site, which squanders time, can be lessened. The strategy discovers application especially where the structure is made out of rehashing units or shapes, or where various duplicates of the same essential structure are being built (Tac, 2002). Prefabrication construction maintains a strategic distance from the need to transport such a variety of professional specialists to the development site, and other confining conditions, for example, an absence of force, absence of water, introduction to exposure of climate or a risky situation are evaded. Against these focal points must be measured the expense of transporting prefabricated areas and lifting them into position as they will for the most part to be large, more delicate and more hard to handle than the materials and parts of which they are made.

According to nowadays construction, there are various systems available for using in building construction, this thesis would try to find the role of prefabrication there. The important point about prefabrication is its classification. According to structural configuration prefabrication could classify in various systems with several subtitles and titles, these systems have several advantages and disadvantages for using in building construction, discovering these features and finding the relationship between prefabrication systems and time and cost are the most striking part of this thesis.

1.2 OBJECTIVE

The aim of this research is to identify prefabrication systems and methods which are existed for developed and developing countries in construction field. There is a strong potential of prefabricated construction systems in both countries which could show effect on the future priority of architecture.

The main objectives of this research are:

1. Theoretical study of prefabrication,
2. Theoretical study of prefabricated construction systems,
3. Study of prefabrication construction systems in developed and developing Countries according to their market,
4. Comparison of different systems of prefabrication construction used in developed and developing countries,
6. Discuss the advantages and disadvantages of prefabrication construction systems
7. Discuss the future role of prefabrication techniques in building construction
8. Discuss the future advantages and disadvantages of prefabrication construction techniques,
9. Determine the prefabrication construction role in future time, costs and energy

efficiency and point out the role of prefabrication in future construction market.

The hypothesis of this study is to propose the use of prefabricated construction systems from developed countries which might be utilized for growing new or comparable products that are suitable for developing countries. There is a considerable measure of strong potential prefabricated construction systems and strategies in developed countries which could be extremely valuable in developing countries.

The main aim of this research is finding the role of prefabrication in reduction of cost and time and explores the hidden advantages and disadvantages of prefabrication techniques in future process of building construction and detect the ways for increase the usage of prefabrication techniques in building construction in future.

1.3 BACKGROUND

Prefabrication is utilized to recognize this procedure from the more ordinary development routine of transporting the essential materials to the development site where all get together is completed (Limthongtang, 2005).

Prefabrication has been utilized since ancient times. Case in point, it is guaranteed that the world's most seasoned known designed roadway, the Sweet Track developed in England around 3800 BC, utilized pre-assembled timber segments conveyed to the site as opposed to amassed on site (Yeung, Chan, and Chan, 2002).

For more than a century, prefabrication has been a solid part of construction. Prefabrication is known as a fast and affordable type of construction. After World War II, prefabricated construction became popular in many countries. The prefabricated home was not widely used until World War II when mobile homes were produced to supply housing to military personnel (Kim, 2009). The need of homes for the men and women who returned to their countries after the war forced builders to build faster. In example, “Eleven million servicemen and –women were returning home to communities where few unoccupied houses were available. By 1947, more than 5 million families had either doubled up with other families in overcrowded dwellings or were occupying temporary shelters” (Kim,2009). To meet the high demand, some builders experimented new housing market by creating their own designs and specifications to help build more and faster. Some builders made off-site building components then delivered them to other builders or home buyers rather than building everything at the site.

Many "House by Mails" were shipped from the factories, and the result of big benefit has attracted many new investors'' (Arieff and Burkhart, 2002). Since then, many investors have been interested in the prefabrication concept. New factories were built for producing building parts which were then shipped to the site, hence the term "prefabricated construction".

Prefabrication construction was created as a part of the development of buildings blocks, and building advancements with rehashed building units. The nature of prefabricated building units had expanded to the point that they may not be recognizable from customarily fabricated units to those that live in them. Prefabricated steel and glass segments are generally utilized for the outside of extensive structures (Downing, 2002).

Prefabricated construction systems spares building time on the development site in structural designing activities. This could be essential to the achievement of undertakings, for example, where climate conditions might only permit brief times of development. Prefabricated components and frameworks offer extension creators and builders critical focal points as far as development time, wellbeing, ecological effect and expense. Construction can likewise help minimize the effect on activity from scaffold building (Reddy, 1996).

Fast-growing economies of some developing countries have forced builders to build faster and more economically. Developed countries in Asia such as China and Hong Kong invest in prefabrication construction research. Just as many developed Western countries, they invent their own construction techniques and conduct their own research, which is suitable for their economies, geographies and populations. Products made in both countries are well distributed locally (Wong, 200).

It is possible to say that, today, many architects prefer prefabricated construction which makes significant impact on both time and budget, from both the private and public sectors, has been put into research and production to create better prefabricated construction product.

1.4 METHODOLOGY

The work with this thesis was initiated with a general literature study to get an overview of construction methodologies of prefabrication systems. To acquire some background knowledge of these kinds of constructions the first step was to look into how prefabrication systems have been constructed historically. The focus of the literature review was to study the different methods that are used today when constructing prefabricated buildings. This was done to get a good background knowledge of construction of prefabricated buildings.

In order to obtain main objectives will be fulfilled by this research, it consists of two parts:

a. literature review of related work in prefabrication and its definition, methods, techniques, systems.
b. materials in building construction, and its advantages, disadvantages and its role in future construction process and market.

There were two categories for this research:

a. Empirical studies: To investigate appropriate prefabrication systems used for building construction.
b. Prefabrication systems assembling behavior: recognizing relationship between prefabrication systems and its assembling process.

Then, in the second part several definitions and results are obtained from previous phase, the thesis explores the advantages and disadvantages of prefabrication systems and investigating the relationship between prefabrication and construction future. The survey connects an empirical observation to practical process, suggesting prefabrication ideas or solutions concerning how people could use prefabrication as a suitable method in future. Collecting relevant data in both phase was very important and it is down by field work, observation and also desk work to obtain different information from different valid sources.

All elements of prefabrication systems were studied and these systems were surveyed in construction development process one after another. This part aims to suggest the possible answer of what is the effect of prefabrication systems on construction market?

In the study of construction methods and methodologies an important source of knowledge has been to study existing prefabricated buildings and how they have been built.

The results from the literature study have served as a basis for the development of a prefabricated construction methodology and sequencing. From the review of today's prefabrication systems the methods that were deemed implementable in the construction of been applied.

This thesis would try to present an appropriate classification of prefabrication systems and link them to present construction market to discover how nowadays construction sector are influenced by various prefabrication systems and find the advantages and disadvantages of prefabrication systems by coordinating relevant data and information comes from valid sources.

2. PREFABRICATED SYSTEMS IN BUILDING CONSTRUCTION

2.1 PREFABRICATION PROCESS

Prefabrication consists of two different words pre and fabrication which means before making. Prefabrication is an improvement industry term used to delineate gatherings that are delivered under production line conditions and a short time later transported to the site for breaker into building, basic outlining works and construction (Arieff and Burkhart, 2002).

Prefabrication is a development industry term used to depict assemblies that are fabricated under processing factory conditions and afterward transported to development destinations for joining into building and structural designing works. The segments of prefabricated structures are fabricated of different materials, for instance, steel, concrete, reinforced concrete, wood, aluminum composites, and plastics, in specific plants of the development business or in on site yards (Best, 2002).

"Prefabrication Construction" is an industrialized development strategy whereby mass-delivered parts are amassed into structures with the guide of cranes and other lifting and taking care of machines. The work of construction is done in two stages assembling of the segments in the industrial facility or workshop, and erection on the site. Prefabricated auxiliary segments are alluded to as "prefabricated units" (Best, 2002). ("prefabricated individuals" or prefabricated components" are terms on the other hand utilized), connoting that they are cast ahead of time and offered time to solidify and secure quality before being taken to the real development site for erection. Construction systems which make utilization of prefabricated parts are aggregately alluded to as "prefabricated construction".

In twentieth century after the World War I prefabrication techniques and systems usage started increasing since the lodging principles were greatly poor for many people especially in European countries, additionally. In twentieth century many developing countries have been trying to transform from an agricultural society to an industrial society. For decades, they have invested a lot of money in education to develop its people in fields that would make its transition to an industrial nation much easier. As a result, labor costs have risen exponentially (William, 1997). So, the prefabricated construction felt as a need in several countries and they started using it more widely with a fix and stable process.

The prefabrication construction process is executed in four phases:

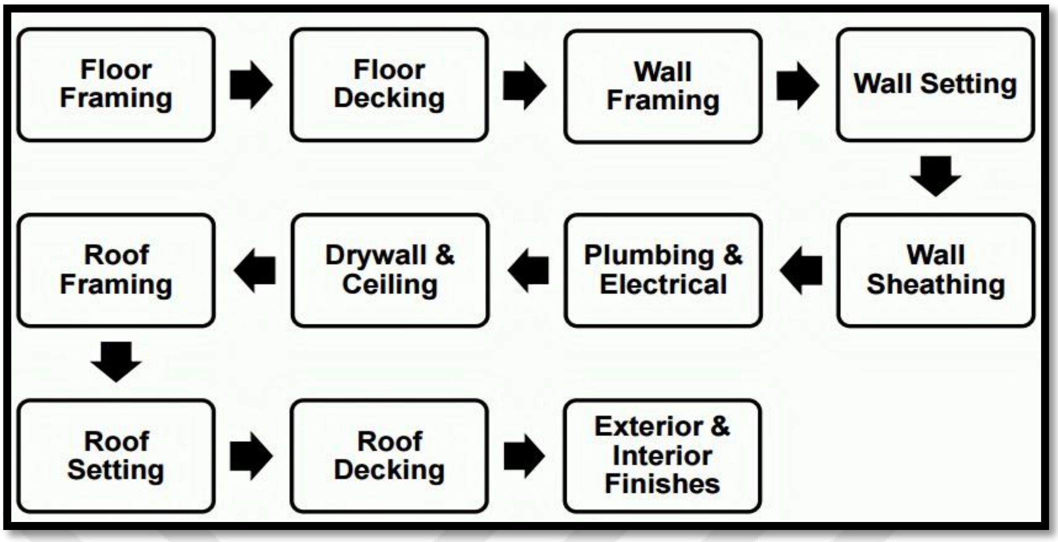
1. Design endorsement.
2. Assembly of prefabricated or precast.
3. Transportation of modules to the construction site.
4. Erection of particular units to shape a completed building.

Prefabrication process is the association and administration of the arrangements, gear, materials and work included in the construction of buildings or components, while in the meantime consenting to all codes, rules and contractual stipulations. The procedure might be intended to run productively, to keep the expenses low and to permit returns on the speculation to be acknowledged as right on time as could be expected under the circumstances.

Dividers, floor boards and rooftop trusses of prefabrication that are inherent a processing factory will require designed drawings and formats for construction regulation endorsement, much the same as whatever other prefabricated basic segment. Board and truss producers are staffed to give built outlines, in light of the developer's structural drawings, alongside the segments and jobsite conveyance. A few makers can offer a "turn-key" answer for manufacturers with the consideration of item establishment via prepared groups (William, 1997).

Manufacturing process is a part with important role in prefabrication process in building construction. The extent of the firm and their particular holders, for example, nearness to dissemination channels, piece of the overall industry, and creation capabilities decide how quite a bit of their operation must be outsourced to different organizations. Most prefabrication facilities follow the kind of specific assembling steps (Figure 2.1)(Smith, 2010).

Figure 2.1: Prefabrication assembling process



*Source:*http://www.alibaba.com/product-detail/Low-cost-steel-frameAssembled_1048556284.html

Prefabrication, regularly, can be classify in sorts of materials or level of prefabrication. First and foremost, sorts of material mean any basic materials that are utilized to construct the construction parts, for example, timber, concrete, steel or in some cases the blend of distinctive materials, in the industrial facility. Second, level of prefabrication construction is a development prepare through which pre-assembled components are gathered on site, from the little piece to the huge piece, for instance, pre-assembled section, boards, tilt-up, and measured systems.

2.2 HISTORY OF PREFABRICATED CONSTRUCTION

Prefabrication has been utilized since ancient times. It is guaranteed that the world's most seasoned known built roadway, the Sweet Track developed in England around 3800 BC, utilized prefabricated timber segments conveyed to the site as opposed to collected (Figure 2.2). Sinhalese lords of old Sri Lanka have utilized prefabricated construction innovation to erect huge structures, which goes back similarly as 2000 years, where a few segments were arranged independently and afterward fitted together (Figure 2.3) (Clini, 2002).

Figure 2.2: Sweet track roadway

Source: http://www.elixirofknowledge.com/2011/01/preserved-through-time-partii.html

Figure 2.3: Ancient City in Sri Lanka

*Source:*https://en.Kuttam.org/Anuradhapura#/media/File:Anuradhapura_Kuttam-Pokuna.jpg

The idea of prefabrication construction is resulting from rationale and originates before industry by a large number of years. It discovers establishes in chasing, workmanship, art and numerous different exercises that are inherently connected to the presence and survival of human being. Prefabrication construction initially took the fundamental type of creating frameworks, either theoretical or real, that prompted the generation of parts that could be utilized as a part of an assortment of ways. Inevitably, construction got to be vital for taking care of the demand for items, nourishment, and diversion of the developing masses. Early cases would be the particular generation of forks, stallion shoes, and bolts.

Beginning in the mid-18th century, The Industrial Revolution had a tremendous impact on building design and construction. All outline was influenced by the normal utilization of new materials, for example, steel and glass. Configuration changes were principal sometimes and offered ascent to new styles whose roots were determinedly planted in the idea of industry (Clini, 2002). Prefabrication techniques were used for the first time in 1779 (Figure 2.4), the first Iron Bridge in the UK built by prefabrication techniques usage (Fetters, 2002).

Figure 2.4: The Ironbridge over the River Sevren

Source: http://www.britainexpress.com/Where_to_go_in_Britain/Destination_Library/ironbridge

The new definition of prefabrication techniques and systems were collaborated in the mid 1920's by Le Corbusier (French architect) built up various mass-created lodging plans amid that time. He likewise composed an exposition "Large scale manufacturing Houses" in which he alluded to the mass-created houses as "House Machine" (Figure 2.5) and Walter Gropius tested the new mass created lodging by utilizing steel to frame the quick assembled lodging structure, where Gropius created "Building Blocks" (Koskela, Howell,Ballard and Tommelein, 2002).

Figure 2.5: Le Corbusier Large scale manufacturing House

Source: http://www.archdaily.com/278569/14-facts-le-corbusier

The post-World War I time in Europe saw a noteworthy increment in the industrialization of building. Because of the decimation of existing structures and the absence of new development amid the intra-war years, there was an intense interest for temperate and basic building frameworks. Lodging saw the best advance in construction as engineers started to all the more broadly acknowledge the utilization of standard parts, steel, and glass. One issue with a number of the building frameworks created amid this time was that adaptability was not piece of the general outline. These frameworks did not give space to an imaginative reaction to a building issue.

In the twentieth century, the force for creating mass prefabrication methods happened after the First World War when the need for the procurement of new lodging could not be taken care of by the exchanges framework and customary building techniques. Prior to the First World War, especially in European countries the lodging principles were greatly poor for many people. There was along these lines an extraordinary existing need to supplant the sub-standard properties in every power and to expand the quantity of properties accessible for rent. The low creation and devastation of the war years was in this way forced on a previous connection of deficiencies in lodging procurement.

World War II was finished up with another lodging emergency both in the United States and Europe. In spite of the fact that United States regions had not seen any activity, there was a requirement for lodging because of the quantity of returning officers who immediately began families. A populace blast went hand in hand with the end of the war. Once again, prefabrication construction was utilized to take care of the demand for lodging. Whole groups, for example, the one in Levittown, NY (Figure. 2.6), showed up with multiple rows of prefabricated buildings, generally indistinguishable houses. Subsequently, the "mushroom farms" were conceived (Smith, 2010).

Figure 2.6: Levittown prefabricated homes

Source: http://instanthouse.blogspot.com.tr/2011/07/levittown-pa.html

Prefabrication construction in the late 20th century was produced on a much greater scale. The advancement of computerized innovation has helped decrease the limit on the outline side and increased the computation consideration. The word, CAD (Computer Aided Design), CAM (Computer Aided Manufacturing) and CNC (Computer Numeric Control) have gotten to be normal words for designers, foremen and producers. This occasion is influencing ''prefab innovation'' improvement, as well as the social developments by which structures are delivered, their agreement structure, and the interface of players.

Computerized creation is possibly a strategy by which the guarantees of construction corresponding increment in outline and generation quality – may be acknowledged.

Today, prefabricated construction has become one of the major components of the developed countries construction and almost 100 percent of building construction utilize prefabricated materials, which suggests that each building is prefabricated to a certain degree regardless of the possibility that it doesn't fulfill the criteria of “manufactured housing “(Somerville, 1999).

2.3 STANDARDIZATION AND CUSTOMIZATION

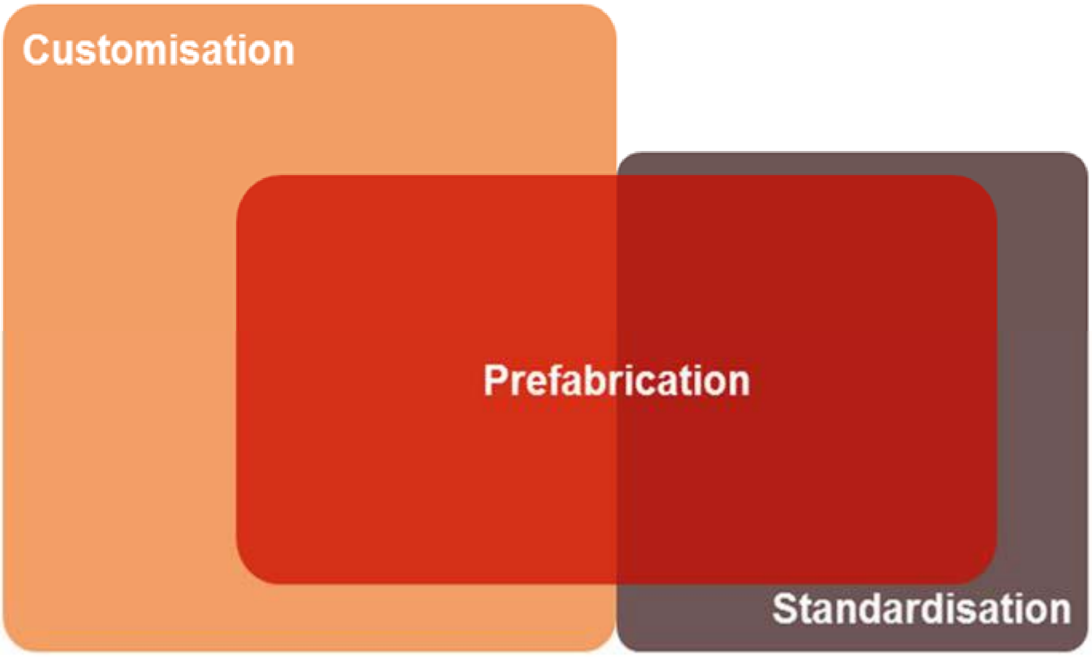
Standardization and Customization play such an important role in prefabrication construction process. To know how they work together their definitions and comparisons are needed to be introduced.

Standardization is the rehashed generation of standard sizes and designs of parts or complete structures. Illustrations incorporate particular elements and completions. This rehashed generation of indistinguishable segments or structures may happen on site (in which case it is just standardization) or it may happen off-site (Tam, Tam, Zeng and Williams, 2007).

Customization, could be defined as the inverse of standardization, and has normally been the pattern, notwithstanding in the matter of components and elements that one may expect could be created in standard formats. Customization may happen either on site (Tam, Tam, Zeng and Williams, 2007).

Therefore, prefabrication is the off-site production of standardized or customized components or complete structures (Figure 2.7) (Blisman, Pasquire and Gibb, 2006).

Figure 2.7: The relationship between customization, prefabrication and standardization



Source:http://www.fhwa.dot.gov/everydaycounts/technology/bridges/pbeswebinartraining/s2_m6.cfm

Prefabrication process occurs mostly in factories, so factories might follow some agendas to be able to The Egan Report "Rethinking Construction" distributed in July 1998 by the Construction Task Force explored the execution of the Construction. The report found that prefabrication construction expected to focus on turning out to be more effective, enhancing the nature of its yield and enhancing the fulfillment of development customers. This recommended industry expected to (Construction Task Force, 1998):

1. Decline construction costs and expenses.
2. Improve the quality of construction process.
3. Move towards manageable development with accentuation on construction
4. Become more creative to streamline the development process.
5. Develop banding together between foremen and suppliers to move towards a debate free industry.

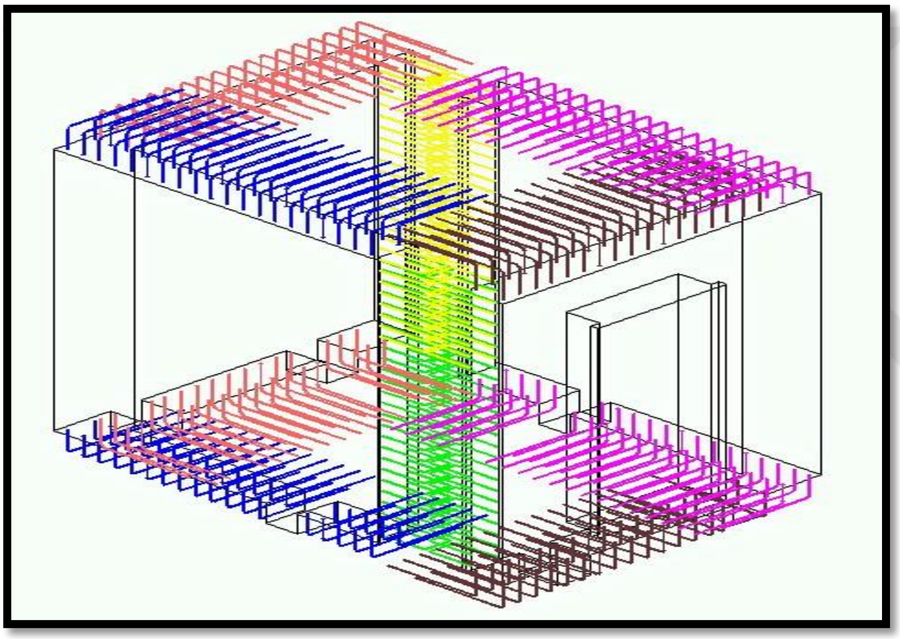
2.4 STANDARD SIZES IN PREFABRICATED COMPONENTS

Prefabricated components have some international size definition which is fixed in all countries and architects have to obey these size definitions in their prefabricated buildings.

a. Prefabricated household shelters

The establishment of the household shelter (HS) is regularly in the basic way of development works and frequently influences the advancement of simultaneous chips away at site. Subsequently, the utilization of precast household shelter set up of the present in-situ configuration will probably lessen the construction period (Figure 2.8). The weight of the household shelter panel is in the order of 5.5 to 6 tones and minimum internal floor area of prefabricated household shelter should defines between 1.8m x1.25m to 2.3m x 1.5m (Construction Task Force, 1998).

Figure 2.89: Prefabricated household shelter

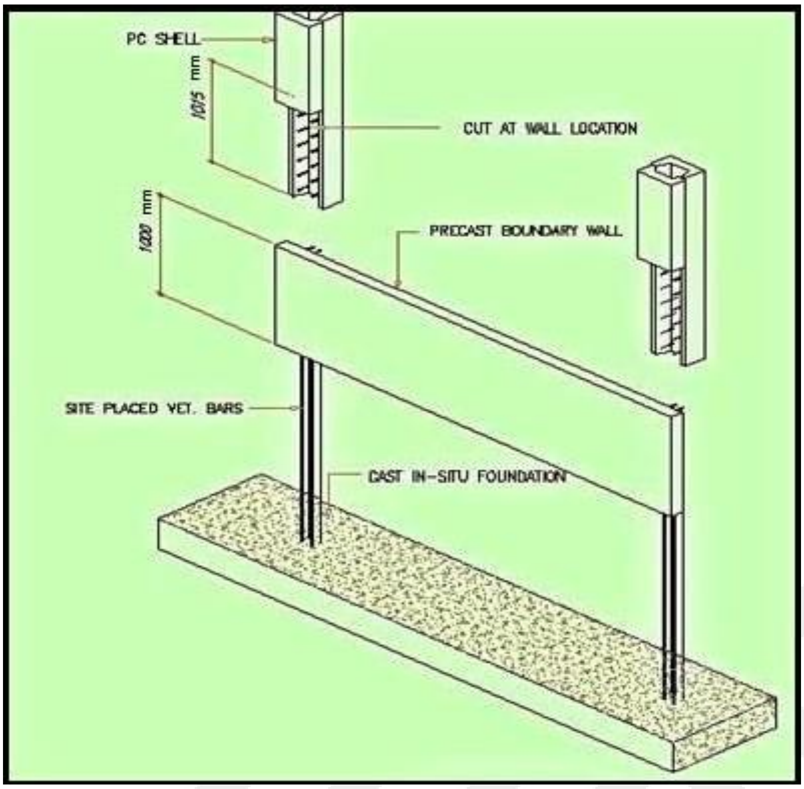


Source: http://dornob.com/6-hours-2-adults-1-post-disaster-prefab-5-person-home

b. Prefabricated dividers

Prefabricated dividers are like traditional divider boards but regularly of littler sizes. This makes them truly perfect for prefabricated construction as the littler boards imply that the builder would have fewer issues with taking care of, transportation and establishment on site. The utilization prefabricated dividers keeps on allowing an extensive variety (60cm to 120cm) of configuration adaptability and development (Figure 2.9). There is no any restriction in their size and weight (Figure 2.10) (Construction Task Force, 1998).

Figure 2.9: Prefabricated dividers in exploded view



Source: http://www.houzz.com/photos/products/query/prefabricated-home

Figure 2.10: Prefabricated dividers in completed view

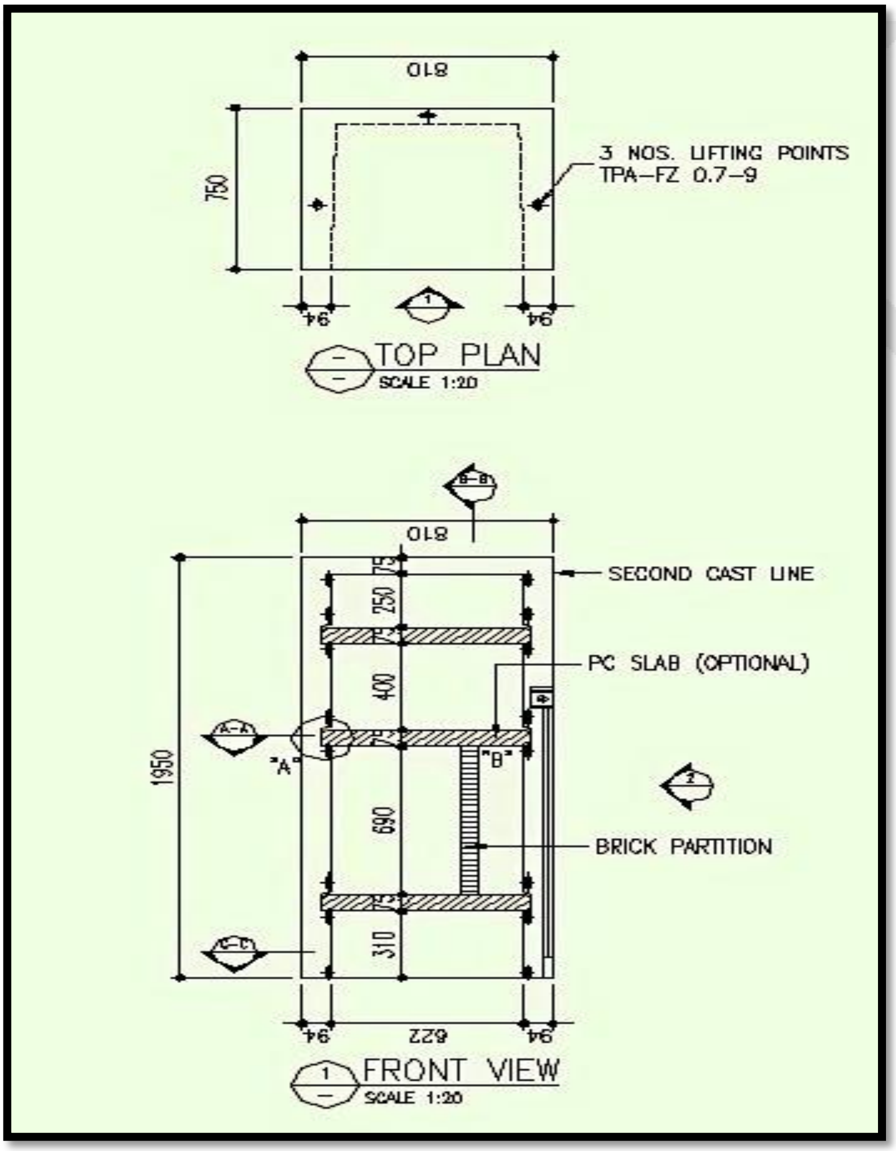
Source: http://www.houzz.com/photos/products/query/prefabricated-home

c. Prefabricated chambers

The prefabricated chamber is manufactured in one certain level: It is the chamber and alternate comprises of precast cement racks which opening into the precast chamber to particular each of the diverse administrations (Figure 2.11) (Figure 2.12).

The measure of the prefabricated chamber is ordinarily 800mm x 800mm x1800mm high. Henceforth, this prefabricated part can be transported and introduced effectively. Besides, the slick and fitting compartmentalization will make it simpler to run and introduce the administrations between the mains, the chamber and the house (Gould and Joyce, 2000).

Figure 2.11: Details of prefabricated chamber



Source: http://dornob.com/6-hours-2-adults-1-post-disaster-prefab-5-person-home/

Figure 2.12: Completed prefabricated chamber

Source: http://www.unitedconcrete.com/pump_stations/head_pump_stations.htm

- Prefabricated staircases

The prefabricated staircases proposed in standard sizes with tread sizes between 225mm to 250mm and risers between 150mm to 175mm. Then again, steel staircases can come in non-standard sizes to suit the structural configuration (Figure 2.13) (Figure 2.14) (Construction Task Force, 1998).

Precast/ steel staircases can be fabricated to a range of various forms and shapes.

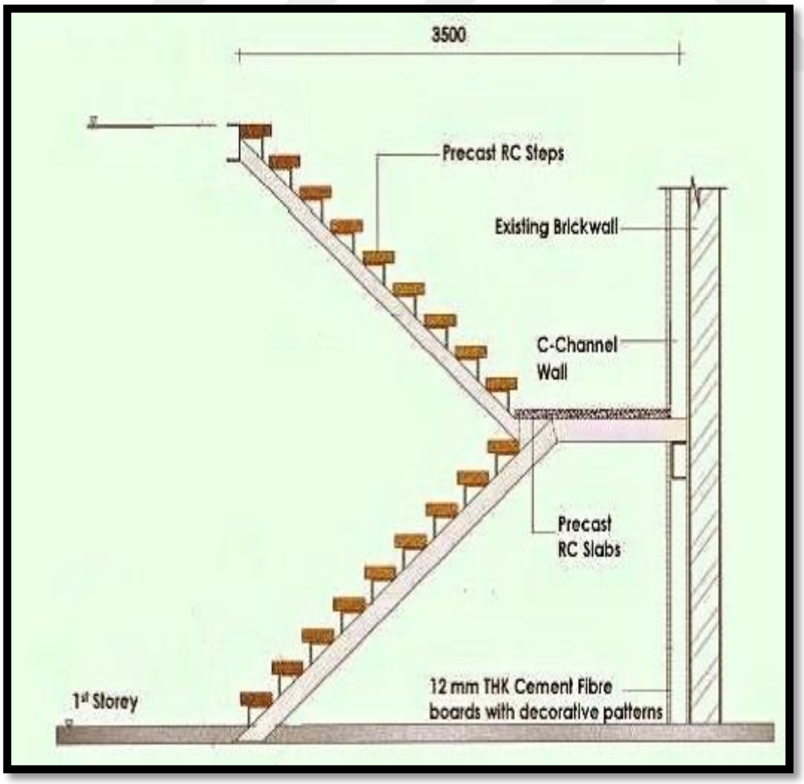
There are three basic staircases profiles (Construction Task Force, 1998):

a. Curved
b. Straight
c. Spiral profile

Figure 2.13: Prefabricated staircase

Source: http://www.discountqualitystairs.com/albany-stair-contractor.html

Figure 2.14: Prefabricated steel staircase details



Source: http://www.discountqualitystairs.com/albany-stair-contractor.html

2.5 PREFABRICATED STRUCTURAL SYSTEMS

Prefabricated structural systems can be divided according to the used materials, methods, structural configuration etc. In this thesis prefabrication systems are illustrated according to their structural configuration. According to the structural configuration all systems are modular (Figure 2.15), these systems are the most completed prefabrication production.

Figure 2.15: Modular prefabricated building

Source:http://kithung.net/modern-contemporary-modular-homes-ideas/kullman-frame-system-modular-house-michigan-also-wooden-exterior-decor

The term modules, in the realm of structural planning and construction, has regularly been utilized to allude to a great extent finished or entire areas of structures constructed at a processing manufacturing and trucked to a site (Anderson and Anderson, 2007).

In most of developed countries such as UK, these systems have been utilized as a part of both residential and commercial buildings.

Utilizing the measured framework can spare a great deal of time and money. The measured unit is commonly manufactured or composed utilizing a standardization framework and measurement which makes it simple to mass produce.

Therefore, prefabrication systems are divided in three different types in terms of structural configuration (Harris, 2006):

1. Frame systems
2. Panel systems
3. Cells system

2.5.1 Frame Systems

The term frame systems in basic designing allude to load-opposing sub-arrangement of a structure. The basic framework exchanges stacks through interconnected auxiliary parts or individuals (Kassimali, 1999).

Most prefabricated frame systems are supported by some form of compression or bending elements. This form of construction has only become more rigorously analyzed and widespread in large structures in the latter part of the twentieth century (Best, 2002).

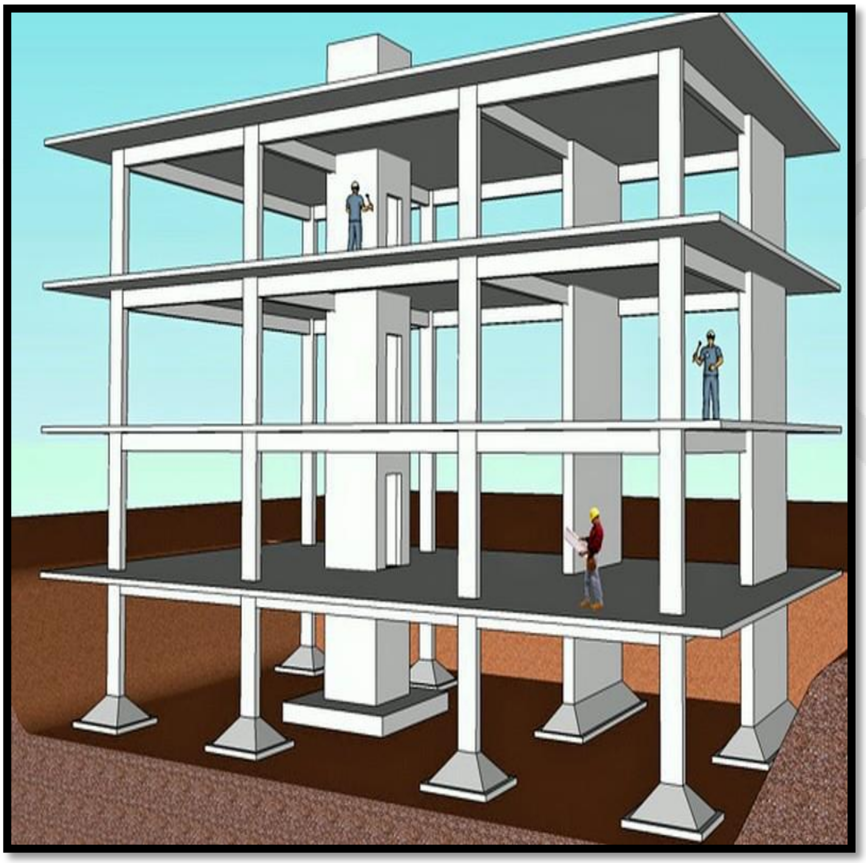
The grouping of development for a building that is confined completely with frame systems framework is basically for a building encircled with ostensible 38-mm. (Kassimali, 1999). The ground floor is surrounded with joists. Mastic cement is connected to the upper edges of the joists, and the board is set down and attached to the upper heavenly attendants of the joists with screws. Steel studs are laid at on the floor and joined to make divider edges. The divider edges are sheathed for noncombustible construction; the divider edges are tilted up, screwed down to the edge, and propped. The upper stage is surrounded, then the upper dividers. At last, the roof and rooftop are encircled similarly as in a confined house. Prefabricated assembled trusses of edge frameworks which are screwed or welded together are regularly used to casing roofs and rooftops (Figure 2.16).

Figure 2.16: Installing roof trusses

Source: http://myhomeimprovement.org/home-remodel/frame-model

Frame systems are an extremely normal - or maybe the most widely recognized kind of advanced building. As the name proposes, this type of building comprises of a casing or skeleton. Flat individuals from this casing are called bars, and vertical individuals are called sections. People stroll on level planes of cement called chunks. Of these, the segment is the most vital, as it is the essential load conveying component of the building (Harris, McCaffer, 2001) (Figure 2.17).

Figure 2.17: Structure of prefabricated Frame System

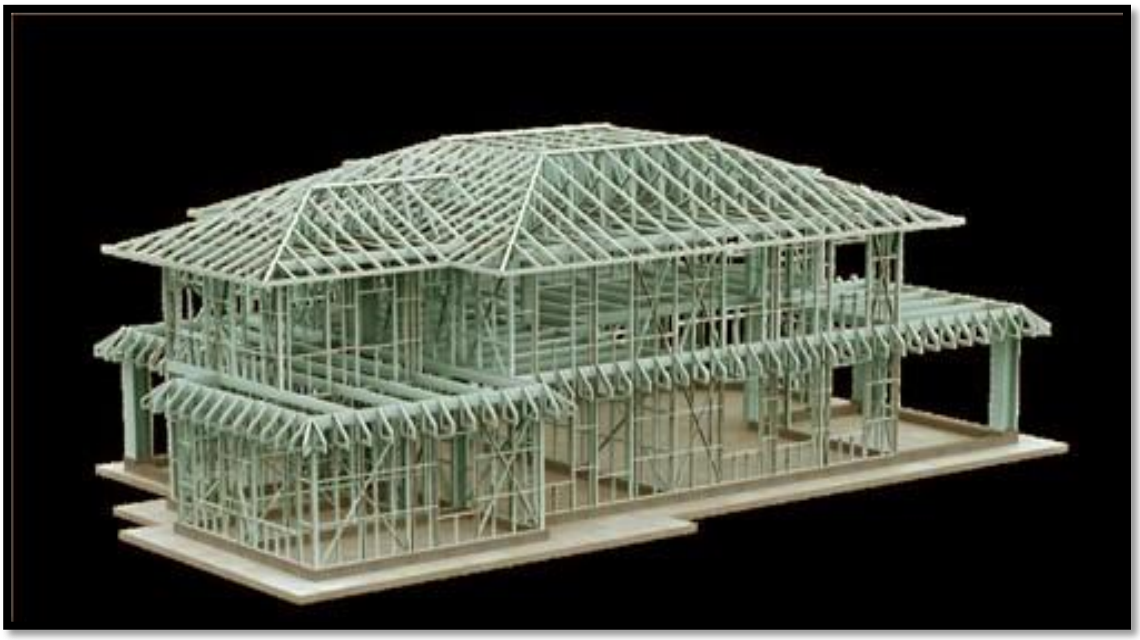


Source: http://www.understandconstruction.com/concrete-frame-structures.html

There is a different meaning between frame systems and framing. Framing, in construction is the timberwork or steelwork that encloses and supports structural components of a building (Baghchesaraei and Baghchesaraei, 2014). The term frame systems in basic designing allude to load-opposing sub-arrangement of a structure (Kassimali, 1999).

Prefabricated frames can be developed utilizing either straight components or spatial pillar section subassemblies. Prefabrication bar section subassemblies have the favorable position that the associating faces between the subassemblies can be put far from the basic casing locales; in any case, direct components are by and large favored in light of the challenges connected with framing, taking care of, and raising spatial components. The utilization of straight components by and large means setting the uniting appearances at the bar section intersections. The beams can be situated on corbels at the sections, for simplicity of development and to help the shear exchange from the pillar to the section. The bar segment joints fulfilled along these lines are pivoted. Then again, inflexible beam section associations are utilized as part of a few cases, when the congruity of longitudinal fortification through the pillar segment joint needs to be guaranteed (Figure 2.18).

Figure 2.18: Timber Frame system



*Source:*http://www.cnbmhousing.com/cms/cms/Product_Concept/Technical_System/Light/2014-07-.html

The beams can be situated on corbels at the sections, for simplicity of development and to help the shear exchange from the pillar to the section. The bar segment joints fulfilled along these lines are pivoted. Then again, inflexible beam section associations are utilized as a part of a few cases, when the congruity of longitudinal fortification through the pillar segment joint needs to be guaranteed.

The frame system in most of countries was only used for heavy construction such as bridges and highways, but when the housing market in some countries raised many developers and contractors started to see more potential from using prefabrication. Prefabricated frameworks have ended up progressively prominent for an average size home structures (Ozcebe, Ersoy, Tankut, Akyuz and Erduran, 2004).

This framework obliges a great deal of data on outline methodology to mastermind the bits of the board into a design plan. Designers must settle on a choice that they need to utilize this framework before the configuration procedure starts. The solid boards that are utilized as a part of this framework are intended to match building heights. Those solid boards are delivered inside the production line. They accompany window opening, electrical and pipes inside the boards. This framework is intended to be a divider bearing framework.

Since the prefabricated frame system is a fundamental structure, the thickness of the boards is 15-20 cm which is thicker than the average block divider. The tallness is between 3- 3.5 m. which is the tallness of one story. This framework can lessen development time on location for average size buildings (pretty nearly 150-200 square meters) from 12 months to as few as 4-5 months (excluding the creation time of every board in the processing plant). Today, most vast private creating organizations have utilized the prefabrication concrete structure as opposed to the skeleton structure (Applied Technology Council, 1996).

The boards are planned by planners or basic designers to match the building rises. The span of the board is equivalent to the stature of a floor to floor (3-4 m.) and the width is equivalent to the compass of the building (5-6 m.). The thickness of this board is 15-18 cm, however a few activities utilization boards as thick as 25cm (Applied Technology Council, 1996).

2.5.1.1 Wood frame systems

Wood frame systems may be constructed to different outlines and particulars. Whether a standard outline is utilized or a hand craft is made to boost inhabitant wellbeing, solace and security and to diminish a building's ecological foot shaped impression. Building configuration might give simple access to individuals of differing physical abilities and adjust to tenants' evolving needs (William, 1997).

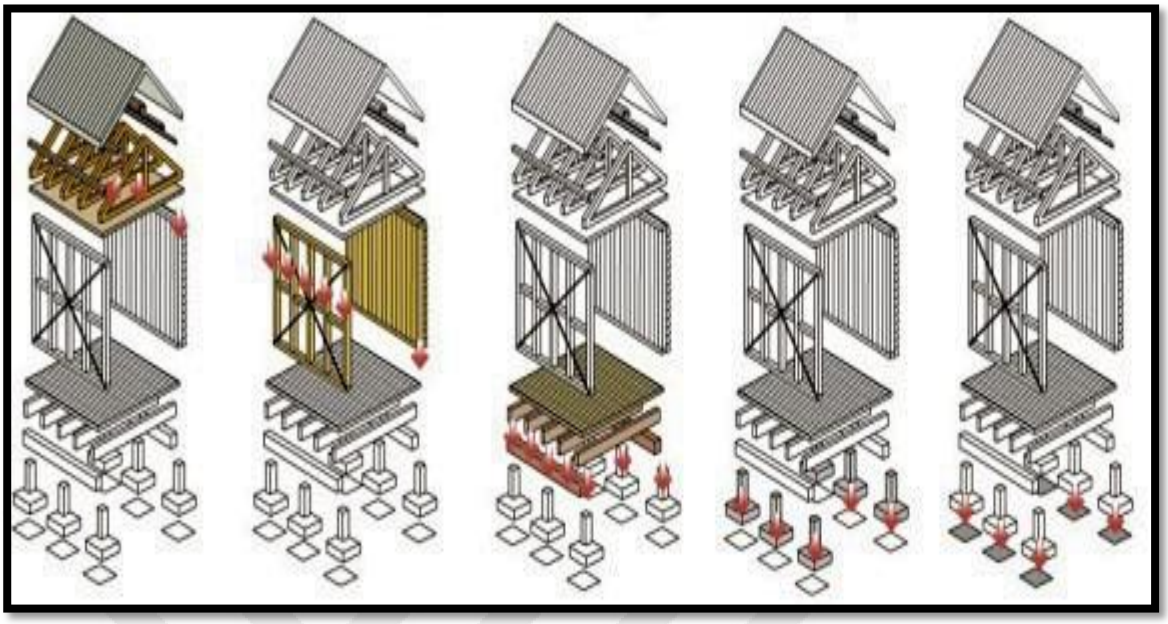
Wood frame systems were first created when some bright carpenters realized that the light partition walls they were putting up inside large heavy timber houses were capable of forming a construction system by themselves. The system was a skin made of timber members covered inside and out by sheeting. It is light, and permits fast development with no overwhelming devices or gear. Each segment can without much of a stretch be conveyed by hand - a building basically turns into an extensive carpentry work. The principle instrument is a handheld nail weapon. It has the capacity adjust itself to any geometric shape, and can be clad with a mixed bag of materials. There are an immense assortment of items and frameworks customized to this kind of development.

Wood is a greatly flexible and ecologically dependable material. It is likewise one of the couple of renewable auxiliary materials. Under insightful and judicious ranger service hones, wood can administration building for a long time (Smith, 2010). Wood edges or timber casings are the most well-known materials for any development. Wood outlines today can be produced with custom joints, a large portion of which now incorporate metal clasp. Most designers and foremen in developed countries are familiar with wood outlines that wood edges have been the essential strategy for prefabrication development (Figure 2.20).

The first level in wood frame system is to position the expanding on the property. The administrations of an area surveyor may be obliged to set up the separations from the establishment to property lines, find the city benefits and set up the design and the profundity of the exhuming. Foundation establishments may continue once the building format has been finished. This can regularly be finished in one day relying upon the sort of hardware utilized and site conditions and around two weeks is expected to install roof boards and wall boards to give climate assurance amid consequent phases of development (Figure 2.19)(Smith, 2010).

Despite the fact that wood encircling is anything but it has difficulties too, designers and builders need to be exceptionally cautious when outlining or utilizing it. On the outline side, wood encircling has some configuration limits. The straightforward rectangle divider is perfect for planning wood encircling. Having parallel top and base plates, for occurrence, is far simpler to computerize in a plant than creating dividers with slant tops or other unpredictable measurements, which may be “stick-manufactured” in the production line without picking up the advantages of the pack nailing hardware. The tallness constraint is additionally another concern when outlining wood outline. Some panelizes cannot without much of a stretch make boards taller than 2.75 or 3 meter (Arieff and Burkhart 2002).

Figure 2.19: Wooden frame system



Source: http://toolboxes.flexiblelearning.net.au

Despite of the several advantages of wood frame system, wood frame systems would typically give approx. fifteen to twenty minutes of smolder time before auxiliary breakdown ought normal in most circumstances. With the appearance of lightweight (designed) sorts of basic segments supplanting routine joists and rafters, the smolder time is extraordinarily lessened. Contingent upon the kind of lightweight get together, disappointment can happen in as meager as five to seven minutes (Arieff and Burkhart 2002).

Wood frame system has a specific process which could be done in a certain and specific process (Somerville, 1999):

1- Floor joints: Joists are horizontal structural members used to carry the floor and ceiling loads (Figure 2.20).
2- Subfloor: The structural floor joined to the joists supports the finish flooring (Figure 2.21)
3- Walls: The vertical framing member in prefabricated buildings (Figure 2.22).
4- Roof Trusses: An assembly of structural members joined to form a rigid framework, usually connected to form triangles (Figure 2.23).
5- Insulation: Material used to restrict the flow of heat or sound from one surface to another (Figure 2.24).

Figure 2.20: Floor joints

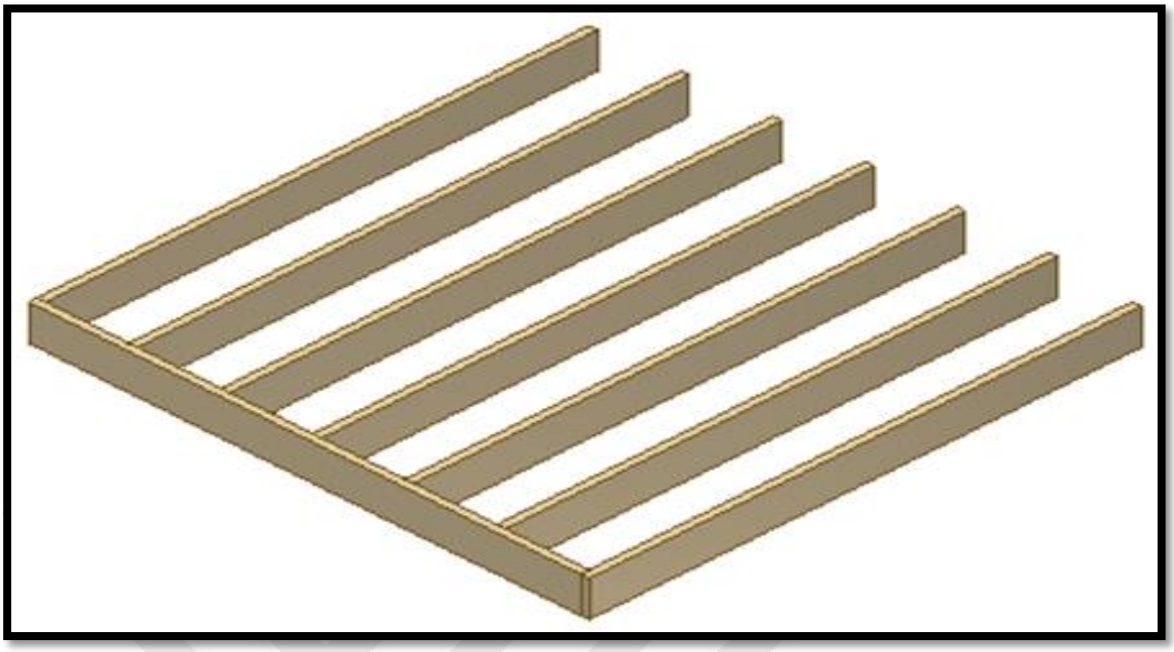


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Figure 2.21: Subfloor

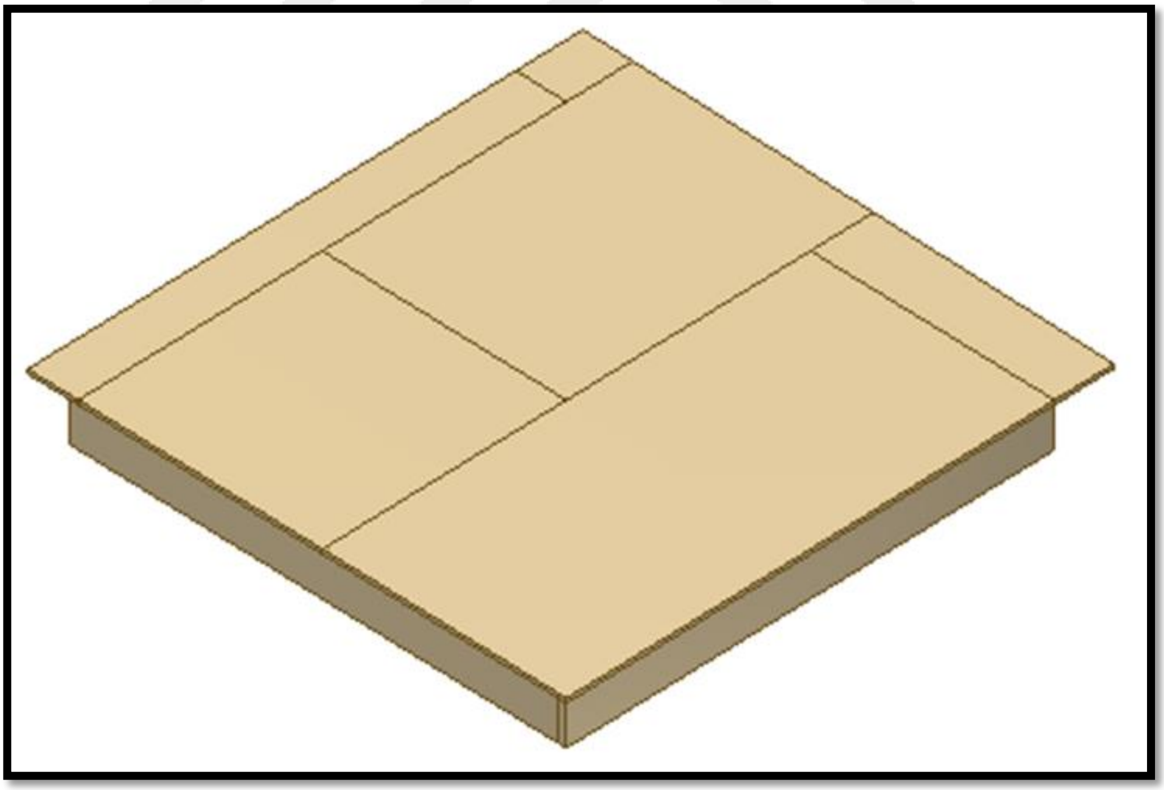

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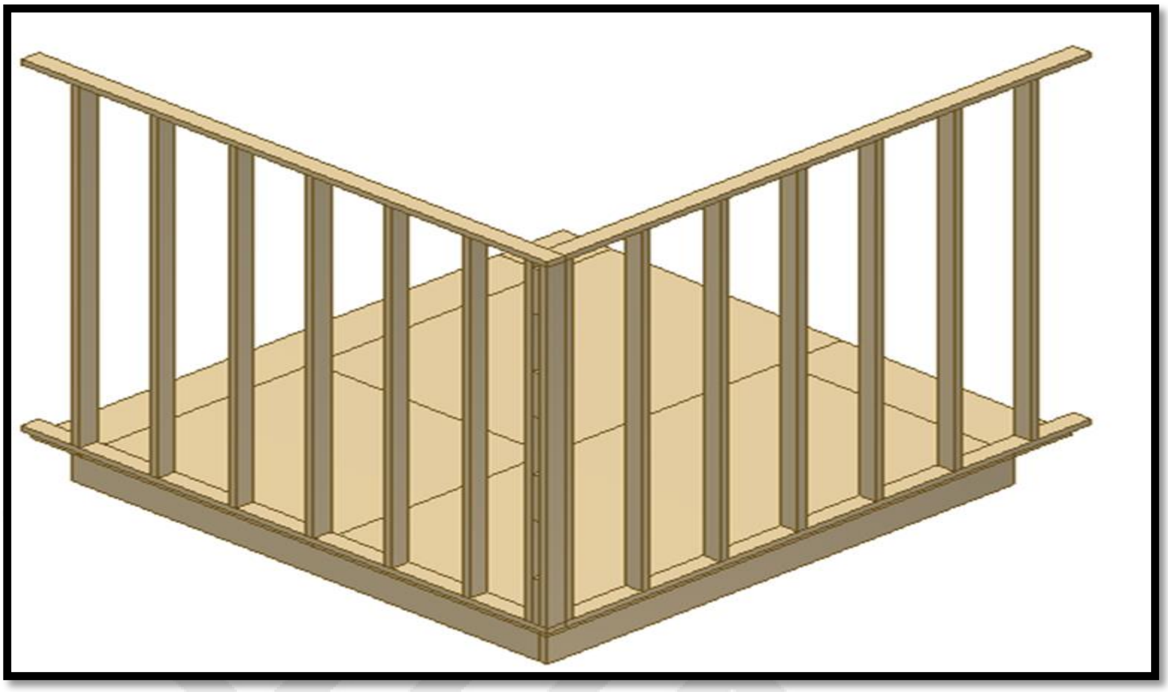
Figure 2.22: Wooden walls



*Source:*https://www.google.com.tr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=12&cad=rja&uact=8&ved=0CFMQFjALahUKEwja1IKH5_nGAhVECiwKHTQVAuY&url

Figure 2.23: Roof Trusses

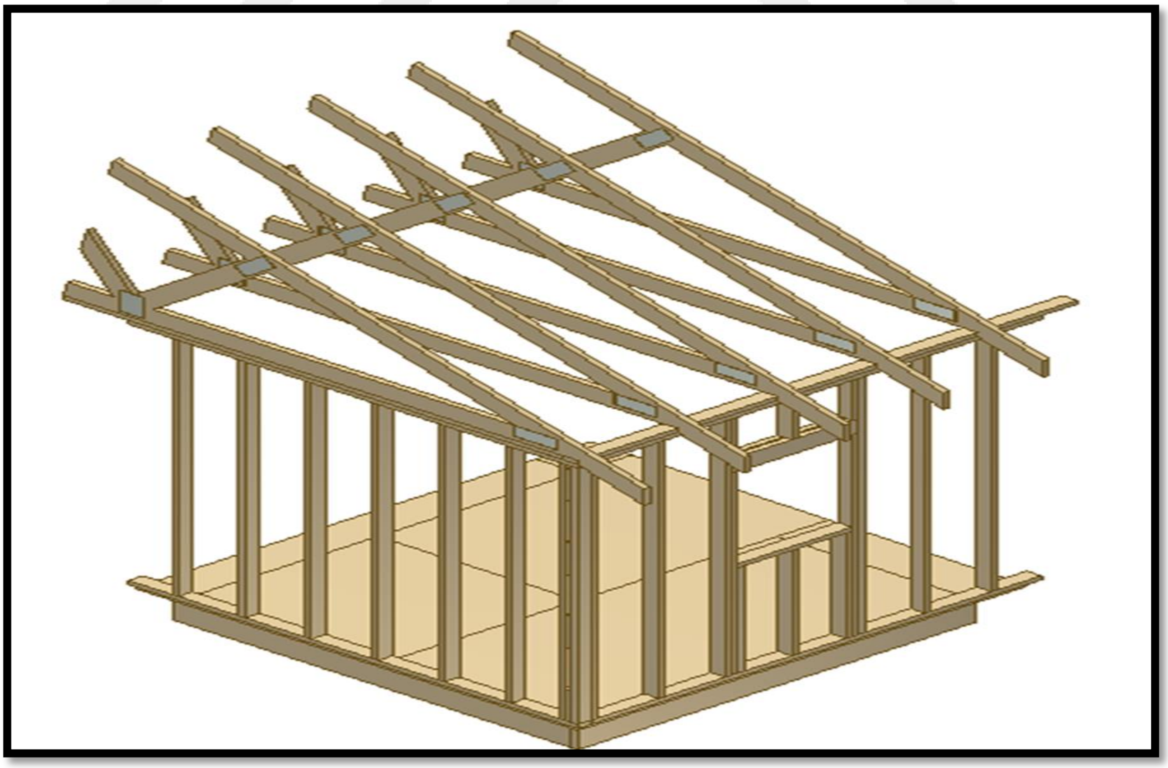


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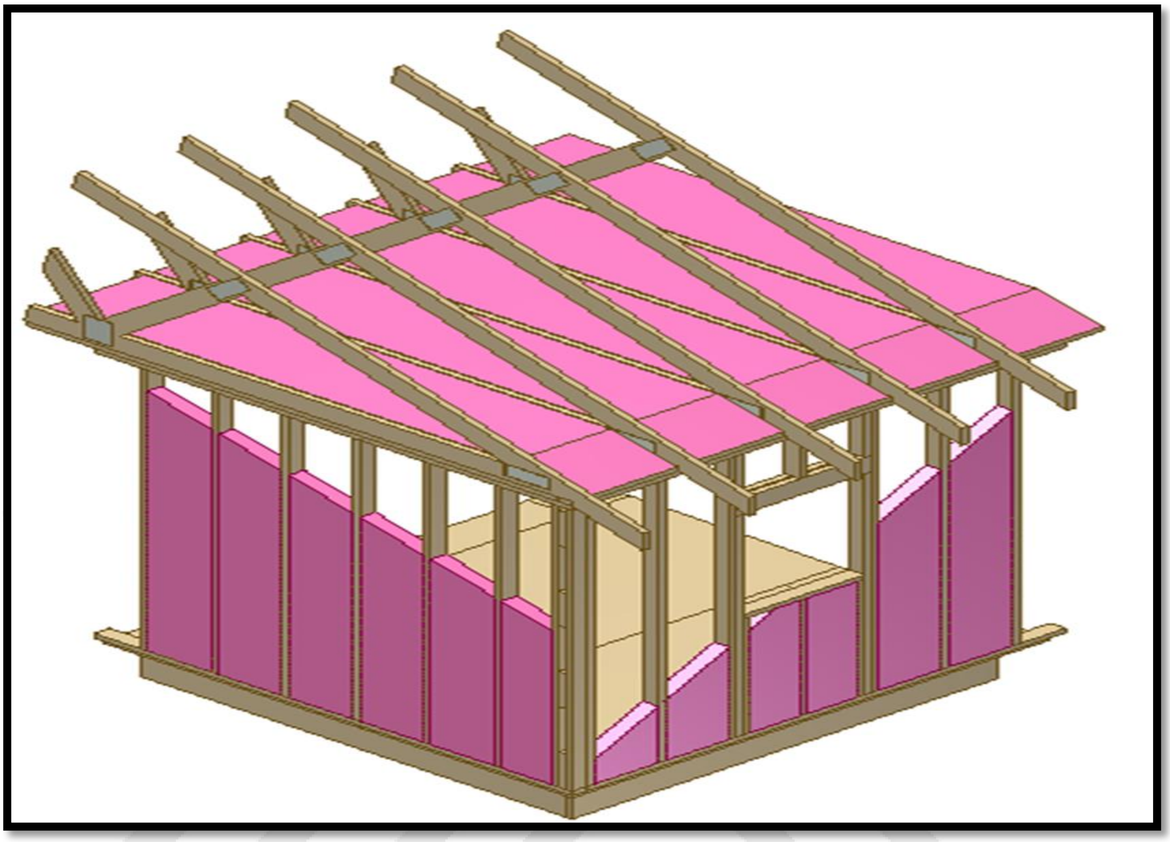
Figure 2.24: Wood frame insulation



*Source:*https://www.google.com.tr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=12&cad=rja&uact=8&ved =0CFMQFjALahUKEwja1IKH5_nGAhVECiwKHTQVAuY&url

Wood edges can be effortlessly connected to solid piece and introduced with different components, for example, entryways, windows, sidings or trim. Wood frame systems according to materials are divided in two different categories (Somerville, 1999):

1. Platform wood frame system
2. Baloon wood frame system

2.5.1.1.1 Platform wood frame systems

The most widely recognized system for wood frame development for building structures is Platform wood frame system (Arieff and Burkhart 2002). A story box and joists making up the stage is based and set on a supporting under structure (ledge plates, headers, or pillars), where it sits level and gets secured down against wind lifting with aroused metal tie straps. When the boxed floor stage is squared, leveled and attached then subfloor, dividers, roofs, and rooftop are constructed onto that starting stage, which can be rehashed floor by floor, without the moderate downs and perils of affixing and leveling unpleasant sawn joists of another floor together to the dividers from steps developing one or even two stories up.

Generally, platform is developed then the dividers based on top of that layer making for speedy proficient work sparing development procedures (Figure 2.25).

Figure 2.25: Example of Platform wood frame systems

Source: http://thecraftsmanblog.com/framing-timber-balloon-platform

From the beginning upwards, the wooden structure for the most part has the accompanying qualities: the shear safe inner and outside dividers comprise of 60x160 mm segment plywood casings situated vertically more or less 60 cm separated. They are joined at the foot and top with proper metal plates and indistinguishable base covered light emissions suitable tallness. These casings are solidified with OSB (Oriented Strand Board) wooden boards no less than 18 mm thick. These components are collected to acquire the essential supporting. Gathering between covered bars and boards uses nails or screws situated at fitting separations (Somerville, 1999).

External walls are then externally covered with thermal cladding and relative silicate silicate plaster, and visible bricks, stones or left with the wooden slats on show.

The wooden structure is connected to the reinforced concrete foundations with suitable threaded steel bars or pressure-fit plugs. The inter-floor floors/ceilings are created with beams resting on plywood, positioned at variable distances depending on the light (Figure 2.26).

Figure 2.26: Platform wood frame systems process

Source: http://subissati.it/en/platform-frame.html

2.2.2.1.2 Baloon wood frame systems

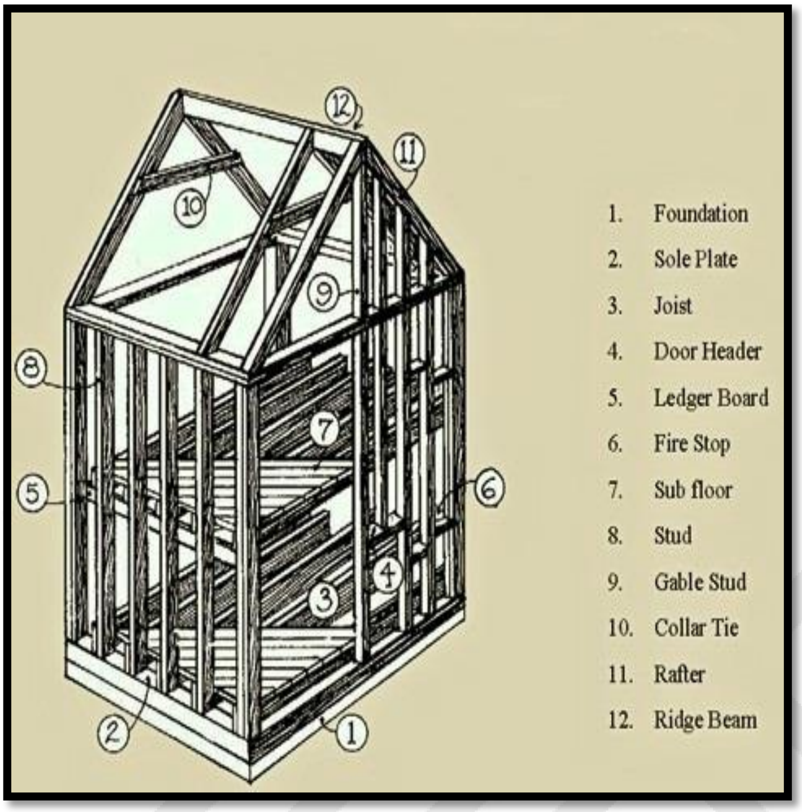
Balloon framing is a system of construction that uses lighter wooden components than customary supported confining, and keeps on being utilized as the primary strategy for wooden casing development (Figure 2.27)(Koncz, 1995).

Figure 2.27: Baloon wood frame system

Source: https://deepenergyretrofit.wordpress.com/blog

As indicated by student of history Kingston Heath, "The inflatable casing is unmistakably a result of the American Industrial Revolution."4 It is described by its utilization of more slender, institutionalized sawn encircling individuals and machine-made nails, instead of the substantial timbers and confounded joinery utilized as a part of customary wooden development strategies. Blow up encircling uses consistent vertical confining individuals, called studs, which convey an equivalent circulation of the building's vertical compressive burden. The studs are typically 2x6 or 2x4 cm and are set more or less sixteen cm separated (Koncz, 1995). A noteworthy distinction between blow up casing and past wood surrounding procedures is its absence of girts, the flat confining individuals that held together the people narrows of conventional encircled structures. Rather than girts, blow up surrounding uses the external sheathing to make the structures inflexible, and the floor joists of upper stories lay on records that are nailed on a level plane over the studs (Figure 2.28).

2.28: Baloon wood frame systems in details



Source: http://global.britannica.com/technology/light-frame-construction

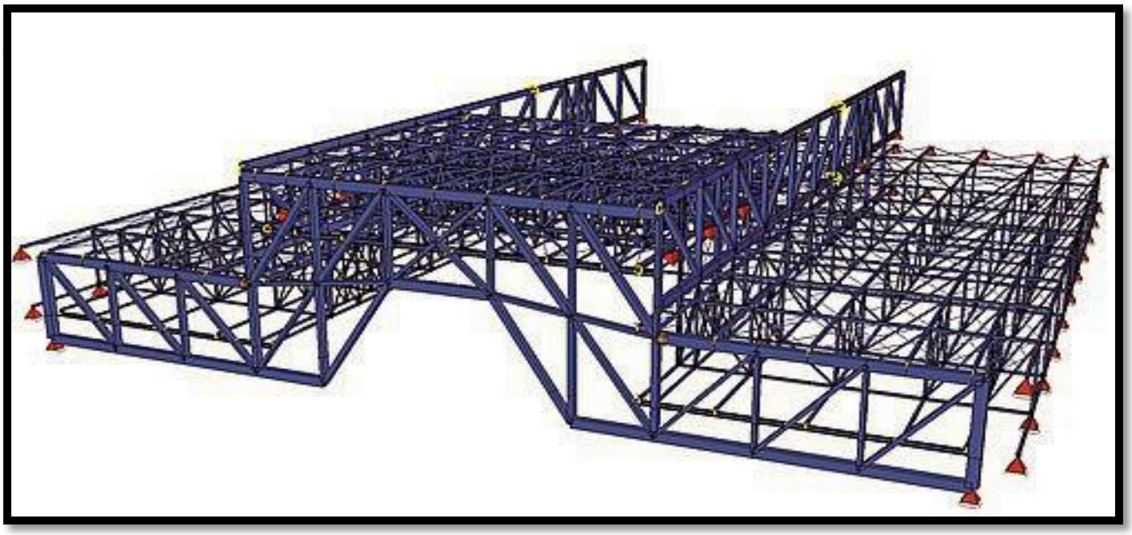
2.5.1.2 Steel frame systems

The quality and flexibility of basic steel frame system, alongside the holding force of associations, make it the perfect material for development in high wind pace and seismic zones. The steel frame is sheet steel that is framed into shapes and sizes that are like what developers are usual to seeing in dimensional steel, 2x4, 2x6, 2x8, 2x10, 2x12 (Koncz, 1995).

A steel frame system, describes the creation of a steel skeleton made up of vertical columns and horizontal beams. This skeleton carries the loads of the roof, floors and walls of the structure (Anderson and Anderson, 2007).

Steel can be framed into a wide range of shapes; it is regularly used to create parts of structures; from the little parts of structures, for example, nails and building equipment to the greater parts of building, for example, sections and shafts (Figure 2.29). Most steel, which is utilized for construction, is remanufactured from an off-site plant. These prefabrication steel individuals come in assortments of sizes and areas. A task designer will focus the sizes and areas of these individuals, which are generally the standard sizes from steel produces, to oblige with a structural outline. Constructing a steel building can be fast. The procedure of steel development is straightforward. Prefabrication steel structures, which are conveyed to the site by the production, can be effortlessly gathered by utilizing jolt or welding systems, which most laborers are acquainted with. Most steel structures utilization steel for just an essential structure which can be called "building skeleton", alternate parts of the building can be regularly seen with different sorts of materials, for example, glass, board or cement.

Figure 2.29: Steel Frame parts



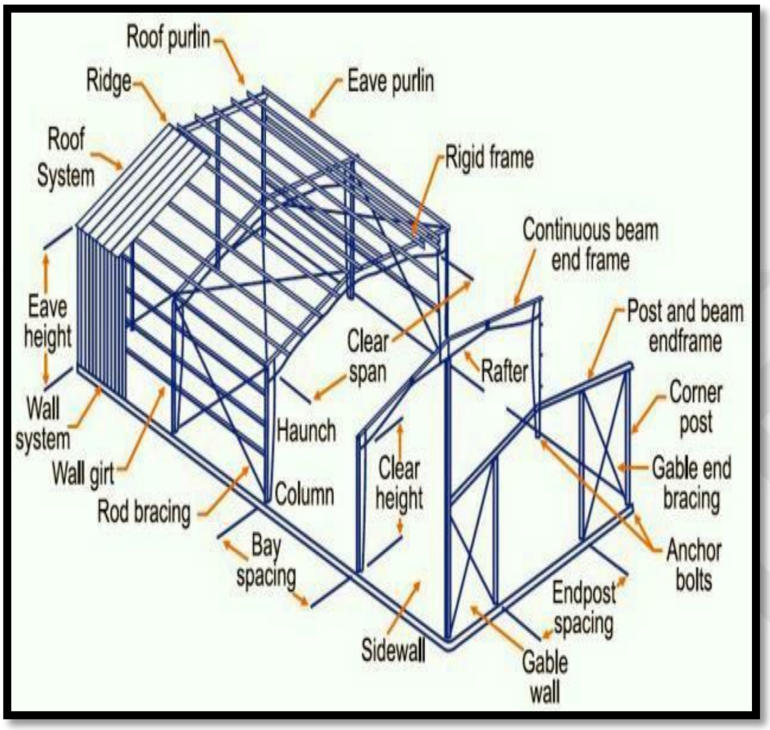
*Source:*https://www.elance.com/samples/autocad-typical-floor-plan-autocad-2d-floor-plan-building-work-architect/57359720

There are a lot of advantages for using prefabricated steel in construction, but sometimes using steel can add more cost to projects. Using steel could enlarge the project cost in comparison with other systems. This cost can be controlled by either architectural design or engineering design. The more custom-designed steel is, the more cost is added to a project (Anderson and Anderson, 2007).

Steel frame systems represent approximately 20 percent of the total cost of the building construction. If the conventional “stick framing” method of construction is used, steel frame system can add 3 percent to the total cost of a building. When only the framing system is considered, studies have shown that the steel frame system can cost 15 percent more than wood frame system (Anderson and Anderson, 2007).

Steel frame system represents with several parts: bearer, floor joist, bottom plate, jack stud, sill trimmer, jamb stud, head trimmer, lintel, top plate, jack joist/ceiling joist trimmer, metal joist strap, hanging beam, ceiling joist, common stud, brace, nogging, sheet flooring (Figure 2.30) (Koncz, 1995).

Figure 2.30: Steel frame in details



Source: http://steelestimatingsolutions.com/metal-building-bid-wizard-2

2.5.2 Panel Systems

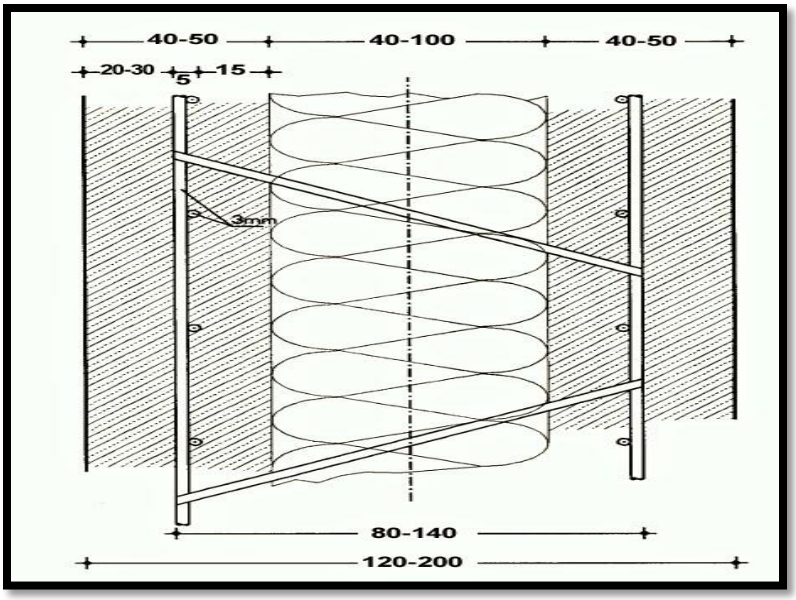
Panel System is one of the prefabrication systems ideal for straight, curved or angled facade applications and has an elegant and light appearance with smooth rounded edges. Prefabricated panel is set in position and layer of cement or mortar are connected to both sides (Figure 2.31). Boards are utilized as a part of the development of outside and inside bearing and non-load bearing dividers and floors in a wide range of construction. The board gets its quality and unbending nature from the inclining cross wires welded to the welded-wire fabric on each side (Haris, 2006). This mix makes a truss conduct, which gives unbending nature and shear terms to full board conduct.

Figure 2.31: Prefabricated panel

Source: http://www.3dpanels.org/3dpanel/benefitsof3dpanels.htm

The thickness of each wythe relies on upon its basic capacity, solid spread, port of connectors, stripping, and completion (PCI Design Handbook, 1985). A wythe is viewed as auxiliary on the off chance that it gives a noteworthy commitment to the heap resistance of the board. The thickness and sort of protection relies on upon the thermal properties of the protection material utilized, the configuration temperature of the structure and the fancied thermal resistance of the panel, a base thickness of 25 mm is utilized (Figure 2.32) (Einea et al. 1991).

Figure 2.32: Standard panel board



Source: Source: http://www.3dpanels.org/3dpanel/benefitsof3dpanels.htm

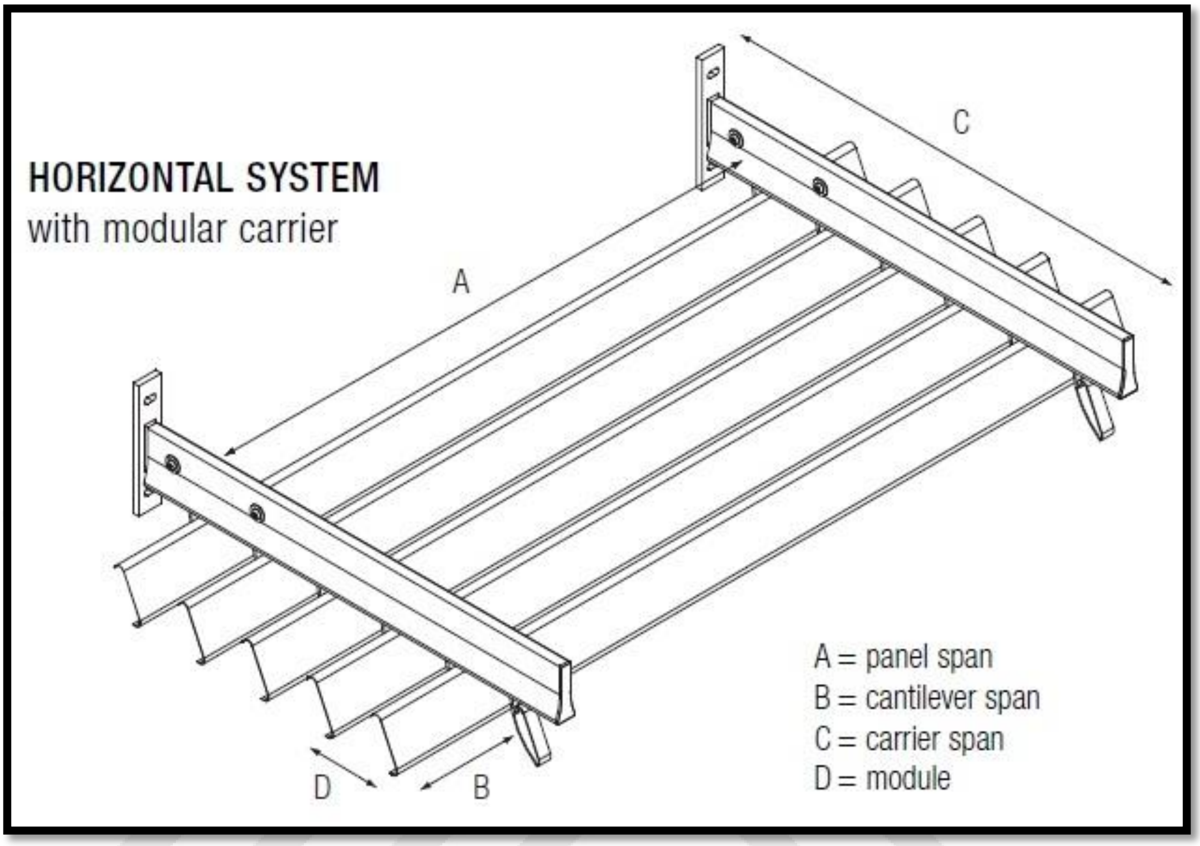
The panel system is the most common used production technique in prefabricated buildings in developed countries, 43 percent of all prefabricated homes in the United States use the light panel system (Smith, 2010). The utilization of panel framework knowledge can be followed back to the 1930s when Frank Lloyd Wright, planned his Usonian house (Figure 2.33). The early board, outlined by Wright, was a non-auxiliary board which did not have a fitting warm control (Anderson and Anderson, 2007). From that point forward, the boards framework has ended up extremely prevalent and has been created with more propel innovation. Today, there are numerous sorts of board in the business. The boards can be modified to utilize either as a basic board or non-auxiliary board. As concluded by "Panels are planer elements used to build structural walls, floors, and roofs, load-bearing or non-load bearing enclosures, and interior partitions" (Smith, 2010).

Figure 2.33: Usonian house

Source: https://www.redfin.com/blog/2013/04/remembering-frank-lloyd-wright-homes-for-sale-designed-by-the-famed-architect.html#.VWJMwk9Viko

Panel System rushes to introduce with not very many devices needed. At the point when the steel divider sections are fitted to the façade, the bearer profiles with (pre-settled) sections and spacers or stringers slide over the divider sections and are effortlessly altered with a jolt through association. The C-molded boards (in full length) are bolted on to the sections (Figure 2.34).

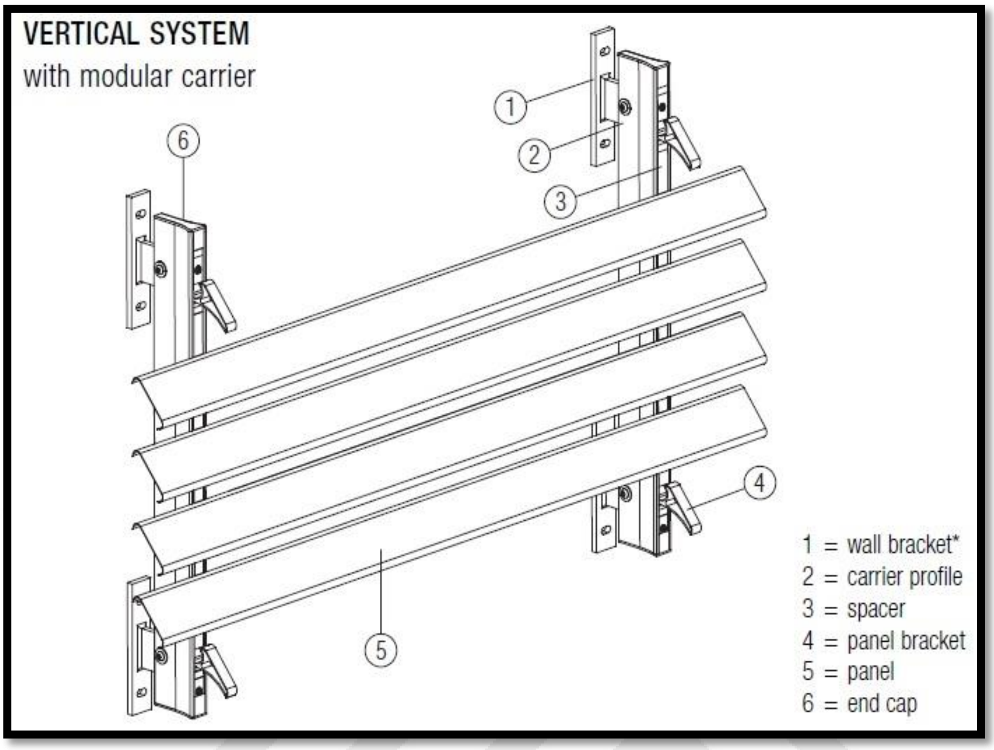
Figure 2.34: Horizontal system with modular carrier



Source: http://www.panelsystem.org/medias/1437921031

An extensive variety of transporter profiles with altered or variable tweak is accessible to guarantee that ideal shading edges and openness are accomplished for every application. Panel Systems can likewise be utilized as ventilated exteriors, they mostly used with panel vertical system (Figure 2.35).

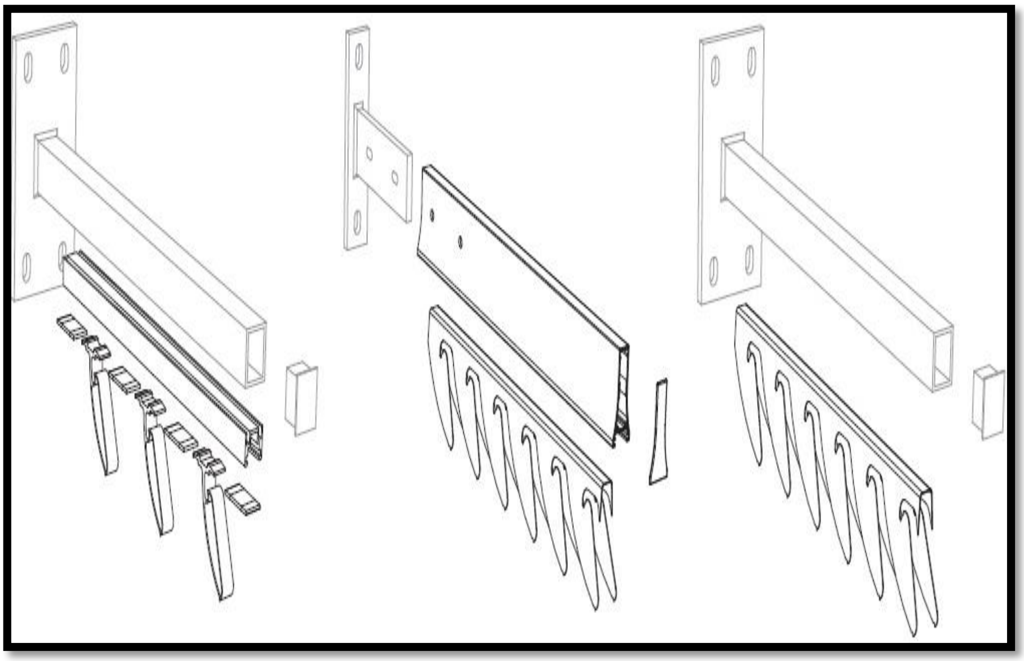
Figure 2.35: Vertical system with modular carrier



Source: http://www.panelsystem.org/medias/1437921532

Mostly in panel systems architects use some support structures for assembling (Figure 2.36).

Figure 2.36: Panel system support structures



Source: http://www.panelsystems.org/medias/1437924370

Large-panel systems according to structural configuration and material are divided in two types (Smith, 2010):

1. Large-panel system
2. Structural insulated panel system
3. Curtain wall panel system

2.5.2.1 Large-panel system

Prefabricated buildings of construction and structures produced using extensive processing factory created board components that are amassed on site. Large panel systems are a standout amongst the most dynamic mechanical sorts of basic components. In cutting edge development they are utilized as a part of building flats, open and mechanical structures, streets, runways, dams, and channels.

They have turn out to be most across the board in expansive scale lodging and common development, where the erection of structures from huge boards made at lodging development consolidates and factory makes conceivable a lessening in development time by an element of 3.5–5.0 cm correlation with erection of the structures from block or other conventional materials, and additionally a diminishing of 30–40 percent in labor consumptions at the development site. The evaluated expense of a square meter of lodging space is 12–15 percent lower than in block structures (Kim, 2009).

The assignment “large-panel system " alludes to multistory structures made out of extensive divider and floor concrete boards associated in the vertical and level headings so that the divider boards encase fitting spaces for the rooms inside of a building. These boards shape a container like structure.

Both vertical and flat boards oppose gravity load. Divider boards are typically one story high. Level floor and rooftop boards compass either as restricted or two-way pieces. At the point when legitimately joined together, these level components go about as stomachs that exchange the horizontal loads to the dividers (Kim, 2009).

Contingent upon the divider format, there are three fundamental setups of large-panel buildings:

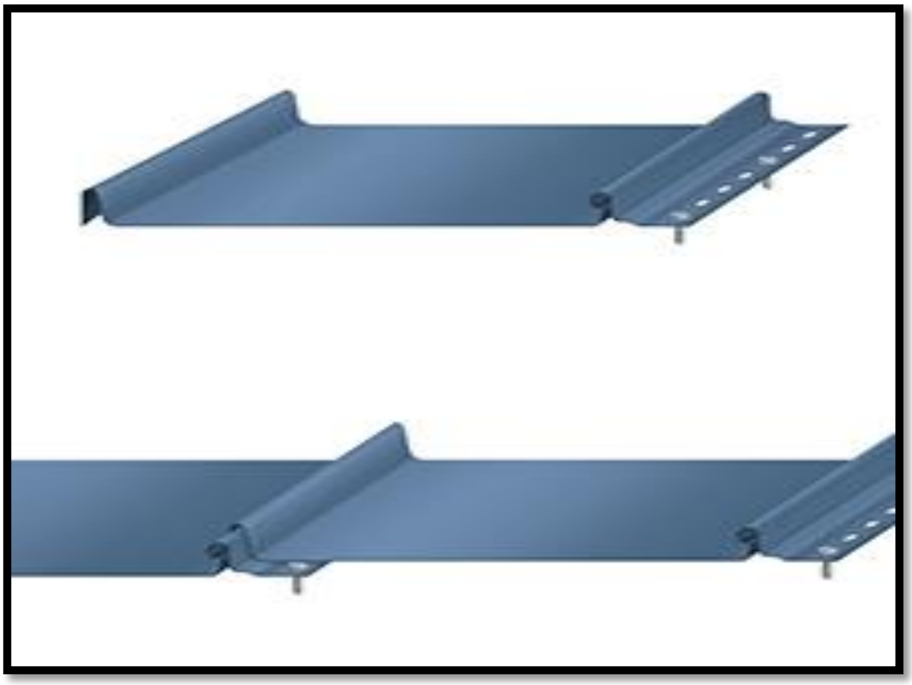
1. Cross-divider framework. The principle dividers that oppose gravity and horizontal burdens are set in the short bearing of the building (Figure 2.37).

2. Longitudinal-divider framework. The dividers opposing gravity and sidelong loads are put in the longitudinal heading; ordinarily, there is one and only longitudinal divider (Figure 2.38).

Figure 2.37: large-panel cross-divider framework

Source: http://www.masterbuilder.co.in/practical-economical-design-aspects-

Figure 2.38: Large-panel longitudinal-divider framework



Source: http://www.masterbuilder.co.in/practical-economical-design-aspects-precast

Panel associations represent to the key auxiliary segments in these frameworks. In view of their area inside of a building, these associations can be ordered into vertical and even joints. Vertical joints interface the vertical countenances of abutting divider boards and principally oppose vertical seismic shear powers. Even joints join the flat faces of the bordering divider and floor boards and oppose both gravity and seismic burdens.
Contingent upon the development strategy, these joints can be delegated wet and dry. Wet joints are built with cast set up concrete poured between the prefabricated boards. To guarantee basic congruity, distending fortifying bars from the boards are welded, circled, or generally associated in the joint district before the cement is set.
Dry joints are built by blasting or welding together steel plates or other steel supplements cast into the finishes of the prefabricated boards for this reason. Wet joints all the more firmly inexact cast set up development, though the power move in structures with dry joints is expert at discrete focuses (Fetters, 2002).
In large-panel system, vertical divider board associations are refined by method for furrow joints, which comprise of a ceaseless void between the boards with lapping flat steel and vertical tie-bars. Level joint support comprises of dowels anticipated from the boards and the barrette snares site-welded to the dowels; the welded length of the lapped bars relies on upon the bar distance across and the steel grade (Koncz, 1995).
Architectural plan in a large-panel building system usually is given by the segments fixing to the divider boards. Limit components are utilized rather than the segments as “stiffening " components at the outside. The solidarity of divider boards is accomplished by method for join bars welded to the transverse fortification of contiguous boards in the vertical joints (Koncz, 1995).

Longitudinal dowel bars set in vertical and even joints give an increment in bearing range for the exchange of pressure over the associations.

2.5.2.2 Structural insulated panel system

Structural insulated panels (SIPs) are a superior building framework for private and light commercial buildings. The boards comprise of a protecting froth center sandwiched between two basic facings, normally arranged strand board (Figure 2.39). Tastes are produced under industrial facility controlled conditions and can be manufactured to fit about any building configuration. The outcome is a building framework that is to a great degree solid, vitality proficient and financially savvy. Building with SIPs will spare you time and money (Figure 2.40) (Doran, 2011).

Figure 2.39: Structural insulated panel

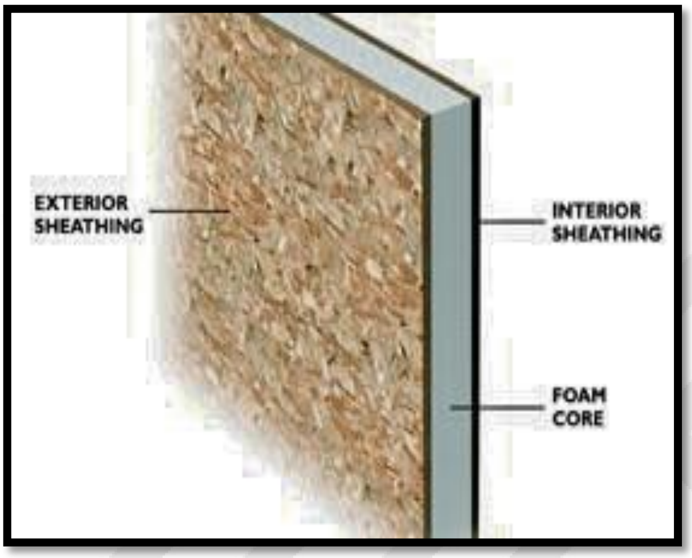
Source: http://share.pho.to/9eEVq

Figure 2.40: Structural insulated panel in building construction

Source: http://share.pho.to/9eEVq

Widely used panel product is Structural Insulated Panels (SIPs). Structural insulated panels (SIPs) are high performance building panels used in floors, walls, and roofs mostly for light buildings. “SIPs are a sandwich panel used as structural and enclosure and strictly infill enclosure for large steel or concrete frame structures. SOPs are manufactured from varying thicknesses of two layers of oriented strand board (OSB) sandwiching an EPS (expanded polystyrene) or PUR (polyurethane) core. In addition to OSB, fiber cement, metal, gypsum board and other materials are beginning to be introduced as sheathing for one side or the other in SIPs" (Smith, 2010) (Figure 2.41).

Figure 2.41: Structural Insulated Panel in details



Source: http://www.powerhousetv.com/

SIPs act likewise to a wide rib steel segment in that the froth center goes about as the web and the sheathing reacts as the ribs. Under hub stacks, the sheathing reacts likewise to a thin section, and the froth center goes about as consistent supporting keeping the boards from clasping. Pretty much as wide spine areas increment in quality with expanded profundity, thicker centers bring about more grounded boards in pressure and twisting.

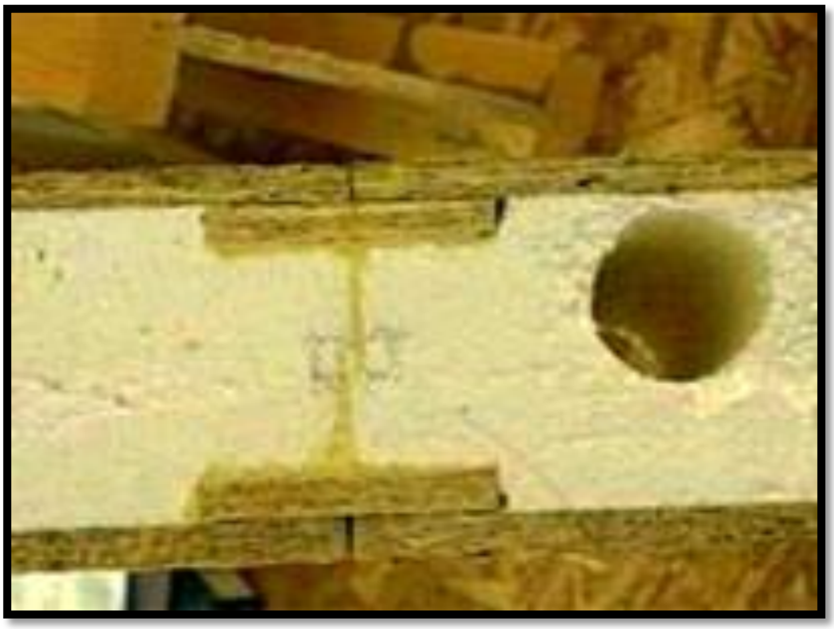
It is basic for establishments for SIPs boards to be level. There is little resistance for differential settlement. On the off chance that there is substructure shift, it will trade off the sealant of the boards' joints which may bring about dampness penetration. Suitable redirection resilience set by the production of the boards and sealants ought to be counseled when planning the establishment. Minor flaws may be suited with watchful, talented establishment (Figure 2.42) (Doran, 2011).

Figure 2.42: Example of SIPs used for roof panels

Source: http://encyclopedia2.thefreedictionary.com/Large-Panel+Structures

The most generally utilized board joint associations are the surface spline and the square spline. The surface spline joint association comprises of segments of OSB or plywood embedded in openings in the froth simply inside every skin of the SIP. The square spline is a slender and restricted SIP get together that is embedded into breaks in the froth along the board edges. The surface spline association and the square spline association bring about a consistent froth center over the boards (Figure 2.43) (Doran, 2011).

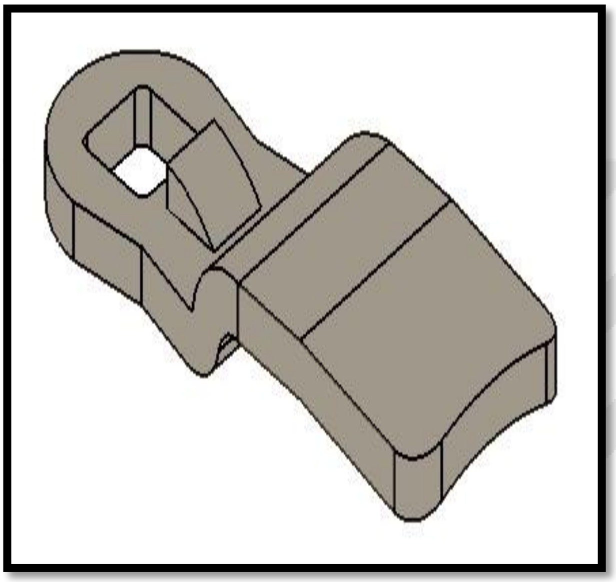
Figure 2.43: Surface spline



Source: http://encyclopedia2.thefreedictionary.com/Large-Panel+Structures

Another joint association, mechanical Cam locks, make a more tightly joint between boards, however make up just a little rate of the business. Likewise, Cam locks must be set in PUR on the grounds that the locks oblige a higher rigidity than gave by different froths and the froth needs to grow and set around the lock's spines. In any kind of association, the crease along the sheathing must be secured with a ceaseless line of froth sealant and/or board tape (Figure 2.44)(Koncz, 1995).

Figure 2.44: Mechanical Cam locks



Source: https://en.wikipedia.org/wiki/Latch_(hardware)

2.5.2.3 Curtain wall panel system

The expression "curtain wall" was initially used to depict the external mass of medieval fortresses. Its utilization in a more contemporary sense is seen in Gothic houses of prayer with their huge spans of daintily surrounded glass dividers between burden bearing supports. Today the term drapery divider is characterized in most writing to be any building mass of any material that is intended to oppose sidelong loads because of wind or seismic tremor and its own self weight, the blind divider is a non-load-bearing divider.

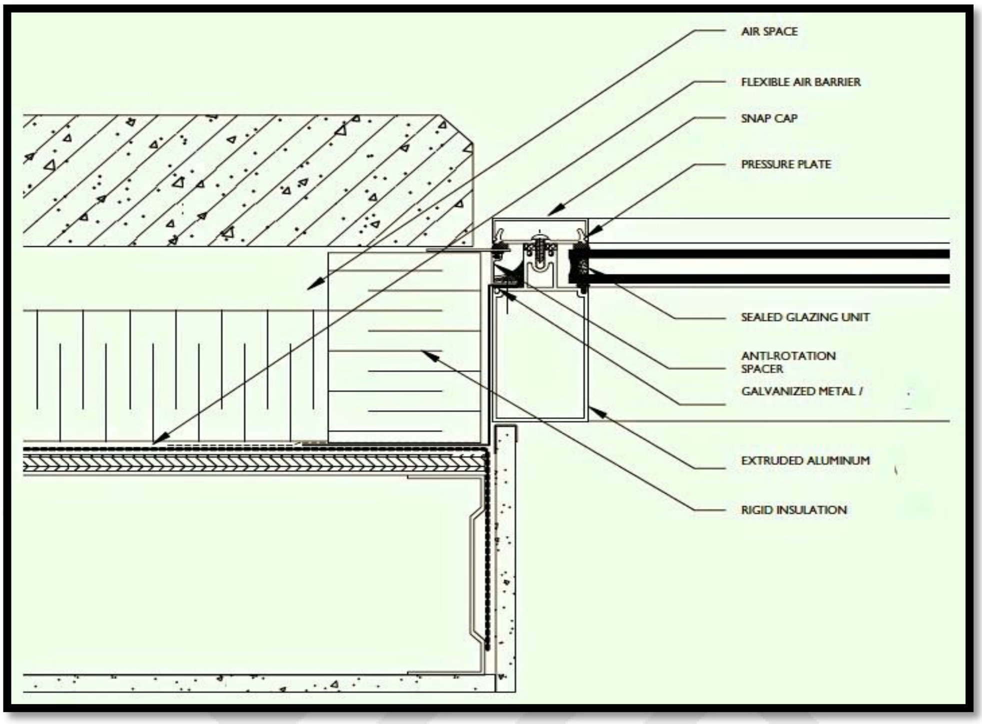
Curtain wall system is one of the widely used panel systems. Curtain wall systems are generally found in downtown areas on numerous new buildings and it is truly prominent as a cladding and outside divider on a wide range of business, modern, institutional and private structures. The drape divider is described with shaded vision and spandrel glass zones, a lattice of aluminum tops and most as of late with metal or stone spandrel spreads

(Figure 2.45). It is likewise consolidated with different sorts of cladding frameworks, for example, precast, block or stone to make appealing and tough building exteriors.

Curtain wall system should be designed using specified overpressure at wall. Glass bite should be minimum 12 mm. Glass units should be attached to framing with structural silicone glazing methods using neutral cure silicone sealant with joints sized to resist specified overpressure. All glazing should consist of laminated glass with minimum 0.76 mm thick polyvinyl interlayer. The end of a window ornament divider at a curtain wall system must incorporate for congruity of warm and air obstruction planes and additionally end in the blazing of the solid divider. Layer from the divider can be conveyed specifically into the coating pocket, over sheet metal if the compass is more noteworthy than 19 mm.

Consideration ought to be taken to guarantee that the part is situated to minimize outside introduction and to amplify inside presentation. For this situation the outside is ensured by constant protection and the inside is uncovered by the situating of the inside completion to one compelling side. A layer good with the divider film guarantees progression of air obstruction between the solid divider and mullion of the shade divider. The film is clipped and held fast to the mullion. Where the hole between the solid liner plane and the mullion surpasses 19 mm a sheet metal support must be given to the layer. The window ornament divider surrounding ought to be shielded from introduction to the air space in the stone work pit divider. Any solid divider glimmering in the pit ought to be ended at the shade divider with an end dam. The hole divider inflexible or semi-unbending protection should firmly about the air boundary conclusion. Any holes in the warm protection at the air hindrance conclusion ought to be loaded with polyurethane froth or compressible protection.

Figure 2.45: Curtain wall system in detail



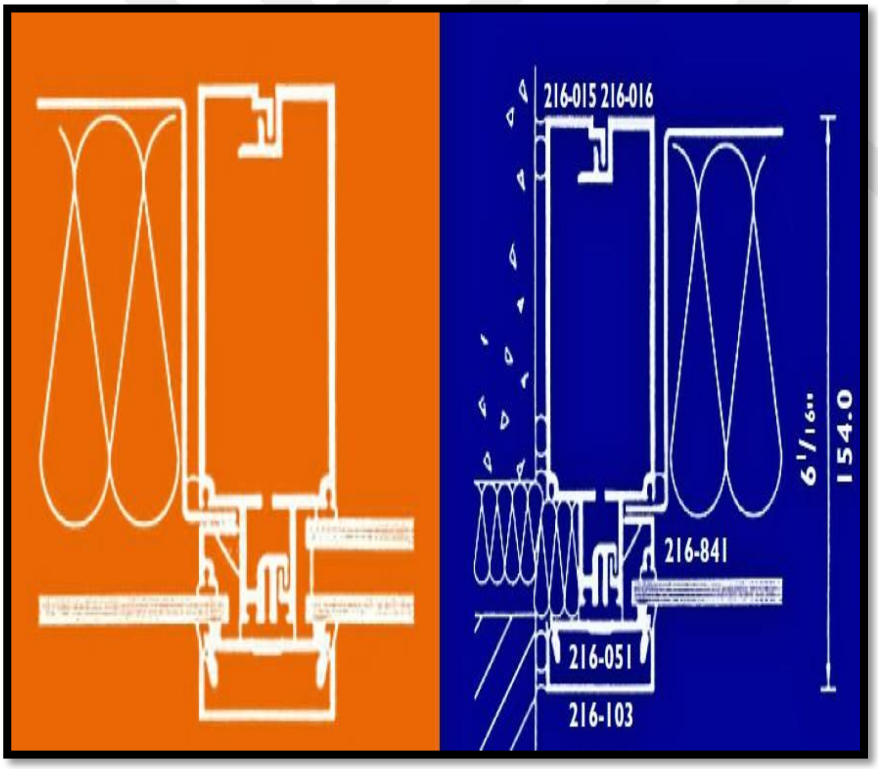
Source: http://www.arcxl.com/architects/detail?type=Curtain+Wall+Head+(in+wall)+Detail

The curtain wall includes a complete cladding and outside divider framework except for the indoor completions. It is by and large collected from aluminum outlines, vision glass and spandrel glass (or metal or stone) boards to encase a building from evaluation to the rooftop. It is accessible in three framework sorts to incorporate the stick fabricated framework, the unitized (or board) framework and the basic coating framework (top less vertical joints). The glass and aluminum drape divider is intended to oppose wind and quake burdens, to point of confinement air spillage, control vapor dispersion, avert downpour entrance, forestall surface and pit buildup and farthest point unreasonable warmth misfortune (or warmth pick up). It is further intended to oppose commotion and flame (Smith, 2010).

The curtain wall fabricated and installed as a panel system is referred to as a unitized prefabricated construction. However, the segments of blind divider in the field, the greater part of the framework segments are amassed in a plant under controlled working conditions. This advances quality gathering and considers manufacture lead-time and quick conclusion of the building.

While the unitized framework offers numerous focal points as for quality get together and rate of on building conclusion, there is one outline concern as for introduced execution and toughness. In a stick assembled framework, there are two joints along every mullion and rail. In a unitized framework, there are three joints along every mullion and rail. These incorporate the two joints and a third joint at the intersection between the half mullions and half rails. Three joints rather than two expands the potential air and water spills by half over a stick fabricated framework. Should an air or water break create at the third joint, there is typically no useful system for getting to the in the middle of board joint for repair (Figure 2.46) unless the maker has given a serviceable joint framework plan. In a unitized framework, the maker must depend on qualified installers to guarantee that the air seals are legitimately introduced between the split mullions (Anderson and Anderson, 2007).

Figure 2.46: Typical Unitized Curtain wall system components



Source: http://pixshark.com/concrete-wall-panel

2.5.3 Cells System

Cells system is a modern system where burden bearing dividers give the essential vertical backing and horizontal solidness for floors. Outside divider boards, lift centers or staircases are utilized to give the obliged longitudinal dependability. Connecting parts, for example, floors, rooftops and pillars are bolstered by the heap bearing dividers or facade divider (Figure 2.47).

Figure 2.47: Cells system in construction

Source: http://www.jensenprecast.com/Orland-b100/

The framework is proper for structures with cell and orthogonal frameworks, with rooms of up to 4mx9m. It makes a basically effective building with elevated amounts of sound and flame protection between contiguous rooms (Standards Australia, 1997).

The prefabricated elements are brought to site 'just in time'. Hidden joints and ties, both horizontally and vertically are grouted in place as the work develops, preventing progressive collapse. Other works such as installation of mechanical and electrical services and finished that are required can start prior to the completion of precast structure.

In cells system, components are conveyed to site 'in the nick of time'. Concealed joints and ties, both on a level plane and vertically are grouted set up as the work creates, avoiding dynamic breakdown. Different works, for example, establishment of mechanical and electrical administrations and completed that are needed can begin preceding the culmination of cells structure (Federation of Master Builders. 2001).

In this system, concrete is a standout amongst the most usually utilized bits of materials for cells construction around the world. Previously, concrete was utilized just by a cast set up strategy. The cast set up solid arrives in a fluid manifestation of blended concrete which makes it simple to cast into a fancied shape. To help expand its quality, the fluid bond is regularly blended with sand and pulverized stone before it is filled a formwork at a development site. Due to its quality and adaptability, concrete is regularly utilized as essential material for building structures, for example, pillars, sections, and floor pieces (Figure 2.48).

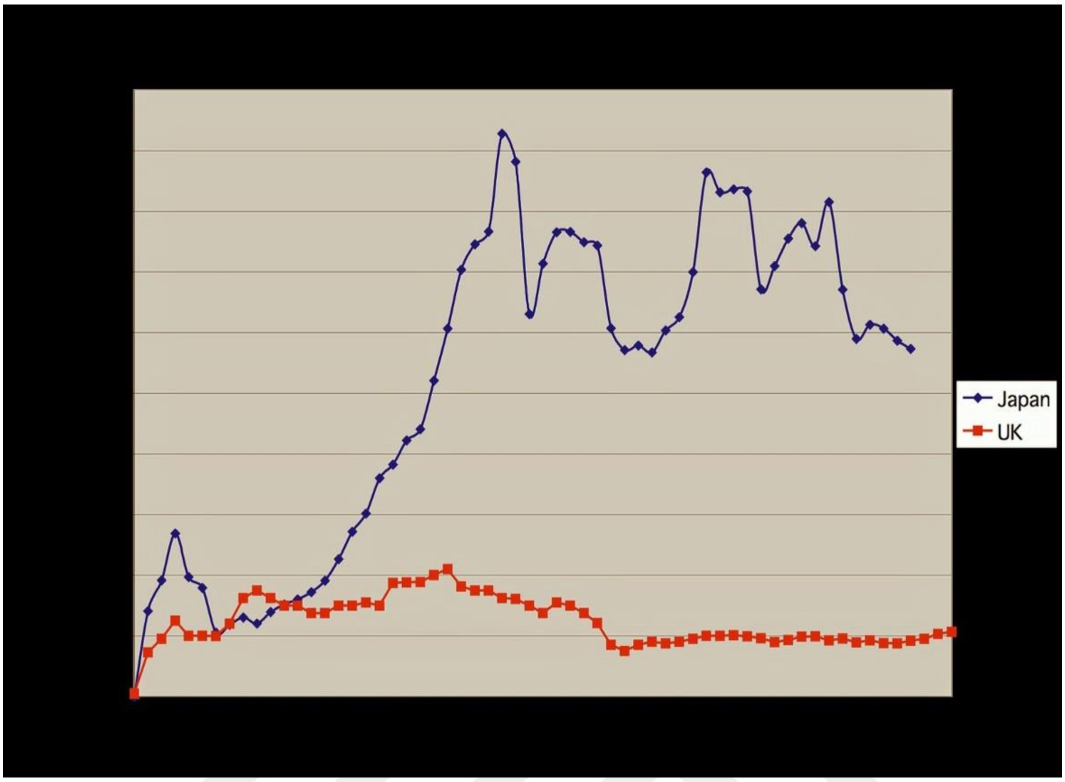
Figure 2.48: Cells system in a building

Source: http://www.lakhlani.com/cell-prefab.htm

2.6 PREFABRICATION CONSTRUCTION MARKET

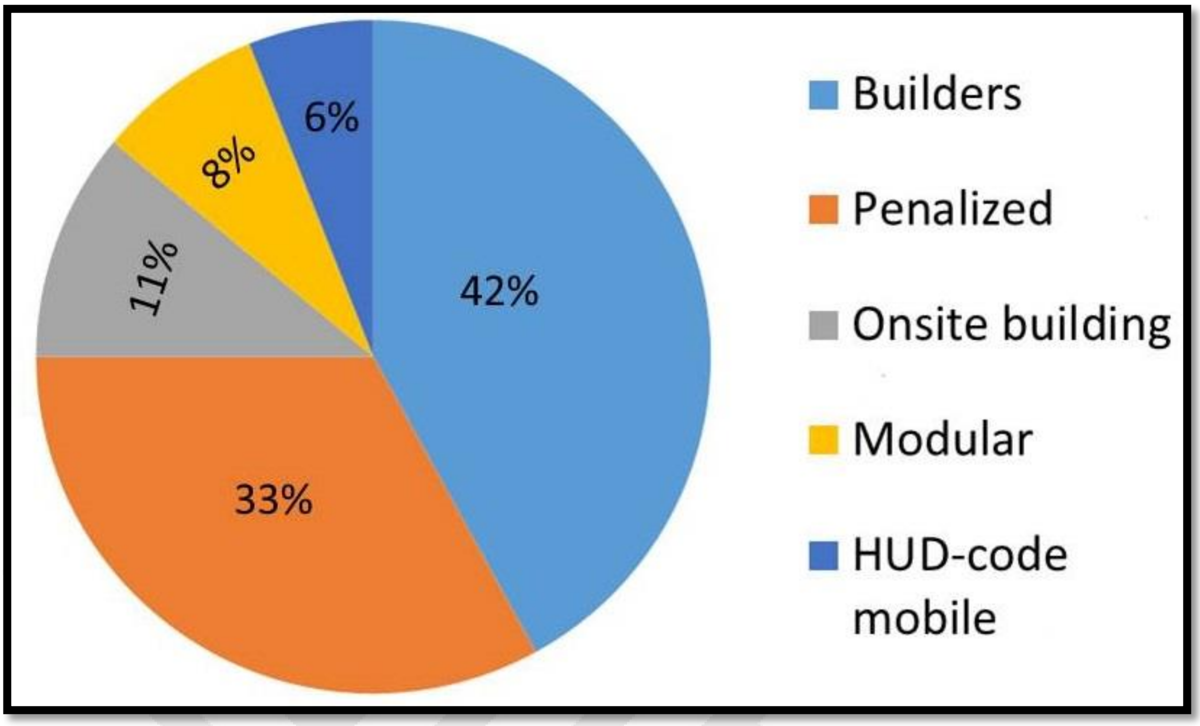
In 1950's, the prefabrication knowledge started to eastern Asian countries. Designers and contractors tried to detect a specific schema for prefabricated buildings market, since wide variety of methods were available and they promoted their knowledge to make the market ready for their works and products. In last decades many problems occurred in construction issues and in many developed countries the governments chose prefabricated buildings as one of their solutions in construction. However the prefabrication market has not been the same in all countries but it illustrates, several market schema in different developed countries but almost in all developed countries it displays rapid increase in tough periods of time such as Second World War (Figure 2.49) (Tam, 2002).

Figure 2.49: Prefabricated buildings completion in Japan and the UK in last 50 years



Source: Adapted from Ministry of Land, Infrastructure and Transport (MLIT) statistics, supplied by Professor Seiichi Fukao, Tokyo Metropolitan University; Parliament Research Paper, 1999; Communities and Local Government, 2007c

In the past, the prefabrication market focused mostly on home's market. Today, the market has extended to other building commercial ventures that incorporate health awareness, instruction, and business structures. Around 85 percent of respondents are utilizing these procedures to outline and develop those business ventures at a few levels in developed countries (Smart Market Reports: McGraw-Hill Construction, 2011). Still, the largest prefabrication market is the housing market. Prefabricated housing can be categorized into modular, mobile (HUD code), production builder, and panelized (Smith, 2010). The market share is given below:



Source: American society of civil engineering, 2013

The market in most of developing countries has developed quickly in the previous 10 years. The significant segments that have pushed the market to develop are movement arrangements, and remote speculations. Those components have constrained their government to put all the more in hi-tech frameworks, for example, sky-prepares and metros in Bangkok, and essential foundations, for example, streets, power and water lines in the farmland. The aggregate estimation of development in Thailand in 2011 was give or take $25,000 million, which was an increment of 9.1 percent from 2010 (www.buildernews.in.th, 2013). The current piece of the overall industry of the prefabrication home is under 30 percent yet the new the lowest pay permitted by law has gone up to 40 percent more than it was a couple of years prior. This has affected the general work business and development business, for example, In November 2013, Krungthep Thurakit Newspaper reported that numerous enormous Thai creating organizations felt that construction could help assimilate the huge work expense increment from the new the lowest pay permitted by law strategy (Krungthep Thurakit, 2013).

2.7 COMPARISON OF PREFABRICATION SYSTEMS IN DEVELOPED AND DEVELOPING COUNTRIES

Prefabricated construction has been a typical development strategy in developed countries for over a century. The idea of "assemble it quick" in the most conservative way has not changed subsequent to the starting; on the other hand, new frameworks have been created to suit the advanced world pre-assembled development. Construction frameworks are not just helping foremen and proprietors get their structures speedier and all the more monetarily however they additionally help decrease construction waste and create high vitality effectiveness structures which bring a long haul advantage to extend (Harris, 2006).

Prefabrication for building construction has been utilized in developing countries for just last two decades, yet it has been developing quickly in the previous five years. As of late, there have been numerous new designers, and builders who have changed from customary construction to prefabrication. Designers in developing countries see prefabrication as the future and are prepared to put more in this kind of construction (Krunthep Thurakit, 2013).

Although, prefabrication systems are a typical technique for construction in developed countries, several developing countries are still not acquainted with those frameworks. Since developing countries have diverse social and monetary frameworks from the developed countries they have a tendency to utilize more genuine labor for prefabricated construction as opposed to modernized prefabrication systems (Barlow, 2003).

Nowadays, different systems of prefabrication are utilized in both developed and developing countries, however the usage of systems is not the same.

This chapter would try to make a comparison between developed and developing countries according to widely prefabricated systems used in each of them.

In developed countries panel systems are the most common used construction system in prefabricated buildings. For example, 43 percent of all prefabricated homes and 68 percent of all prefabricated buildings in the USA use the panel system (smith, 2010). Curtail wall system mostly is used for facades of the buildings in developed countries especially for facades with glass components especially in medical and commercial buildings (Figure 2.50). Structural insulated panels mostly used for producing sound and fire insulations there and Large-panel system is mostly used for residential zone constructions (Naaman, 2004).

Figure 2.50: The prefabricated hospital in USA

Source: http://www.modular.org/htmlPage.aspx?name=First_Prefab_Hospital

Frame systems are the widely used system for tower constructions in developing countries, since the frame system especially the steel frame system is an appropriate option for complicated structures (Barlow, 2003). Steel frames system give the chance to designers to predict every obstacles of the project before the beginning of the construction process and they have systematic computation, in the other hand the steel frame system is stronger enough to resist against earth quakes, so 52 percent of all towers in japan use the steel frame systems (Barlow, 2003).

Wood frame systems mostly are used in small projects in developed countries especially platform wood frame system. Timber and wood are easy access materials in many developed countries and the fast execution of the projects is the main advantage for using the platform wood frame system there (Naaman, 2004)(Figure 2.51).

Figure 2.51: Prefabricated wood frame building in UK

Source:http://www.timber-building.com/features/green-is-the-colour/image/green-is-the-colour-3.html

Cells system is widely used in countries with specific climate conditions, since producing components in diverse and hard climate is hard and cells system is an appropriate system for producing them in factories under favorable positions. At present, enormous prefabrication construction showcases in developed countries are in progress and prefabrication construction has shown its potential in development process there (Kim, 2009).

Prefabricated construction in most of developing countries especially in eastern Asian ones such as: Philippine, Thailand and Vietnam are in view of area in preparing plants and after that sent to their ceaseless region. The way that these structures can be inborn separate parts, makes them less requesting to gather and transport. Perhaps, it is the pace of improvement, simplicity, versatility of design and environment welcoming structure, which is the principle catalyst behind present solicitations. In spite of the fact that construction has been utilized for development as a part of developing countries for over a quarter century, was not exceptionally well known until the previous five years (Reddy, 1996)

Unfortunately in many developing countries the shortage of expertise does not allow them to use prefabrication in its best way, since the industrialization rate is not in suitable rate and without appropriate factories prefabrication construction cannot work properly (Rippon, 2011).

Most of developing countries do not have any specific model for their prefabrication construction. They prefer to utilize types and methods which can be perform and execute with accessible materials. So, wood framing is one on the most popular types in developing countries particularly in eastern Asian countries where their climate is suitable for wood usage and it is accessible; however unlike the developed countries Balloon wood frame system because of its easier execution is used in developing countries (Rippon, 2011).

One of the upscale particular item that is at present accessible on the prefabrication construction system is the steel frame system, however the steel frame system is very expensive and its computation needs enough knowledge is not that much usual like developed countries, and in the other hand because of the lack of experience they mostly cannot predict the project obstacles (figure 2.52) (Rippon, 2011).

Figure 2.52: Steel frame system in Iran

Some small builders in developing countries have come up with a very cheap way to build prefabricated buildings. This prefabricated system is known as an knock-down system which is affordable small-size building that is either assembled from the factory before being transported to a site or factory-prefabricated building components that are transported to a site before being assembled (Figure 2.53) (Smith, 2010).

A knock-down building is constructed from modest materials, for example, wood or metal studs with cellulose-concrete board. Many designers define this system as impermanent natural surroundings in the greenhouse or a little coffeehouse; notwithstanding, this system is additionally utilized as a perpetual building for low-pay individuals. In any case, these sorts of buildings do not have a construction standard to control them, so the vast majority of them are casual buildings. There is no insurance on the quality of this item (Kim, 2009).

Figure 2.53: A knock-down buildings in Vietnam

Source: http://teakdoor.com/construction-in-thailand/1119-teak-trailer-houses-2.html

3. ADVANTAGES AND DISADVANTAGES OF PREFABRICATION SYSTEMS IN BUILDING CONSTRUCTION

There are numerous potential advantages related when delivering and developing building by prefabrication. The accompanying segments have been separated under two headings keeping in mind the end goal to intelligently introduce these thoughts (Ripon, 2011). The construction assembly advantages components will basically consider upgrades connected with the real gathering of prefab frameworks, though the assembling advantages area will look at the preferences emerging from the generation of these frameworks in a controlled manufacturing factory setting.

3.1 ADVANTAGES

Using prefabrication in a project allows the time dealing with on site to be decreased. This implies that the effect of the site on the nearby environment is for a shorter time of time. Site work is customarily defenseless against interruption from extremes of climate, by utilizing construction the site will be powerless for less time thus the danger of deferral and prerequisites for assurance will be lessened for a given task. Some significant retail customers are effectively focusing on persistent decrease in the site advancement time with a general lessening of 50 percent in venture time being accepted to be a sensible objective, construction is a dynamic piece of the procedure that will help to convey these investment funds.

Where prefabrication is being utilized as a part of a task it is imperative to incorporate it in the process as ahead of schedule as could be expected under the circumstances, and preferably at idea outline stage (Phillipson, 2001). Issues of absence of similarity and coming about expanded expenses are regular where pre-assembled parts are not considered until later all the while. Construction obliges that all included in the process experience an expectation to absorb information to upgrade the advantages of utilizing the framework. Changing the configuration of a progressing venture that uses pre-assembled parts presents a scope of issues for realignment as segments are by and large conveyed to site to fit a particular arrangement of measurements.

3.1.1 Construction & assembly

In connection to the routine strategy for site-fabricated development, prefab frameworks offer development organizations numerous chances to shave costs and enhance their primary concern. Since the 2007 building emergency, many countries in the world such as the USA now witness a collapsed building market (Rippon, 2011). The failure to secure financing for purchasers has driven down, and thusly, the requirement for a huge segment of the private development industry. With this sudden increment in business rivalry, numerous contracting outfits and development organizations now depend on prefabrication building parts as a method for expanding their net revenues. As a result, prefabrication assembling can diminish on location work and lessen the general crude material waste.

a. Reduced labor hours

One of the biggest accommodations with building and collecting buildings with prefabricated segments is the capacity to lessen the quantity of on-site labor hours. For some development firms this is pivotal on the grounds that each additional hour you stay on the worksite your risk, overhead expenses, and laborers remuneration increments. The accompanying table was adjusted from a study performed by the Wood Truss Council of America (WTCA) and the Building Systems Council of the National Association of Home Builders (NAHB) (2008). It gives a correlation in the work hours needed to build two indistinguishable 780 sq. m. buildings (Table, 3.1). One encircled with pre-assembled segments and the other confined traditionally on-site (Blisman, Pasquire and Gibb, 2006).

Table3.1: Man hours to frame 780 sq. m building

Elements	Man Hours to Frame	
	Site-Built Method (hrs)	Prefabricated Method (hrs)
Floor Truss Framing	38	12
Roof Truss Framing	256	99.5
Wall Panel Framing	93	26.5
Total	387	138

Source: Structural Building Components Association 2008

Obviously this Table shows building and amassing site-manufactured buildings can oblige a generous measure of work hours, when contrasted with the prefabrication option. A comparable study performed by FP Innovations – (Phillipson, 2001), on two 930 sq.m. triplexes, found that prefabrication had the capacity develop the building to secure up stage 395 worker hours, contrasted with its traditional site-assembled partner at 551 worker hours. This huge lessening in labor furnishes development organizations with the chance to cut direct work costs, and any leftover overhead that may come about because of sitting unmoving at the worksite. This diminishing in get together time is an advantage for the contracted organizations, as well as a vital angle for property holders who esteem fast building times as well.

b. Reduced material waste

In the genuine production of indistinguishable buildings, prefabrication frameworks ordinarily use a comparative level of materials as site-constructed development. (Phillipson, 2001), According to Chan et al, prefabrication penalization utilized 2.3 percent more wood however 1.8 percent less OSB sheathing than the site-fabricated methodology. Albeit absolute material utilization may be comparative, prefabricated buildings give far less on location squander as opposed to customary home development.

The below table shows the reduced material waste qualities gathered by FP Innovations (Chan et al., 2008).

Table 3.2: Build Alberta: Framing the Future' construction data

	On-Site Building Time	**Lumber Consumption**	**OSB Consumption**	**Lumber Waste**	**OSB Waste**
Units	Hours	FBM*	Sq. Feet	FBM*	Sq. Feet
Panelization	395	13,421	6,784	482	357
Site-Built	551	13,107	6,912	745	570

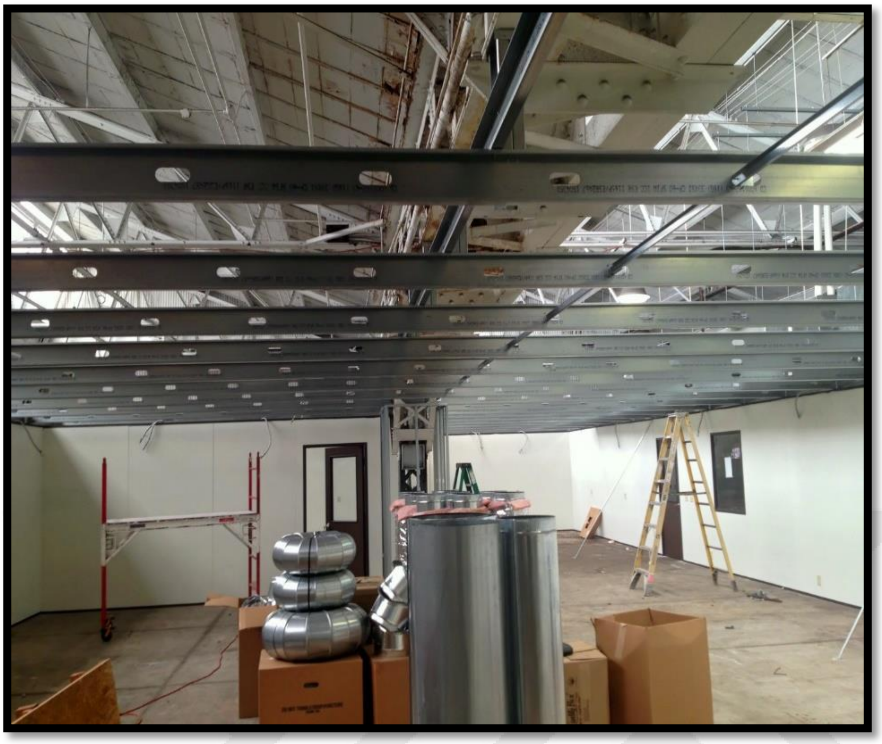
Source: FP Innovations - Forintek Division 2007

The Lumber and OSB waste affirm that site-built assembling delivers altogether all the more on location material waste than collecting with panelized construction frameworks. Site-constructed development represented 55 percent more timber waste and 60 percent more board waste. These elements are higher in site-assembled development on account of the expanded measure of machining that must happen at work site. In the study performed by WTCA and Building Systems Council of the NAHB (2008), costs coming about because of amassed waste at work site were recorded to be $425 for site-assembled and $100 for prefab (Chan et al., 2008). This may not appear like all that much every building, but rather if the organization builds by and large 45 of these 780 sq. m. buildings every year, they might spare around $15, 000 yearly. The larger part of these waste investment funds are because of the way that prefabricated segments are machined in a controlled domain. Therefore, assembling buildings in a shut office give better work climates than both workers and modern gear. By lessening the measure of machining and assembling that happens on location, prefabrication construction frameworks permit manufacturers to create less waste and acquire less cost in reusing and transfer charges.

3.1.2 Enclosed work environment

Fabricating an extensive part of the building in a controlled domain takes out numerous cerebral pains that may experience at work site. Case in point, in light of the fact that panelized and secluded development happens in an encased office, building materials are less inclined to climate debasement. In the development of the 1100 sq. m. triplexes, Forintek recorded that site manufactured assembling represented 551 hours of aggregate building time (Chan et al., 2008). This process out to be somewhere around 11 and 13 weeks that the building is liable to any climate harm that may grow over that period. Most of the time the harm is not so evident to perceive immediately but rather will later get to be clearer as checking, rot, and even form. A higher measure of value control is another critical highlight generally credited to assembling segments in an industrial facility setting. In correlation to most site-manufactured development, prefabrication organizations are more inclined to have quality-control projects executed into their assembling methodology (Harris, 2006). Encased structures give a more agreeable workplace for their representatives also, conceivably enhancing productivity and efficiency of the difficult work (Figure 3.1).

Figure 3.1: Installation of floor joists in an enclosed environment



Source: http://amezz.com/blog/author/derick-fowler/

3.1.3 Computer optimization

Computers and optimization equipment are getting to be progressively critical in today's producing enterprises. With steadily expanding wages, a lack of talented laborers and an ascent in rivalry, the construction industry is constantly quick to embrace new innovation for their current operations. Securing hardware and machines that depend on computer improvement is one route in which these producers have possessed the capacity to minimize expenses and build yearly efficiency. Assembling prefabricated segments in a controlled domain permits organizations to use this computer optimization streamlining hardware to its maximum capacity. Different advantages that match with the utilization of this gear incorporate lessened assembling span, an increment in task security, an increment in item quality, and the capacity to make distinctive components all the while (Harris, 2006).

The potential throughput and efficiency of new mechanized handling gear is significant in connection to what it was 10 years back. Robotized multi-capacity preparing units, for example, the new Hundegger SC-3 are fit for machining more than 3500 truss parts or 18,200 ft. of I-Joists in a solitary 8-hour shift (Rippon, 2011) (Figure 4.2). In spite of the fact that this may appear to be exorbitant for most offices, organizations that create 300 buildings or all the more on a yearly premise can truly advantage from such high yield hardware. The heavenly level of machining quality and constrained variety between slices is another preference to utilizing computer mechanized hardware.

Figure 3.2: Hundegger SC-3 automated component saw

Source:https://circle.ubc.ca/bitstream/handle/2429/36342/Rippon_Jordan_WOOD_493_Project_2010.pdf?sequence=1

3.2 DISADVANTAGES

Although there are numerous advantages connected with developing and assembling buildings utilizing prefabrication construction frameworks, a few constraints can likewise exist. The majority of the concerns emerge from transportation viewpoints confronted by the prefabricated buildings industry (Kim. 2009). The accompanying area will address some of these potential concerns.

3.2.1 Transportation limitations

Contingent upon the way of the prefab framework and area of the site, certain muddling can emerge in transport for this technique for prefabricated buildings. As a result of the inalienable contrasts in the level of culmination of measured and panelized buildings, shipping constraints will shift. Measured homes are regularly sent from the office with drywall, electrical fixtures, plumbing, carpet and cabinet work effectively introduced. Panelized makers then again, for the most part ship solitary, detached, basic segments. The divider boards, floor segments, and rooftop trusses are sent independently with a majority of the equipment being introduced on-site.

Transportation can be an expensive use for prefab makers and homebuyers. The real sending expense is in view of a few imperative elements (Bailey and Cameron, 2007). Transport separation, grant allocations, and the quantity of trailers are the factors that influence the expense structure of transporting a prefabricated building. Transportation separation from the factory to the last building site is normally the absolute most critical consider delivery of prefabricated building (Figure 3.3) (Figure 3.4). Notwithstanding, when the vehicle is considered over-limit, expenses get to be unavoidable. Much of the time, state law will oblige police escorts amid the evening to abstain from impeding nearby movement (Bailey and Cameron, 2007).

Figure 3.3: Prefabricated building being transported by vehicle

Source: http://modernprefabs.com/prefab-homes/sml-series-l/methodhomes-smlcostallarge-prefabhome-trucktrailertransport-960x409/

Figure 3.4: Prefabricated components being transported by vehicle

Source: http://www.ideassonline.org/innovations/brochTesti.php?id=189&brId=39

3.2.2 Shipping constraints

Shipping limitations are likely the biggest disadvantage confronting the prefabricated building segment. The normal prefabricated building ordinarily delivers inside 400-650 km as a greatest fair separation from the factory (Bailey and Cameron, 2007). Challenges confronted all through the transportation procedure include: dimensional requirements, load imperatives, and any potential defers because of license approvals or traditions issues.

3.2.3 Plain decoration

The decoration and facade of prefabricated building is not plain by the experience of past application. A large portion originate from workmanship instead of configuration lacks. These encounters introduce a hindrance to a few (Kim, 2009). Additionally, the other hand, this is presently being countered through coincidental showing frameworks where close supervision of site movement ought to guarantee that the final result is an item with workmanship quality identical to that of conventional frameworks, in other, unlike the structure and segments in decoration part of prefabricated buildings mostly traditional methods has been used so far, and it is why most of prefabricated buildings look plain.

4. FUTURE POTENTIAL OF PREFABRICATION SYSTEMS IN BUILDING CONSTRUCTION

One of the ways to deny the accumulation is using fast and suitable methods because rising prices of land and building materials. The awareness of methods such as prefabrication with a higher density will be a key for solving the problem considerably, with reduction cost and time and using accessible building material. As a result, in order to do so new priorities need to be work with prefabrication to fulfill the present problems. These methods will give a new schema for prefabrication systems.

4.1 PREFABRICATION AND SUSTAINABILITY

Researchers are progressively ready to display exact proof about the ecological effect of a dangerous atmospheric devotion, including rising temperatures, soil disintegration, and deforestation, falling water tables, ice liquefying, loss of biodiversity and creature living space, dangers to nourishment security and the faulty utilization of grain to deliver fuel for autos. Striking changes are expected to decrease carbon discharges; an unnatural weather change additionally constrains us to reevaluate the way we manage populace development, urban advancement, carbon-and vitality serious construction systems, straight and unsustainable material streams, utilization and urban life when all is said in done (Doran and Giannakis, 2011).

Sustainability advantage that can be foreseen from prefabrication will rely on upon the particular frameworks picked. It could be utilized which have a more disruptive natural execution than run of the mill conventional development, yet the potential exists for construction frameworks to have better ecological execution. One specific evidence being developed with EC funding has been quoted as having the following potential anticipated benefits (Doran and Giannakis, 2011)

1. 50 percent reduction in the amount of water used for construction of a typical house;
2. 50 percent reduction in the use of quarried materials used in the construction
3. At least 50 percent reduction in the energy consumption.

Whether these execution upgrades are attained to merits examination, yet by suggestion construction is being considered to show expanded execution when contrasted with conventional development in no less than three of the Movement for Innovations execution markers for maintainability. Another imperative variable connected with prefabrication systems is that of the decrease in waste connected with development.

The impact of an expanding on neighborhood nature and species will be unequivocally impacted by configuration and finishing which ought to be to a great extent autonomous of whether the building is obtained through conventional or construction courses. Be that as it may, one issue that could be essential is that connected with harm brought on by contamination amid development.

Sustainability is turning out to be more essential as it is vigorously esteemed by both designers and the administration. Waste lessening keeping in mind the end goal to drag out the administration lives of the landfill territories is squeezing hard. Embracing construction can be one of the approaches to decrease material wastage (Wong, 2000).

There are different impediments experienced in the selection of construction, for example, the long haulage of prefabricated parts, the hesitance of originators and experts in receiving construction which obliges plan adaptability, fitting preparing and instruction are expected to change the demeanor of the development business. Further, three stimulators are proposed to encourage and support the selection of construction, including executing more stringent ecological control and regulations, highlighting the reserve funds came about because of the more beneficial incline prefabrication systems.

Prefabricated buildings could have more control connected with industrial facility based construction, which ought to decrease the danger of some of this contamination to the nearby environment (Table 4.1), (Figure 4.1) (ASCE, 2012).

Table 4.1 proves the positive effect of the sustainability indicators on using prefabrication. The table evaluates the effect of using prefabrication in operating energy, embodied energy, transport energy, waste, water and species, it depicts how the prefabrication usage can show its role on sustainability indicators. It shows that using prefabrication appears as a positive exposure in all items except transport energy and transporting energy depicts negative behavior on it.

Table 4.1: Qualitative Performance of Prefabrication against the Environmental Performance Indicators

Sustainability Indicator	Effect of Using Prefabrication
Operational Energy	**Positive** – improvements in manufacture quality ought to guarantee predictable guidelines of protection and administration establishment.
Embodied Energy	**Positive** – Diminished waste and expanded reusing in off-site production ought to lessen the typified vitality partner with the assembling of a given part.
Transport Energy	**Negative** – Development of prefabricated parts will require the transport of some extra volumes of air.
Waste	**Positive** – Assembling of components in an industrial facility environment ought to lessen a significant part of the waste presently connected with site movement.
Water	**Positive** – Assembling of components that oblige water in their production in a manufacturing plant environment ought to permit more control, and potential for water reusing than would be found on site.
Species per hectare	**Positive** – Decrease of contamination on site by undertaking produce in a controlled domain might utmost the effect on existing species. The configuration and arranging of the proposed improvement is prone to be critical by the decision of construction

Source: American society of civil engineers, 2012

4.2 PREFABRICATION AND AUTOMATION

Due to the various way of assembling strategies found in prefabrication industry, three different levels of mechanization will be investigated. These three levels have been embraced. The three levels of automation are delegated manual, semi-mechanized, and fully automated. Among these levels, the labor and apparatus utilized will fluctuate enormously. Division will be in view of the material transportation, material measuring, material attaching, and machining innovation at the organizations (Wong, 2000).

These methods have broad automation in regards to material taking care of frameworks and machining capacities. Obliging just a small amount of the quantity of specialists as a manual operation, some of these completely mechanized industrial facilities will possibly deliver up to 1,000 buildings yearly (Mitchell and Hurst, 2009). It is common to discover multifunction Computer Numerical Control machines with full level automation.

A definitive target of automation in prefabrication is to enhance profitability, quality and security, which will add to cost diminishment. The kind of automation innovations definite in this study spins around real development extends and also inquires about exercises that are identified with building frameworks: that is, development parts, manufactured modules, boards, buildings and so on. It is logical to presume that some type of automation will be the standard in all production prefabricated buildings without bounds (Mitchell and Hurst, 2009).

The main and critical part of prefabrication process is done in factories by professional architects and engineers and for each process especially material process some certain machines and tools could work with each other. Table 4.2 would try to introduce some of these tools according to material process in prefabrication development (Figure 4.2).

Table 4.2: Automation found in a fully mechanized facility

Material Process	Machine / Tool Used
Sizing sheathing	Computer Numerical Control router
Sizing stud lumber or joists	Computer Numerical Control saw
Transporting sized components	Conveyor system
Attaching studs or joists to frame element	Multi-function Computer Numerical Control
Transporting gypsum or sheathing onto element	Multi-function Computer Numerical Control
Fastening gypsum or sheathing to element	Multi-function Computer Numerical Control
Flipping element	Butterfly table
Inserting components into element	Manually (by hand)
Manufacturing stairs	Computer Numerical Control router

Source: Technology Assessment of Automation Trends in the Modular Home Industry

The advancements that reformed assembling industry, prefabrication manufacturers might profoundly enhance the effectiveness with which it delivers final items - structures. The future architects will assess approaches to enhance efficiency through the use of incline generation, data and computerization advances. It will incorporate productive systems for warehousing, create procedures to decrease construction squander, and embrace strategies for reusing. It will create and convey innovations for deformity free transportation of the prefabrication segments.

4.3 PREFABRICATION AND PROJECT MANAGEMENT

Project management is the procedure and movement of arranging, sorting out, rousing, and controlling assets, techniques and conventions to accomplish particular objectives in investigative. A venture is a makeshift attempt intended to create a remarkable item, administration or result with a characterized starting and end attempted to meet unique objectives and destinations, regularly to realize valuable change or included worth (Nokes, 2007).

Construction laborers regularly are presented to elevated amounts of clamor, dust and airborne particles, antagonistic climate conditions, and different variables that can bring about weariness and wounds and in this way diminish effectiveness and profitability. Prefabrication techniques can make an action physically less demanding to perform, simpler to control, more exact, and more secure for development specialists. Correspondingly, prefabrication construction can lessen the heaviness of development parts, which thus can make them less demanding to handle, move, and introduce. Assembling building segments off–site accommodates more controlled conditions and considers enhanced quality and accuracy in the creation of the building components (Harris, McCaffer, 2001).

Prefabrication construction procedures include the get together or creation of building frameworks and parts at off–site areas and plants. Once finished, the frameworks or parts are delivered to the construction site for establishment at the fitting time.

Prefabrication will help the project management by controlling the weather, quality control and materials under the factory supervisions and in the other hand, reductions in material waste, air and water pollution will help the project management process. In addition, prefabrication will help the management process by giving this chance to engineers for writing an exact schedule for project construction process.

There will be several advantages in project management by using prefabrication systems in building construction (Doran and Giannakis, 2011).

1. More controlled conditions.
2. Fewer occupation site ecological effects
3. Compressed undertaking timetables
4. Reduced prerequisites for on-site materials stockpiling

5. CONCLUSIONS

The way to accomplish prefabrication products and systems is that the vast majority of countries have qualities over a large portion of the current modern prefabrication products in the construction and its market. Vitality sparing and simple gathering are two primary key which make modern prefabrication products fascinating with the vicinity items. Nonetheless, there are different elements which many specialists could see before putting resources into their countries. High quality items are not generally the most craved items. Builders need to build up their products to suit with the nearby climate, geography and local desires. In the other words, the deal cost will not make the products offer well in many countries. So, producers need to secure their factories provincially or join with extensive local wholesalers and producers, to be aggressive with the value.

Prefabrication will keep on growing in many different countries as the interest for quick reasonable building increments. Innovation exchange of construction procedure, including materials and advanced instruments, can influence nature, economy and society of the accepting nation contrarily. Therefore, the future of prefabrication can be seen as the improvement of the current market and the new development pattern market. At first, the construction's idea was a technique for building quicker and all the more monetarily. The early construction extends basically were moderate tasks; reasonable buildings on site that early engineers attempted to get up to speed with a profoundly productive method for construction. Today, prefabrication is not just being seen as a development strategy for moderate activities however it has additionally ventured into the extravagance market. Creating top notch building parts from a processing factory will exceptionally basic in near future. Since the innovations of large scale manufacturing for customer items will grow quick, these advances can help build the nature of building components to a higher standard.

Prefabrication systems might have some potential of increased use in future because of their characteristics. Table 5.1 depicts these factors and potential and explain the effect of prefabrication on them.

Table 5.1: Effective factors in increased used of prefabrication systems in future

Effective factor	Effect of using prefabrication
Program	The ability to progress work as a parallel operation in a factory and on a construction site
Factory tolerances and workmanship	They will show a higher quality and consistency to that achieved on site
Energy consumption	Reduction in energy consumption due to the automation
Labor markets	Access to cheaper labor markets according to factory base systems
Program certainty	Greater program certainty as a result of computerization
Safety	The factory environment can allow better safety than the construction site

Architects, engineers and contractors are adjusted in the conviction that the essential drivers to future utilization will be the upgrades that construction and modularization can give to components of efficiency including task timetable, expense, security and quality. A key metric of efficiency is the task plan. 66 percent of client respondents demonstrated that construction/modularization procedures have a positive effect on undertaking calendars, with 35 percent of those respondents showing that it can decrease the venture plan by four weeks or more. Another key profitability metric is task cost as measured by the venture spending plan. 65 percent of client respondents showed that the utilization of construction/modularization had a positive effect on venture spending plans, with 41 percent demonstrating that it diminished undertaking spending plans by 6 percent or more. More respondents (34 percent accept that construction and modularization can enhance site wellbeing versus the individuals who think the practices decrease security (10 percent).

Most clients accept that these procedures are wellbeing impartial (56 percent) (Guidelines for design, construction and implementation of prefabricated systems, 2008).

In future construction process, four factors might persuade countries to use prefabrication techniques in construction buildings more:

a. PROCESS

Manufacturers would present prefabrication techniques with a blend of off-site and on-site advances. In parallel to this organizations, can move toward more institutionalization with quite lessened outline portfolios. This implies engineers might be included at an opportune time, and that customers need to finish all progressions before production starts.

b. OBTAINMENT

This includes early association of customer, architects and engineers. In any case, different partners, for example, moneylenders, back up plans, arranging and building control powers require more inclusion.

c. LEARNING

There is contradiction about which advancements matter most, and how prefabrication effects can be measured when there is no concurred criteria to survey execution past expenses. The advantages of time, quality, wellbeing and security, and sustainability are frequently concealed and not completely acknowledged. Advancement of trials is expected to better comprehend these advantages.

d. TRAINING

Training is important since in spite of general conviction, Prefabrication techniques won't fundamentally adjust for shortage of skills. A comprehension of the methods and exactness included in prefabrication is fundamental. There is a need to prepare staff on the more drawn out term advantages of prefabrication and to lessen staff turnover by elevating a comprehensive way to deal with construction.

It is understood that, Prefabrication techniques could be used more in building construction if the disadvantages of prefabrication are removed and more suitable way are detected to find an appropriate relationship with prefabrication techniques with priorities like sustainability, project management and seismology (particularly in developing countries and countries in seismic zones), these could be done by architects, engineers, producers and even by clients.

Prefabrication systems would exhibit some depletion such as:

1. Maximum load capacities of site carnage and temporary gantries.

2. Space and building elements held back for access/installation routes.

3. Additional cost of temporary bracing for transportation and/or lifting or permanent framing to support prefabricated assemblies.

4. Additional cost of pre-assembly in the factory prior to dismantling for transport and delivery.

5. The insitu work abutting prefabricated assemblies requires a higher degree of accuracy than is normally associated with on-site building work to avoid interface problems

Prefabrication implies that gathering is detracted from site and performed in industrial facility conditions, prompting enhanced quality and reliable workmanship. It can likewise streamline chip away at site and empower site staff to proceed with other vital works without being hindered by different specialists. To cut expenses and enhance consistency and quality is the drive for more prominent utilization of prefabrication systems. Prefabrication systems might help decline construction time and on site costs. It is conceivable to enhance effectiveness and quality confirmation of the parts and improve ecological execution and site security. Prefabricated construction will include broad utilization of institutionalization and modularization. This methodology speaks to a noteworthy change in the way building systems have generally been indicated and outlined. To accomplish the genuine advantage for building administrations gear and conveyance, construction must frame a principal piece of the incorporated and composed configuration system for the building. It is possible to say that further improvement of prefabrication systems will prompt a closer joining between building construction and future potential of prefabrication.

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