

ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAIT)

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Prefabrication Construction as an Alternative Structural Frame Construction Method for 40/60 Housing Projects in Addis Ababa – A Case Study on Megenagna Site

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(Construction Management and Technology)

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This is to certify that the thesis prepared by Belachew Yilma, entitled *Prefabrication Construction as an Alternative Structural Frame Construction Method for 40/60 Housing Projects in Addis Ababa – A Case Study on Megenagna Site* submitted in partial fulfillment of the requirements for the Degree of Master of Engineering (Civil Engineering – Construction Technology & Management) complies with the regulations of the university and meets the accepted standard with respect to originality and quality.

Approved By Board of Examiners

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Abbreviation

AARH	Agency for the Administration of Rental Houses
CMC	Cooperativa Muratorie Cementisti"
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
HCB	Hollow concrete blocks
HOB	Housing and Development Board
AAHDE	Addis Ababa City Housing Development Enterprise
ICT	Information Communication Technology
IHDP	Integrated Housing Development Program
IMS	Institute for testing of materials
MHI	Manufactured Housing Institute
P.B.P.P.E	Prefabricated Building parts production Enterprise
PCI	Precast/pre-stressed Concrete Institute
PHF	Prefab Housing Factory
RCC	Reinforced cement concrete
UK	United Kingdom
UN	United Nations
US	United State of America
USD	United State Dollar
WWII	World War II

Keywords

- Comparison Between Construction Methods
- Construction Cost
- Construction Quality
- Construction Speed
- Precast Construction
- Cast in-situ Construction
-40/60 Saving House Project

Abstract

It can be easily noticed how there are numerous defects in almost all of the concrete buildings in Ethiopia. Anyone who works in the construction industry would have witnessed poor quality of work in several projects. If such a person has an engineering and construction management background, the quality problems and subsequent technical risks would stand out even more.

This MEng final project is about precast construction as alternative method of construction for mass housing projects, specifically, about the significance of this construction method being introduced in Ethiopia. Despite the array of structural, serviceability, and quality problems that are very common, it is exciting to think of the tremendous opportunities that such a fresh start as precast construction would bring. Where the equipment and production space is available, structural concrete elements could be cast and cured in a controlled manner on the ground level. This could be seen as a characteristic feature of the precast method of construction

The reader will find brief descriptions of the in-situ construction method, other countries experience on prefabrication and overview of Ethiopian policy towards housing for the past three regimes .

The research then goes on to study the cost benefit analysis of precast construction over conventional method of construction , Using a case study 40/60 saving apartment building in Addis Ababa, Ethiopia, the aim of the study was to evaluate the differences in cost, quality ,delivery time for both construction technologies in delivering the house to the end users, in order to determine which of the two had lower cost, good quality and time saving; and would be a better-performing alternative for the Ethiopia's construction industry.

The findings are mostly as would be expected. Mainly, the precast method was found to be better in cost saving ,quality, resources, and time, than the in-situ construction method. It was also found that there are certain types of buildings that are more suitable to be constructed using the precast method. Finally, the research reveals that 36% cost saving if we use prefabrication for mass house development project..

This is a major reason that this topic was chosen for MEng project. It was arrived upon while searching for ways of modernizing the construction process in leaps and bounds. With the degree of out datedness of the construction process in Ethiopia, a catapulting change is needed just to cop up with where the modern world has already reached.

1 Introduction

1.1 Background and history

As the population continuously growing rapidly, so the need of rapid or fast construction is requirement of current and future generation. Precast concrete construction methods are become feasible and alternatives method or solution in such applications likes buildings and bridges. The primary benefit of precast construction is the speed of construction (i.e. reduction in time of construction), waste management, and cost efficient construction. Precast elements can be cast in controlled environment conditions at a pre casting yard in advance of when they will be required, stocked, and transported to the construction site carefully as required. The structure can then simply be assembled precast elements. The construction of members or element is design by industrial method **(1)**.

In general, precast construction systems are said to be economical when compared to conventional (i.e. cast-in-place) residential construction (apartment buildings).The use of tools, heavy machinery, and other modern equipment, usually automated, in the production of precast element, interchangeable parts and products. As the precast elements are manufactured in controlled environment there is an elimination of weather effects on it.

Now a day's many developing countries looking for quality product of construction and increasing the productivity of precast element. Precast concrete is the ideal solution for residential because the structure of residential buildings are somewhat standard so the construction of same type of elements are easy and result in to cost saving on if its production is in bulk. Precast concrete provides durability, flexibility, sound, durable and versatility with cost effectively. Precast concrete construction required less construction process which saves money on financing costs. Cost saving on labor policies, skills development of employ, providing training to them is major factors. Maintenance cost will also reduce in precast concrete construction **(1)**.

The rapid population growth of most of the developing countries makes effective and efficient service delivery difficult for governments, to satisfy the need of their residents. Housing is considered to be one of the basic requirements for human survival, but it still remains to be a major obstacle for developing countries that are unable to fulfill the housing needs of the people. Ethiopian economy is growing at a faster rate especially in the past two decades. In which the construction industry is believed to have the major contribution. Construction Industry contributes to economic development by satisfying the basic objective of development including output generation, employment creation, income generation and redistribution. It also plays a major role in satisfying basic physical and social need including a production of shelter, infrastructure and consumer goods **(1)**.

The history of prefabrication in the West begins with Great Britain's global colonization effort. In the sixteenth and seventeenth centuries, settlements in today's India, the Middle East, Africa, Australia, New Zealand, Canada, and the United States required a rapid building initiative. Since the British were not familiar with many of the materials in abundance in these countries, components were manufactured in England and shipped by boat to the various locations worldwide. The earliest of such cases recorded was in 1624, when houses were prepared in England and sent to the fishing village of Cape Anne in what is now a city in Massachusetts [(2)].

In 1954, the mobile home industry expanded with the need for affordable rapidly constructed housing. Similar to the UK temporary housing programs, mobile homes were completely built as a module on a chassis in a factory and then trucked to site. Mobile homes kept their wheels, making them capable of transport, but in most cases were never moved. By 1968, mobiles accounted for a quarter of all single family housing in the United States [(2)].

1.2 Research Method

Based on the research goal, this research can be categorized under applied research. This is because the results of the research analyses are meant to be applied instead of solely enriching the knowledge base; based on research objectives, it is both a descriptive and exploratory research. The reason it could be under these two categories is because the research has both aspects. It has abundant descriptions of its topics of consideration, wherever it is deemed necessary, while it also critically explores topics that need to be analyzed, explained, and put in perspective.

Based on research approach, it is again both a qualitative research and quantitative research; It has a quantitative approach when it deals with the quantitative data, and it takes on a qualitative nature for numerous non-number data. Based on research design, it is a Non experimental type, as it does not involve any experimental works in its data collection and analysis; Accordingly based on data type, it is secondary research (desk study), as no experimental works were needed.

The approach to data collection adopted for conducting this research is fieldwork (primary data collection) specifically the survey approach. Personal interviews and archives from P.B.P.P.E are the basic research instrument to collect data. The information obtained from those sources were analyzed and the summarized.

1.3 Scope of the Research

This paper focuses on the application of prefab concrete technology for housing development sector and the cost comparison conducted mainly focuses on the total cost for constructing the structural elements of a 2B+G+12 and 18 40/60 condominium houses, including supervision

costs, interest cost, related opportunity costs. The cost analysis part of this paper doesn't include walling, finishing, sanitary, electrical, electromechanical, etc. costs.

1.4 Research limitation

The problems encountered while preparing the research

- Unavailability of written literatures and required data particularly on prefabrication system in Ethiopia.
- The unwillingness of officials to provide information, so that the investigation was carried with very limited data obtained.
- Monopolization of prefabrication by one company limits the versatility of costing the buildings
- Lack of code of practice for prefab design which limit the versatility of building types
- Since the project focus on the structural frame construction. Hence will not give full comparison on finished building
- There is no systematic way to control the inventory of material supply for 40/60 apartment project on Megenagna project site which limit to analyze and compare the wastage of material with the prefab building method

1.5 Statement of the Problem

Housing is the major problem currently Ethiopia is facing. The combination of high population ,poor delivery system 40/60 condominium house by government and urban growth rates coupled with a high occurrence of urban poverty and migration from rural areas to urban areas have contributed to enormous strain on Ethiopian cites especially on Addis Ababa.

The characteristic of the construction industry contributes significantly to housing problems in Ethiopia. These are its late delivery system, expensiveness, poor wastage management, poor quality which results in a high maintenance cost and poor workmanship on construction sites. These problems create a gap between the demand and supply of housing by prohibiting effectiveness as well as efficiency on cost, time and quality.

In order to improve these characteristics of the industry, an alternative technology should be adopted to transform the current conventional way of construction to more advance, fast and economical construction technique. One of these alternatives is considered to be prefabricated technology. That has been used for years and it has been proven to be effective in building large scale housings in the world.

1.6 Hypotheses

- Prefabrication Construction is more economical alternative than conventional construction methods for 40/60 Condominium Housing Projects.
- Faster return on investment for the client and public can be achieved by using prefab construction.
- Shorter durations for fixing and erection operations this advantage gives the government higher rate of house transfer to the demanding public in parallel with faster modernization of the city.

1.7 Objective of the study

1) To carry out total project time and cost comparison between prefabrication and conventional structural frame construction methods for Addis Ababa housing development projects specifically on 40/60 Condominium projects located at Megenegna site.
2) To identify which construction method is Affordable and offers fast delivery of houses to the growing society
3) To Assess the experiences and best practices of developed and developing countries on prefabrication technology for mass housing projects
4) To Assess the current prefabrication industry in relation to the housing Demand and supply and to come up with recommendations to improve our prefabrication technology practice

2 Literature Review

2.1 Definition of Prefabrication

Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located.

The term “precast concrete” or “prefabricated concrete” is a construction product produced by casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted into place. These include; foundation walls, sound-barrier walls, retaining walls, floor and roof slabs, architectural panels, paving elements, modular housing, manholes, box culverts, utility boxes, grease and oil interceptors, septic tanks, treatment plants, precast tanks, bridges, piers and tunnels [(3)].

A prefabricated building is a type of building that consists of several factory-built components or units that are assembled on-site to complete the unit. Modular construction' is a term used to describe the use of factory-produced pre-engineered building units that are delivered to site and assembled as large volumetric components or as substantial elements of a building [(3)].

2.2 Origins of Precast Construction

Ancient Romans used to pour concrete into molds to build aqueducts, culverts and tunnels beginning around 100 B.C. In modern times, precast was first utilized in Liverpool, England by then city engineer John Alexander Brodie in 1905. Later, the method was widely adopted in Eastern Europe and Scandinavia. In the US, the precast concrete “products” industry, which mostly encompasses non-pre-stressed precast products for utilities construction is represented by the NPCA. Meanwhile, the precast concrete “structures” industry which includes pre-stressed precast concrete and other precast elements used in buildings, bridges, and parking structure.

2.3 Brief History of Precast Construction

Precast construction started to be widely used in the U.S.S.R. in 1954. The products mainly consisted of separate precast elements that would all be assembled on site. Since 1958, precast cell systems started to be produced. “By this new concept, individual large sections of buildings are manufactured instead of separate precast concrete elements…”. Parts of apartment buildings, as big as one complete living unit at once, started to be precast and assembled. “… entire cells of

buildings, for installation as completed sections of a block of apartments, have been manufactured" [19]. Figure 2.1 shows such an assembly.

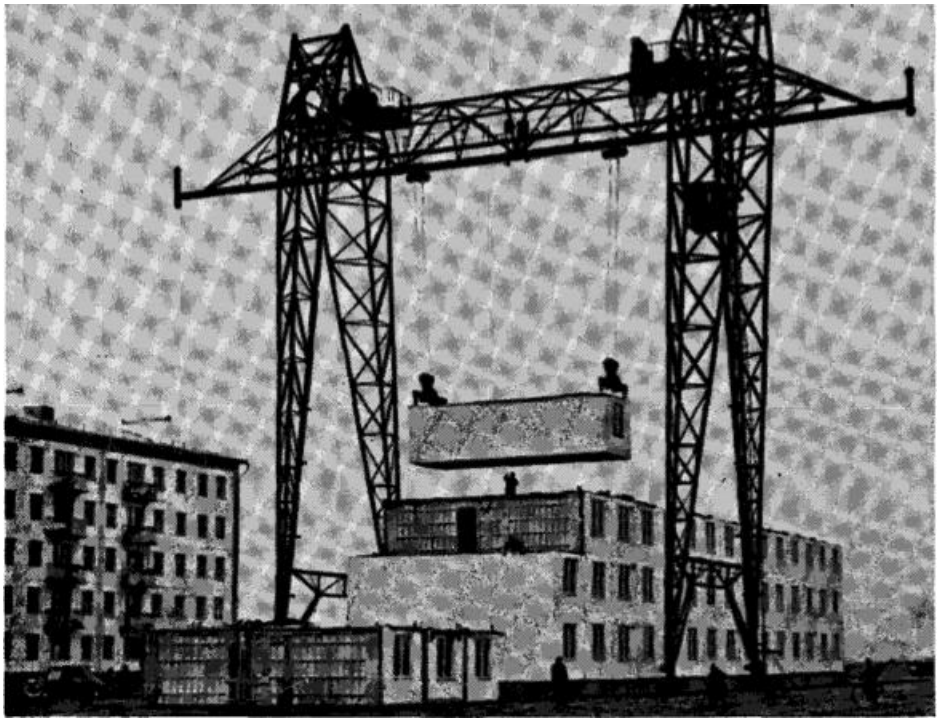


Figure 2:1.Apartment construction in the U.S.S.R. using prefabricated cells to make up the structure [19]

Marked use of machinery for concrete production, and the use of pre-stressed reinforcement became very prominent after this method of construction sprung up and gained popularity in the developed countries. In 1949, there was no precast pre-stressed concrete production in the US. In 1974, 1.4 billion dollars' worth of precast was sold by North American precast plants.

The first major pre-stressed structure built in the US is the Walnut Lane Bridge in 1949. It was designed by a European engineer, Gustave Magnel.

In a Canadian Conference on Pre-stressed Concrete in 1954, Magnel criticized the American production industry saying that they have highly specialized machinery which has resulted in a "save labor" hilosophy that prevented Magnel's team from producing 100,000 identical bridges. Special fittings like sandwich plates and rubber cores for the Walnut Lane Bridge were only needed in a few hundred which no one in America was interested in "machine tooling", so they had to be manufactured in Europe.

Mikhailov states that in the beginning, there were five factors that mass production of pre-stressed concrete depended on.

i. Availability of 7-wire cold drawn stress relieved steel strand, i.e. pre-stressing wire.

ii. Development of a workable strand vise, used to apply tension on the pre-stressing wire.

iii. Efficient production of high strength concrete.

iv. Implementation of the long straight line casting bed concept.

v. Development of standard cross sections"[19].

These are factors that affect PBPPE's production process. For example, the pre-stressing strand has to be imported from either Europe or India if production is being carried out. The wedge and barrel that are used to lock the pre-stressing wire could now be produced in-house, although they used to be imported for most of the plant's lifetime. "These five accomplishments made possible the rapid development of a mass production manufacturing industry in pre-stressed concrete" [3].

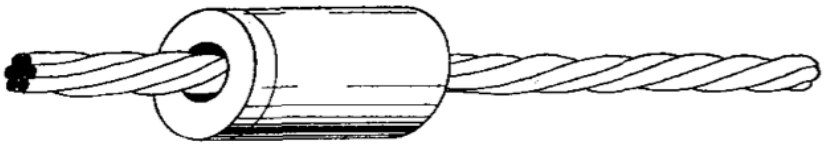


Figure 2:2. Seven-wire strand and strand vise [3]

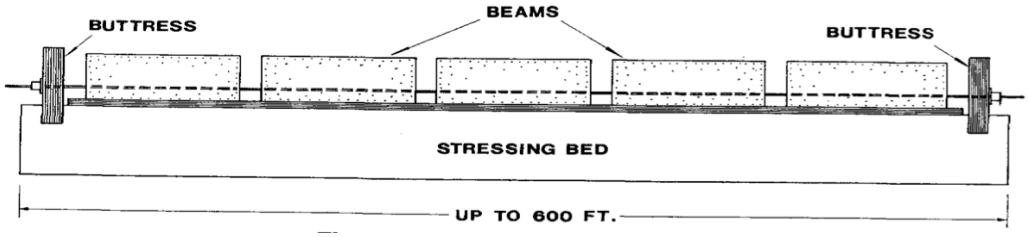


Figure 2:3.Long Line Casting Bed. [3]

A different method of pre-stressing had been tried prior to this classic method, which included winding wire "around rectangular beams to pre-stress them externally". Magnel mentioned additional concerns he had about pre-stressed precast production in the US stating that the high strength, zero slump concrete required for pre-stressing could not be achieved because the contractor preferred to save labor. They had to settle for 2 inch slumps which went down to 6 inch slumps towards the end of the project.

This led the American concrete production industry to use the vacuum process, "where relatively high-slump concrete was cast in special vacuum forms, and a low water-cement ratio was then obtained by removing the excess mix water by means of vacuum". There are advanced methods that are being used now which can get much higher strength with zero slumps but "in the early 50's the vacuum process gave the fledgling industry a way of obtaining high-strength concretes without decreasing the ease of placement" [3]. The Vacuum system was very large and expensive.

The long line casting method was another crucial development in precast production. Instead of casting individual elements in separate forms and on separate pre-stressing beds in rapid succession, it provides the more economic way of casting on a 150 meters long bed with pre-stressing wires of the same length jacked at the ends of the bed. As can be imagined, this method in itself presented enormous challenges relating to the shape of the structural element and the varying steel profile in each of the elements, which were required for the structural efficiency of the element.

Precast production seems to be most appropriate for producing precisely alike shapes and lengths of concrete members repetitively, but this is not frequently the case in most buildings. The long line process allows for the customization of concrete elements without losing the advantages of fast and highly controlled precast production for bridges and other lineal road structures. The repetitive production serves great benefits of saving time and money.

2.4 Major Advances and Current Status of the Precast Industry

With the comprehensive technological advancements of concrete, precast concrete has also found applicable features. The Design Build Institute of America has published a paper discussing the widely applied inventions and citing other more specialized innovations on concrete.

The publication states that "new advancements in concrete and cement-based products are completely changing the design and construction worlds". As in most North American publications on precast, equal importance is given to the architectural decorative aspect of concrete in the paper as it is to structural and workmanship aspects. However, since the focus of this thesis is on quality, cost, and construction or production time of structural concrete members, the applicable technologies have been included here.

Load-Bearing Wall (LBW) system is gaining recognition in high-rise buildings with repetitive cell layouts, such as hotels and apartments. "… The walls and slab are poured simultaneously when using the innovative tunnel form construction method".

The improvements in tilt-up systems have been quite remarkable that precast load-bearing walls can be lifted to large heights. This allows for different installations within the walls. "…The Tilt-Up industry is reaching new heights with the record lift nearing 100 feet. Production is streamlined with embedded facers cast integrally with wall panel to greatly reduce labor requirements with conventional brick and mortar veneer".

Aerated Autoclaved Concrete (AAC) is one of the most exciting inventions in concrete technology. "Lightweight Masonry takes the form of AAC block. With sufficient structural capacity to be used as low-rise bearing walls, AAC block greatly reduces masonry partition wall weights for elevated slab construction". Moreover, the porous nature of AAC allows for a thorough curing on a micro granular level of internal concrete structure.

The following probably offer more advanced solutions than the basic kind that the aforementioned innovations would provide, but the rapid competition within the international construction industry could pose such demands in the near future.

A pro-level knowledge on the common characteristics of concrete suggests that traits such as heavy weight, surface cracks and chipping are usually linked to the presence of coarse aggregates in concrete. Despite their side-effects, coarse aggregates are what provide the majority of compressive strength to the concrete. "Reactive powder concrete is extremely workable, durable and yields ultra-high strengths without using coarse aggregates. Reaching compressive strengths of 30,000 pounds per square inch (psi)…". Ideally, this is one solution that can be used nearly problem-free reinforced concrete members.

Self consolidating concrete is not really as recent as the other technologies mentioned above. It has even been put to use in some large construction projects in Ethiopia. It is an important innovation that allows for large size concrete bodies that would not be easy to consolidate using conventional means such as vibration. "Self Consolidating Concrete (SCC) eliminates the need for mechanical consolidation and yields a smooth surface finish without mix segregation. SCC and computerized precision color are revolutionizing the precast industry" [21].

A number of other inventions are gaining popularity in concrete construction ranging from fiber reinforcements as in Ultralite to long-span yet shallow truss systems such as Pre-stressed Open Space Truss (P.O.S.T.). Fiber reinforcements are briefly discussed as follows.

The earliest that the precast industry started to make use of fiber reinforced polymer (FRP) as an reinforcement alternative for concrete is in the early nineties in the United States. "The most common use of FRP in infrastructure is for repair and strengthening of existing structures. FRP is an attractive choice for these applications since it is often cost-effective, easy and quick to install, and does not significantly affect the mass or geometry of a structure…".

So far, the use FRP in concrete construction has not been wide spread, but it is forecasted to be more utilized in precast construction in the future. "…Recent advances in the precast concrete industry have enabled more widespread use of FRP in new construction with a variety of new applications emerging".

Fiber reinforced polymers can be made in different forms like sheets, plates, bars, and grids. Offering a wide range of applications for construction. "Construction of the panels consists of: (1) casting the bottom layer of concrete, (2) placing the insulated rigid foam with FRP grid, and (3) casting the top layer of concrete" [21].

Insulated Concrete Form walls (ICF) provide speed, sustainability, and endurance to concrete structures. "In addition to rapid construction, energy savings and increased durability, owners also gain a healthier and quieter environment. Most recently, blast-test experiments [on ICF walls] showed exceptional results for resistance to catastrophic loadings, including fire, wind, and tornados".

PBPPE uses post-tensioning to pre-stress concrete members in precast construction projects. "Post-Tensioning has new construction and retrofit applications. An intumescent material creates fire-resistant PT strands for bridge deck and parking garages. The 'Spider' method retrofits buildings for earthquake protection, while External Post-Tensioning (EPT) helps solve strength and serviceability problems".

Another finding that can be incorporated into precast construction systems is MMFX, a new highly corrosion resistant form of steel that can reduce the speed and precision of concrete mat construction. "…'Reinforcement Carpet' gives a unique solution to reduce shipping and erection costs… Galvanized and stainless clad rebar offer less expensive, but corrosion resistant alternatives to stainless steel rebar. The latest technology of MMFX micro composite steel gives a high-strength, corrosion-resistant product with a cost-effective price" [21].

2.5 Clarification of Terms Used in Precast Construction : Pre-stressed ,Pretension ,Post-Tensioned Concrete

"Pre-stressed concrete is concrete that has had internal stresses introduced to counteract, to the degree desired, the tensile stresses that will be imposed during operation". Pre-stressing tendons could be "individual hard-drawn wires, cables of hard-drawn wires, or bars of high strength alloy steel". They may be used for Pre-tensioning or post-tensioning the precast concrete members.

Pre-tensioning is a process that involves pulling pre-stressing tendon in a frame or between anchorages that would stay at the end surfaces of the member, and pouring fresh concrete around it. After the concrete has set, the tensioned steel is released slowly to transfer stress to the concrete that it has already bonded with. It takes a certain distance from the ends of the member for the force to transfer and this is called the transfer length.

Post-tensioning is when the concrete is cast around ducts through which pre-stressing tendons would pass. After the concrete sets, the tendons are passed through the concrete member, "tensioned by means of portable jacks" and fastened to the ends of adjacent members. Anchorages are used for the fastening and they are left embedded in the concrete to maintain the longitudinal compressive stress that they had transferred to the precast members. The ducts are usually grouted to protect the tendons form rust. "Post-tensioning can be done on the job site without any need of heavy temporary anchorages. Anchorages are needed for each tendon, however, which is a significant cost item" [9].

2.6 Application of prefabricated Concrete in housing industry

2.6.1 Types of precast systems

According to the World Housing Encyclopedia (WHE), precast systems can be divided into the following categories, based on the load-bearing structure, precast systems can be divided into the following categories:

- Frame systems
- Slab-column systems with shear walls
- Large-panel systems
- Cell systems
- Mixed systems **(4)**.

Frame systems: can be constructed using either linear elements or spatial beam-column sub assemblages. Precast beam-column sub assemblages have the advantage that the connecting faces between the sub-assemblages can be placed away from the critical frame regions; however, linear elements are generally preferred because of the difficulties associated with forming, handling, and erecting spatial elements. The use of linear elements generally means placing the connecting faces at the beam-column junctions. The beams can be seated on corbels at the columns, for ease of construction and to aid the shear transfer from the beam to the column. The beam-column joints accomplished in this way are hinged. However, rigid beam-column connections are used in some cases, when the continuity of longitudinal reinforcement through the beam-column joint needs to be ensured **(4)**.

- Precast concrete frames involve an entire structure being fabricated off-site.
- Structural components can be supplied for incorporation into a structure on-site.
- Frames can simultaneously achieve both structural and decorative design requirements
    - ✓ Wide variety of mixes, colors and finishes can be accommodated.

- ✓ Architecturally-finished precast structures can be left exposed to exploit concrete's high thermal capacity in a building's "green" energy management system [(4)].

Slab-column systems with shear walls: Is a system that uses horizontal pre-stressing in two orthogonal directions to achieve continuity. The precast concrete column elements are 1 to 3 stories high. The reinforced concrete floor slabs fit the clear span between columns. After erecting the slabs and columns of a story, the columns and floor slabs are pre-stressed by means of pre-stressing tendons that pass through ducts in the columns at the floor level and along the gaps left between adjacent slabs. After pre-stressing, the gaps between the slabs are filled with in situ concrete and the tendons then become bonded with the spans. Seismic loads are resisted mainly by the shear walls (precast or cast-in-place) positioned between the columns at appropriate locations. This technology has been used in Yugoslavia during the last 40 years under the proprietary name, "IMS Building System," and it can be found in all major Yugoslav cities, including Belgrade, Novi Sad, Nis, and in other countries, such as Ethiopia, Cuba, the Philippines, and Egypt [(4)].

Large-Panel Systems: The designation "large-panel system" refers to multistory structures composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building.

Mixed Systems: In this type of structures all the three types or the two types of the structural precast system can be applied at a time [(4)].

Cell Systems: These are systems where all fittings (electrical and mechanical systems) and finishing's are all installed during pre-casting. Whole units such as kitchens and bathrooms are done on ground level and installed at desired locations.

2.7 Prefabricated Building components

The basic components of a building that can be prefabricated are the wall and slab elements. However more innovative ways of prefabrication still exist. The main precast concrete structural elements are;

a) Precast Slabs

Filler slab

The basic concept behind use of filler slab is to remove substantial portion of concrete below the neutral axis, which does not contribute to the tensile strength of the slab. Various types of filler slab can be used, such as coconut shell; HCB slab etc. use of filler slab contributes to the

economy the construction compared to the conventional RCC slab. Such slab is comparatively lighter in weight, and has increased insulation properties because of voids between the tiles [(5)].

The principal advantages of precast floors are speed of construction, absence of scaffolding, large variety of types, large span capacity, & economy.

Precast floors can also be classified according to their manufacture into totally & partially precast floors.

- Totally precast floors are composed of units, which are totally cast at the plant. After erection, the units are connected to the structure & the longitudinal joints are grouted. In some cases a cast in-situ structural topping screed is added.
- Partially precast floors are composed of a precast part & a cast in-situ part. Both parts are working together at the final stage to achieve the composite structural capacity. The main totally precast system types are described hereafter [(6)].

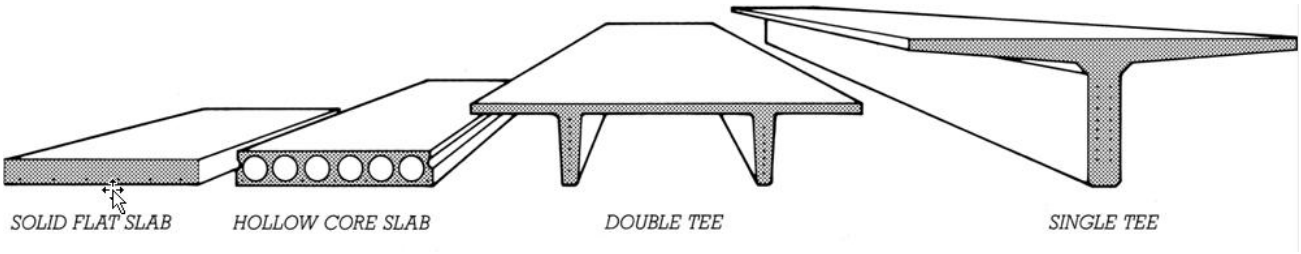


Figure 2:4 Different types of Precast Slabs [6]

b) Precast Walls

→ Hollow Concrete Blocks (HCB) wall;

Different types and sizes of hollow concrete blocks for wall construction can be produced. The most common type of HCB is the one with two openings. Sometimes it may be produced with poor quality. However, with the same mix ratio, it is possible to increase the compressive strength by using different mold types with increased number of openings. As test results show, HCB with three openings acquire a greater compressive strength than with two openings. This is because as the number of openings increases the contact area also increases hence have greater bearing capacity. Additionally, making one side of the HCB closed results in reduction of mortar wastage and increase productivity [(6)].

→ Precast concrete wall;



Figure 2:5 Precast Concrete Wall [6]

c) Precast concrete columns



Figure 2:6.Precast Concrete Column [6]

d) Precast concrete Beam

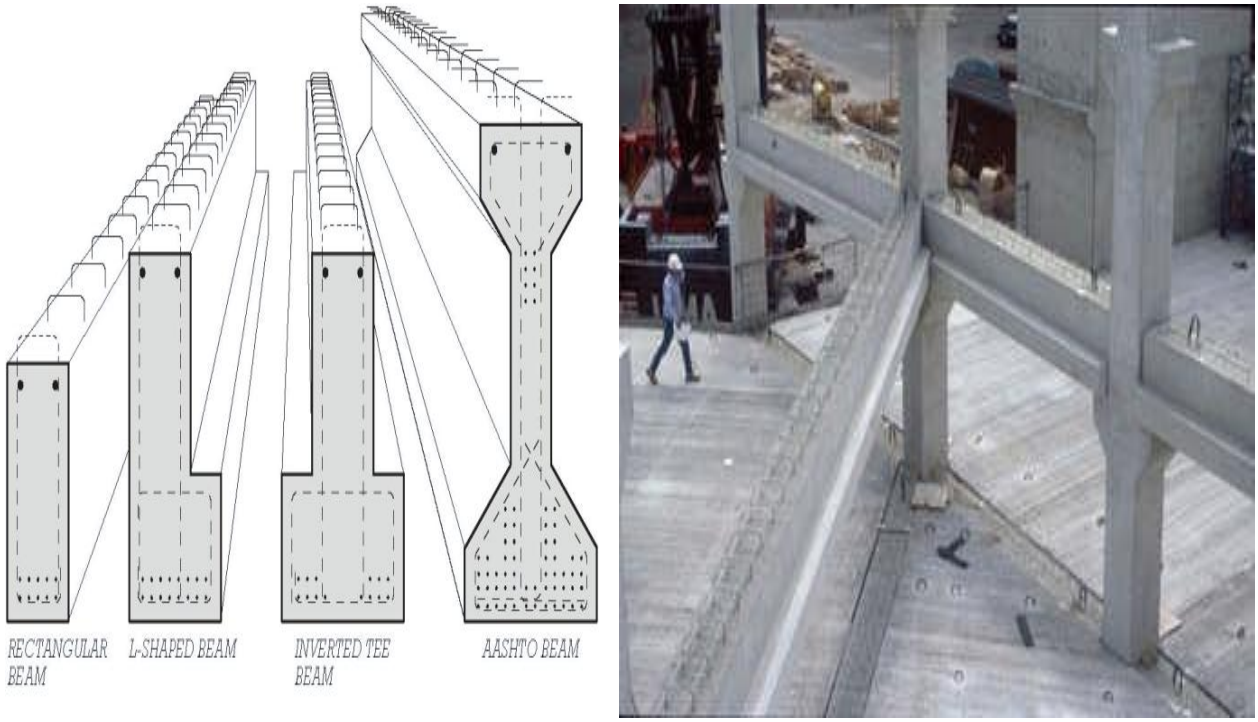


Figure 2:7 Precast Concrete Beam & Inverted Tee beams supported on precast columns[6]

e) Precast concrete Stairs



Figure 2:8.Precast concrete Stairs[6]

2.7.1 Design Concepts for Precast Concrete Buildings

The design concept of the precast buildings is based on the build-ability, economy and

standardization of precast components. In design of precast members and connections, all loading and restraint conditions from casting to end use of the structure should be considered. The stresses developed in precast elements during the period from casting to final connection may be more critical than the service load stresses. Special attention should be given to the methods of stripping, storing, transporting, and erecting precast elements [(7)].

When precast members are incorporated into a structural system, the forces and deformations occurring in and adjacent to connections (in adjoining members and in the entire structure) should be considered. The structural behavior of precast elements may differ substantially from that of similar members that are monolithically cast in place. Design of connections to transmit forces due to shrinkage, creep, temperature change, elastic deformation, wind forces, and earthquake forces require special attention. Details of such connections are especially important to insure adequate performance of precast structures [(7)].

Precast members and connections should be designed to meet tolerance requirements. The behavior of precast members and connections is sensitive to tolerances. Design should provide for the effects of adverse combinations of fabrication and erection tolerances. Tolerance requirements should be listed on contract documents, and may be specified by reference to accepted standards. Tolerances that deviate from accepted standards should be so indicated [(7)].

All details of reinforcement, connections, bearing elements, inserts, anchors, concrete cover, openings and lifting devices, and specified strength of concrete at critical stages of fabrication and construction, should be shown on either the contract documents prepared by the architect/engineer of record or on the shop drawings furnished by the contractor. Whether this information is to be shown on the contract documents or shop drawings depend on the provisions of the contract documents. The shop drawings should show, as a minimum, all details of the precast concrete members and embedded items. The contract documents may specify that portions of connections exterior to the member are also to be shown on the shop drawings. The contract documents may also require the contractor to provide designs for the members and/or connections

The contract documents should show the loads to be considered in design of the precast concrete elements of the structure, and they should indicate any special requirements or functions (for example: seismic loads, allowance for movements, etc.) that should be considered in design assigned to the contractor. In this case, the shop drawings should include complete details of the connections involved [(7)].

2.7.2 Production and Transportation

Designers exert more control over the final appearance of the structures using precast concrete because they can view finish and range samples as well as mockup panels prior to full-scale production. The architects, engineers and owner can visit the precast plant to monitor progress, ensuring that no surprises arise at the site. Plant production's high quality-control standards result in tighter tolerances. This approach ensures a smoother, faster fit during erection that speeds construction and minimizes the need for on-site adjustments. As the single source for so many architectural and structural components, the precast producers can work closely with the construction team to ensure satisfaction with the design and quickly alleviates any on-site challenges that may arise [(7)].

When these structural and architectural components are completed, they are temporarily stored and then transported directly to the project site for erection. These finished components make only one trip to the construction site through the congested city traffic. On the other hand, were these components fabricated at the project site, repeated trips to the site during working hours would have been required to transport workers, materials, and equipment's as well as the removal of debris, to accomplish the same results. Furthermore, the precast components can be transported during off-peak hours, such as in the middle of the night, when vehicular traffic is at its lowest volume [(8)].

2.7.3 Erection Considerations

Once the site is selected and the design is approved from structural, aesthetic, and budgetary aspects, there are additional considerations with which the construction team creates an efficient construction process [(2)].

These include:

- **Site restrictions**; including nearby buildings that will require special efforts to man oeuvre around to bring in materials or erect components. In many cases, staging areas can be located nearby, away from the congested area, or trucks can be picked directly as they arrive each day with the scheduled components, avoiding the need for space at the site for storage;
- **Owner requirements**; such as needing minimal disruption to the site so business can continue to be conducted or customers can access adjoining locations. Owners can also

require designs to match existing aesthetics or even align with existing buildings for walkways or connecting bridges between them. Precast producers can help with these various requirements, including working in off-peak hours as needed;

- **Site logistics**; including the need to close off streets or avoid damage to a wooded location;
- **Scheduling**; to ensure that each trade has access to the needed spaces when those crews have been scheduled to be there. The ability of precast concrete to enclose the shell quickly and get the project into the dry helps expedite scheduling and allows interior trades to begin work earlier; and
- **Project management;** such as bringing all of the elements together rather than keeping each construction-team member focused on a specific element of design, construction, materials, or systems[(2)].

2.7.4 Typical Connection of Precast Concrete Elements

- **Column to Column Connection;**

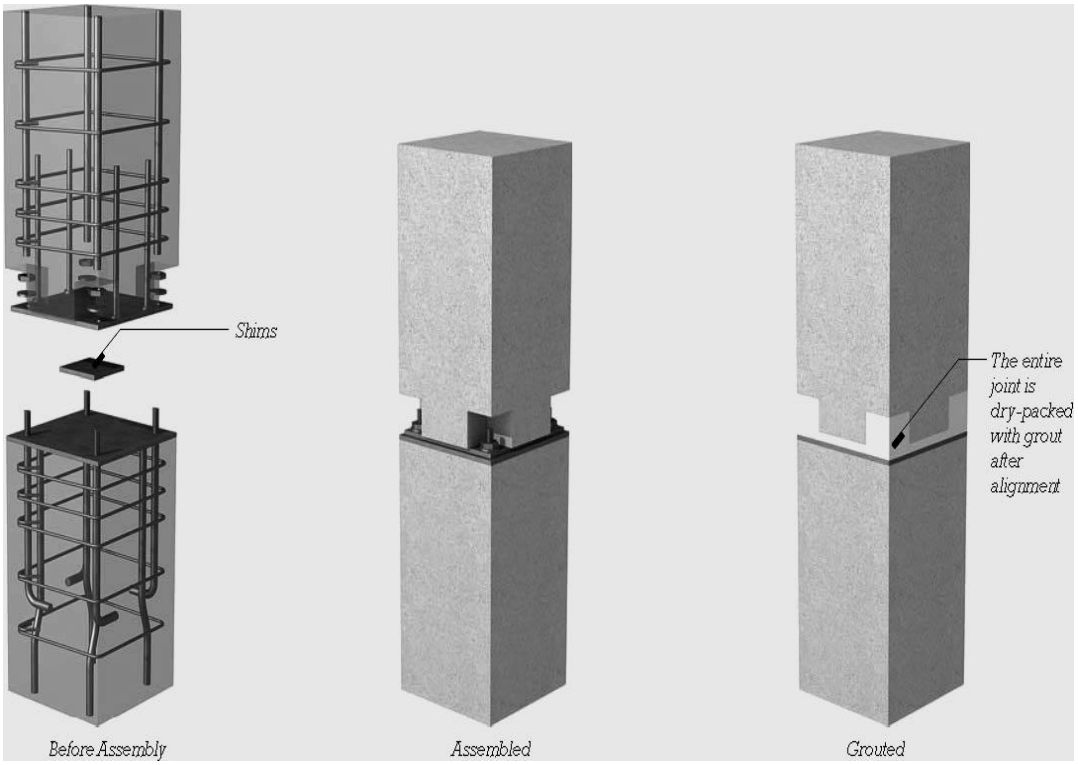


Figure 2:9 Precast Column Connection [7]

- **Beam to Column Connection;**

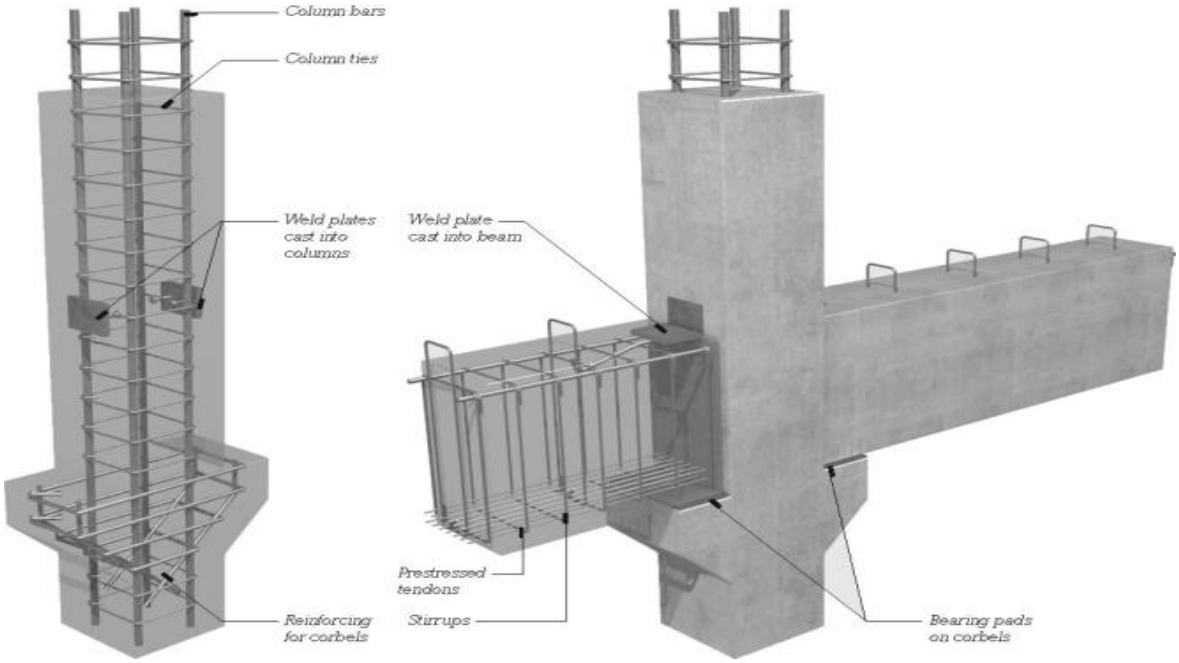


Figure 2:10 Precast Beam to Column Connection[7]

- **Slab to Beam Connection;**

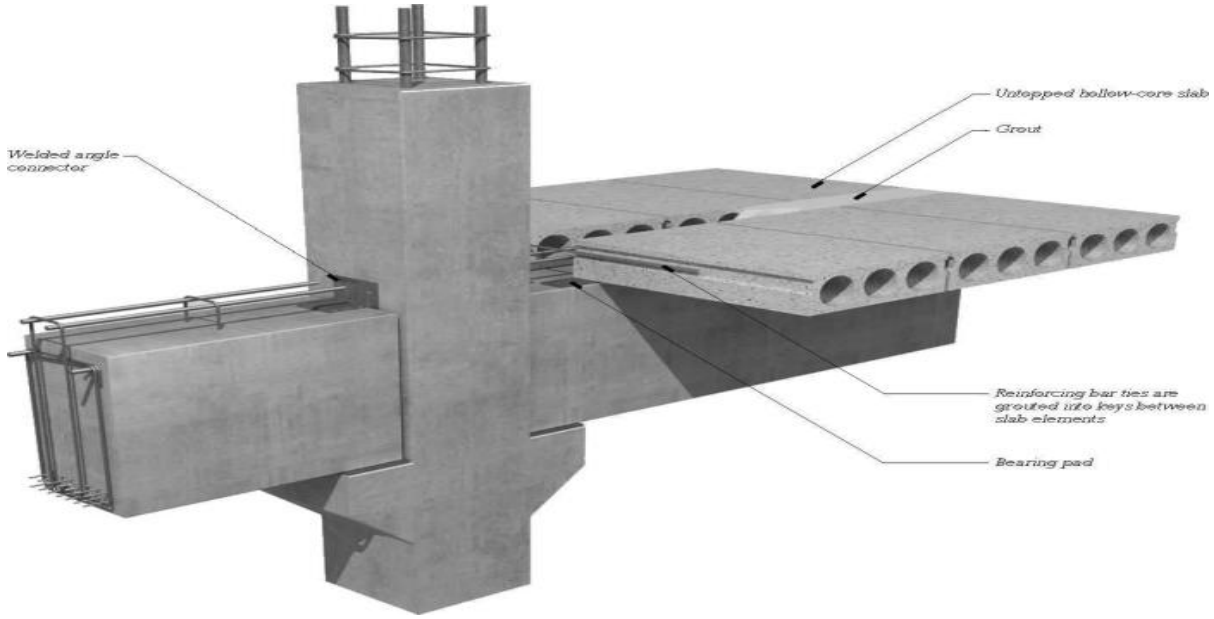
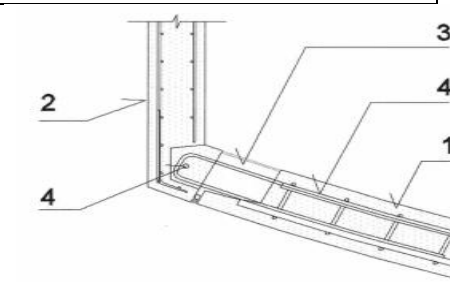
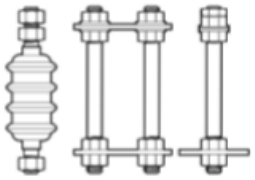
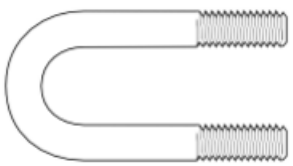


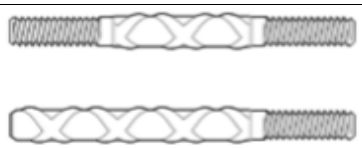
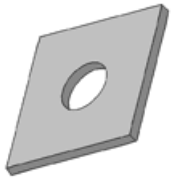
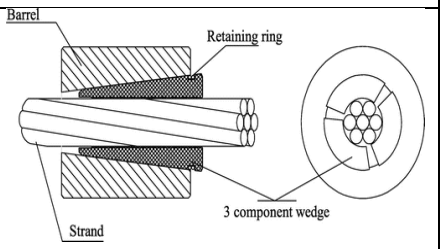
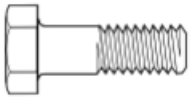
Figure 2:11.Precast Slab to Beam Connection [7]

2.7.5 Elements of Precast Fixtures and Tool

There are different elements that are used in precast construction which are not requirements for in-situ construction. They are briefly described here to give the reader an idea of what they are used for and simplified picture of what they could look like.

Table 2-1.Precast Fixtures and Tools with Corresponding Illustrations

Precast Fixture or Tool Illustration	**Illustration**
Joints - in situ concrete joints and grouting joints commonly used; precast elements prepared with space at their ends for in situ concrete joints; section '3' shows an in situ concrete joint	
Precast Fixture or Tool Illustration Anchor Rods - have various types and sizes depending on what they are used to anchor	
Multi-strand Post-tensioning Anchor	
90° Anchor Bolts - commonly used to anchor steel to concrete	
Round U-Bolts - connect concrete surfaces to adjacent parallel surfaces	

Threaded Re-bars - anchor different structures, being used in Ethiopia as a means of lengthening re bars without splicing	
Plates - used as a membrane between concrete and steel fixtures like wedges and barrels in posttensioning	
Wedge - thick conical steel element that is inserted in a barrel and grips the pre-stressing tendon also known as a Bullet or Carrot Barrel - grips the wedge and anchors it to the ends of the pre-stressing bed. It is also known as a collar, cone, or a chuck	
Hydraulic jack for tension cables - applies tension to pre-stressing tendons during the curing stage of concrete	
Barrier Pins - used in road construction	
Hex Bolts - commonly used as construction fasteners	
Structural Bolts - heavier than hex bolts, have structural purposes	

In addition to the fixtures illustrated in Table 2.2, the following parts should also be considered.

a. Corbel - a projection jutting out from a wall to support a structure above it. Precast slabs would rest on corbels that are an extension of the supporting beams.

b. Pre-stressing Tendons - Steel cables or bars that transfer pressure to reinforced concrete in order to resist tension that is subsequently imposed on the concrete member.

c. Longitudinal Transferring Re-bars and Holes - The reinforcing bars jut out of the end of one precast member and are inserted into holes at the end of an adjacent member and

grouted. The re-bars and holes would have lengths of one-third of the member into which the transferring rebar is inserted. They ensure structural continuity between aligned members.

Furthermore, precast construction joints can be classified into wet joints and dry joints. The types of the precast element connections differ, according to the type of precast system to be used. Generally, connections can be categorized into wet joints and dry joints.

If wet joints are to be used, precast elements would have to have holes at the ends where extended rebars from adjacent elements would be inserted. The holes would be of slightly larger diameter than the rebar diameters to ease the insertion. Then, the remaining space in these holes is grouted and allowed to set. This process better resembles the cast in place concrete construction.

Dry joints are done by welding steel plates or fixtures at the ends of one precast element to those at the ends of an adjacent precast element. "Using one of these methods, each elements of a building structure are attached to their adjacent counterparts and assembled to form the whole building.

2.8 The Precast Preparation Process

Precast construction includes the casting of reinforced concrete (RC) members on the ground level at a precast plant, or on a portion of the ongoing construction site. Briefly stated, the casting process first requires reinforcement bars (re-bars) to be placed in the molds. Next, fresh concrete is poured into the molds and vibrated for consolidation. Then, these cast reinforced concrete members are placed in a curing pond, or a curing chamber so that the concrete can completely undergo hardening reactions.

There are a number of ways that each of the above processes can take place. First, the location of where to cast the RC members has to be decided. Availability, price, and, convenience of using heavy trucks for transportation or heavy duty precision cranes for onsite installments have to be compared. Whether or not to make the whole operation labor intensive or machinery intensive has to be thought about and compared. Availability of sufficient space for production and storage may also be a deciding factor.

The next decision would be based on whether the RC members are designed to be pre-stressed or not, pre-tensioned, or post-tensioned, what kind of bolts to use to fasten the elements together, the amount of tension to be applied to the rebars, and similar factors that have to do with rebar arrangement in precast.

Consolidation is one of the most important processes that must be applied to freshly cast concrete. It is primarily done by vibrating the freshly poured concrete mix. Vibration could be done using

hand-held internal vibrators as is the usual case in almost all site-mixed concrete works in Ethiopia. Other alternatives that would provide a more even coverage include using external board vibrators that are installed at different intervals on the formworks. Additional types of concrete vibrators are rebar shakers and external rotary vibrators. "…instead of the regular head that's inserted into the concrete, [a rebar shaker] uses a proprietary device that is slipped over the top of the rebar, and uses the rebar itself to transmit vibrations into the concrete". As for external rotary vibrators, They are "small, handheld vibrators…usually powered by cordless drills" [18].
When it comes to curing, the major comparison should be between immersing members in a curing pond, which is sure to provide a total coverage of all the concrete surface and thorough penetration into the concrete body in the days the concrete member is allowed to sit in the pond, or placing RC members in a curing chamber where water vapor is used instead of liquid water, in order to let the higher temperature increase the rate of curing. The latter option would require more energy to keep the water steaming, while the former might take longer number of days for complete curing.

The above descriptions are about the casting phase of precast construction. What follows would be the installation or erection phase, which deals with lifting the precast pieces to their final positions on the building and attaching them on to their adjacent counterparts. These activities can also be carried out using different kinds of methods.

2.9 Construction Management

Construction Project Management: is the planning, organization, monitoring and control of all aspects of a project and motivation of all involved to achieve project objectives safely and within a defined time, cost and performance.

The project management in the prefab construction site is not that much sophisticated as that of the conventional one. This is because the major construction materials like the cement, sand, aggregate, reinforcement bars, formworks and others managed in the conventional technology are not present at site during prefab construction and there are few number of manpower at the construction site to be managed. Therefore the headache of managing the construction projects in the conventional technology can be significantly reduced in the prefabricated construction projects.

And due to the precise estimation of the prefabricated component's costs, the project will be finished as per the schedule, claims raised by contractors for extension of time and claims for escalation of the cost can be minimized.

Prefabrication is not easily used in traditional design-bid-build projects. Prefabrication is much more easily used in projects that use integrated project delivery or in design-build projects, where design and construction decisions are made with a view toward maximizing cost and schedule efficiencies and where all participants share in the risks and the rewards of project execution. Project participants must work together and be open to new approaches to realize the full benefits of prefabrication **(6).**

For achieving the benefits and advantages of prefabricated technology in the construction, the project construction management team should plan, organize, monitor and control well the project using appropriate management skill and techniques.

A good management skill and techniques helps not only to retain the cost saving mechanisms considered during the design phase but also to attain additional cost saving techniques. However, if the project is not well managed it may incur additional cost. Therefore, greater attention should be given to construction management that encompasses the inception till completion of the project.

2.10 Other countries Experience

2.10.1 American Experience

Initially, in North America, the housing industry was fragmented and substantially diluted having more regional nature than in many European countries**(1)**. Nevertheless, as a result of precast concrete systems successful application in Europe, a great deal of interest was generated in the 1960s. With the involvement of large precast companies of Europe who were interested to expand their markets, many different systems were introduced in the United States and Canada, but very few were successful in precast housing**(9)**. The reasons behind this was

1) High costs of the systems relative to the existing traditional housing construction

2) Initial capital costs could not be justified

3) Inadequate feasibility study and incorrect marketing strategies and

4) Problems in plant management and production in as well as major fluctuations in market demand.

Although, the precast concrete construction for housing was not successful as expected, great efforts have been carried out to promote the industry in other civil engineering fields [(1)]. To this end, the "Precast/pre-stressed Concrete Institute" (PCI) was established in the United States to enhance the development of pre-casting, in order to carry out the dissemination of up-to-date research developments, to prepare and distribute design manuals and guidelines among producers and professionals. In addition the institute promotes new methods and facilities for marketing, technology and production of precast concrete. The institutehave a regular magazine through which new developments in the field are made known to the public. Since the early 1960s the precast concrete has been used in the United States[(9)].

In 1976, Congress passed the National Manufactured Housing Construction and Safety Act. At the same year, HUD (Department of Housing and Urban Development) started to establish the industrial standard for manufactured housing. According to the data from MHI (Manufactured Housing Institute) – Cost and Size Comparisons of Manufactured Homes & Site Built Homes (1990-2008), the manufactured housing takes 12% percent of all residential homes in 2008 [(10)].

2.10.2 Yugoslavian (Czech Republic and Slovenia) Experience

The construction industry in Yugoslavia was problems in difficult condition immediately after the end of the World War II. The reasons for the construction industry's crisis lie both in the general crisis the country was undergoing and in the builder's' inadequate organization which consequently did not allow the proper application of knowledge and modern technology. So, the solution was based on the builders' greater independence and thereby their greater responsibility for their own fate and the tasks that society has entrusted to them [(9)].

The demand for building of housing units efficiently and inexpensively pointed out to look for a precast technology application which is classified as industrialized building system. The new building technology of precast concrete, the IMS system, was meant to fulfill all requirements adequately i.e. structural safety, the fast rate of building and rational use of building materials and labor. Over the forty years of its application this building technology has proven its flexibility and adaptability to newly arisen situations and demands [(9)].

Because of the stated characteristics, the IMS building technology has found its application in other countries as well, which were on very different levels of development which proved its compatibility to local conditions [(9)].

The IMS is based on modern building materials, technology and it employs materials and labors in the most efficient way compared to any other building technology. It is formed from precast concrete elements to be assembled afterwards in structures of different 'spans and different uses. The assembly of the elements is achieved through their pre-stressing by steel cables or ropes, in a way to form the monolithic entity [(9)].

Yugoslavia has started rapid post war expansion of housing development, the building of new house states and expansion of urban areas. To this end the introduction of the IMS prefabricated technology has played an important role. The first IMS buildings were erected in 1957 and by 1982 some 60,000 housing units and many schools, health institutions, office buildings, hotels had been erected [(9)].

2.10.3 Singapore Experience

Precast concrete was adopted as a solution of choice for up grading Public Housing in Singapore. The Housing and Development Board (HOB), the sole public housing Authority are responsible for providing high quality houses at affordable prices in Singapore, has launched a program to upgrade the quality of the existing stock of public housing. Since its inception the HOB is credited with constructing more than 750,000 apartments for housing 86 per cent of Singapore's population. Prefabrication technology was used to overcome the many difficulties associated with the construction of high rise apartment extensions in heavily populated areas. The use of precast concrete elements helped to over-come the special difficulties of construction work in the congested areas. The upgrading mainly consists of a newly added space stack which is designed to be completely on new independent foundation[(9)].

The technology and construction methods chosen in the upgrading program meet the basic requirements such as [(9)]

1) Enhanced safety and security where there is control on the noise and dust pollution arising from the construction site

2) It is a dry construction process that result in faster construction time

3) Cost effectiveness responds to the budgetary constraints.

The extensive use of prefabrication methods that hinge around offsite/on-line factory production techniques of building components fit the requirements. At the same time, prefabrication ensured better standards of construction workmanship and reduced the need for skilled foreign labor[(9)].

The implementation of the program started in 1991 and 21,000 housing units have been upgraded by 1994 in three phases. The validity of the use of prefabrication in public housing upgrading hinges on ensuring that the component designs are kept simple and streamlined; standardization of precast concrete components is imperative; there must be an optimum number of repetitions of components; the size and weight of the components must be kept to the minimum[(9)].

The standardization and the repetition of components go with the architects requirements for aesthetics and flexibility of design. In the highly built up nature of the existing sites it would have been difficult if not impossible to construct using conventional cast-in-place methods [(9)].

The cost of construction of the added space was found to be 4 times less than the construction cost of a new block of apartments with conventional cast-in-place methods. The lower cost of construction, the shorter time of construction, the non-existence of noise and dust pollution have contributed to the success of the program showing the importance of precast concrete[(9)].

2.10.4 Japan Experience

The manufactured housing in Japan starts around 1960s. Due to WWII, lots of houses were destroyed. After the baby boom, the demand for residential house is urgent. In order to construct more houses without sacrificing on quality, Japanese companies used the “prefabricated housing” approach. Some of the leading companies are Taisei Corporation, Sekisui House, Daiwa House, and Misawa House (10).

Japan has its own industrial standard for prefabricated housing, which is different from the US. It is said that a house is made by prefabricated housing if the 2/3 or more construction process is finished in factory and the main parts of house, such as walls and floors, are pre-made following certain industry standards. In this sense, 20%~25% of new residential houses are prefabricated housing in year 2002. If we include houses that used the prefabricated modules, then the percentage goes to nearly 85% and more for year 2002(10).

2.10.5 China Experience

In Hong Kong, the housing industrialization began at 1953 when a big fire occurred and a lot of houses were burnt down. Nearly 53000 people became homeless. By the end of 2002, the

prefabricated materials take up to 17% of the total construction materials in respect of cubic meters of cement. This percentage increased to 65% in 2007(10).

In Mainland China, the housing industrialization began in 1998. In this year, the Chinese government implemented the commercial residential building reform. In about ten years (from 1998 to 2008), there is a significant growth in demand in the housing market. Different from the US, Chinese people usually lives in apartment buildings with many floors because of the huge population and limited land. How to build more houses faster and with higher quality is an important problem for Chinese real estate companies (10).

Vanke is the leading residential developer in China with RMB 41 Billion sales, 2.34% market share, 5,570,000 square meters sold in 2008. Vanke started the prefabricated housing research in 1999. In 2006 and 2007, Vanke has finished two prefabricated housing projects (10).

2.10.6.South African Experience

Precast concrete technology has been used in South Africa since the early 1960s, with most of the technology being imported from Europe. Now there are approximately 60 major precast manufacturers in South Africa, while the total number of precast manufacturers, including small block yards, is estimated to be in excess of 1,000. Precast concrete is widely used for infrastructural and structural components in South Africa. A variety of precast concrete technology have been used in south Africa like breakwater systems, radiation shields for medical treatment, precast concrete toilets, stadium seating elements, single-cast precast bus shelters, harbor walls and boat quays, highway barriers, bridge elements and dry dock support columns. Precast concrete is now widely used for infrastructural and structural components in South Africa (11).

2.11 Construction in Ethiopia

The Ethiopian construction industry is one of the country's predominant industries with substantial amounts of expansion and advancement. It takes a considerable portion from the federal budget and has a number of noticeable results in the country's infrastructure.

"The development of the construction industry can be measured using its Gross Value of Production GVPC). The GVPC, at constant market price increased from Birr 7.6 billion in 1996/97 to Birr 18.9 billion in 2006/07 depicting an average annual growth of 9.6 percent over the period…".

The Ministry of Finance and Economic Development (MoFED) specifies the types of manufactured articles that are included in the construction industry as follows, relocating input production towards the manufacturing industry.

"…In the case of Ethiopia, …the activities actually covered under the [construction] industry are the construction and maintenance activities of: (1) Residential buildings in urban and rural areas, (2) Nonresidential buildings, i.e. factory buildings, ware houses, office buildings, garages, hotels, schools, hospitals, clinics, etc., (3) Other construction works, like roads,dams, dikes, athletic fields, electricity transmission lines, telephone & telegraph lines, etc. [MoFED, 2005]" [12].

The first step in concrete works is obtaining the required materials. These materials are then mixed as per the mix ratio specified in the design. Water-to-cement ratios should be provided and complied with while mixing. The whole of the mix ratio calculations would be redundant and the concrete would be weak if too much water is used during mixing. Next to the mixing of the fresh concrete, pouring is followed by consolidation works. Hand held vibrators of varying sizes are most widely used for this purpose.

Curing plays an equivalently important role in the quality of the final product as the previously explained steps of mixing. How well a finished concrete is cured is a decisive factor for the strength and quality of the finished product. In typical construction sites in Ethiopia, curing is usually done manually with a watering hose or by sprinkling water out of a bucket using a jug.

Through all the steps of preparing, pouring, and curing concrete, there should be as little impurity as practically possible in the concrete mix. For this reason, there should be a mixing area which is clean, flat, smooth, and lined with a material that the concrete wouldn't bond with. Examples would be "bricks or lean concrete or iron sheets, of a size as per requirement of the volume of concrete to be mixed. Commonly a platform made of iron sheet having 3m2 in size with strips or curbs are used".

If concrete is to be manually mixed, the required quantity of sand should first be spread evenly on the mixing platform. Next, cement in the required amount should be dumped on to the sand and spread out evenly. The sand and cement should be mixed using shovels and "turning the mixture over and over again until it is uniform in color" [13]. Following this, coarse aggregate is spread out uniformly over the sand and cement mix. Care should be taken not to dump the coarse aggregate on one spot on the sand cement mix. Mix it from the center to the side, side to center, and center to side again.

The next step is to add water into the dry mix. First, a depression should be made in the center and one half to three quarters of the required amount of water should be added. The material should then be turned towards the middle with a shovel and the remaining quantity of water should be poured slowly during this time. The mixture should be turned over and over repeatedly until it has uniform color and consistency throughout. It is best to add the water with a gardener's can fitted with a rose-head. Water added all at once will wash away the cement from the mix.

In construction sites where all of the mixing, pouring, consolidation and curing is carried out by daily laborers, the presence of a site supervisor with a clear understanding of the basics of concrete technology is absolutely important. As nearly all daily laborers are illiterate, the supervisor should have a consistent follow up routine of all concrete work either directly or through a foreman. This continuity in follow up would decrease any risk of compromise in the quality of the finished product.

Untrained manual labor is one of the culprits preventing the systematic measurement of aspects of time and cost expenditure in regular Ethiopian construction. "During an interview with one of the project managers, it was learnt that productivity standards are used during the preparation of their main schedule but I believe that, it is meaningless if the information used during planning is not transferred to the crew by planning. From the above finding we can understand that the project management objectives are not appropriately transferred down to their crews showing that coordination that could have been obtained by this is lost" [14].

The first step to improving an existing system is to measure its performance. Regular Ethiopian construction practices are nearly impossible to measure even during the construction phase. To use such advanced tools, such as embedded microchips to measure their long-term structural performance is highly unlikely with such messy on site working conditions. The precast system of construction would fundamentally alleviate this problem. "…This production standardization produces high quality precast that can be delivered to a site just-in-time. There's no waiting around for concrete to cure on-site and no need to stockpile… In particularly sensitive applications, these same microchips can send a signal to indicate excessive movement or impact. This is particularly useful for bridges, tall buildings and structures in earthquake zones".

Developing countries are the ones most affected by environmental pollution and its consequences. Probably the third most dominant source of pollution in the capital city of Addis Ababa is the carelessly disposed waste and dust from construction sites (the first and second being sewage waste and vehicular fumes). "The production of precast concrete in an off-site manufacturing

plant means that construction sites are cleaner, quieter and safer…much less construction site debris and potential pollution to streams and natural areas…".

Precast concrete systems greatly reduce unnecessary or surplus building materials from ever reaching a project site.

Production and finishing materials and the waste they produce never even reach the project site… In addition, construction of a precast concrete structure generates very little dust decreasing the likelihood of problems with dirt and poor air quality, the most common causes for complaints from residents near construction sites… Sustainable plant upgrades using emission control equipment recycle concrete dust and concrete washout water used in precast product manufacturing.

A hush-hush approach is habitually implemented when workers' safety measures are compromised and accidents befall as consequences, which leads one to wonder, how many of these types of accidents have happened so far and have been kept guarded from the public eye. Insurance policies are not made available to site workers, unless for international projects, which reflects poorly on most contractors' professional character.

Other nuances such as discontinuity in between, or in the middle of project activities, noise pollution, workers' fatigue, unsightly construction sites and over expenditure of energy can serve as indications to some inefficiencies that most Ethiopian contractors exhibit while implementing in-situ construction methods. "Vibration, sawing and other noise-pollution activities that are part of concrete pours on the job site are eliminated because the precast is produced offsite. This results in substantially quieter construction sites. The easy installation of precast products makes for less noise pollution from the construction site, a significant benefit to those inhabiting or working in adjoining properties" [15].

2.11.1 Coopertiva Muratori'e Cementisti (C.M.C)

The Special Housing Project in Addis Ababa came into vision in order to accommodate the needs of the large diplomatic community and many expatriates working in international organizations. The project was intended to use a large area for the development of a housing and commercial complex. In the first phase of the program, it was envisaged to construct 2,500 apartments including commercial services, sports and health facilities, and embassy residences. The Ministry of Urban Development and Housing being a client has assigned the construction of the first 500 apartments to Cooperativa Muratorie Cementisti (C.M.C) of Ravenna Italy. The foreign currency

component of the contracts has been funded by a pool of Italian Banks with special facilities granted by the Italian Government (9).

The C.M.C has built a precast concrete factory for the Special Housing Project on an area of 124,000 square meters to produce precast concrete components used in the construction. All the systems and equipment needed for the production of precast elements were installed in the factory. The production of slabs was with a potential daily output of 300m2 of slab. The precast elements produced at the site include cladding panels finished in smooth marble chipping with decorations, partition walls, stairs and landings, balcony parapets, and cornices. As many as 40 elements, amounting to 400 square meters, could be produced in the central section of factory out of which 10,000 elements were used for Special Housing Project. Chemical additives and steam were used to speed up the concrete curing process (9).

The investment made including all the machinery used for the Special Housing Project and the various workshop for pre casting, amounts to approximately $10 million US dollars (9).

The Special Housing Project constitutes to be the first project where precast concrete elements were used efficiently, especially by a foreign construction firm to introduce diverse designs in Ethiopia. The design calculation is based on Italian standards and has made use of automated process (9).

The precast concrete produced by the C.M.C. was later utilized for two projects, the UN Economic Commission for Africa head office complex in 1994 and the Patriarch Palace Building project in 1996 both in Addis Ababa. The decorated wall panels used for the construction of these buildings are architecturally attractive and the Palace building has some carved features of ancient Ethiopian building styles of Lalibela and Axum (9).

2.11.2 The Prefabricated Building Parts Production Enterprise (PBPPE)

Due to its highest technical effect, modern methods of construction – prefab against traditional construction- has been considered as a leap to transform society to the future through industrialization. Among the steps taken in this direction, the establishment of the IMS system, the Prefab Housing Factory, in Addis Ababa constitutes the corner stone in the evolution of the building industry (9).

In the late 1970's and 1980's, the demand for housing was immense that the government being the only facilitator for shelter could not meet the ever rising demand. As a result it was decided to introduce a new building technology, the prefabrication of concrete structural elements. The

technical assistance was obtained from the former Yugoslavia and the IMS system, of a Yugoslavian firm with more than 30 years of experience in the field was selected. The IMS system was a patent of the Institute for Testing Materials for pre-stressed concrete, and its acceptance led to the establishment of the former Prefab Housing Factory for prefabrication in 1984. The Factory was organized administratively under the former Ethiopian Building Construction Authority (9).

The initial total cost of the factory was estimated to be Birr 13 million which late on raised to Birr 17 million due to the delays in the implementation. The prefabrication factory started the production of structural elements in 1986 (9).

a. The main objectives of the factory were:

- To alleviate the shortage of housing in Addis Ababa and the surrounding area,
- To promote the building industry by raising the capacity for mass production of structural elements,
- To produce building parts and execute the erection of such parts at building sites,
- To reduce the construction cost required per built up floor area,
- To minimize the use of formwork and by so doing conserve the natural forest,
- To produce quality and standardized structural elements as per the need of potential house builders of the inhabitants of Addis Ababa,
- To expand concrete production technology through prefabrication of large wall panels, doors and window[(9)].

The design and erection of the first Ethiopian prefabricated residential building constructed on the Bole road which consisted 150 flats, has opened new opportunity to implement various technical and architectural possibilities in the IMS system. The construction of the building commenced in April 1985.There after similar design and construction solutions have been used on several construction works where the IMS system was deemed suitable [(9)].

To familiarize the technology, the products of the factory were assumed to be taken by the then Ministry of Construction for the mass production of residential buildings under the existing housing policy guidelines. However, as a result of the frequent changes in the policy, the presumed coordination was not materialized as was expected[(9)].

b. Re-organization of the Enterprise

The Prefabricated Building Parts Production Enterprise (PBPPE), previously known as Prefab Housing Factory (PH F) at a department level under the former Ethiopian Building Construction Authority (EBCA) was reestablished as an autonomous business entity in accordance with the new economic policy in 19903. It was generally in charge of the three phases of prefabrication process, the production, transportation and assembly (erection). The production of the structural components take place in the factory about 10 kms from Addis Ababa at Kaliti. Transportation of the produced components to the construction site is carried out by heavy vehicles of the establishment and consequently the erection has been performed by the technical staff assigned for the work. Initially, in order to make prefab viable, the distance to the construction site, the weight of the components as well as its easiness for transportation were taken into consideration in the design of the precast elements **(9)**.

The company has a designed capacity of 50,000m^2/year, the enterprise has the ability to finish a G+12 building in 1 year. The building components are made using standard molding devices. Clients who are interested in using precast concrete elements should keep in mind of the standard sizes provided by the company and arrange their designs accordingly **(9)**.

After the re-establishment of the factory, in order to make the enterprise profitable, it was decided to extend its functions with additional tasks parallel to the production and erection of precast concrete. Consequently, the following were included in the work schedule of the enterprise **(9)**.

- Preparation of precast ribbed beams for the condominium housing projects.
- Production of agro stone panels
- Production of Hollow concrete blocks.
- Provides ready mix concrete using truck mixer wherever needed all around Addis Ababa,
- Based on work orders, produces concrete products such as fence poles, stairs, manhole and covers, curbs etc.,
- Hire or lease out the services of construction equipment such as truck cranes (Kato cranes), tower cranes, loaders, excavators and rollers,
- Produces metal" doors, windows, water tanks and gates receiving work orders,
- Take office/residential building contracts engaging in conventional construction works using precast as well as cast-in-situ concrete methods and finishing works **(9)**.

Since its establishment the P.B.P.P.E has built a number of buildings in Addis Ababa. Some of those are PEACOCK BUILDING, OLYMPIA BUILDING, TANA BULIDING, ASSAI

PUBLIC SCHOOL, MINA BUILDING, AYU SHASHE BUILDING, AAWSA HEAD OFFICE BUILDING, and APARTMENT BUILDINGS IN BOLE ROAD AND OTHERS [9].



A.) MINA BUILDING



B.) AAWSA HEAD OFFICE BUILDING



C.) AYU SHASHE BUILDIN



D.) APARTMENT BUILDING



E.) ASSAI PUBLIC SCHOOL



F.) RAS AMBA HOTEL



G.) BISRAT BUILDING



H.) RIFT VALLEY HOTEL



I.) ETHIOPIAN SPRING S.C BUILDING



J.) WARYT BUILDING

Figure 2:12.Some of the Buildings Built by P.B.P.P.E

2.11.3 Current Status of Prefabrication Technology

Currently the application of prefabrication technology is very low compared with application in the past. The previous P.B.P.P.E is now integrated with other governmental owned construction companies and is called Ethiopian construction Works Corporation.

This company is now engaged only in one governmentally owned office building which is located in ICT Park. According to the project manager of the project, the company has accomplished one G+2 office building and now other agreement has been signed by the company with Ministry of communication and technology to construct B+G+8 office building. In addition to this other production works of precast beams, Hollow concrete blocks both for wall and for Ribbed slab construction in implemented. Even though as described above the production capacity of this company is 50,000m^2/yr, the company is almost not performing as the capacity it have.



Figure 2:13. Recent accomplishment of P.B.P.P.E in "Goro" ICT Park

In addition to that, there is high knowledge and experience gap within the consultants and Engineers throughout the country on prefab housing construction and related design aspectsof the technology.

2.12 Ethiopian Housing Policies

Production of housing is a very expensive process. Governments often give less priority to the housing sector due to their shortage of investible resources. In a country like Ethiopia which strives to get quick return from investment. It can be expected that the housing sector would be given a marginal position owing to the fact that a significant investment in the housing sector would also result in resolving social problems which the city is now facing[(12)].

Apart from this, concerning operational problem on investment in housing, Ethiopia becomes one of the developing countries to allocate a very low percentage on housing sector, which is estimated to be 2.5% of its national income. This figure is below the minimum standard set by the United Nations for developing countries, which is 6% of GDP[(12)].

In fact one of the key problems to provide adequate housing facilities is associated with the difficulty to make adequate investment on housing. At the conceptual level the total housing need encompasses:

1. Housing required accommodating newly formed families.
2. Housing required replacing dilapidated houses.
3. Housing required easing over-crowding.
4. Housing need associated with the desire to accommodate homeless households.
5. For emigrants from rural area and regional towns

The housing sector has been subject to a variety of interventions over the last 30 years, which provide important lessons to any effort that aims at drafting an appropriate and coherent housing policy[(12)].

2.12.1 The Pre 1975 Situation

Housing provision in pre 1975 was predominantly handled by the private sector and it can be said that the government didn't attempt to exert any effort in the provision of housing for low-income people. The housing market during this period can be characterized as operating somehow on free market principles as land lords were leasing urban land and construct residential houses to tenants, and there was no restriction as regards to the selling and buying of houses. No formal housing policy was adopted during that period and most of the poor people in the city were lived in extremely overcrowded areas. Nevertheless there was a need in some form of intervention particularly in the low income housing sphere as it has been evident for several years that the then workings of private enterprises in housing have not tackle the problems which existed in Addis

Ababa and in Ethiopia at large. More over this laissez faire condition was one of the factors blamed for the unplanned development of most of the urban centers in Ethiopia particularly in Addis Ababa. Poor qualities of housing and unplanned sites are also attributes to the deterioration of physical condition of houses, which made the provision of infrastructure difficult[(12)].

2.12.2 Housing Development between 1975 and 1993

Policy Proclamation no. 47/1975 nationalized all urban land and extra houses, high-rise apartments and office buildings without any compensation. The main target of the proclamation was to get rid of the right of landlords. The most important immediate effects of the proclamation were a regressive reduction on the amount of rent by 50 per cent for tenants who were paying a monthly rent less than 144 birr. /The then price 1USD = 2.07 Birr Then the government has a direct involvement in the sphere of housing provision[(12)].

Production of Housing As far as the production of new dwelling houses is concerned different programs undertook the provision of housing and at the beginning the government allocated budget to construct newly rental dwelling houses, which are administered by the Agency for the Administration of Rental Houses AARH. On the other hand self-help and assisted self-help housing as well as housing cooperatives flourished to assist the low-income group. Low-income people, whether they are worked in formal or informal sector, offered a house plan free of charge and technical assistance from the government. The applicants were also be able to get loan from governmental bank (Housing and Construction Bank HCB) with reduced interest rate of 6 and 4.5 per cent for self-help housing and housing cooperatives respectively. Most importantly anybody could get land free of charge whatever the project might be. This was however subject to the following conditions:

- The person should testify that he/she does not have another house, which is to be ascertained by local authorities 'Kebele.'
- The person must afford to build the type of house, which he/she wants to construct, and the builder must either have the cash, which must be deposited, in a bank in blocked account or the housing and savings bank must prove his/her credit ability considering their level of income.
- The builder must complete the house within 6 months' time after receiving proper documents from the municipality.

Although the government took over the responsibilities of building rental houses to those who cannot afford to build their own houses, it has done a little in this regard because of its financial constraints[(12)].

2.12.3 The Current Situation Policy

Following the change of government in the country, the transitional government of Ethiopia come up with a land lease policy no. 80/1993 which enables people to possess land so as to build houses for residential as well as for rental purposes. According to the policy any Ethiopian citizen could buy land on a bid bases. Urban land possession differs according to the type of services and the maximum would be 99 years of lease for residential plots. It was only after 1993 that the government gave signals about its possible tolerance of private sector participation in the provision of housing. Buying land on a bid tender, individuals can build residential houses, services and facilities with the right to sell or rent. According to the newly adopted policy the government starts to liberalize the housing sector by taking measures which include the selling of houses administered by the public sector, abortion of the assistance of subsidized building material delivery and ceasing the subsidy of interest rate loans from the financial sector[(12)].

Since the late 1970s housing cooperatives have also provided an avenue for home ownership. This delivery method was established in 1978, through Proclamation No. 138. The approach is for citizens to organize themselves into small groups (between 10 and 20 people), register as a cooperative group for land allocation, develop savings capacity, prepare settlement plans, receive land and secure tenure, and largely build their housing themselves incrementally. Cooperatives have received varying levels of government support over the last 40 years. Between 1986 and 1992, housing supply by cooperatives did increase due to the significant subsidy of construction materials (60 per cent), land being allocated with no charge, and low mortgage interest rates, but this help was inadequate to meet the magnitude of housing demand. Between 1975 and 1992 housing, cooperatives produced a mere 40,539 units. In addition to its small scale, cooperative housing is challenged by the undesirable peripheral location of land allocated, low quality of allocated land making construction costly and difficult, and the exclusion of the poorest sector of society who more often than not do not have a savings capacity at the scale demanded by this relatively expensive approach[(13)]. The government estimates that the current housing deficit is between 900,000 and 1,000,000 units in urban areas, and that only 30 per cent of the current housing stock is in a fair condition, with the remaining 70 per cent in need of total replacement[(13)].

In order to improve these condition, since 2005 Ethiopia has been implementing an ambitious government-led low- and middle-income housing Program: The Integrated Housing Development Program (IHDP). The initial goal of the Program was to construct 400,000 condominium units, create 200,000 jobs, promote the development of 10,000 micro - and small - enterprises, enhance the capacity of the construction sector, regenerate inner- city slum areas, and promote homeownership for low- income households in the first GTP.[(13)].

Based on the research held by UN Habitat showed, the Program has not met all of its original targets, according to the information from Ethiopian News Agency, until February 11/2016 it has built only 143,482 and 61,349 housing units respectively in Addis Ababa and other regional towns. According to the ministry of urban development, housing and construction, within the second GTP the government plan to construct about 750000 houses in urban areas and 1.7 million houses in rural areas throughout the country [(14)]. From then until today, the demand for housing increased but in contrary the performance of housing development agency decreased Specially in this year (i.e. 2016/17 G.C or 2009 E.C), construction of new housing detained completely due to financial problem according to prime minster Hailemariam Dessalegn's report to journalists. So, it is difficult to satisfy the increasing demand of housing by this performance and the deficit will continue to the future.

From the above literature review one can see that the experience and intention of Ethiopia towards prefab industry implementation is very poor as compared with the rest of the world. As I have reviewed in this chapter many countries in the world implemented prefabrication technology to solve their short and long term housing problem sustainably. But when I see the past and the current experience of our nation is in contrary to others. To fill this deficit, using only conventional methods, will not meet the demand within a certain period of time in addition to its expensiveness. So, alternative construction methods shall be applied. Prefab technology can be one alternative solution. Having an easily built house has been always one of human wishes and prefabricated home makes this wish come true because of its affordability and fast completion. But there is no any policy or proclamation that supports this construction technique in Ethiopia. One of the major objective of the policy and strategy of the housing sector is to support labor intensive construction method in order to support job creation in addition to constructing housing, due to this; the policy doesn't initiate prefab technology.

3 Research methods and Methodology

3.1 Research methods

3.1.1 Study Area

The location where research is carried out in Addis Ababa, as it is where the research subjects are located. Addis Ababa is the capital city of Ethiopia. It is also the nominated capital of the African Union (AU) and the United Nations Economic Commission for Africa (ECA). The city is located at the center of the country and spans from 2200 to 3000 m above mean sea level in altitude. Its topography ranges from rolling to hilly areas with relative steep gradients. The municipality expands over 540 square kilometers, 10 sub-cities, and 116 “Woredas". It has 220 square kilometers allocated for green area and a vegetation cover of 80km2, and the number of inhabitant more than four million peoples.

Addis Ababa is also known for being an up-and-coming construction center in Eastern Africa. The whole city seems to be under construction for buildings, roads, and other similar utilities. This makes the research highly relevant.

The research will focus on Prefabrication Construction as an Alternative Structural Frame Construction Methods for 40/60 housing projects in Addis Ababa, a case study on Megenagna 40/60 project.

3.1.2 Study design

Based on the research goal, this research can be categorized under applied research. This is because the results of the research analyses are meant to be applied instead of solely enriching the knowledge base; Based on research objectives, it is both a descriptive and exploratory research. The reason it could be under these two categories is because the research has both aspects. It has abundant descriptions of its topics of consideration, wherever it is deemed necessary, while it also critically explores topics that need to be analyzed, explained, and put in perspective.

Based on research approach, it is again both a qualitative research and quantitative research; It has a quantitative approach when it deals with the quantitative data, and it takes on a qualitative nature for numerous non-number data. Based on research design, it is a nonexperimental type, as it does not involve any experimental works in its data collection and analysis; Accordingly based on data type, it is secondary research (desk study), as no experimental works were needed.

The choice of method designed for this research was the Case Study method. This method helps the researcher ―gain better understanding of the whole by focusing on a key part (Gerring, 2007). The case study method can fortify the research which generally intended to be explanatory and descriptive. Case study is a preferred strategy. for better understanding of a control over events, and when the focus is contemporary phenomenon within some real-life context .The case study method, in this context, can help track the system in which AAIHDP was developed through, and compare and clarify the major changes that occurred within the processes and the organizations. The AAIHDP condominium housing is scattered throughout the city and this method can trace the changes in actor and planning and design process that occurred within AAIHDP for better understanding as well as.

Quantitative and qualitative observational study will be conducted on 40/60 Condominium Housing Projects located around Megenagna which includes 2B+G+12 and 2B+G+18 and Some of the Buildings constructed By Prefabricated Building Parts Production Enterprise in Addis Ababa.

Questioners will be distributed to different stockholders for gathering information regarding rental rate of house near by the project area and experts opinion regarding the project

3.1.3 Sample size determination and sampling technique

The required sample size will be determined by using single population proportion formula. For the calculation, 95% confidence level with 5% marginal error will be assumed. Since the study area is specific to 40/60 housing project located at Megenagna (Ehil Nigde and Tourist site) the sample size is predetermined and the sampling method becomes purposive random sampling, and the Buildings constructed by Prefabricated Building Parts Production Enterprise (P.B.P.P.E) will be selected based on **purposive method of sampling**.

3.1.4 Method of data collection

To achieve the mentioned objectives we will collect and review relevant primary and secondary data's from relevant sources. The information's will be obtained from;

The **primary data** will be obtained by desk studies, semi-structured interviews, closed type questioners and Case study 40/60 condominium(2B+G+12) located at Megenagna project site and comparing with Model prefabricated building from ICT park which is G+8 , consultant, client, house users, prefab producer (supplier), and small enterprises. All the relevant data for the case study is collected through desk study , interviewing, acquiring contract document from concerned stack holders like client ,consultant, contractor and ministry of works and urban development.

The **secondary data** source includes books, previous researches, publications and journals

3.1.5 Research Variables

Simply put, independent variables are values in a research that the researcher manipulates in order to see the effect that the manipulation has on the results that will be reported. The results that change due to such manipulation are the dependent variables. Correspondingly, the independent variables of this research are: construction basic cost components; influencing factors of in-situ and prefabrication construction cost; and 'time saving and cost', 'time', and 'quality' measures and records from PBPPE.

The dependent variables are: precast construction total direct cost; precast construction overall indirect cost; in-situ construction total direct cost; in-situ construction overall indirect cost; quality grade

3.1.6 Plan of data analysis

The collected data will be organized in appropriate ways and it will be analyzed to find out what the data is telling us which lead to conclusion.

3.2 Research Methodology:

The methodology used for this research will include an in depth review of Prefabrication Construction and its applicability as an Alternative Construction Method for structural frame construction of 40/60 condominium house in Addis Ababa. Cases studies on 40/60 condominium projects located on Megenagna site and the prefab houses will be conducted in order to compare construction cost ,cost advantage from time saving and construction durations. Here the total cost for structural frame construction of the project be considered in the comparison of construction costs. Discussions with different stakeholders will be conducted to learn stakeholders understanding, opinion and view on the conventional construction method and the proposed prefabrication technology. Since 40/60 saving house projects are government owned and the project is awarded selectively without bid computation the price is taken directly from the contract document and the cost for prefabrication is taken from Prefabricated Building Parts Production Enterprise (P.B.P.P.E), market study will be made for rental rate of different type of house with questioner. Then those collected data and information's will analyzed by using different techniques. And after analyzing the data conclusions and recommendations towards our objectives will be made.

4 Presentation and Analysis of Data

4.1 Cost Estimation Methodology

4.1.1 Method of Cost Comparison in Construction Industry:

During the past decade a large number of such studies has been carried out and published. In the existing studies three principal approaches for comparing costs of building projects among countries can be distinguished

- Comparison of standardized identical buildings
- Comparison of standard buildings with local modification
- Comparison of functional similar buildings

4.1.2 Comparison of Standardized Identical Buildings

With the first method exactly the same building work is priced on the basis of the same drawings and specifications. This is possible only in the theory, largely as a result of national (or regional) differences which exist in architecture, standards, availability of products, etc. the building and the costs will be comparable. But they are not necessarily representative.

4.1.3 Comparison of Standard Buildings with Local Modifications:

Better representative can be achieved when modifications for local circumstances, like buildings codes, standards, specification levels, are taken into account.

4.1.4 Comparison of Functionally Similar Buildings:

The third approach, typical, functionally similar buildings are compared: this means building types, which are representative. Not only locally divergent circumstances and quality - levels are taken into account, but also various performance and aesthetic criteria, which reflect typical client requirements or tenant expectations for buildings in that sector. The buildings and the cost are representative, but not necessarily comparable .Arguably 'apples' are being compared with ‘oranges’. A meaningful comparison must take into account all relevant (time- dependent and quantity -dependent) cost components, classified as follows

- Lab our;
  - ✓ Direct
  - ✓ Indirect
- Materials

- Investment
- General expenses(site and plant)
- Transportation (for system construction only)
- Overhead

As for this study the method of cost comparison used standardized identical buildings and functionally similar buildings while the unit is cost per gross floor area.

Building Type

In this cost comparison G+12 40/60 apartment building is considered which is already on practice. An equivalent area G +8 prefabricated house type is considered in order to get comparative sample. We used modularized prefabricated building elements that can be produced by **Prefabrication Building Parts Production Enterprise (PBPPE)**. As we know the enterprise has good reputation in producing and installing structural elements for the construction of office buildings, apartments, hotels and residential buildings. From the enterprise products, we can use prefab Columns, slabs, footings, shear walls, stair flights and landings using this we execute the structure of the condominium house.

The dimensions of the prefab model are not identical with the 2B+G+12 model due to limitation in production of customized building elements by PBPPE. Hence, for the purpose of this paper building elements that are modularized and readily available are used.

In this cost comparison only the costs that are associated with construction of structural frame of the 2B+G+12 building is considered in both cases.

4.2 Financial Assessment of the Prefab and 40/60 Apartment Buildings

4.2.1 Structural Description

The 40/60 housing project are made with a concrete is C-30 and the structural steel used is S-400; whereas the prefab houses are of a concrete grade is C-40. The reinforcement steel used is S-400. The Pre-stressing wire has characteristics strength of 1400mpa. In prefab buildings tight quality control ensures that components are produced with uniform consistency.

Concrete mixes with low water/cement ratios are enabled by factory-controlled batching and immediate placement of concrete to yield higher strength mixes averaging 40 Mpa or more precisely controlled air entrainment also results in minimal expansion and contraction and reduced cracking

and surface scaling. But in the condominium type it is difficult to control quality of every material quality, water to cement ratio and even the bar spacing.

The summary of the building is presented as follows

Table 4-1 Summary of the building

Parameters	Conventional Condominium Building	Prefabricated Condominium Building
Building type	• 2B+G+12 and 2B+G+18 40/60 apartment Buildings	• Modularized G+8 prefabricated building
Total	• 13,776.04 m2 structural floor Area of building for 2B+G+12	• 8232.84m2
Function	• For public housing	• Office building in ICT Park (Customized for use as condominium housing)
Location of site	• Addis Ababa	• Addis Ababa
Construction method	• Convention construction method that is currently in practice	• Building method currently practiced by PBPPE
Building elements	• Ribbed slab and solid slab	• Slab frame system

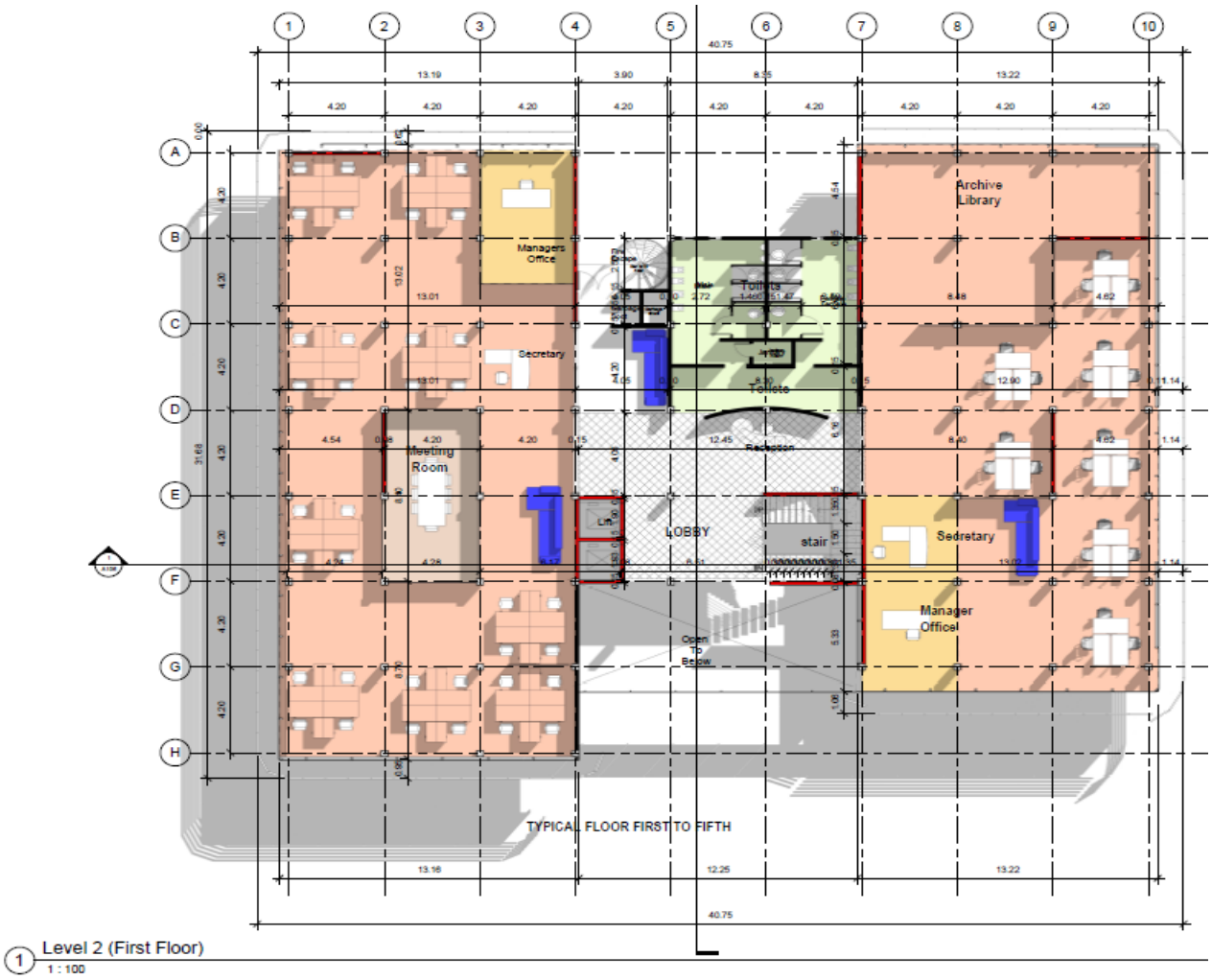


Figure 4:1. Sample Floor Plan of ICT Park Prefab Building [Source:ICT Park project office]

The ICT park building which is G+8 includes, one basement for parking and the rest utilized for the purpose of office and conference hall on 7th floor.

I have used the cost of concrete Fram construction from the above table 4:5. Summarized Price for B+G+8 Prefabricated Building for the subtract and super structure part which amounts 33,588,592.85 birr including vat.

Table 4-2. Summary of Floor Areas ICT Park Prefab Building

Floor	Unit	Area	No of Floors	Area per Floor
Basement	**m^2**	**914.76**	**2.00**	**1,829.52**
Ground Floor Area	**m^2**	**914.76**	**1.00**	**914.76**
1st-7th Floor Area	**m^2**	**914.76**	**8.00**	**7,318.08**
Total Area of Super Structure			**11.00**	**10,062.36**
Total Cost for Super Structure Fram work				**33,588,592.85**
Construction Cost /m^2				**3,338.04**

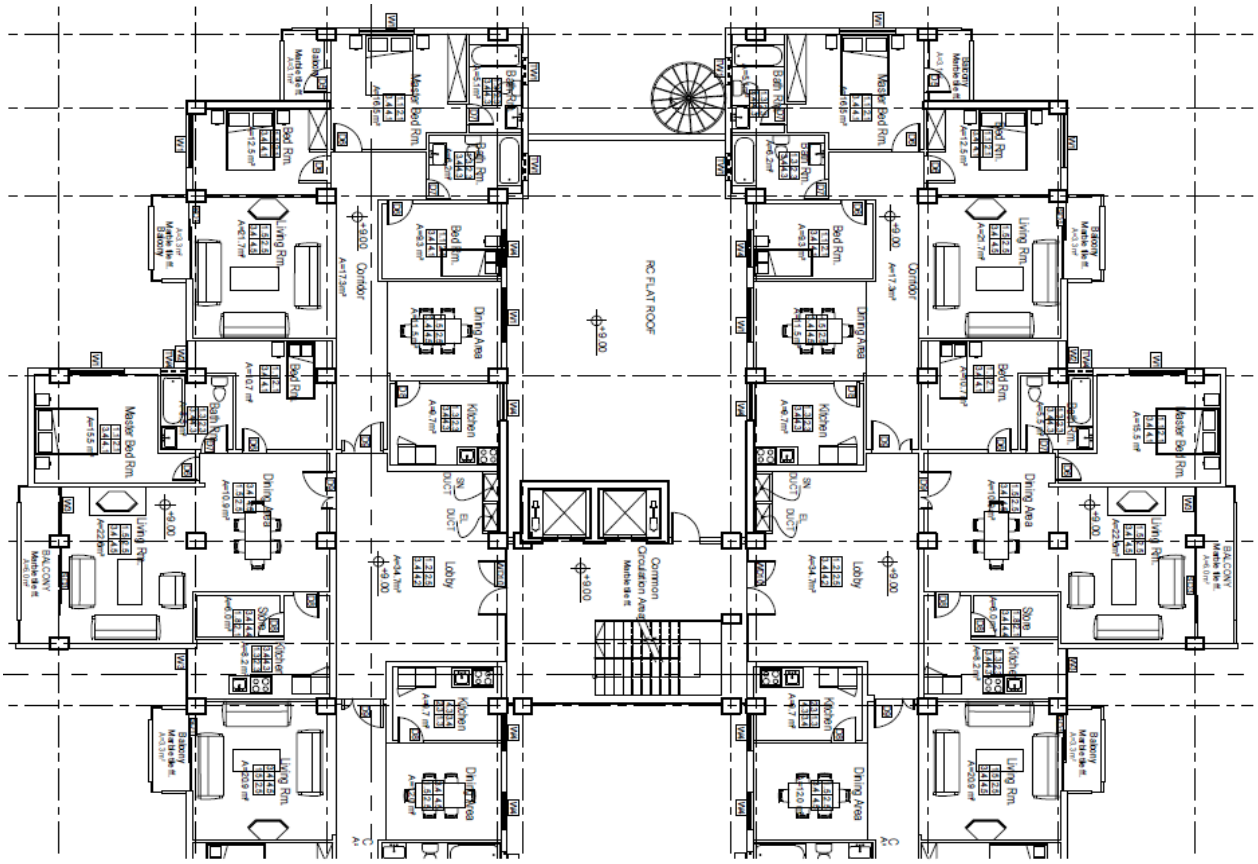


Figure 4:2. Sample Floor Plan of 40/60 Apartment building[Source :Project office]

The 40/60 building which is 2B+G+12 includes, two basement for parking, for purpose of commercial area use ground ,1st and 2nd floors and the rest utilized for the purpose of housing (3rd - 12th)

I have used the cost of concrete Frame construction from the above table 4:4. Summary of Cost For 40/60 Conventional Construction Building for the sub structure and super structure part which amounts 33,588,592.85 birr including vat.

Table 4-3. Summary of Floor Areas of 40/60 Apartment Building

Floor	Unit	Area	No of Floors	Area per Floor
Basements	**m^2**	**1329.31**	**3.00**	**3,987.93**
Ground	**m^2**	**1329.31**	**1.00**	**1,329.31**
1st	**m^2**	**1154.075**	**1.00**	**1,154.08**
2nd	**m^2**	**948.205**	**1.00**	**948.21**
3rd -12th	**m^2**	**1034.45**	**10.00**	**10,344.45**
Total Area of Structure			**16.00**	**17,763.97**
Total Cost for Structure Fram work				**71,811,592.73**
Construction Cost /m^2				**4,042.54**

4.3 Bill of Quantity of Selected Buildings

4.3.1 Cost analysis of 40/60 (2B+G+12)Conventional Construction

Table 4-4. Summary of Cost For 40/60 Conventional Construction

	SUMMARY OF PRICE FOR 2B+G+12 TYPOLOGY CONVENTIONAL 40/60 BUILDING		
	A-SUB STRUCTURE		
1	Excavation and Earth work	Birr	3,846,613.78
2	Concrete Work	Birr	21,521,956.09
3	Stone Masonry Work	Birr	166,529.09
	TOTAL A.....	Birr	25,535,098.96
	B. SUPER STRUCTURE		
1	Concrete Work	Birr	40,922,907.15
2	Block Work	Birr	4,020,492.52
3	Roofing Work	Birr	1,517,678.75
4	Carpentry and Joinery Work	Birr	2,544,710.00
5	Metal Work	Birr	1,838,655.97
6	Plastering Work	Birr	8,185,868.85
7	Steel Structure	Birr	7,563,384.45
8	Finishing Work	Birr	6,018,774.50
9	Glazing Work	Birr	1,409,111.49
10	Painting Work	Birr	296,998.70
11	Sanitary Installation	Birr	771,114.17
12	Electrical Installation	Birr	1,132,103.36
	Total B …….....	Birr	76,221,799.91
	Total A + B	Birr	101,756,898.88
	VAT(15%)	Birr	15,263,534.83
	Total A + B	Birr	117,020,433.71

4.3.2 Bill of Quantity of Prefabricated Model ICT park B+G+8 Building

Table 4-5. Summarized Price for B+G+8 Prefabricated Building

SUMMARY OF B+ G+8 MIAN BUILDING (PREFABRICATED AND ERRECTED)			
	A. SUB STRUCTURE		
1	**Excavation and Earth work**	**Birr**	**1,439,153.2**
2	**Concrete Work**	**Birr**	**1,659,848.0**
3	**Stone Masonry Work**	**Birr**	**64,619.3**
	Total A	**Birr**	**3,163,620.6**
	B. SUPER STRUCTURE		
1	**Concrete Work**	**Birr**	**27,547,624.0**
2	**Block Work**	**Birr**	**2,208,575.3**
3	**Roofing Work**	**Birr**	**912,846.8**
4	**Carpentry and Joinery Work**	**Birr**	**799,070.0**
5	**Metal Work**	**Birr**	**39,798,194.5**
6	**Plastering Work**	**Birr**	**1,750,324.1**
7	**Steel Structure**	**Birr**	**506,280.4**
7	**Finishing Work**	**Birr**	**22,130,024.6**
8	**Glazing Work**	**Birr**	**224,580.6**
9	**Painting Work**	**Birr**	**297,441.9**
10	**Sanitary Installation**	**Birr**	**5,729,816.0**
11	**Electrical Installation**	**Birr**	**29,869,918.0**
12	**Mechanical Installation**	**Birr**	**33,062,355.0**
	Total B	**Birr**	**164,837,051.2**
	Total A+B	**Birr**	**168,000,671.8**
	Vat(15%)	**Birr**	**25,200,100.8**
	Grand Total	**Birr**	**193,200,772.6**

4.3.3 Cost Comparison the selected 40/60 apartment building(2B+G+12) and Prefab model G+8 Building

From the above tables of bill of quantity summery, cost of prefabricated building structure frame and conventional 40/60 apartment building structure frame are 33,588,592.85 Birr and 79,806,044.48 Birr including VAT respectively and the cost for concrete works in structure frame is considered for the purpose of this project. But, as we have mentioned earlier the height of the conventional 40/60 apartment building and the prefabricated building are 2B+G+12 and B+G+8 respectively. Due to this reason the construction cost we obtained above in the BOQ should be factored to get an Estimate made equivalent height of building.

The cost of construction highly related with number of story and there will be cost variation with floor level. Standard textbooks on building economics usually provide little hard evidence to back the reasonable claim that unit construction cost teds to rise with building

Tall buildings are invariably more expensive to build than two- or three- story buildings offering the same accommodation, and the taller the building the greater the comparative cost .. What are the reasons for this ?

i. The cost of the special arrangements to service the building particularly the upper floors
ii. The necessity for the lower part of the building to be designed to carry the weight of the upper floors…. Also the whole building will have to bed designed to resist a heavy wind loading
iii. The cost working at a great height from the ground when erecting the building
iv. The increase area occupied by the service core and circulation

In UK , Stone(1963,p.49) also reported a moderate rise in unit building cost with building height for blocks of flats and maisonerres in London and the province similarly ,Seely (1983,p.26) quoted a Department of the Environment study which reported that the cost of apartment building rose 'fairly uniformly by about 2.0% per floor when increasing the height above four stories. based on this I have used 2.0% increment per floor , accordingly 2% for 9th floor,4% for 10th floor,6% for 11th floor and 8% for 12th floor and total of 20% to compute equivalent height cost of the prefabricated building cost for 2B+G+12 building

Table 4-6.Cost Comparison per m2 area of structural frame construction

Equivalent Cost of Prefab building for 2B+G+12 per m2						
Item No	**Project**	**Total Floor Area**	**Actual Cost(Birr)**	**Cost/Area (birr/ m2)**	**Building Height Adjustment Factor**	**Cost/Area (birr/ m2)**
1	40/60 Conventional Frame Construction	17,763.97	71,811,592.73	4,042.54	1.00	4,042.54
2	ICT park Building Frame Construction	10,062.36	33,588,592.85	3,338.04	1.20	4,005.65

4.4 Analysis of Cost Savings Related To Construction Time

As we know one of the construction costs that are directly related to duration of construction time are Consultancy/ supervision cost, bank interest and rental cost/income (depending on the evaluation). Hence we have tried to compute this cost savings that are attributing to prefab buildings due to reduced construction time. In order to get the monthly supervision cost as follows

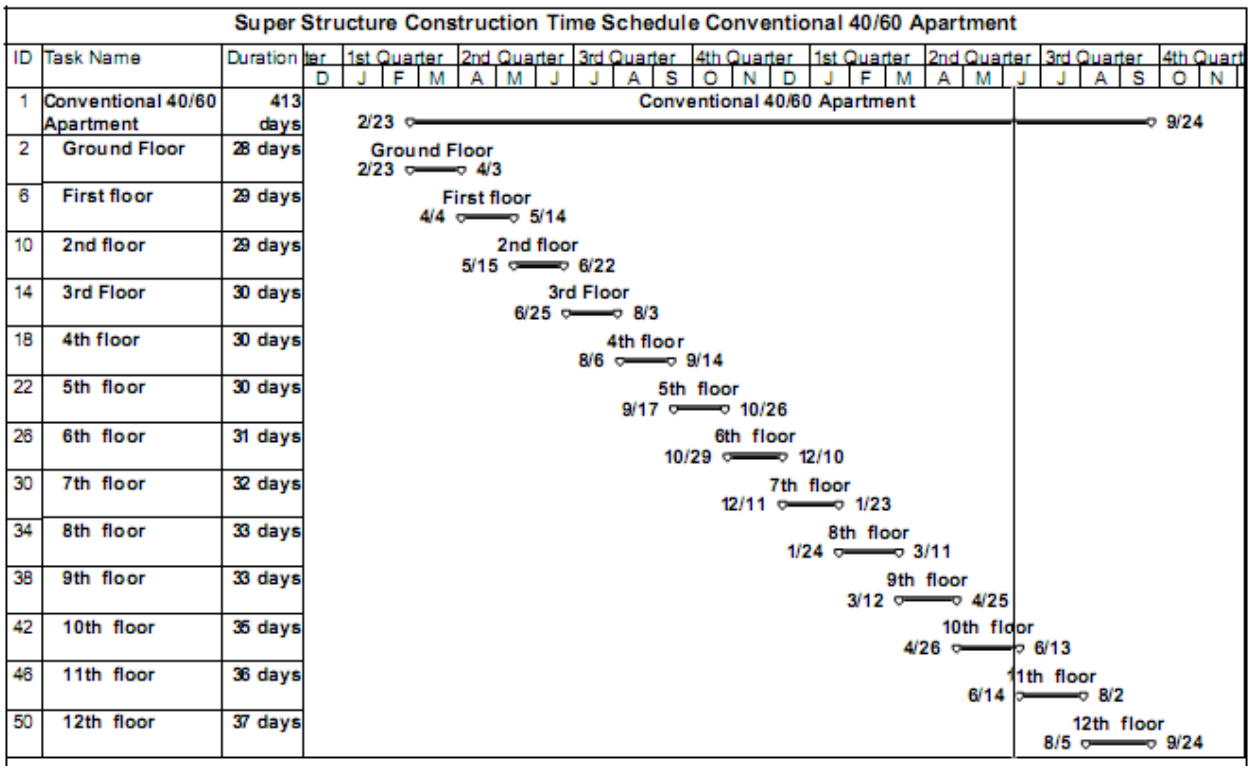


Figure 4:3. Construction Time Schedule for Conventional construction

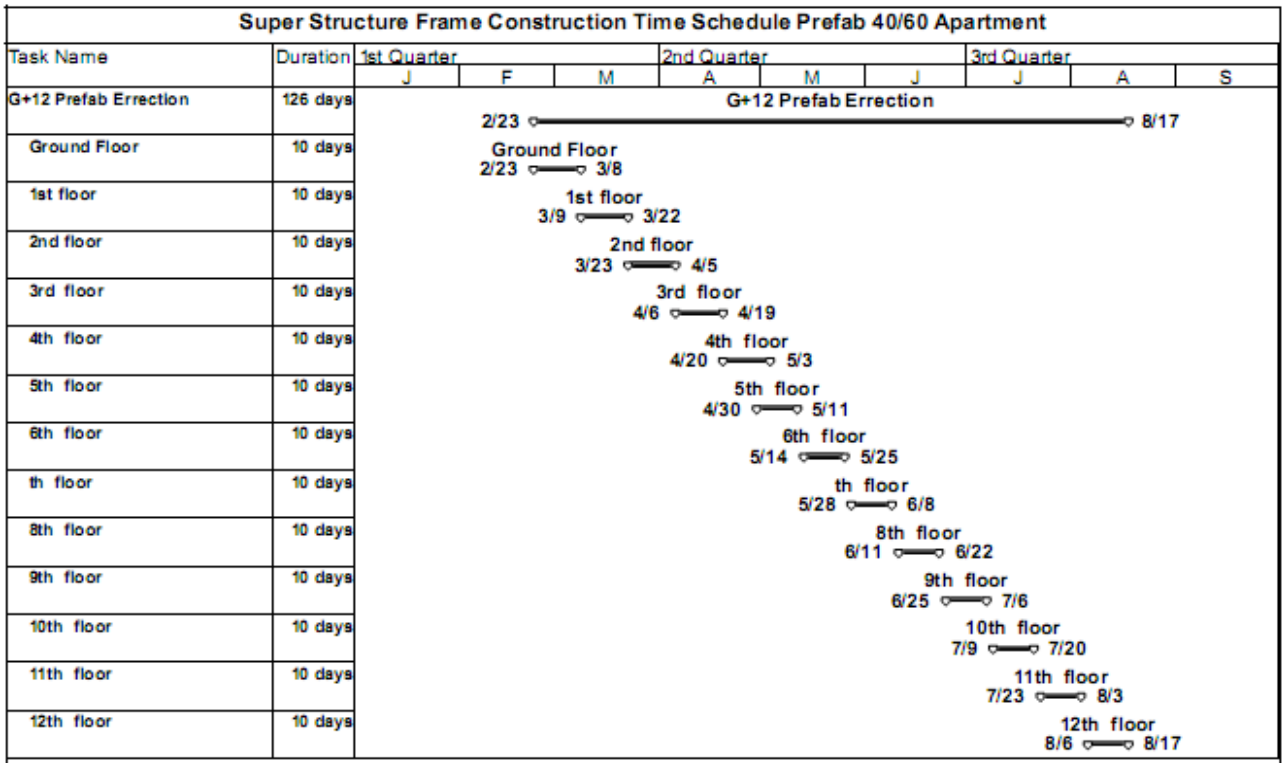


Figure 4:4. Construction time schedule for prefab building

The production capacity of the prefab is known and company has a designed capacity of 50,000m2/year, the enterprise has the ability to finish a more than three G+12 buildings. The building components are made using standard molding devices. Clients who are interested in using precast concrete elements should keep in mind of the standard sizes provided by the company and arrange their designs accordingly.

The inputs to the scheduling of both method of construction are gathered through, on site data collection, interviews of the projects staffs, from consultant and contractor recordings, weekly site plans and actual sample data collection on site

According to the schedule shown above the time required to finish the structural frame construction are 413 Cal days and 126 Cal days for Conventional construction and prefabrication and erecting respectively. Which means the time gap between the two methods of construction becomes 287 Cal days (9.60months). From this difference I have calculated the under described cost savings

4.4.1 Computation of Monthly Supervision cost

The consultant assigned for the supervision of the 40/60 housing projects located at Megenagna (Ehil Nigd and Tourist sites) projects is YOHANNES ABBAY Consulting Architects &

Engineers. The project includes two sites on opposite side of the road connecting "24 kokeb building" to Megenagna " Derartu Tulu building" .There are six 2B+G+12 buildings in Ehil Nigd project site and eleven 2B+G+18 buildings included in Tourist project sites . Total of Seventeen buildings are under construction with the supervision of YOHANNES ABBAY Consulting Architects & Engineers. And the monthly payments for supervision service are shown in the table 4:8, 4:9 and 4:10.

Table 4-7.Summery of Professional assigned for 17 Blocks

Position	Assignment	Min Qty	Unit	Monthly Rate Birr	Total
Key Staffs /Full time staff					
Project Coordinator	1 per project	19	Man Month	22,500.00	427,500.00
Resident Engineer (RE)	1 per project	19	Man Month	20,000.00	380,000.00
Quantity Surveyor	1 per project	19	Man Month	8,000.00	152,000.00
Site Inspectors	1 per 2 blocks	18	Man Month	8,000.00	144,000.00
Site Inspectors	1 per 2 blocks	18	Man Month	8,000.00	144,000.00
Site Inspectors	1 per 2 blocks	18	Man Month	8,000.00	144,000.00
Site Inspectors	1 per 2 blocks	18	Man Month	8,000.00	144,000.00
Site Inspectors	1 per 2 blocks	18	Man Month	8,000.00	144,000.00
Site Inspectors	1 per 2 blocks	18	Man Month	8,000.00	144,000.00
Site Inspectors	1 per 2 blocks	18	Man Month	8,000.00	144,000.00
Site Inspectors	1 per 2 blocks	18	Man Month	12,000.00	216,000.00
Sanitary Inspector	1 per project	18	Man Month	8,000.00	144,000.00
Electrical Inspector	1 per project	18	Man Month	8,000.00	144,000.00
Intermittent staffs					
Intermittent Structural Engineer	1 per project	4	Man Month	8,000.00	32,000.00
Intermittent Architect	1 per project	4	Man Month	8,000.00	32,000.00
Intermittent Electrical Engineer	1 per project	4	Man Month	8,000.00	32,000.00
Intermittent Sanitary Engineer	1 per project	4	Man Month	8,000.00	32,000.00
Intermittent Geotechnical Engineer	1 per project	4	Man Month	8,000.00	32,000.00
Pre-Cast Elements Production Inspector	1 per project	4	Man Month	8,000.00	32,000.00
				Total Sum	2,663,500.00

Table 4-8. Summary of Professional Fee for 17 Blocks

Item No	Costs	Unit	Monthly Rate per block	No Blocks	Total Month	Total Contract Amount for 19 months
1	Total Fee Before VAT	Birr	8,246.13	17	19	2,663,500.00
2	VAT	Birr	1,236.92	17	19	399,525.00
3	Total Amount	Birr	9,483.05			3,063,025.00

Table 4-9. Reimbursable Office, Office Facilities, Report and Professional indemnity and other insurance Expenses

Item No	Description of Cost	Quantity	Unit of Measure	Unit Price	Total Price /month	Total Contract Amount for 19 months
1	Local transportation	1	Month	10,000.00	10,000.00	190,000.00
2	Communication	1	Month	2,500.00	2,500.00	47,500.00
3	Paper and stationary	1	Month	2,500.00	2,500.00	47,500.00
					Total	285,000.00
					15% VAT	42,750.00
					Total fee including VAT	327,750.00

I have prepared the work schedule for both Conventional Construction and prefabrication construction of structural frame of the buildings for proportional height and area of building like 40/60 apartment building. The schedules are prepared based on the actual data from site like production per hour, material, equipment used, manpower assigned and by neglecting unreasonably excess material and time wastage. According to the schedule of construction one can see the time gap in completion time of both method of construction for equivalent building. The time saving and the related cost advantages with respect to supervision are presented in the table 4:11 below.

Table 4-10. Cost Saving from Supervision Fee per block

Item No	Description	Amount Per month	Time Saved (Months)	Total Saved Amount Birr
1	Professionals Service Fee	9,483.05	9.6	91,037.28
2	Reimbursable	17,250.00	9.6	165,600.00
	Total Amount	26,733.05		256,637.28

In the above table it is shown that, as we can complete the structure works of prefabricated building 9.6 months earlier than the conventional we can reduce a 9.6 month supervision cost that is estimated to be about 256,637.28 birr per Block.

4.4.2 Computation of Cost Saving from Bank Interest

Then we will compute cost savings related to Bank interest. Here I have assumed 70% of the construction cost is borrowed from bank with a Bank average nominal interest rate of 17.5 % per year on intermediate term loan base. Thus, Interest savings will be as follows. Here I have considered the total construction time of the project from the schedule to compute the bank interest. The factored project is calculated based on the total floor area of conventional building multiplied by the unit cost of prefabricated construction per m2 before any adjustment.

Table 4-11. Summary of Saving From Bank interest

Bank Interest					
project	**Factored project cost (A)**	**Project loan 70% (A)**	**interest/month (17.5%/yr)**	**project duration**	**Total. Int.**
Conventional	71,811,592.73	50,268,114.91	1.46%	18	9,212,353.98
Prefab	59,296,900.11	41,507,830.08	1.46%	12	4,719,897.85
Saving from Bank Interest cost					**4,492,456.13**

Since we can complete the building 6 months early, one can reduce associated Bank interest cost an amount of **4,492,456.13**.

4.4.3 Computation of Cost Saving from house renting by End users

The third cost saving is associated the cost that the end user inures for renting house somewhere else until the project is completed and transferred to the end user. In the building we have considered 10 households to per floor that means 90 households per block. And we have collected the average renting price near by the project area through questioner for different type of house and presented in the table below

Table 4-12. Summary of Condominium House renting price

Item No	Location	Number of Bed Rooms		
		1	2	3
1	Gergi Condominium Average	5000	7000	8000
2	Balderas Condominium Average	6500	9500	10500
	Average	**5,750**	**8,250**	**9,250**

Table 4-13. Summary of Number of households per floor/Block

Item No	Location	Number of Bed Rooms per floor		
		1	2	3
1	Number of house per floor	2	6	2
2	Total Number of floors	10	10	10
	Average	20	60	20

Table 4-14.Total saving by end users from house renting.

Item No	Location	Number of house	Rent per month	Time Saving (Months)	Total amount Saved (Birr)
1	One bed room	20	5750	9.6	1104000
2	Two bed rooms	60	8250	9.6	4752000
3	Three bed rooms	20	9250	9.6	1776000
					7,632,000.00

The above three tables shows the saving with respect to the time saving correspondingly I have obtained that rental expense of 7,632,000.00 birr will be saved from the pocket of the end users, in other words rental expense that would have been paid for 9.6 month for living in rental house will be saved.

Finally I have summarized the total cost savings and I have obtained the net adjusted cost per m^2 for prefabrication compared it with conventional construction cost per m^2 in the table 4:6 above. From the table the cost per m^2 for conventional construction is greater than that of prefabrication construction before adjustment for height difference of the buildings under study. The prefabricated building in ICT Park is B+G+8 where us the 40/60 apartment considered for this study is 2B+G+12. Then I have introduced adjustment factor 2.0% increment in cost for each floor increment in total 20% that will compensate the cost increment due to height increment and

structural load increment which is not included in B+G+8 prefab building design and construction cost pricing . Finally I have associated cost advantages that comes with reduced construction time in case of prefab and the results are presented in the table 4:15 below. Structure construction costs per m^2 of area before adjustment are 4,042.54 Birr/m2 and 4,005.65 birr/ m^2 for conventional and prefab building respectively. However, after computing the associated costs the cost/ m^2 area become 2,964.51birr /m2 and 4,042.54 birr/ m2. Hence, have learnt that the total cost of construction of structure using prefab is lower than the conventional and its total cost will be lowered by 36%.

This cost is not taking into account all the material, and untimely maintenance waste evident in the in-situ construction method. In addition to the direct cost component, some foreseeable indirect cost components have been discussed. Along with the apparent major difference in direct cost, the precast construction method is shown to be lower in overall cost than its in-situ counterpart.

Table 4-15. Total Cost Advantage from Time saving of prefab house

Total Cost Advantage from Time saving of prefab house	
Description	Amount
Consultancy Fee Saving	256,637.28
Bank Interest Saving	4,492,456.13
Early return on Rental / Rental cost saving	7,632,000.00
Total (A)	12,381,093.41
Factored Construction cost of prefab (B)	47,634,731.68
net cost of prefab C = (B-A)	35,253,638.28
Total Area of prefab	11,891.88
Prefab Adjusted cost /m2	2,964.51
Conventional Adjusted cost /m2	4,042.54
Total Net Construction cost difference /m2 (Birr)	1,078.03
Prefab Adjusted cost /m2	2,964.51
Conventional Adjusted cost /m2	4,042.54
% cost increased	36%

5 Discussion

As it is known, the need for housing is vulnerable in the current Ethiopia. Due to many reasons cost of housing construction is highly expensive and makes it difficult to have a shelter for most of Ethiopians especially for the young generation. So all of the attention is focus on the government to provide affordable houses. But, by the way of the current construction, it is impossible to meet the demand within a reasonable period of time. So, the government should give attention to other alternative technologies like prefabrication. But there is no any special policy or strategy set by the government in order to support the adaptation of this technology throughout the country to use for the current housing development. Currently the plan of the government is to create plenty of job opportunities and promote the development of micro and small – enterprises. Since the focus of the government is on conventional construction method to attain those plans, prefabrication is neglected. But the demand of housing should give more concern than the job creation political decision of the government even if it is not met yet.

Even though since 1984 the prefabrication technology has been introduced and implemented for the housing and other sectors in our country, the development and utilization of the technology has been declining rapidly. It has been known and determined the advantages gained by looking at the prefabricated buildings, which have high durability, low maintenance cost, good aesthetics and many other advantages specially by comparing with the recently build condominium housing using the conventional technology.

There is no clear reason behind the declining usage of this technology, but due to the poor initiatives of the stake holders in the construction industry for the advancement and modernization of the industry the technology has now been utilized as it was desired.

As we have tried to mention earlier the cost assessment is made by considering a single 2B+G+12 40/60 apartment blocks by evaluating the costs of constructing the structure using conventional construction system vs. prefabricated construction. The result of this assessment initially showed that the cost of prefabricated construction system is lower than the cost of conventional system. one of the major reason for this is that the cost for the prefab is for B+G+8 building which is located in ICT bark compound and for the conventional construction I have taken the cost of 2B+G+12 40/60 apartment building which is located at Ehil Nigd site . And then I have considered 2.0% increment in cost per m2 of prefab building for each floor rise in order to compensate the cost increment due to height of the building and the load increment in foundation

and column then to compare in equivalent bases .This is because this cost only considers the costs that directly will be paid to the contractor, in other words the total construction cost that will incur during the project life cycle were not considered. As we all know the total construction cost should include construction cost (that will be directly paid to the contractor, design and supervision costs, interest costs and opportunity costs. And the costs of both method of construction taken from AAC Saving Houses Development Enterprise (SHDE) for conventional construction and P.B.P.P.E for prefabrication. The main reason is the cost for conventional construction is fixed by AAC saving houses development enterprise and contractors are invited to undertake the construction with fixed price base and for the prefabrication since the sector is monopolized by one P.B.P.P.E there is no other option to consider.

Due to the reduced duration of construction period, the prefab method will have advantage in respect of supervision costs, interest costs and house rent saving costs. Thus, for comparison purpose when we deduct this cost advantage from the initial cost of the prefab, its total cost decreases from **4,005.65**Birr/m2 to **2,964.51** birr/m2 and the difference becomes **1,078.03** birr/ m2 , and that of conventional house (**4,042.54birr/m2)** .

In addition to this, maintenance costs and the service life of the buildings should have been considered in the total construction cost. And considering this cost advantage of prefabrication will be highly maximized. Moreover this cost analysis is limited to one G+12 block, but in high-rise modular and mass housing projects the cost saving from prefabricated housing projects will be again maximized due to reduced equipment utilization factor per block.

6 Conclusions and Recommendations

6.1 Conclusions

This chapter presents an overview of the technical merit and scientific value gained from the study and concludes with the lessons learned. The conclusions include analysis results, followed by recommendations for future research and practice.

In general, the overriding purpose of this study was to determine the level of acceptance that the Ethiopian construction industry would have for the precast construction system. In order to accomplish that goal, it was necessary to reach some prerequisite goals. The research has shown Determining what precast construction is and how this system affects the country's construction industry assumed a high degree of importance during the literature review conducted for this study. Related to that effort, it became necessary to reach an understanding about the nature of Ethiopia's construction method. To provide for the possibility that precast construction could be perceived and measured as a viable method of the booming construction business, it was important to systematically compare the method of construction that is currently being used with the precast method. Once these fundamental steps were achieved, this research was able to go forward. This chapter reports the conclusions and recommendations that resulted from this study

Prefabrication housing construction technique is not developed and expands as its age since it was started to practice in Ethiopia. There are so many reasons, but the main one is that it is not the target of the government, the factory was left forgotten for a long period time and there is no even a single policy or strategies that discusses and support the case of prefabrication technology for housing development sector.

Based on the cost analysis we observed that the structural frame construction cost of prefabricated building is lower than the conventional structural frame construction method. As per our analysis we can save more than 36% of the cost incurred for structural frame construction of conventional building by using prefab technology where the figure will be considerably huge in the case of mass housing projects. As an example for one block the saving will be **12,819,784.69** Birr per block from structural frame construction only.

Due to the poor initiatives of the stake holders in the construction industry for the advancement and modernization of the industry, the technology has now been utilized as it was desired.

Most of the developed and developing countries know a day's use prefab technology as a solution for their low and middle income societies affordable housing demand within a short period of time.

6.2 Recommendations

The government has to pioneer in this area as it has in other areas in the past. The five year growth and transformation plan set in motion by the FDRE is having the result of a country under construction. The amount of ongoing construction in the country is currently at its all-time maximum. This demands faster and more reliable construction solutions to be delivered immediately. As per the results of this research, precast construction is a viable and fitting method for the construction industry, which brings about the conclusion that many more precast plants in different regions of Ethiopia should be set up and commence operations.

Finally I have forwarded the under listed recommendation from my study

1. Accordingly, the study recommends that the government pay due attention to developing precast construction as a viable solution to improve the quality, speed, and economy of upcoming construction activities. It is also recommended that many more studies should be done to further show any other ways in which the current precast plant can be enhanced in order to provide the required information for the expansion of the precast industry in Ethiopia.
2. All the results in the above sections conclusively show that precast construction is considerably more economic, and extremely faster than the in-situ method and further studies should be carried out in order to find more practical ways to incorporate this system into the Ethiopian construction industry.
3. Expansions of the prefab factories in different districts of the country also have a positive impact for increasing production capacity and to address for the whole society. In order to attain this goal train professionals and skilled man powers so as to increase availability of working force throughout the country.
4. Support researchers and research institutions in order to make studies and researches to improve the technology and to adapt it in an appropriate way to our country. As we have seen from this research to create awareness about the prefab technology to the society and decision makers in order to increase the use of the technology. Since the policy and decision makers are the politicians following the demand of the public.

5. The government and other major stakeholders in the industry must have an initiation in introducing such type of technology that will save the countries huge resources. And those bodies must create awareness.
6. One of the major actions is to preparing appropriate policies and strategies that support for the creation of a fertile ground in order to adapt the use of prefabrication technology in a great extent.
7. Urban planning is another area, which can contribute to effective development and use of available urban space. Feasible attempts must be made to improve the financial position of the municipality, which is expected, among other things, to develop urban land. This may take the form of revising tax rates, tariffs, land prices which are connected with urban build up areas or other sources of income collected by the city council, or to look for additional revenue by expanding tax bases.
8. Something must also be done in regard to urban management. This refers to the need to coordinate the activities of various offices under the council. If such activities properly coordinated, it would undoubtedly contribute to lowering the cost of provision of services. In this regard, the implementation of site and services can facilitate the construction of additional housing stock.

7 References

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8 Appendix

APPENDIX A

LIST OF PARTICIPANTS

PBPPE experts

- Abedu Jemal . (Resident Engineer of Virtual consulting ICT park)
- Desalgn Mekonen (Project Manager of ICT park building)
- _____ (Construction Engineer in ICT park)
- _____ (Site Engineer in ICT park)
- _____ (Office Engineer in ICT park)
- _____. (Production Forman)
- _____ (Erecting Forman)

AAC Saving House Development Enterprise

- Ato Tesfaye (Contract Administration Department Head of AACSHDE)
- Ato Denku (Design Department Head of AACSHDE)

Yohannes Abbay Consulting Architects and Engineers plc

- Ato Zerihun (Project Coordinator of 40/60 condominium project)
- Ato Zelalem (Resident Engineer of 40/60 condominium project)
- Ato Tesfaye (Work inspector of 40/60 condominium project)
- Ato Henok (Work inspector of 40/60 condominium project)
- Ato Bayu (Work inspector of 40/60 condominium project)
- W/o Tigist (Work inspector of 40/60 condominium project)

APPENDIX B

INTERVIEW

Interview Questions to PBPPE Staff Members

1. How long have you worked in PBPPE?
    1.1. More than 0 years and less than 5 years
    1.2. More than 5 years and less than 10 years
    1.3. More than 10 years and less than 15 years
    1.4. More than 15 years
2. In your opinion, is PBPPE functioning up to its capacity?
    2.1. Yes
    2.2. No, but it can
    2.3. No and it cannot
3. In your opinion, does PBPPE need any major renovations?
    3.1. Yes
    3.2. I cannot say
    3.3. No it is working well enough
4. If you answered "Yes" to question number 3, please discuss which elements you would suggest for renovations.

_____
_____
_____
_____

5. Do you think PBPPE offers a fair price for construction?
    5.1. Yes
    5.2. I cannot say
    5.3.No, but it should
    5.4.No, and it should not
6. What is your justification for your answer to question number 5?

_____
_____
_____
_____

7. What do you say is the biggest obstacle against the development of the plant?

_____
_____
_____

_____

8. Do you think that PBPPE has become obsolete?

_____

_____

_____

_____

9. Do you think a precast plant is a requirement in Ethiopia?

_____

_____

_____

_____

10. In your opinion, is there anything that should be noted about the history, works, development, or challenges of PBPPE?

11. What score, from 1 up to 5, 1 being very bad and 5 being very good, would you give PBPPE on issues of the NPCA Grading Schedule topics with no data to back them up?

12. Please provide records or notes of any quality control measures that have been taken by the plant in the last ten precast building projects.

13. In your opinion, what are major benefits that precast construction has that in-situ construction does not? Choose from the list below.

A. controlled consolidation
B. no material wasted
C. modularity (repetitive production)
D. controlled curing
E. shorter time
F. finished surface at form removal
G. little supervision needed
H. in-house lab testing
I. no false work needed
J. repetitive formwork reuse
K. safety
L. fixed rebar positions
M. little maintenance needed
N. less no. of laborers (easy HR management)
O. Controlled casting

14. From the benefits of precast construction you chose in question number 13, please give a score of 1, least beneficial, up to 5, most beneficial.

A. _____
B. _____
C. _____
D. _____
E. _____
F. _____
G. _____
H. _____
I. _____
J. _____
K. _____
L. _____

M. _____ O. _____

N. _____

15. Please choose which precast construction benefit in 'Column B' is important to the building type listed in 'Column A'. Several choices can be selected for each building type.

COLUMN A	COLUMN B
A — modular real estate houses	i.Controlled consolidation
B — mixed use buildings (malls, city centers)	ii. No material wasted
C — apartment buildings	iii. Modularity (repetitive production)
D — schools	iv. controlled curing
E — hospitals	v. Shorter time
F — office buildings	vi. Finished surface at form removal
G — residencies (individual designs)	vii. Little supervision needed
H — dual home-work compounds	viii. In-house lab testing (embassies, international organizations, universities)
I—religious/worship buildings (churches, mosques)	ix. No false work needed
J — national landmarks (palaces, museums)	X. repetitive formwork reuse
	xi. Safety
	xii. Fixed rebar positions
	xiii. Little maintenance needed
	xiv. less no. of laborers (easy HR management)
	xv. Controlled casting

APPENDIX C

INTERVIEW WITH TENANT

Interview Questions to tenant of condominium house and other

1. How long have you lived by renting house?

    1.1. More than 0 years and less than 5 years

    1.2. More than 5 years and less than 10 years

    1.3. More than 10 years and less than 15 years

    1.4. More than 15 years

2. In your opinion, where do you want rent your house?

    2.1. In local house

    2.2. In condominium house buildings

    2.3. Kebele house

    2.4. Public housing Agency

3. In your opinion, does condominium housing with conventional construction method of construction is convenient to A.A?

    3.1. Yes

    3.2. I cannot say

    3.3. No it is time taking

4. If you answered “Yes” to question number 3, please discuss which elements you would suggest for renovations.

_____
_____
_____
_____

5. Do you think house renting price in Addis Ababa is fair price?

    5.1. Yes

    5.2. I cannot say

    5.3. No it is very expensive

6. If your answered "No ", What do you think about the cause of high price of house renting ?

_____
_____
_____
_____

7. How much do you pay for renting around megenagna?

7.1 . Single Class_____

7.2 . One bed room _____

7.3 . Two bed room _____

7.3 . Three bed room _____

8. How much do you pay for renting in Balderass (Signal) Condominium?

8.1 . Single Class_____

8.2 . One bed room _____

8.3 . Two bed room _____

8.3 . Three bed room _____