



**ADDIS ABABA INSTITUTE OF TECHNOLOGY**  
**SCHOOL OF CIVIL AND ENVIRONMENTAL**  
**ENGINEERING**

**Challenges of Finishing Works on Integrated Modulus  
System (IMS) Building Technology: A Case Study on  
Projects under Construction in Addis Ababa**

By

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The undersigned have examined the thesis entitled Practice of Construction Planning in the Ethiopian Building Construction Industry: A Case Study on Selected Contractors in Addis Ababa presented by Yididiya Tesfaye, a candidate for the degree of Master of Engineering and hereby certify that it is worthy of acceptance.

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## **Declaration**

I declare that this project work was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification.

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This MEng Project has been submitted with my approval as a university advisor

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Advisor's Name

Signature

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## CONTENT

Page No.

**ACKNOWLEDGMENTS**

**I**

## TABLE OF CONTENT

**List of Figures**

**V**

**List of Tables**

**VIII**

**List of Charts**

**IX**

**ACRONYMS**

**X**

**ABSTRACT**

**XI**

### **1. CHAPTER ONE; INTRODUCTION**

1.1. Back Ground	1
1.2. Scope of the Research	2
1.3. Research limitation	3
1.4. Significance of the Study	3
1.5. Statement of the Problem	3
1.6. Hypotheses	3
1.7. Objective of the study	4
1.8. Research Method	4
1.9. Study Strategy	5
1.10. Research Instruments	6

### **2. CHAPTER TWO; LITERATURE REVIEW**

2.1. Introduction	7
2.2. Categories of Precast Building Systems	11
2.2.1. Large-panel systems / Space girder systems	11
2.2.2. Frame systems / Linear girder system	12
2.2.3. Slab-column systems with walls / Surface girder systems	14
2.2.3.1. Lift-slab system with walls	14
2.2.3.2. Pre-stressed slab-column system	15
2.2.4. Mixed systems	16
2.3. IMS Building Systems	17
2.4. General Features of the IMS System	18
2.5. Advantages of IMS Building Technology	27

2.6. Experiences in Precast Concrete	35
2.6.1. The Soviet Union / Russian Experience	35
2.6.2. The European Experience	36
2.6.3. The American Experience	37
2.6.3.1. The Boston College Parking Structure	38
2.6.4. The Yugoslavian Experience	39
<b>3. CHAPTER THREE; THE ETHIOPIAN EXPERIENCE</b>	
3.1. Historical Background	41
3.1.1. The ESBU Model Project	41
3.1.2. CMC Special Housing Project	43
3.1.3. IMS manufacturing Plant in Ethiopia	47
3.1.4. Capacity of the Factory	50
3.1.5. The IMS Building System	52
3.1.5.1. Structural System	52
3.1.5.2. Production System	53
3.1.5.3. Connection System	57
a) Wet Connection	57
b) Post Tensioning	61
3.1.5.4. Equipment for Erection of The IMS System	64
3.2. Buildings Built Using the IMS System	66
3.3. Short Comings in the implementation of the IMS System in Ethiopia	71
3.4. Recent Developments in Ethiopia Construction Industry	73
3.4.1. Light Weight Aluminum Formwork Construction Technology	73
3.4.2. Post Tensioning (PT) System by	76
<b>4. CHAPTER FOUR; RESEARCH METHODS AND METHDOLOGY</b>	
4.1. Research Methods	82
4.1.1. Study Area	82
4.1.2. Study Design	82
4.1.3. Sample Size Determination & Sampling Technique	82
4.1.4. Method of Data Collection	83
4.1.5. Research Variables	83
4.1.6. Plan of Data Analysis	83
4.2. Research Methodology	84

<b>5. CHAPTER FIVE; DATA ANALYSIS AND DISCUSSION</b>	
5.1. Analysis;	85
5.2. Cost;	85
5.3. Time;	88
5.4. Quality;	89
5.5. Discussion;	89
<b>6. CHAPTER SIX; CONCLUSIONS AND RECOMMENDATIONS</b>	
6.1. Conclusions	90
6.2. Recommendations	92
<b>BIBLIOGRAPHY</b>	93
<b>APPENDIX</b>	95

## List of Figures

	<b>Page No.</b>
Figure 2.1: A large-panel concrete building under construction	12
Figure 2.2: Components of a precast reinforced concrete frame system of	13
Figure 2.3: A lift-slab building of “Seria KUB” under construction	14
Figure 2.4: Post-tensioned slab-column connection	15
Figure 2.5a: Precast footing pad (inverted) at the production plant, ready to be transported	19
Figure 2.5b: Precast footing pad arrangement on site	19
Figure 2.6a: Precast columns	19
Figure 2.6b: Precast initial column erection at AAMZLA/MCH	19
Figure 2.7a: Precast slab during lifting	20
Figure 2.7b: Precast Slab arrangement on columns	20
Figure 2.8a: Precast cantilever slab on steel supports	21
Figure 2.8b: Precast Cantilever Slab after Post Tensioning	21
Figure 2.9: Precast girder	22
Figure 2.10a: Precast shear wall on a special transportation lorry	23
Figure 2.10b: Precast Shear wall at Kality production plant	23
Figure 2.11a: Single flight stair case	24
Figure 2.11b: Double flight stair case and landing at Kality production plant	24
Figure 2.12: Variant stair solution	28
Figure 2.13: Variant utilities and window solution	29
Figure 2.14: The Boston College car parking structure	33

Figure 3.1a: Awash customs authority check point during construction	42
Figure 3.1b: Togo’cahalle customs authority check point	43
Figure 3.2a: Satellite view of apartments built by Cooperativa Muratori e Cementisti (C.M.C)	45
Figure 3.2b: Apartments built by Cooperativa Muratori e Cementisti (C.M.C) during the Final Stages of Construction	46
Figure 3.3: IMS manufacturing plant – Ethiopia	51
Figure 3.4a: Prefabricated skeleton ICT incubation center (ICT Park) front view	52
Figure 3.4b: Prefabricated skeleton ICT incubation center (ICT Park) top view	52
Figure 3.5a: Footing pad molds at Kality production center	53
Figure 3.5b: Footing pad rebar tying jigsaw at Kality production center	53
Figure 3.5c: Kality Production facility	54
Figure 3.6a: Slab mold at Kality production center	55
Figure 3.6b: Slab mold at Kality production center (a close-up view)	55
Figure 3.6c: Rebar tying jigsaw for slab at Kality production center	55
Figure 3.7a: Stair mold at Kality production center	56
Figure 3.7b: Prefab stair at Kality production center	56
Figure 3.8a: Column mold at Kality production center	56
Figure 3.8b: Prefab columns at Kality production center	56
Figure 3.9a: Placing of a thick cement rich grout on top of lean concrete	58
Figure 3.9b: Footing pad placing on top of the cement rich grout	58
Figure 3.10a: Initial column hoisting by mobile crane	59
Figure 3.10b: Wooden wedges to brace/hold the initial column in place until the fresh concrete hardens	59
Figure 3.10c: Initial column placing and concrete vibration to connect the initial column with the footing pad	59
Figure 3.11a: Connection between initial landing and grade beam	60

Figure 3.11b: Connection between initial stair case & grade beam	60
Figure 3.12a: Top Tie Beam Casting at ICT incubation building project	61
Figure 3.12b: Prefab column to column connection	61
Figure 3.13a: A concept of operation sketch	62
Figure 3.13b: Post tensioning tendons in between slab and between edge girder and a slab	62
Figure 3.13c: Post tensioning tendons with a wedge & barrel at the end of a prefab building	62
Figure 3.14: Post tensioning jacks and hydraulic oil pump set	63
Figure 3.15a: Steel squares for supporting slabs	64
Figure 3.15b: Steel diagonal braces for holding in position for columns	64
Figure 3.16a: Steel square support for cantilever slab with diagonal bracing	65
Figure 3.16b: a close-up view of the above picture	65
Figure 3.17 (a – i): Buildings built using the IMS construction system in Ethiopia	
a. G+7 Prefab. Building ICT Incubation Center (2021)	66
b. Kotebe Metropolitan University Administration Building	66
c. AAWSA Head Office building	67
d. Mina Building	67
e. Bole Apartments	68
f. Helen Building	68
g. Ras Amba Hotel	69
h. Ministry of Finance & Economic Cooperation	69
i. Revenue and Customs Authority Building	70
j. Prime Minister Office	70
Figure 3.18a: Conduits and electrical wiring under a Prefab slab.at AAMZLA/MCH	72
Figure 3.18b: Pipes, ventilation ducts, conduits and electrical wiring under a Prefab slab at ICT	72
Figure 3.19a: Sample mock-up of the Kumkang aluminum formwork	74
Figure 3.19b: 3D view of staircase	74

Figure 3.20a: Front auxiliary view of the sample aluminum mold	75
Figure 3.20b: Rear auxiliary view of the sample aluminum mold and casted concrete structure	75
Figure 3.20a: Front auxiliary view of the sample casted concrete structure	75
Figure 3.21: Stalks of books pressed laterally	77
Figure 3.22a: Mono-strand un-bounded tendons	78
Figure 3.22b: Multi-strand bounded tendons	78
Figure 3.23a: 3D design of Elilita RE building	79
Figure 3.23b: RC Structure of Elilita RE building Prior to construction of the bridge	79
Figure 5.1a: Ventilation ducts, conduits and electrical wiring to be covered by ceiling at ICT	85
Figure 5.1b: Conduits and Electrical wiring to be covered by ceiling at AAMZLA/MCH	85
Figure 5.2a: Vertical ventilation ducts	86
Figure 5.2b: Vertical sanitary system, conduits and electrical wiring	86
Figure 5.3a: Fire suppressing system piping	87
Figure 5.3b: Fire suppressing system piping as it connects from one floor to the other	87

## **List of Tables**

	<b>Page No.</b>
Table .1: Prefab footing types with dimensions	54
Table 3.2: Challenges and results achieved on Elilita RE building	80
Table 5.1: Additional cost per floor for Armstrong ceiling AAMZLA/MCH administration block	87
Table 5.2: Additional cost per floor for piping at AAMZLA/MCH administration block	88
Table 5.3: Prefab extended hour work per floor of AAMZLA/MCH administration block	88

## **List of Chart**

	<b>Page No.</b>
Chart 1.1: Work flow chart showing study strategy	5

## ACRONYMS

AAMZLA; Addis Ababa Meles Zenawi Leadership Academy

ADB; African Development Bank

BDE; Building Design Enterprise

BTCS; Building Technology and Construction Sector

C.M.C- Cooperativa Muratori and Cementisti- di-Ravenna

EASE; East Africa Specialized Engineering

EBCA; Ethiopian Building Construction Authority

ECWC; Ethiopian Construction Works Corporation

ESBU; Ethiopian Schools Building Unit

FWI; Foster Wheeler Italiaana

GOE; Government of Ethiopia

IMS; Integrated Modulus System

ISO; the International Organization for Standardization

MCH; Mothers and Children Hospital

PBPPE; Prefabricated Building Parts Production Enterprise

PHF; Prefab Housing Factory

PT; Post-tensioning

RC; Reinforced Concrete

UNECA; United Nation Economic Commission for Africa

WWII; Second World War

## ABSTRACT

In Ethiopia prefabrication was introduced by a technical assistance from the former Yugoslavia. Government in 1980's, former Prefabricated Building Parts Production Enterprise PBPPE is now under the Ethiopian Construction Works Corporation Building Technology and Construction Sector (ECWC BTCS). Though the company has changed its name, it is still using the same system at the time of installation of the plant in the 1984 without updating the technology and a major renovation work on the production plant.

Obviously, this posed a challenge on the adaptability of the Integrated Modulus System (IMS) with time as technologies develop and the standard of living improves especially, with the finishing touches of a building. That is what this research tries to address the problem that arises with the issue of an updated technology on the building construction sector of our times.

The study was made by conducting a detailed observation and analysis on three projects namely ICT G+7 Incubation Center, former Addis Ababa Meles Zenawi Leadership Academy AAMZLA (now Ayat Mothers and Children Hospital MCH) and Kotebe Metropolitan University Administration Building which are under construction and employ IMS building construction system to identify the inconveniences that comes with the beginning of finishing works on a site. A through interview was also conducted to further strengthen the issue at hand.

The results of the study show that the building system has regressed in our country as compared to the international practice, as difficulties arises in coping with finishing works that needs a lot of piping and wiring in our days of construction period. These difficulties had led to an additional spending in terms of cost, time and quality of the projects under consideration.

And finally a recommendation is forwarded for the concerned bodies that the system needed to be updated before this technology is lost with the decaying power of time to get a better result that comes with the use of a controlled production of building elements or prefabrication.

Key words

Construction Cost, Construction Quality, Construction Time, Finishing Works, IMS Building Technology, Precast Construction, Post Tensioning,



## CHAPTER ONE

### INTRODUCTION

#### 1.1 Back Ground

Prefabrication “is the assembly of buildings or their components at a location other than the building site. The method controls construction costs by economizing on time, wages, and materials. Prefabricated units may include doors, stairs, window, wall panels, floor panels, roof trusses, room-sized components, and even entire buildings.” [1].

By this definition one can see that prefabrication is the production of the whole or parts of a building in a controlled environment in a factory or a construction plant to improve productivity and quality. This is the result of the ever growing demand of countries due to the growth of their economies or to rebuild their infrastructure after the Second World War (WWII).

In the early 1950’s, the former Yugoslavia had a great problem of housing space deficit, which represented a challenge for the great constructor Prof. Branko Zezelj and his team, first of all the engineer Bosko Petrovic, with whom he developed and applied, at the time, a new building material – pre-stressed concrete. Designing bridges and halls unique in the World, he got a great idea to apply the material and technology of pre-stressed concrete in the field of building houses [2].

The idea was simple – to build standard buildings by use of standard elements, as children do with Lego bricks. The toughest problem – the connecting of the elements of the concrete frame, made of prefabricated columns and slabs, was resolved through the application of steel cables aimed for the post-tensioning process. It was a revolutionary idea that required numerous researches and proofs. First of all, in the field of durability and stability and in the field of architectural design and architectural possibilities it needed to be justified in practice as a universal technology for all kinds of high-rise structures.

IMS building technology is an advanced system for accelerated construction with pre-casted elements of the skeleton. This unique system based on the pre-stressed connection of the structure elements was developed by Prof. Branko Zezelj at the IMS Institute in Belgrade. It was

first implemented in 1957 and is since constantly being upgraded [3].

Numerous buildings and prefabricated element factories have been built – more than 150.000 apartments in former Yugoslavia, Italy, Angola, Philippines, Egypt, Ethiopia, Cuba, Hungary, Russia, Georgia, Ukraine, Bulgaria and etc. [3]. Pre-fabricated pre-stressed skeleton has been tested in theory and experimentally, under all kinds of possible loads (static, dynamic, seismic, impact, fire...) and it always showed, without exception, high safety coefficients. Verification and attesting of elements, joints and structure, as a whole, have been realized in former Yugoslavia, Hungary, Italy, Austria, Russia, Uzbekistan, Cuba, China and USA. The research results are verified on numerous international congresses of specialized experts and scientific organizations [2]. IMS Building Technology is used for virtually any type of buildings: residential, office, industrial, school, hospitals, houses, garages etc.

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering titled “Prefabrication Construction as an Alternative Structural Frame Construction Method for 40/60 Housing Projects in Addis Ababa – A Case Study on Megenagna Site” conducted by Belachew Yilma states in detail the cost savings of the IMS system by concluding that.

“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/m<sup>2</sup> to 2,964.51 Birr/m<sup>2</sup> and the difference becomes 1,078.03 Birr/m<sup>2</sup>, and that of conventional house (4,042.54 Birr/m<sup>2</sup>)” [4].

Both of the above theses show the advantage of the IMS frame system by focusing on the structural system of the construction method as compared with the conventional or cast in situ construction method which clearly shows the advantages with respect to cost and time, where by keeping the finishing works for the two systems the same.

That is what this study tries to address by focusing on the finishing work challenges that the researcher has faced working and observing with the IMS system.

## **1.2 Scope of the Research**

The scope of this project thesis is to study the challenges of the IMS construction system on the finishing works and analyze the findings in terms of cost, time and quality.

## **1.3 Research limitation**

This study is only limited to the difficulties and cost of finishing works upon the implementation of the IMS building system as compared with the cost of finishing on undertaking cast in place construction method.

The IMS system in Addis Ababa is offered by only the Ethiopian Construction Works Corporation, Building Technology & Construction Sector (ECWC BTCS) the former (PBPPE – Prefabricated Building Parts Production Enterprise) as a result, all the project site under consideration and observation for the IMS system are under the above company.

## **1.4 Significance of the Study**

The research is believed to alarm stake holders in the IMS building system by showing the current status of the construction capacity in contrast with the initial intended purpose during construction at the introduction stage of the system into our country.

## **1.5 Statement of the Problem**

In this project thesis the researcher have faced challenges as a site engineer working with the IMS system on site, that normally anyone wouldn't have faced working with the conventional cast in place (cast in situ) construction method This challenge has led the researcher to wonder if there may be a room for improvement of the technology that we are working within our country,

## **1.6 Hypotheses**

As the IMS system in Ethiopia has not been improved since its implementation in 1984, it is likely to cost more than the conventional construction system with respect to finishing works as it needs additional work to cope with the current amount of pipe laying and wire lugging, as the

IMS technology system has stayed stagnant rather than progressig.

## **1.7 Objectives**

### **1.7.1 General Objective**

The objective of this research is to study the challenges that arise with the use of IMS building system with respect to finishing works that are under construction in Addis Ababa.

### **1.7.2 Specific Objective**

The specific objective of this study is to identify the difficulties in undertaking finishing works on the IMS building system under construction in Addis Ababa. Also, to analyze the costs those arise with the difficulties of using this system specifically on finishing works.

And formulate a recommendation based on my findings to, be it a government or private entity as what can be done to alleviate this challenges or difficulties for further developing the technology.

## **1.8 Research Method**

The type of research employed on the preparation of this research work is explanatory – experimental. This is because of the fact that the IMS system is an already established engineering method of construction, but the problems that led the researcher to study the problems he have faced needed to be analyzed and explained why this is happening. As explanatory or analytical research aims to understand phenomena by discovering and measuring causal relations That is, it looks for causes and reasons. This study is also experimental in the sense of comparing two groups i.e. the IMS construction system and Conventional or Cast in Situ construction

The study could also be categorized under Applied Research as it is designed to solve practical problems of the modern world, rather than to acquire knowledge for knowledge's sake. Applied research also yields findings that can be evaluated in terms of local applicability [6] which is one of the specific objectives of this study.

### 1.9 Study Strategy

The study is carried out in four major phases, following the identification of the problem from observation of construction projects that use the IMS building system. At the first phase, a detailed literature review on prefabrication in general and IMS building system specifically was conducted. The system was investigated from different point of view such as speed, economy, flexibility, cost and so. During the second phase, data were collected through observation, interview and desk study. The third phase of the study was to analyze the collected data and discuss on the results obtained. And finally conclusions and recommendations were forwarded to improve the current practice of IMS building system in Addis Ababa.

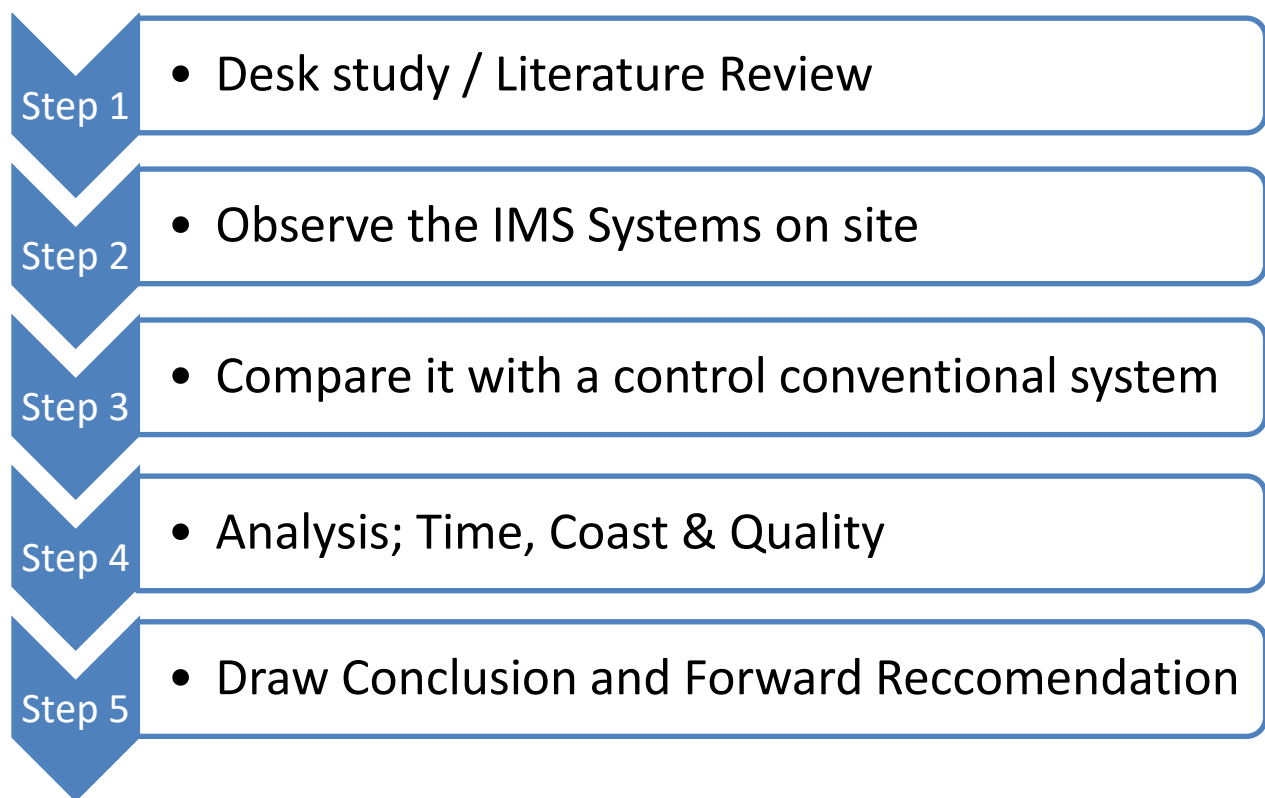


Chart 1.1: Work flow chart showing study strategy.

### **1.10 Research Instruments**

Observation, interview and desk study were the three major instruments that were employed during the course of this study. Interview was conducted among stakeholders of the IMS building system such as foremen; site Engineers, project managers and Production Managers at different level of responsibilities. Accordingly finishing work items were selected for further study and will be presented in chapter four and results will also be presented consequently in chapter five.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Introduction

Civil engineering and building construction is one of the oldest and most conservative human activities, seems to be faced with the challenge of industrial production, whose basic principle is serial production of standard elements [7].

The reason behind the standardization of elements is because of numerous objective factors, for example urban, architectural, humanistic, aesthetic, functional, those simple principles in building are not easy to be applied. Housing deficit in many countries, especially in cities, establishes demands for building apartments. Classic or traditional trade building way cannot accomplish efficient project realization within housing sector. In those situations industrial production application is unavoidable,

Standardized elements are made of various materials – wood, steel, bricks, concrete, plastic materials, which can be bought on market or produced in special factory section according to definite projects. Sections aimed for building elements, production requires certain investments proportionate to section capacity and to the desired building speed. Section capacity defining factor is the economic rationality and completed building price.

Our world is faced with a series of global problems now a days like the issue of environmental protection, energy saving, food and residence, appropriate for the numerous population of the world. All these problems have been mainly considered in two aspects: technical and economical. The difficulty of solving these problems lies in their enormous demands and on the other side financial and other potentials are disproportionate with the requirements. The problem of building of cheap residential units is very urgent in the developing countries, but it is also not negligible in the developed ones.

To overcome these shortages peoples have come about by devising solutions through the ages of the history of the construction industry. Here are some of the stages of developments below [7].

- i. **Traditional constructing** – masonry and concrete works are done at a construction site “in situ”.
- ii. **Advanced traditional constructing** – use of portable, sliding, space-tunnel and other forms aimed for concrete work in-situ, incorporating concrete and brick semi-prefabricates of less dimension and weight.
- iii. **Industrialized constructing** introduces a serial production principle of standardized building parts structure, accompanied by the classic constructing use of other building elements.
- iv. **Industrial constructing** – total prefabrication followed by the aspiration for serial production of all building elements as standardized.

**i. Traditional constructing**

Requests significant labor capacity for the realization of almost each building type. The building process is long lasting; trade methods are applied, without complete division of labor; machinery is not in use at all or is used in the lowest quantity; all operations are realized at the site, such as processing of forms, reinforcement cutting, bending & placing, plastering of concrete surfaces. Small dimensioned hollow concrete or brick elements are used for constructing. Finishing and installation works are processed in a trade way, without any more significant parallel process, accompanied by repeated working up of finally processed building parts accomplished after trade works [7].

**ii. Advanced traditional constructing**

Shortens the building period by the use of simple equipment and half-prefabricates employing trade constructing way and lesser plant investment. Advancing refers to concrete preparation in constant sections and delivered at the site by truck mixers, to already-made reinforced assemblies brought at the site and then incorporated and to special forms, as well, aimed for complex use, concrete incorporation plant – form or poker vibrator, small dimensioned elements – lintels, ceiling slab stems, staircase, installation assemblies of water supply and drainage, windows, doors; wall, floor and ceiling covering [7].

### **iii. Industrialized constructing**

Combines industrial principles – labor division and serial production of elements (the most usual structure prefabrication) – followed by advanced trade constructing ways for the buildings parts, where standardization and prefabrication are not rational or offer rigid and non-functional architectural solutions (different form types for repeated use portable, sliding or tunnel are applied). Serial production of selected standard elements, organization and parallel activities concerning production and prefabrication process, abbreviate the constructing period, use material and labor rationally, controls work and element quality but requires significant investment in equipment, transport and erection facilities for larger and heavier elements or adequate forms [7].

### **iv. Industrial constructing – prefabrication**

Absolutely respects the division of labor principle and a serial element production of the whole building. Elements are, as a rule, multi-functional, so that they contain, for example, installations, incorporated windows, doors or ceramics. Several various materials are used in section, which makes the production technology complex [7].

Compared with the other three construction systems prefabrication or industrial constructing system requires a significant initial investment for setting up an organization (production facility), production equipment, transport and assembly and specialized labor, as well.

Prefabrication is the process of manufacturing of standardized products of components prior to assembly on the site essentially to mechanize the traditional site operations also commonly known as prefab, has gained the attention of housing experts as an option for low-cost housing.

There exists different traditional prefabrication technologies applied all over the world, These include prefabricated moveable thatched roofs in Ethiopia, Vietnam and Mexico, bamboo panels in Latin America and in Asian architecture, the prefabricated timber elements. Such prefabrication technologies are mostly encountered in informal and unauthorized housing areas in the developing countries.

The use of precast concrete members by the construction industry has increased rapidly throughout the world over the past decades. Advantages such as speed of erection, better quality, dimensional precision and above all, reduction of cost have made precast concrete superior to the cast-in-situ concrete. The satisfactory performance of a precast structure as a whole, and its economy, depend to a great extent on the proper selection of appropriate range of elements available and its connections. Basing on present practice experiences, positive and negative, it is possible to choose an optimal construction way for given local conditions, to organize needed sections and to resolve a social problem – building necessary number of suitable quality apartments within the required period [7].

Optimal results in modern constructing are reached by regular estimate of element prefabrication level of a building, by estimate of economic rationality of series, relevant for building performance quality and for satisfying future users' requests, as well. According to this, previous investments in production section get lower, while necessary assortment of building elements is completed from the market. The mentioned utilization way of element prefabrication is called “open prefabrication”. According to contemporary tendencies in building, especially in housing, open prefabrication is considered as one of several acceptable ways aimed for project realization of a wider scope.

Whereas Pre-casting avoids the traditional restraints inherent with in-situ work such as formwork erection, steel fixing, Concreting and Service installation. It allows removing the risk of delay in any of the critical activities that completely hinder the progress of construction works [2].

The concept of precast construction also includes those buildings where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. These components are manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost. The main features of this construction process are as follows [8].

- The division and specialization of the human workforce
- The use of tools, machinery, and other equipment, usually automated, in the production of standard, interchangeable parts and products

This type of construction requires a restructuring of the entire conventional construction process to enable interaction between the design phase and production planning in order to improve and speed up the construction. One of the key premises for achieving that objective is to design buildings with a regular configuration in plan and elevation.

Many countries used various precast building systems during the second half of the 20th century to provide low-income housing for the growing urban population. They were very popular after the Second World War, especially in Eastern European countries and former Soviet Union republics. In the former Soviet Union,

## **2.2 Categories of Precast Building Systems**

Precast buildings constitute a significant fraction of the building stock in the republics of the former Soviet Union and Eastern European countries. Depending on the load-bearing structure, precast systems can be divided into the following categories: [8].

Large-panel systems / Space girder systems – box units

Frame systems / Linear girder system – columns & beams

Slab-column systems with walls / Surface girder systems

Mixed systems

### **2.2.1 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. These panels form a box-like structure (see Figure 2.1). Both vertical and horizontal panels resist gravity load. Wall panels are usually one story high. Horizontal floor and roof panels span either as one-way or two-way slabs. When properly joined together, these horizontal elements act as diaphragms that transfer the lateral loads to the walls [8].

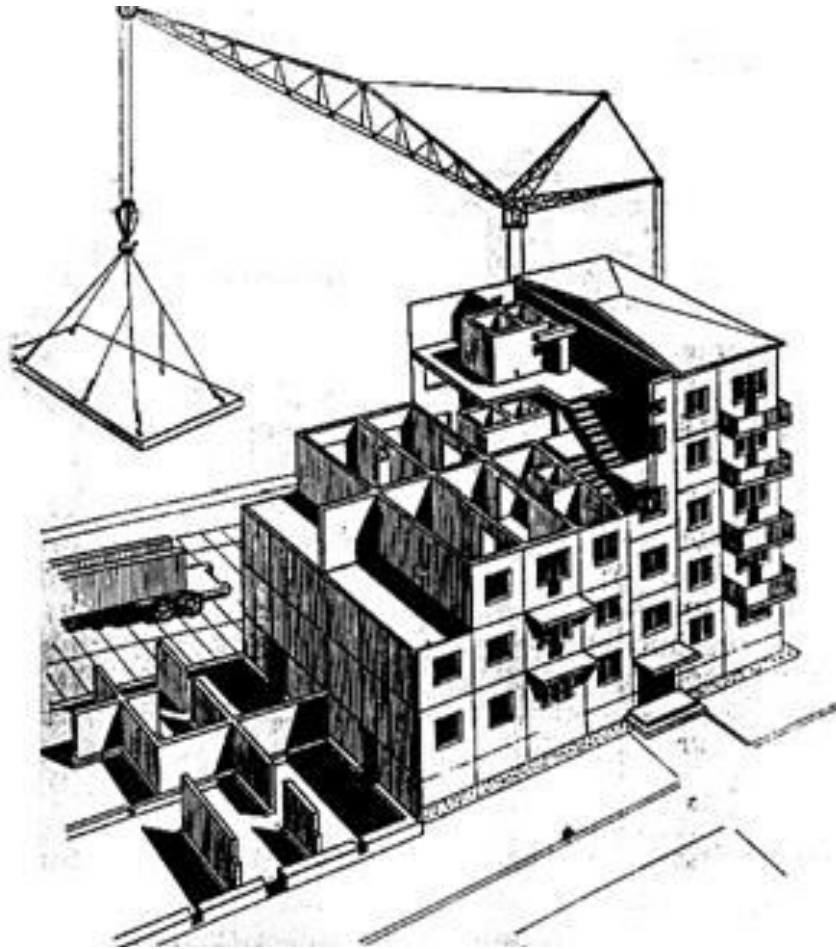


Figure 2.1: A large-panel concrete building under construction [8]

The above system can also be categorized under Space girder systems – box units.

### 2.2.2 Frame Systems

Precast frames 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 [8].

Frame systems have privilege at the structural system choice because of the lowest limitations for architectural design. Those systems enable flexibility and varying of architectural-urban solutions, minimal material structure consumption, and easy prefabrication. Weight and volume can be adapted to means of transportation. Building structure requires a material, which successfully captures all kinds of loads, and concrete imposes itself as optimal, because wood and steel are sensitive at fire [7].

Other building elements are defined in accordance with basic dedicated functions. Frame closing is possible by non-payload-bearing elements and can be made of material possessing more favorable characteristics for thermal and acoustic protection. Frame in-filling is possible on traditional mode using available materials and labor, such as in-filling of prefabricated elements, for example: for facade and partition walls, sanitary panels or cabins – if they are present at the market or if it is financially justified to produce them in a factory section [7].

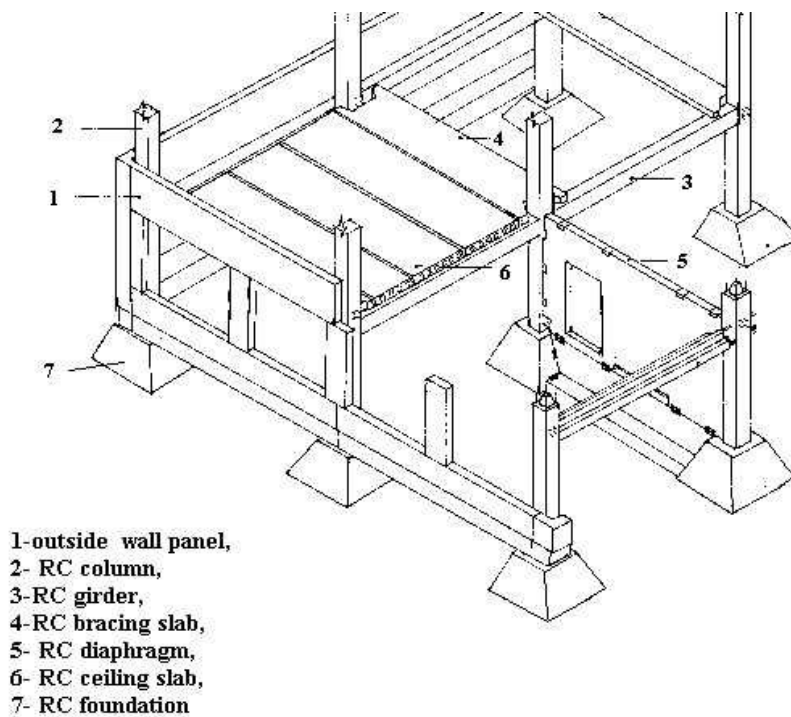


Figure 2.2

Figure 2.2: Components of a precast reinforced concrete frame system [8]

### 2.2.3 Slab-Column Systems with Shear Walls Surface girder systems – bearing walls, slabs

These systems rely on (cross and longitudinal bearing walls) shear walls to sustain lateral load effects, whereas the slab-column structure resists mainly gravity loads. There are two main systems in this category.

- a) Lift-slab system with walls.
- b) Pre-stressed slab-column system.

#### 2.2.3.1 Lift-slab system with walls

Lift-slab systems were introduced in the last decade of the Soviet Union (period 1980-1989) in some of the Soviet Republics, including Kyrgyzstan, Tadjikistan, and the Caucasian region of Russia, etc. This type of precast construction is known as “Seria KUB.”

The load-bearing structure consists of precast reinforced concrete columns and slabs, as shown in Figure 2.3. Precast columns are usually two stories high. All precast structural elements are assembled by means of special joints. Precast concrete floor slabs are lifted from the ground up to the final height by lifting cranes. The slab panels are lifted to the top of the column and then moved downwards to the final position. Temporary supports are used to keep the slabs in the position until the connection with the columns has been achieved. [8]



Figure 2.3

Figure 2.3: A lift-slab building of “Seria KUB” under construction [8]

### 2.2.3.2 Pre-stressed Slab-column system

It 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 Cuba, the Philippines, and Egypt.

A typical building under construction is shown in Figure below.

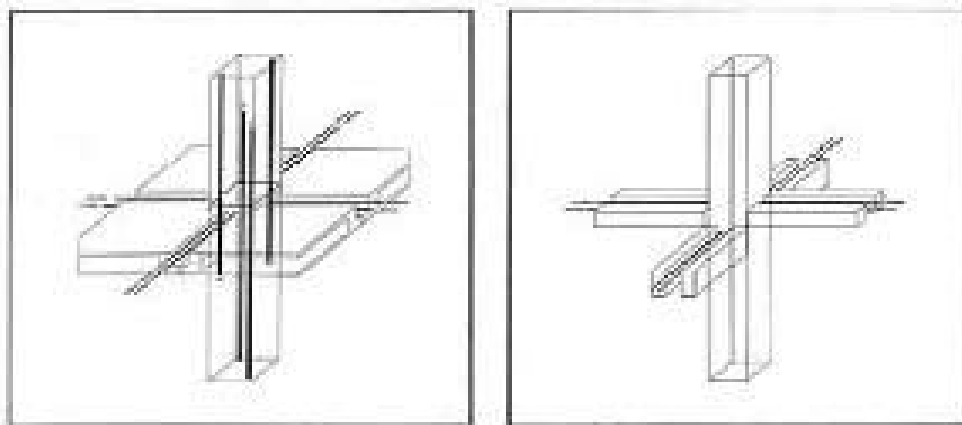


Figure 2.4

Figure 2.4: Post-tensioned slab-column connection [8]

#### **2.2.4 Mixed Systems Combination of Linear and Space girders – columns, beams, walls and slabs.**

Structural system realization, be it one of the above systems can be achieved by construction technologies. Large scope and efficient project realization from the housing field comprises industrialized building system application. Many countries' experience confirms it, developing or developed ones, which resolved or are resolving the housing deficit problem. The most favorable results are accomplished by standardized building elements for the construction of non-standardized spatial building solutions [7].

This is the basic criteria for the construction mode choice with the starting assumption for industrial efficiency achievement (speed, quality, price) and the possibility of getting the authentic housing quality for the definite environment and user (architectural space design, individual needs and possibilities of each participant of a building house process

At the choice of a building system technical/technological characteristics are considered, as well as resulting financial effects, then characteristics relevant for urban and architectural design, as well as specific demands caused by the location (earthquake, storm winds, development state of a local building practice etc.).

### 2.3 IMS Building Technology

IMS system, as flexible and open in relation with spatial building form and interior space contents, but also with styles in architectural design, seems to be convenient for the realization of the most various urban-architectural assignments. Success of designed solution is proportional to the integration level of architectural decisions with structural element characteristics and their production process and, as well, erection at the site.

The IMS Building Technology is an advanced system for accelerated construction with prefabricated elements of the skeleton.

This unique system is based on the pre-stressed connection of the structure elements was developed by Prof. Branko Zezelj at the IMS Institute in Belgrade. It was first implemented in 1957 and is since constantly being upgraded. The idea was simple – to build standard buildings by use of standard elements. The toughest problem – the connecting of the elements of the concrete frame, made of prefabricated columns and slabs, was resolved through the application of steel cables aimed for the post-tensioning process. It is a revolutionary idea that required numerous researches and proofs, first of all, in the field of durability and stability and the in the field of architectural design and possibilities to be justified in practice as a universal technology for all kinds of high-rise structures [2].

The Technology is used for virtually any type of buildings: residential, schools, hospitals, houses, offices, light industrial edifices and various others. The testing of the adaptation of this structure to local conditions was not only limited to Yugoslavia. The feasibility studies for this technology application with obligatory adaptation to local resources, were also done for many other countries (Angola, Australia, Azerbaijan, Belgium, China, Cuba, Egypt, Ethiopia, Georgia, Indonesia, Iran, Israel, Italy, Malaysia, Hungary, Philippines, Russia), while in many of these countries, the IMS building technology has been successfully applied [2].

According to Goran Petrovic more than 150,000 numerous Buildings, Apartments and have been built in the above listed countries.

## 2.4 General Features of the IMS System

The Integrated Modulus System (IMS) building technology is a system of load bearing construction with prefabricated elements of the skeleton. IMS is a modular system. A square or a rectangular module is, 3.6m by 3.6m up to 7.2m by 7.2m and forms the basic unit. All other combinations can be made in the range between 3.6m to 7.2m. The module is composed of four columns and the floor between them. Slabs and columns are linked together by post tensioning. Full set of components includes; Column, Normal or Cantilevered Floor Slabs and Stairway-supporting Staircases Girders and Steps, Edge Girders, Shear walls (Stiffening Diaphragms), Exterior wall Panels, Partition Walls [9].

Basic standard reinforced concrete elements (Footing pads, columns, floor slabs, beams, stiffening walls (Shear walls), and stairs) which define space, where untypical spatial solution can be realized.

Complementary elements (facade and inner walls, sanitary walls, sanitary cabins, non-standard staircases etc.) defined according to definite project requirements (choice of material and technical solution), assign a building category as “low cost”, “affordable housing” or others by its quality and price.

An important characteristic of the IMS Building Technology is that it represents an open system which can accommodate various sub-systems, differing in both Technology and Materials. It offers a wide variety of different buildings produced out of relatively small number of typical elements [9].

**Footing Pads** (concrete grade M 40), used to transfer the whole load of the prefabricated system to the ground. Their sizes can range from 80 x 80 - 140 x 140 and 200 x 200cm depending on the soil conditions of the site in which the building rests on. It also depends on the use of the structure, for example for either Commercial or Residential as they use different factors for calculating active and dead loads imposed on the structure.



Figure 2.5a



Figure 2.5b

Figure 2.5a: Precast footing pad (inverted) at the production plant, ready to be transported

Figure 2.5b: Precast footing pad arrangement on site at AAMZLA

**Columns** (concrete grade M 40), continual through maximum 3 stories (depends on their cross-sections and story height or possibilities of the crane used for erection), possessing square cross-section – dimensions: 30 x 30 – 60 x 60 cm.



Figure 2.6a



Figure 2.6b

Figure 2.6a: Precast columns

Figure 2.6b: Precast initial column erection at AAMZLA

**Floor slabs** (concrete grade M 40) cover space between columns and can be manufactured with or without concrete ceiling, as one-piece (spans until 3.6 x 4.8 m) or multi-pieces aiming to adapt dimension for transportation and erection(ceilings made for the span 9.0 x 9.0 m are constructed from nine standard elements); the marginal girder and waffle web height is 20-40 cm (depending on column span between which space is covered), floor slab depth between coffer webs is 4-6 cm, and the ceiling one is 3cm.



Figure 2.7a



Figure 2.7b

Figure 2.7a: Precast slab during lifting

Figure 2.7b: Precast slab arrangement on columns

**Cantilever floor slabs** (concrete grade M 40), which replace edge beams in architectural solutions where balconies, loggias or other housing space out of column span are required and which are connected only to two columns (as a cantilever) and their height and length correspond

to floor slabs near which they are erected, while their maximal width is limited on  $1/3$  of the longitudinal span. They are waffled and can be with or without concrete ceiling.



Figure 2.8a



Figure 2.8b

Figure 2.8a: Precast cantilever slab on steel supports

Figure 2.8b: Precast cantilever slab after post tensioning

**Edge girders** (concrete grade M 40) have a boundary position in order to form frame beams and facade construction. Their lengths and depth are the same as at corresponding floor slabs with which they form a frame beam and their width is chosen according to architectural requirements for the adequate type of facade walls.



Figure 2.9; Precast girder [8]

**Stiffening walls** (Shear walls) (concrete grade M 40) are reinforced concrete panels (minimal depth – 15 cm), which stiffen the frame. They are positioned, by the rule, in the axis of two adjacent columns, having a function to form, together with columns, a structural element from foundations to the roof, ready to receive required intensity horizontal forces (in practice, those elements are often set in concrete in situ, especially at larger spans for the reasons of huge dimension, weight and slow frame erection).



Figure 2.10a



Figure 2.10b

Figure 2.10a: Precast shear wall on a special transportation lorry [7]

Figure 2.10b: Precast shear wall at Kality production plant

**Stair cases** (concrete grade M 40) they may be a single or double flight according to the architectural requirements of the building in consideration they came in a standard size of 1.2 m width in Ethiopia. If the stairs used are double flight then we introduces the next element which is the Landing.

**Landing** (concrete grade M 40) this elements are used for two flight stairs in between the consecutive floors. They are produced in a standard size as that the center to center distance between two consecutive columns, usually 4.22 in Ethiopia's case.



Figure 2.11a



Figure 2.11b

Figure 2.11a: Single flight stair case

Figure 2.11b: Double flight stair case and landing at Kality production plant

Elevator manholes – in practice those elements are set in concrete in situ, because of non-rational series (small number of elements in constructing building in relation with the mold price for manufacturing within the own section), which, by the rule serve for the acceptance of horizontal forces together with stiffening walls. Stair elements for one-flight, double-flight or triple-flight stairs with monolith or prefabricated steps.

The envelope of the building – façades and roofing, as well as interior walls and surfaces, installations and equipment are not standardized. That means that any type of local material or procedure can be applied in order to obtain sustainable, energy-efficient and cost-efficient housing.

Contemporary housing requirements are related with the building performance standards which are described here under [2].

- Stability under static, dynamic, seismic, fire loads.
- Building functionality followed by appropriate comfort and architectural, urban, aesthetic and other requests.
- Preservation function – physical, thermal, acoustic, fire protection, protection from atmospheric influences, environment and identity protection, as well.
- Power savings during the construction process and premises exploitation.
- Financially acceptable price for the appropriate standard and minimally established building qualities.
- As an absolute priority request, stability is provided by the system choice of the building construction. Load acceptance and transferring forma construction system or a structural system.

The international practice of the IMS system contains additional complementary elements from the basic standard reinforced concrete elements (columns, floor slabs, beams, stiffening walls and stairs) which define space, where untypical spatial solution can be realised.

Complementary elements are facade and inner walls, sanitary walls, sanitary cabins, non-standard staircases etc. defined according to definite project requirements (choice of material and technical solution), assign a building category as “low cost”, “affordable housing” or others by its quality and price.

An important characteristic of the IMS Building Technology is that it represents an open system which can accommodate various sub-systems, differing in both Technology and Materials. It

offers a wide variety of different buildings produced out of relatively small number of typical elements [9].

IMS system, as flexible and open in relation with spatial building form and interior space contents, but also with styles in architectural design, seems to be convenient for the realisation of the most various urban-architectural assignments. Success of designed solution is proportional to the integration level of architectural decisions with structural element characteristics and their production process and, as well, erection at the site [2].

Flexibility in essence, the IMS system is defined as flexible and open for various technical and spatial solution applications. For architectural design the following kinds of flexibility are significant

- i. Structural flexibility (flexibility of the structure), choice possibilities of structural span followed by variant solutions of system complementary elements, by shape and processing level, of various floor slabs (with or without complementary acoustic and thermal protection or finishing ceiling processing):
- ii. Spatial flexibility (flexibility of space), possible architectural solution variant within a housing unit or building, which might be realised during designing, construction or exploitation.
- iii. System flexibility, In both of the above cases (structural and spatial) it enables efficient building realisation within phases. Miscellaneous comfort building realisation from the same structural elements is possible (works influencing standard and comfort do not influence essential changes of the production process).

Choice of structural spans;

Structural spans are defined basing on architectural building solutions, considering the building function, conditions of the element system production, transportation and erection. Rational spans are 2,4m-7,2m. Larger spans can be realised as well, but the choice is approved by economic justification.

The span choice is essential because it indirectly determines form and dimension of other system

elements, but the building character in a whole, as well. Spans lower than 4,8m, in all combinations, are regularly realised through single floor slabs. Dimensions might cause a problem of public traffic transportation, in a case when elements are larger than 3,6m x 4,8m; this is the reason why larger spans are divided on two or more parts. At the same time appears the possibility of greater span number realised with the same elements. The slab example, dimensions 7.2m x 7.2m, shows that three-part slabs easily form following spans: 2.4 x 7.2, 4.8 x 7.2 and 7.2 x 7.2m, which enables architects to offer more various solutions during space shaping using standard structural elements [2].

Smaller spans use narrower cross-section columns (for technological reasons minimal span is 30 x 30 – 40 x 40cm), so they are convenient for medium storey housing buildings. Larger spans are appropriate for buildings which, besides housing, possess some other function – garages, offices, and do not need a large number of columns (cross-section 60 x 60 cm). Depending on a span, material consumption discretely varies.

Standards, norms, comfort;

All system elements, basic and complementary, used for architectural solutions, are brought into accord with relevant regulations of the country where they are to be applied (designing and constructing). When minimal requirements are realised, referring to space, static and dynamic stability, fire protection; minimal housing standard buildings are obtained. Quality and comfort of the building as a whole, but the quality that defines a higher standard, as well, are determined by finishing works, amplified thermal and acoustic protection etc.

Facade – extern and inner walls;

Facade and inner wall position is not limited by structural requirements of the IMS skeleton system. Facade walls can be foreseen in continuity out of basic structure plane – “hidden assemblage”, or with interruptions for each storey height - “visible assemblage”. Walls can be realised in a trade way or using prefabricated panels (one-layered or sandwich) or combining the both, depending on building function and chosen materials.

Loggias, balconies, closed bay windows;

All common elements used for forming spatial plastic on building facade – loggias, balconies or bay windows can be realised by the IMS system. Cantilever floor slabs and edge beams are used for balconies and various bay windows.

Vertical communications;

Stairs (one-flight, double-flight or other) are designed in the framework of especially defined floor slabs, easily manufactured within a plant.

Architectural solutions of staircase space (stairs and elevator) are desirable, containing space between columns, so that there is no need to manufacture non-standard slabs.

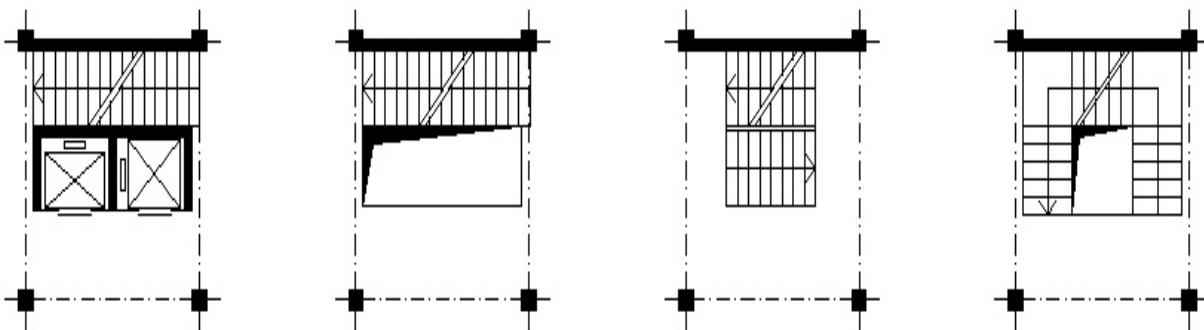


Figure 2.12

Figure 2.12: Variant stair solution [2]

Utility Ducts/ Lines;

All vertical utility ducts (plumbing and sewerage pipes, ventilation conduits, chimneys etc.) rally by the rule and are to be placed through previously defined apertures in floor slabs, which are manufacture in plant sections without changes of the production equipment. Small dimension openings for individual vertical conduits can be realised in a trade way, on erected skeleton, in situ. All other designing decisions do not especially differ at the IMS system.

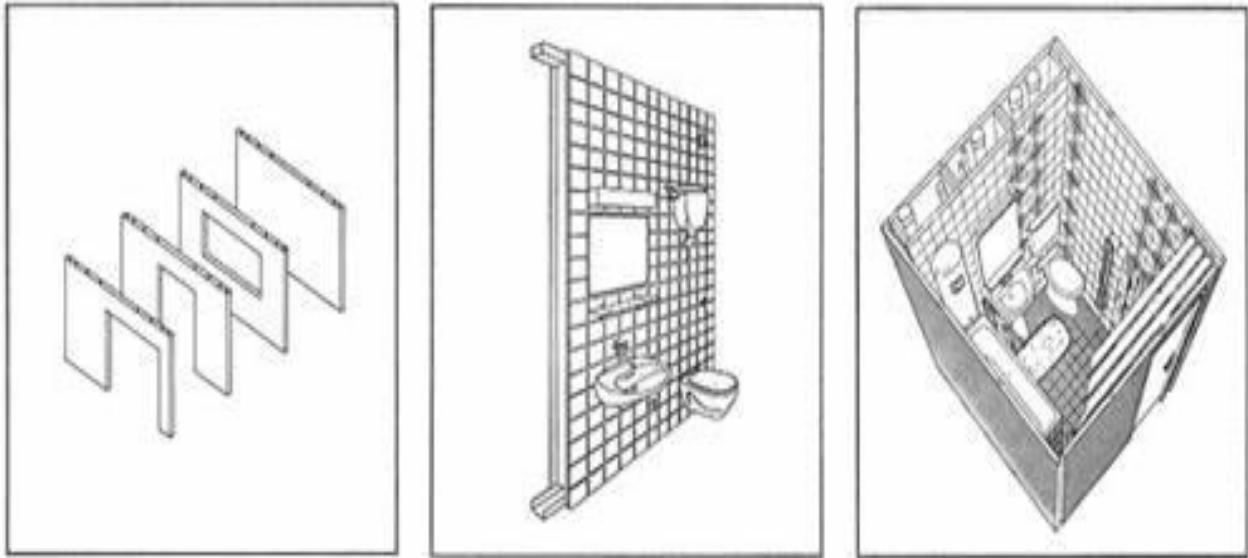


Figure 2.13

Figure 2.13: Variant utilities and window solution [2]

Ecological Regularity;

All basic IMS system elements are made of reinforced concrete, and, by the rule, are considered as ecologically regular. Complementary elements chosen for definite design project should possess proves of the used material ecological regularity.

Durability;

Basic building elements of the IMS system are made of durable materials and so are the buildings. By the material choice for complementary elements durability of the building, as a whole, is defined. High level of spatial flexibility concerning the IMS system enables, according to the needs, building reconstruction and rehabilitation, which offer functional durability.

Some of the benefits of the IMS systems are mentioned as follow [3];

- Construction takes shorter time and the investor will be able to use the building for the intended purpose in a shorter time.
- Minimizes the use of concrete and steel.

- Reduction in cost of formworks, scaffoldings and temporary supports can be achieved. For instance, 1m<sup>3</sup> of monolithic concrete requires approximately 0.12 to 0.15 m<sup>3</sup> wood for formwork and scaffolding, while 1m<sup>3</sup> precast concrete requires not more than 0.01 m<sup>3</sup> of wood.
- Reduced amount of wet work on site which reduces the demand of local site labor.
- Adverse weather conditions do not affect the construction of precast system.
- Precise molds could be used for the mass production of units and these molds could be re-used for considerable repetitions.
- Due to the use of trained and specialized personnel working under factory conditions, good and standard units can be produced. Thinner and more efficient shaped members could be produced.
- Sub-standard products can be inspected and rejected before the erection of the system.
- Conduits for other services can be incorporated into the units during production of the units.
- Different shapes and finishes may be achieved after a long experience of using variety of materials.
- Extension of structures or if required, the dismantling of certain structure and re-erect elsewhere is possible.
- It offers better fire protection and requires little maintenance.
- Specifically, the IMS system precast concrete construction does have considerable saving in material and labor. The indices of material and manpower input in the IMS framework construction per m<sup>2</sup> total area for 4.20x4.20m span is 0.1374 m<sup>3</sup> concrete, 10.33kg reinforcement, 1.4kg pre-stressing steel and a total of 3.06 hours for manpower involvement in production, assembly, and cable tensioning. The cost indices per m<sup>2</sup> of apartment space indicate 45% of material and 35% of labor saving compared to the conventional building construction system. Totally, a cost saving of 25% can be achieved using the IMS system.

However, on the other hand, the shortcomings of precast as compared to the cast-in-situ concrete can be summarized as follows [3];

- The high quality units produced at factory always pose the greatest problem at joints between the members.
- Last minute changes cannot be accommodated once the units are cast, therefore a high standard of design, detailing and checking is required.
- The units require some additional reinforcements for handling, transporting and erection as well as for stress conditions pertaining to the same.
- Large size units may require considerable storage area, transportation and erection costs.
- Pre-casting is economical only for regular feature buildings and for molds with high degree of repetition.
- The lifting capacity and range of cranes available govern the size and weight of the precast units.

Also **Radovan Dimitrijevic** states the original concept of the IMS building technology consists of several basic features, namely [10];

- the load-bearing structure is represented by concrete skeleton strutted by shear walls, which offers a universal possibilities of applying the structure in highly seismic zones, that is, in zones with the strongest winds;
- the joints between the elements of the load-bearing structure are implemented by pre-stressing with the use of adequate equipment;
- the selected IMS structural system has universal application for all types of buildings in housing which results in maximum flexibility offering architects a wide range of possibilities and liberties as regards functional and architectural shaping of buildings with a very small number of restrictions;
- relatively small number of standard structure elements, together with a simple way of production, prefabrication in large series and in factory conditions (either in workshops or in outdoor plants), enable the construction of unique architectural structures;

- high-quality materials - concrete and steel are applied, as this is a precondition for stability and durability of the load-bearing structure, as well as for low operating costs, while the quantity of the applied materials is rather small;
- it is possible to apply secondary systems from "open prefabrication" (elements which are also used in other building systems), as well as local materials and products, with the participation of the local manpower;
- relatively small number of standard structure elements, together with a simple way of production, prefabrication in large series and in factory conditions (either in workshops or in outdoor plants), enable the construction of unique architectural structures;
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- it is possible to apply secondary systems from "open prefabrication" (elements which are also used in other building systems), as well as local materials and products, with the participation of the local manpower;
- there is wide range of possible structural spans, which means that the IMS skeleton structure can be used to form very diversified designs, both regarding the layout and the volume; efficient organization of designing by using catalogues of structural elements, with computer data processing, enables very fast estimation of different variant solutions; quality control systems are applied on designing, production and assembly of elements.

### 2.5 2.7 Advantages of IMS Building Technology

Belachew Yilma has concluded that the IMS building technology is cheaper as a structural system than the Conventional cast in situ construction system.

In his research Belachew has concluded that “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.” [4].

This shows that the IMS system is more economical than the traditional or conventional system by a detailed scientific method unequivocally. Here are also the benefits of the IMS system as forwarded by Goran Petrovic, B. Sc. Architect [2]

- **Low-cost:** Significantly reduces building costs and accelerates investment turn over time; Minimizes the use of concrete and steel; Increases building durability; is a high return investment; does not require high-tech equipment.

The cost of IMS superstructure is relatively low. The reasons are various: first of all, this is an industrialized system, all structural components are studied theoretically, by full scale tests and in course of many years of practical application – low consumption of materials is fully justified; second, steel molds can be applied hundreds of times, IMS assembly equipment makes the use of expensive timber negligible; third, IMS Building Technology is de facto not sensitive to rainy seasons and typhoons– minimum precaution measures can practically neutralize negative impact of these; fourth, IMS superstructure construction is fast and the progress is fully controllable.

- **Safe:** Pre-stressed structure dissipates kinetic energy caused by seismic activity or hurricanes and resists to earthquakes up to 9 degrees of Richter’s scale.

Is a unique technical solution, providing fully integrated structural framework composed of the pre-cast elements and assembled by post-tensioning. All joints have

the capacities that are at least equal to the capacities of the joined member sections; specific application of post-tensioning, theoretically studied and experimentally proved joints and appropriate assembly technology secure this. No weak joint stake place and the assembled pre-cast post-tensioned framework superstructure acts as a fully integral structural system. In course of almost 50years of the worldwide application, no cases of structural failure have been recorded.

- Fast: Accelerates building and diminishes construction time; Prefabricated elements can be produced in any season, weather or climate.
- Sustainable: Local materials or procedures can be applied on façades, roofing and interior surfaces, in order to obtain sustainable, energy efficient and cost-efficient housing; Local human resources can easily be trained both to produce elements and carry out the building construction; Enables flexible solutions, greater space-planning capabilities and wide range of possibilities for building interior design.
- Using high quality of materials as are pre-stressed concrete and steel for pre-stressing, information technology for search on knowledge bases, certain algorithms for different resistance calculations, expert systems for quick evaluation of solution from different aspects, the IMS technology enables, in every real case, a choice and optimization of the suggested solution, that is of the building system.

## 2.6 Experiences in precast Concrete

### 2.6.1 The Soviet Union / Russian Experience

The Russian started experimenting with precast concrete in the pre-war years; precast concrete members were manufactured by the most primitive methods mainly at the building sites with few specialized and well equipped factories. So the production was focused on the production of heavy members at the place of installation and the members were produced at casting yards using wooden molds and formworks. The manufactured members were cured in the open air. The erection of the precast members was carried out with the aid of booms, derricks, tower cranes and crawler cranes, which were not sufficiently provided for all building sites.

The advantages of precast concrete over monolithic concrete and metal structures have led to its popular use in the Soviet Union. The growth in the production of precast concrete was coupled by the growth of enterprises engaged in the manufacture of these products and the improvement of the production technology. Precast concrete technology was introduced in the former Soviet Union in the late 1920's, but it found especially wide application between 1930-1936, mainly for industrial constructions and for the erection of single-story buildings. The most interesting building structures built with precast concrete members witness the scope of its application at that time. In 1950 and 1955 the volume of precast concrete equaled 1,290,000 m<sup>3</sup> and 5,260,000m<sup>3</sup> respectively. In fact the precast members were combined with monolithic reinforced concrete, wooden and sometimes steel structures in the same construction project [11].

Buildings erected with precast concrete in the former Soviet Union / Russia from 1925 to 1940 are so many out of which it is worth mentioning one - story industrial buildings, a number of 3-5 story production blocks, etc. The precast concrete has been in use for a long time mainly for the construction of single-story industrial buildings, but was not employed for residential buildings until recent years. The assortment of precast concrete products was considerable and it comprised of the following structural elements.

- rectangular columns, with length reaching up to 15m,

- Roof beams rectangular, T-, I- and box sections up to 10m. length,
- Crane runways, continuous simple beams with spans of 6m.
- One story single-span frames made up of one member or composite (comprising columns and girders)
- Roof trusses with 15 to 22m spans and arches with 27.5m spans
- Small span slabs (solid and ribbed) and stair ways and landings.

### **2.6.2 The European Experience**

Extensive development of the precast concrete industry has taken place in Europe following the Second World War as a result of specific, social and economic conditions at that time. System building in Europe was spurred as a result of housing shortage following the war. The reasons behind the shortage of housing was the destruction of the housing stock by bombing, and the fact that housing construction had been interrupted for the major portion of the war years, increasing numbers of new households and a large degree of resettlement and relocation. Not only the physical shortage of housing, but also shortage of skilled labor in construction industry has coupled the problem leading more towards systems building, especially precast concrete construction [11].

Precast concrete construction required fewer skilled workers than the traditional construction, and also significantly reduce the required time for construction of housing. In addition to the wide spread shortage of lumber and structural steel across Europe for formwork precast construction of housing stood as the exclusive choice of the time.

The main factors that contributed to the success of precast concrete systems in Europe can be attributed to the intervention in the housing market on the part of the governments. Governments especially in Eastern European countries, where government controls over the construction industry and the land market, have realized the incredible need for housing, and have extensively funded numerous programs. For instance in Russia between 1950 and 1968 housing was provided for almost 120 million people the majority of this housing being precast concrete systems. As quoted by Sullivan, in 1953 in France, the government through the Ministry of Housing sponsored a large scale precast concrete housing project for over 4,000 units. By formulating

favorable policies and sponsoring large-scale housing projects governments in Europe aided and encouraged the development of pre-cast concrete construction. [11]

### **2.6.3 The American Experience**

Initially, in North America, the housing industry was fragmented and substantially diluted having more regional nature than in many European countries. 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 [11].

The reasons behind this was

- high costs of the systems relative to the existing traditional housing construction
- initial capital costs could not be justified
- inadequate feasibility study and incorrect marketing strategies and
- Problems in a 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. 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 institute has a regular magazine through which new developments in the field are made known to the public. [11]

Since the early 1960s the precast concrete has been used in the United States and some of the major projects can be mentioned here to show the degree of its utilization for civil engineering works.

### 2.6.3.1 The Boston College parking structure

The 989 Car parking seven story building has 29,800m<sup>2</sup> of floor space. The cost of the structure was \$12 million US dollars out of which the precast contract amounted to \$4.3 million US dollars. The predominantly precast concrete parking structure shown in figure 2.15 is composed of 960 varieties of architectural and structural precast/pre-stressed concrete components. It provides an aesthetic and functional link between the colleges lower and middle campuses. The objectives of project were to optimize the number of parking places and to facilitate smooth traffic flow while providing the college with an economical and aesthetically pleasing structure. [11]

Precast concrete was an ideal solution for the structure because it had to be built within a tight budget and on a fast track schedule. Since completion, the parking structure has received high praise from the college and design community. It was selected as the recipient of the "Best Parking Structure" award in the 1995 PCI Design Awards Program.



Figure 2.15

Figure 2.14: The Boston College car parking structure

#### 2.6.4 Yugoslavian Experience

The problem of the construction industry in Yugoslavia was 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 [3].

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. 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 [11].

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.

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.

Citing only some of the most noteworthy buildings and housing estates erected by the IMS system, one can show the success of the system over the past years. A large number of residential buildings of this system have certainly been erected in Belgrade. Between 1963 and 1980, Napred of Belgrade built about 6000 apartments and in 1978 a work on 3600 apartments was commenced. Using IMS technology one contractor, Neimar, alone has built some 15,000 apartments, several office blocks, schools a departments store and a hotel in Novisad.

Several contracting firms have been using the IMS technology. Two of them, the Technograd of Tuzla, has built 2500 apartments in new Alipasino Polje housing state in Sarajevo, and the contracting firm Kozara, has built about 7000 apartments in Banja Luka and its environs in the period from 1962 to 1982. These buildings have brought the IMS system valuable credentials since they withstood, with negligible damage or only slight damage to the secondary elements, the catastrophic earthquakes which hit the region in 1969 and 1981. [11]

The IMS system has also gained recognition outside of Yugoslavia. It has been widely accepted in Cuba. It is applied in Hungary, Egypt, Angola, China, Russia, Austria, Italy and Ethiopia of course.

## CHAPTER THREE

### THE ETHIOPIAN EXPERIENCE

#### 3.1 Historical background

The utilization of concrete as a building material was not that much widespread before the Italian invasion, as Engineer Tadele Butul (one of the first practicing engineers during the reign of Haile Selassie II) described on a Television interview aired by Fana Broadcasting Corporate FBC [12]. During the Italian occupation a wide range of plain and reinforced concrete arch bridge structures were built all over the main highways. Stone was used for the construction of buildings which stand to the present day in the military garrisons of that time and these eventually grew to urban centers. Even after the independence, the utilization of concrete as a building material was mostly limited to the capital city, Addis Ababa.

##### 3.1.1 The ESBU Model Project

The first of its kind prefabrication project in Ethiopia is the Ethiopian Schools Building Unit (ESBU) which was the first intervention of the African Development Bank (ADB).the Primary Teacher and Secondary Education Project (referred to as the Education I Project), that was approved in March 1983. It was financed by ADB (16.579 million) and Government of Ethiopia GOE (2.109 million). The project aimed at improving primary education, upgrading polytechnic and secondary schools, development to vocational technical schools, in addition to institutional development. All facilities have been completed and are fully operational [13]

The implementation of the Education I Project experienced serious difficulties leading to delays. The major cause of the delays was the poor performance, and eventual collapse, of the Ethiopian Building Construction Authority (EBCA), that had initially carried out the construction contracts, under Force Account Other delaying factors included the prevailing security problems of the mid-1980s and the related chronic shortage of building materials. However, the completed facilities have had a high impact, especially within the context of the current reconstruction of the country.

The ESBU model elementary schools can be seen in various parts of the country. Locally available materials were mostly used in the construction except reinforcement, steel and roofing. The production of the elements was carried out on the site and the time required for erection was small. The main elements produced were an I-shaped columns and small solid wall elements. The columns were light in weight that the requirements of crane were out of question. Ultimately, the unit emerged as a big construction entity, the former Ethiopian Building Construction Authority (EBCA), in charge of conventional construction works abandoning the precast concrete works.

This type of construction is still used by the former PBPPE the now ECWC BTCS as it is one of the company that was incorporated in the former EBCA. The buildings can be seen in the compound of the company and the latest project implemented in “Weha lemat fund” in 2017. The latest projects being handed over are the Ethiopian Government Revenue & Customs Authorities Galafi, Kombolcha, Awash & Togo’Challe check points.



Figure 3.1a

Figure 3.1a: Awash customs authority check point during construction



Figure 3.1b

Figure 3.1b: Togo'challe customs authority check Point.

Also precast concrete fence poles mostly used for the fences of big projects and large areas are produced. In general, the use of these poles is limited to the localities where other construction materials are scarce. The quality of such precast concrete poles usually depends on the quality control, the skill of workers as well as the conditions of the production site. Usually, as little attention is given to the quality control; one can observe inferior quality products in different places.

### 3.1.2 CMC Special Housing Project

The 500 special housing project was executed from 1987-1992 in Addis Ababa (Ethiopia) around Kotebe area (which was the name of an area near to the construction site at the time of construction, but now the area of the construction was named after the contractor CMC). The contracting parties for this project were Ministry of Work and Urban Development of Ethiopia as an employer from one part and Cooperativa Muratori and Cementisti-C.M.C-di-Ravenna as contractor from the other part. The consulting engineers were Foster Wheeler Italiaana (FWI)

with collaboration with Building Design Enterprise (BDE) up to 84% of the work and the remaining 16% was completed with consulting service of BDE alone.

The Project oriented pre-casting - Special housing project 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 general program of special housing project was for the construction of 2500 apartments to be completed in four phases. The 500 apartments, under consideration, were the first phase of this program over 27 hectares of land with 56 blocks. The contract completion time of the project, prepared by FWI, was 731 days.

The project was intended to use a large area for the development of a housing and commercial complex. 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 Muratori e 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.

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 300m<sup>2</sup> 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.

### **Special Housing Project**

The client of this project was the Ministry of Urban Development and Housing, the construction work was carried out by the CMC's Sector for building projects, civil and public buildings. The

Area of the project is located in Addis Ababa, The contract value of the project was €36.800.000.

Construction of 500 apartments for diplomats and urbanization works on an area of 22 hectares, 56 buildings.

The 500 apartments created are of varying typology, ranging in size from 70 to 180sqm and providing total living space of 60.000sqm [14].



Figure 3.2a

Figure 3.2a: A Satellite view of apartments built by Cooperativa Muratori e Cementisti (C.M.C) [14].



Figure 3.2b

Figure 3.2b: Apartments built by Cooperativa Muratori e Cementisti (C.M.C) during the final stages of construction [14].

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. 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.

The precast concrete produced by the C.M.C. was later utilized for two projects, the United Nation Economic Commission for Africa (UNECA) 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.

### 3.1.3 IMS manufacturing Plant in Ethiopia

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 at that time 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 (EBCA) [11].

The IMS prefabrication technology was introduced in Ethiopia in an integrated manner in 1985. (1978 Ethiopian Calendar) The establishment of Prefab Housing Factory in Addis Ababa under the Ethiopian Building Construction Authority (EBCA) as known as Prefab Housing Factory (PHF) with the agreement of the Ethiopian and Former Yugoslavian government for economic corporation.

In Ethiopia (Addis Ababa), a factory of the IMS building technology was erected in 1983, with the purpose of constructing residential and office buildings, and the annual capacity of 50,000 square meters. Transfer procedure similar to the above-mentioned ones was applied, so that the local partner constructed the factory and the buildings with technical management by the IMS Institute. The engagement within the framework of technical assistance in Ethiopia was 10 worker months, carried out by 5 experts from Yugoslavia [15].

It was then reestablished in 1993 (1985 in Ethiopian Calendar) under the Ethiopian Government Public Enterprise Authority by the Council of Ministers (በሚኒስትሮች ምክር ቤት ደንብ ቁጥር 118/1985) as the Prefabricated Building Parts Production Enterprise (PBPPE) as an autonomous business entity in accordance with the new economic policy in 1993.

Once again it has joined as one of the third companies which have founded the Ethiopian Construction Works Corporation (ECWC) as Building Technology and Construction Sector

(BTCS) in October 2016.

The PHF prefab housing factory has brought new techniques for the construction industry during its establishment and it was supposed to cater the solution for the vast building needs. The aim was to accommodate the ever increasing demands of housing within the shortest possible time, to overcome the shortage of accommodation and meet the future demands, and to minimize the pressing need of timber for formwork and consequently conserve the natural forest.

The theoretical design capacity of the enterprise was estimated to reach 50,000 m<sup>2</sup> of built-up floor area per year, but the maximum attained capacity to date is 33,000 m<sup>2</sup>. The production output of the enterprise was designed to build three categories of buildings: the residential buildings up to 5-storeys, residential buildings up to 10-storeys and public buildings up to 10 story. The types of structural elements produced by the factory are over 38 which include various types of columns, slabs, footings, girders, shear walls, stair flights and landings [11].

Some of the previous projects carried out by this company since the establishment are Ministry of Finance Office, Meskel flower Hostel, Beklobet building Office, T. Berta Office/shopping, Ayu Shashe & family Office/Shopping, Rift Valley Hotel, Helen building Ledeta Office/Shopping, Barek Agency, Debre Zeit Road Office, Civil Aviation Garage/Store Conventional, Nyala Insurance Office, Mina Trading PIC Office/Shopping, Lemiwodish Building Office, Arega (Almesh Building) Office, Telecommunication Manholes Production (R.P.C), Ras Amba Hotel, Council of Ministers office and the list goes on, refer to annex no. 1.

Immediately after its foundation, the Prefab Housing Factory started the production of structural building parts. At the time the Ministry of Construction was supposed to take all the products for mass housing construction works.

As a result of low development of the construction industry in Ethiopia, the only establishment to perform the erection of prefab elements was the Prefabricated Building Parts Production Enterprise (PBPPE). So the factory has been engaged in the production, transportation as well as the erection of the prefabricated structural elements since its foundation. The involvement of other contractors was limited to finishing works of the assembled building.

The initial total cost of the factory was estimated to be Birr 13 million which later on rose to Birr 17 million due to the delays in the implementation. The prefabrication factory started the production of structural elements in 1985.

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.

The design and erection of the first Ethiopian prefabricated residential building constructed on the Bole road that consisted of 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 1986.

There after similar design and construction solutions have been used on several construction works where the IMS system was deemed suitable. 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.

The factory was generally in charge of the three phases of prefabrication process, the production, transportation and assembly (erection). The production of the structural components takes place in the factory about 10 km from City center 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, and the weight of the components as well as its easiness for transportation were taken into consideration in the design of the precast elements.

After the re-establishment of the factory, in order to make the company more profitable, it was decided to extend its functions with additional tasks parallel to the production and erection of precast concrete. Consequently, the following works were included in the responsibility of the sector.

- 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, covers, curbs, HCB Blocks etc.,
- Precast reinforced concrete beam,
- Produces metal or wooden doors, windows, and other products upon receiving work orders,
- Engaging in construction works, be it commercial or residential building contracts using precast as well as conventional cast-in-situ concrete methods and finishing works.

### **3.1.4 Capacity of the Factory**

The production of members is organized in a factory with the design capacity to produce structural elements for the construction of 50,000 m<sup>2</sup> built up gross surface area. The initial capacity was estimated based on the following assumptions.

- Member production for residential buildings with up to 5 floors (45%)
- Member production for residential buildings with up to 10 floors (45%)
- Production of members for public buildings (10%)
- Annual working days of 250 and 44 hours per week with one working shift
- Capacity of finished members storage on the factory grounds 30- 60 days'

The additional conditions required for the production include the following.

- Steam curing chambers are to be used to accelerate concrete hardening for floor slabs and all soffits,
- Conveyance of fresh concrete from concrete plant to the work station is carried out by crane scoop,
- Vibrating tables, immersed vibrators and hand tools are to be used,
- Traveling cranes are to be used to provide in door conveyance of members and tower crane for depositing of the products at the storage site and for their consequent loading on transport vehicles.

The production of members for residential and public buildings stipulate that the residential buildings constitutes a gross surface area of  $45,000\text{m}^2$  ,50% of which is for buildings with up to 5 floors and 50% for buildings with up to10 floors. The production of members for the construction of public buildings of gross surface area of  $5000\text{ m}^2$  is also taken as the annual capacity of the factory [11].



Figure 3.3

Figure 3.3: IMS manufacturing plant – Ethiopia [2]

Please note that the actual capacity of the plant at this moment is less one third of the design capacity [11]. This is because of the old age of the machinery and equipment of the factory. There is a frequent break down of the batching plant and overhead crane, also the steam curing chamber is out of service as a result of the corrosion and decaying of the piping in the boiler room.

### 3.1.5 The IMS Building System

IMS building technology is based on reinforced concrete prefabricated skeleton, composed by basic reinforced concrete elements of the IMS system: This system can further be divided in to three sub systems or modes which are

#### 3.1.5.1 Structural System

Prefabricated skeleton made of columns, beams, floor slabs, staircases and stiffening walls – IMS frame system.



Figure 3.4a



Figure 3.4b

Figure 3.4a: Prefabricated skeleton ICT incubation center (ICT Park) front view

Figure 3.4b: Prefabricated skeleton ICT incubation center (ICT Park) from top

### 3.1.5.2 Production System or Mode

Besides common equipment used in concrete prefabrication and assemblage, there is a specific equipment for IMS building technology composed of production system elements molds and equipment and devices for the assemblage and erection.

Elements are composed of robust steel molds, where many elements can be manufactured without special reconstruction, but followed by regular maintenance. Those molds are so conceived to possess certain flexibility, so that, for example, story height of some buildings can differ from the standard one, same molds for floor slabs can be used for various column cross-sections, more exactly, they use lost Styrofoam or some other material forms, which at the same time has a function as a thermal insulation. Molds for definite span diapason can be used.



Figure 3.5a



Figure 3.5b

Figure 3.5a: Footing pad molds at Kality production center

Figure 3.5b: Footing pad rebar tying jigsaw at Kality production center



Figure 3.5c

Figure 3.5c: Kality Production facility

The footing pads at the kality production plant comes with three different sizes, the following table summarizes the footing pad types with their dimensions.

Description	Footing type 1	Footing type 2	Footing type 3
Length	1.2m	1.6m	2m
Width	1.2m	1.6m	2m
Depth	0.8m	0.8m	0.8m

Table 3.1: Prefab footing types with dimensions



Figure 3.6a

Figure 3.6a: Slab molds at Kality production center

The above picture shows the vibrating tables in front and on the right side of the bottom pictures are the steam curing chambers.

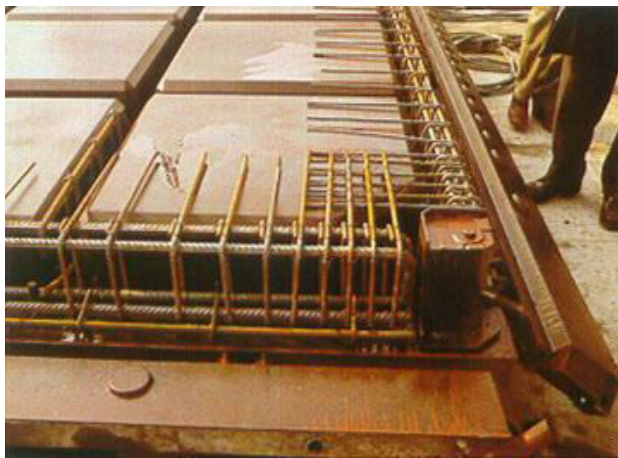


Figure 3.6b

Figure 3.6b: Slab mold at Kality production center (a close-up view)



Figure 3.6c

Figure 3.6c: Rebar tying jig saw for slab at Kality production center



Figure 3.7a



Figure 3.7b

Figure 3.7a: Stair mold at Kality production center

Figure 3.7b: Prefab stair at Kality production center

The stair case molds at the prefab factory only have a double stair flight with landing. If one would like to have a single flight or a three flight stair case, you have to use a cast in situ or the combination of the two systems on site.



Figure 3.8a



Figure 3.8b

Figure 3.8a: Column mold at Kality production center

Figure 3.8b: Prefab columns at Kality production center

The column height can rise up to three stories high but the thickness of it is limited to either 30cms or 35cms column.

### **3.1.5.3 Connection System or Mode.**

There are two types of connections with the IMS system.

- Wet Connection and
- Post Tensioning (PT) Connection.

#### **a) Wet Construction Connection**

The first connection is the connection between two elements of the IMS system with wet concrete or grouting connection, as the name implies this type of connection does not necessarily need tensioning, the connection is established using concrete as a binding chemical. This type of connection is usually found at the beginning and/or at the end of the construction phase. To mention some

- The connection between footing Pad & Lean concrete.  
This is done by grouting with thick cement and water mix before placing the footing pad on the lean concrete.



Figure 3.9a



Figure 3.9b

Figure 3.9a: Placing of a thick cement rich grout on top of lean concrete

Figure 3.9b: Footing pad placing on top of the cement rich grout using a mobile crane

- The connection between the Initial Column and the Footing Pad  
This process is done by pouring concrete in the cup of the footing pad after placing the initial column. Note that the bottom of the initial column is flat. Wooden wedges are used to hold the column in place until the concrete sets.



Figure 3.10a



Figure 3.10b



Figure 3.10c

Figure 3.10a: Initial column hoisting by mobile crane

Figure 3.10b: Wooden wedges to brace/hold the initial column in place until the fresh concrete hardens

Figure 3.10c: Initial column placing and concrete vibration to connect the initial column with the footing pad

- The connection between Grade beam and the initial Stair and Landing



Figure 3.11a



Figure 3.11b

Figure 3.11a: Connection between initial landing and grade beam

Figure 3.11b: Connection between initial stair case and grade beam

- Connection between column to column and the last column with top tie beam. The column to column connection is done through overlapping reinforcement bars and thick grouting. Top tie beam is usually casted on site by using the extension of the final column re-bars with top tie beam reinforcement and it is casted monolithically.



Figure 3.12a



Figure 3.12b

Figure 3.12a: Top tie beam casting at ICT incubation building project [2]

Figure 3.12b: Prefab column to column connection [2]

### **b) Post Tensioning PT Connection**

Post – tensioning PT provides a means to overcome the natural weakness of concrete in tension to make better use of its strength in compression. The use of post-tensioning is a specific way of joining basic reinforced concrete frame elements so that, by the rule, all joints are exposed to the pressure and stress adequately endured by the concrete.

(Please refer to Recent Developments in Ethiopia Construction Industry for more on PT)

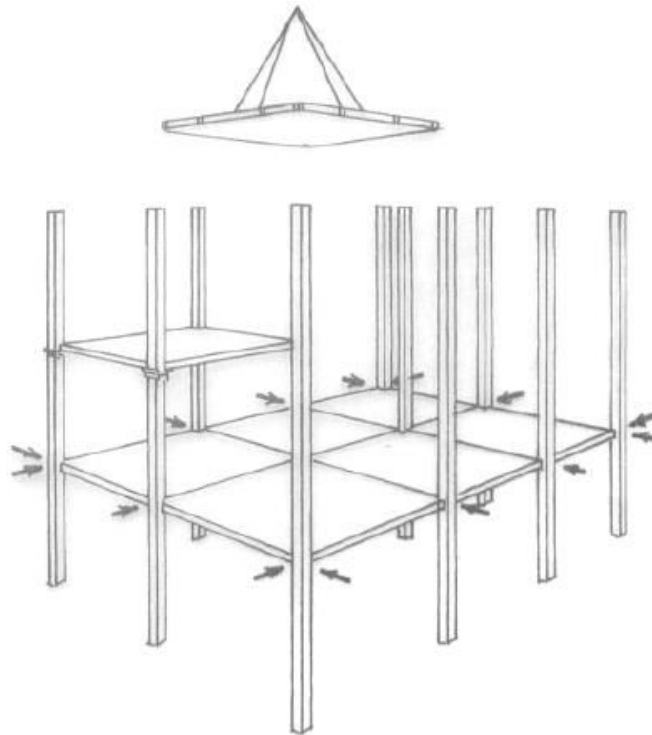


Figure 3.13a

Figure 3.13a: A concept of operation sketch [16]



Figure 3.13b



Figure 3.13c

Figure 3.13b: Post tensioning tendons in between slab and between edge girder and a slab

Figure 3.13c: Post tensioning tendons with a wedge & barrel at the end of a prefab building

The load-bearing elements of the assembled framework are joined together by pre-stressing cables and strands. There are two (2 x 4 07mm) cables in each duct used in residential buildings with a nominal force of 340 - 400 KN. The same cables are used for joining large spans of public buildings that can produce a nominal force of 600 - 800 KN. with two (2x12 07mm) cables per duct depending on the span and the load. [2]

The cables are straight at the time of pre-stressing. After anchoring they are forced down by special devices at one third length from each end and fixed in the designed position for heavy loads. The equipment used for pre-stressing, cable pressing jacks, anchor bushes and wedges and hydraulic pump sets for driving expansion wedges.



Figure 3.14a

Figure 3.14a: Post tensioning jacks and hydraulic oil pump set [16]

### 3.1.5.4 Equipment for Erection of the IMS System

Erection equipment and device consist of:

Steel squares – capitals tightened to the columns at the height of each floor structure as temporary support of floor slabs and edge beams during erection until Post Tensioning is done;

Diagonal steel brace for column fixing and precisely regulated vertical position till straining of the first floor plane, when columns are multi-story;



Figure 3.15a



Figure 3.15b

Figure 3.15a: Steel squares for supporting slabs

Figure 3.15b: Steel diagonal braces for holding in position for columns

For Cantilever slabs we use larger steel squares and smaller diagonal braces as shown in the figure till their connection by post-tensioning;



Figure 3.16a



Figure 3.16b

Figure 3.16a: Steel square support for cantilever slab with diagonal bracing

Figure 3.16b: a close-up view of the above picture

### 3.2 Buildings Built by Using the IMS System

Since its establishment, the Prefab Company has built a number of different buildings which are serving for be it residential, office, commercial or health services, hotel and hostel services etc. Here are some examples with photographs.



a) G+7 Prefab. Building ICT Incubation Center (2021)



b) Kotebe Metropolitan University Administration Building (2020)



**c) AAWSA Head Office building**



**d) Mina Building**



**e) Bole Apartments**



**f) Helen Building**



**g) Ras Amba Hotel**



**h) Ministry of Finance & Economic Cooperation**



**i) Revenue and Customs Authority Building**



**j) Prime Minister Office**

Figure 3.17 (a – j): Buildings built using the IMS construction system in Ethiopia

### 3.3 Short Comings in the implementation of the IMS System in Ethiopia

Eventhough, the IMS system has evolved since its first implementation in 1957 but, in Ethiopia it has remained the same with out any modification or development since its establishment in 1985 with the help of the then Yugoslavian government.

“The IMS precast structural system was found to be structurally sound, stable and flexible system, if sufficient alternative design solutions are reviewed even with the existing modules and sizes. The missing modular sizes can be incorporated through appropriate formwork and structural designs at the existing premise or such modular sizes could be imported from the IMS Institute. But, before taking such measures, comprehensive study incorporating the merits and demerits of the existing sizes, the cost incurred due to the introduction of new sizes and the demand for the new modules, should be carried out in order to evaluate the economic feasibility.” [11]

The above thesis was conducted on June 1998, even after 22 years since the above recommendation nothing has changed things only got worsen as if the tecnology has regressed rather than progress as the knowledge fades and the equipments decay with the unwavering power of time on all things. This is a sad thing to observe first hand on the construction.

There are also a number of structural firms left that can appropriately work using this technology or system. The company that worked on all the structural components of the projects under consideration on this study is KENIMOS (Kenimos Tesfaye & Abrham Lelisa)

The international experience with the IMS technology has improved through the years with improved span length to flexiblity of spatial and structural systems to accommodate the current demands of our contemporary human livelyhood.

It has also encorporated utility lines i.e. all vertical utility lines like plumbing and sewerage pipes, ventilation conduits, chimneys and so on. But this level of encorporation is not observed on the project sites that employ the IMS building thechniques except for window openings on a single site.

This lack of development has led to additional costs and loss of time in order to lay utility lines

by drilling or by chiseling like down pipes, sewer lines, electrical cables, data cables etc. in addition to the additional works there is the case of esthetics, as the utility lines especially electric wires for lighting are stretched below the soffit of the slabs becomes visible which causes discomfort for the viewer.



Figure 3.18a

Figure 3.18a: Conduits and electrical wiring under a Prefab slab.at AAMZLA/MCH



Figure 3.18b

Figure 3.18b: Pipes, ventilation ducts, conduits and electrical wiring under a Prefab slab at ICT G+7 incubation center

These are the problems that caught the reserachers attedntion and led for the preparation of this project study

### 3.4 Recent Developments in Ethiopia Construction Sector

There are numerous building construction projects that are being undertaken by both national and international contractors in the heart of this country Addis Ababa. Here the financial district at the center of the city which is located at Mexico is one of the areas of the capital that is being transformed rapidly in to the sky line of the city. To mention some of the projects,

- The Commercial Bank of Ethiopia Head Quarter, Hiberter Bank Head Quarter, Zemen Bank Head Quarter, Nib Bank Head Quarter, Nile Insurance Head Quarter

In the city, it is also observed that there is a boom in housing construction throughout the city in both the Municipality and Private sectors. Here under are the projects that are being implemented in both sectors to show the recent developments in the city's construction sector.

- Light Weight Aluminum Formwork Construction Technology
- Post Tensioning (PT) System

#### 3.4.1 Light Weight Aluminum Formwork Construction Technology

This Technology is the first of its kind being implemented in Ethiopia, Addis Ababa by Federal Housing Corporation at Gerji Site "Gerji Modern Residential Village Construction Project with New Technology" being the Owner/Developer, in partnership with different stake holders. The contractor is OOUID Construction, the construction technology provider is Kumkand Kind and the designer is PARIN SHAH Architects

The project is also one of the few projects to implement Building Information Modeling (BIM) fully in Addis. Construction of the project began in mid-2020.

The construction technology provider Kumkand Kind is a South Korean based company that specializes in the manufacturing of Modular building construction units (the new paradigm of modern construction system), Steel Pipes, Scaffolding system, Shoring system and Formwork system which are used for different purposes.

The formwork systems include Scaffolding materials include safety decks, K-Steel or K-Wood formwork, Pier Formwork, Pier Table, Box culvert system, Immersed Tunnel and so on. The particular form work type used for the execution of the Geri Modern Residential Village Construction Project is made of high strength aluminum extrusion which, compared with steel formwork, allows a large but lightweight panels. This will not only achieve better concrete finishing but also allow a faster construction phase [17].

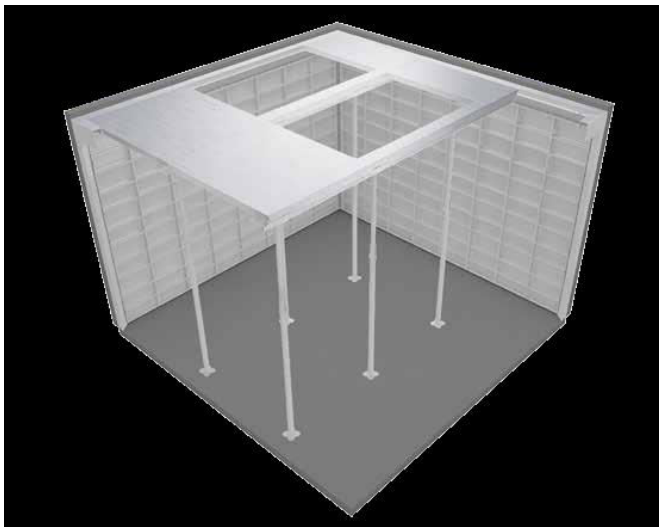


Figure 3.19a

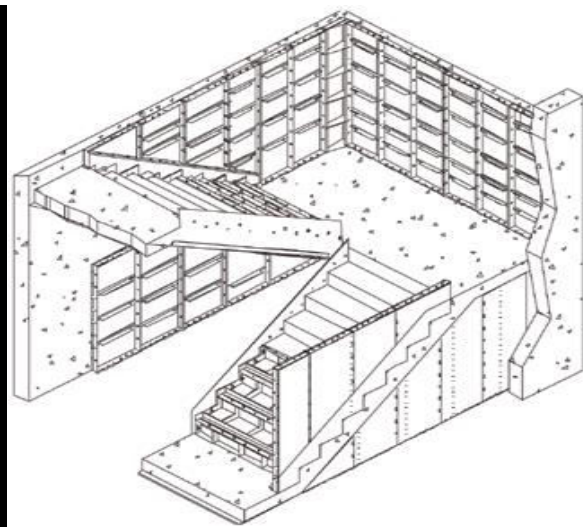


Figure 3.19b

Figure 3.19a: Sample mock-up of the Kumkang aluminum formwork [17]

Figure 3.19b: 3D view of staircase [17]

The above picture shows a sample mock-up to demonstrate the system for users in simple terms. This demonstration is also displayed at the site of the project as shown below.



Figure 3.20a



Figure 3.20b



Figure 3.20c

Figure 3.20a: Front auxiliary view of the sample aluminum mold

Figure 3.20b: Rear auxiliary view of the sample aluminum mold and casted concrete structure

Figure 3.20c: Front auxiliary view of the sample casted concrete structure

Now days, the most important aspect of a successful structural construction is the formwork system. Here under are the advantages of the formwork system as stated by the manufacturer.

- The formwork allows an average of 4-7 days cycle compared to 14-30 days cycle with the conventional method.
- With a smooth surface and accurate dimension of panels, there is no requirement of plastering or remedial work after concrete casting.
- No need to remove props and prop heads when dismantling slab panels.
- No need for skilled workers or carpenters.
- The formwork panels will be transferred manually to the next level through a slab transfer box; thus, the crane can be used for other tasks.
- It is a “modular” formwork; there is no constraint on any architectural or structural design.
- Manufactured through an aluminum alloy extrusion, formwork can be repeated over 300 times.

### 3.2.2 Post Tensioning (PT) System by EASE - CCL

Post-tensioned (PT) construction is a method of reinforcing (strengthening) concrete with high-strength steel strands or bars with specialized anchorage assemblies, typically referred to as tendons.

There are PT applications in almost all sectors of construction. In many cases, PT applications allow construction that would otherwise be impossible due to site constraints, architectural requirements or budget limitations. PT application is the construction choice for engineers, designers, contractors and project developers/owners, throughout the world

EASE (East Africa Specialized Engineering PLC) is a subsidiary of Africa Specialized Engineering B.V., a Netherlands-based engineering firm specializing in providing unique and tailor-made construction solutions that optimize existing or new concrete based-construction projects since the early 1950s. [18] EASE works in partnership with CCL which is a UK based construction solution provider that has more than 80 years of experience under its sleeve.

Post – tensioning provides a means to overcome the natural weakness of concrete in tension to make better use of its strength in compression. The principle is easily observed when holding together several books by pressing them laterally. Under such pressure the whole row gains enough stiffness and strength to ensure its integrity. [19]

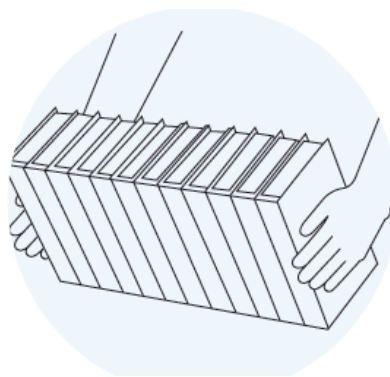


Figure 3.21

Figure 3.21: Stalks of books pressed laterally [19]

In concrete structures, this is achieved by placing high-tensile steel tendons/cables in the element before casting. When concrete reaches the desired strength, the tendons are pulled by special hydraulic jacks and held in tension using specially designed anchorages fixed at each end of the tendons. This provides compression at the edge of the structural member that increases the strength of the concrete for resisting tension stresses.

The company provides multi-strand bonded and mono-strand un-bonded post-tensioning systems. The later has a single strand tendon system which is quick to install while the former accommodates more than one strand.



Figure 3.22a



Figure 3.22b

Figure 3.22a: Mono-strand un-bounded tendons [19]

Figure 3.22b: Multi-strand bounded tendons [19]

There are a number of projects that East Africa Specialized Engineering (EASE) has been involved in engineering projects in Ethiopia. Some of the projects are Shegole and Kaliti Bus Depots, Pan Africa Apartment Building, Yeka Parking a public parking project, Foreign Affairs is a 42-story Public Project, U Street Apartment is a 3-Basement, Ground Floor +12 residential/commercial project, Pullman Hotel, Tamrain Office and Showroom a four-story car showroom, and the most recent being Elilta RE Building is residential/commercial project.

Elilita RE Building is residential/commercial project in Addis Ababa, Ethiopia. EASE-CCL’s Post-Tensioning System was incorporated to design and execute the bridge connecting the two blocks shown in the picture. [18]



Figure 3.23a



Figure 3.23b

Figure 3.23a: 3D design of Elilita RE building [20]

Figure 3.23b: RC structure of Elilita RE building prior to construction of the bridge [19]

The challenges faced on this particular project and results achieved are shown by the table below.

The main challenges faced on this project	EASE-CCL solutions were able to achieve
<ul style="list-style-type: none"> <li>➤ 33m span bridge and a structure light enough to be carried by the foundations and columns.</li> <li>➤ 70m free height above ground.</li> <li>➤ Adhere to the architectural plans of the building.</li> <li>➤ Constraints of scaffolding (propping for a 70m clear height).</li> <li>➤ Constraints of cranes.</li> </ul>	<ul style="list-style-type: none"> <li>✓ PT beams of adequate sections to span 33m and still light enough.</li> <li>✓ The floor system used was in accordance with the architectural plans.</li> <li>✓ By applying a simple casting methodology, the scaffolding and crane constraints were solved.</li> <li>✓ Faster execution using easier scaffoldign systems and less curing time was achieved as compared to the conventional method (7 days instead of 21).</li> </ul>

Table 3.2: Challenges and results achieved on Elilita RE Building

The above results were achieved through a long engineering process which is done in two phases as summarized below. [20]

### 3.2.2.1 Phase I

- Casting of Vertical Elements & Corbels

All vertical elements (columns and shear walls) supporting L19 are to be cast (to the soffit of the member being supported) along with the corbels.

- Neoprene Pads Installation

After the corbels are cast, the neoprene pads can be installed and executed on site. The duration for this activity can be estimated to take 5 days. However, the next activity can take place at the same time which is, erection of scaffolding.

- Propping & Scaffolding Installation

The installation of the propping and scaffolding can take place in parallel with the casting of the vertical elements and the corbels. The scaffolding are to be designed to support the concrete horizontal structure based on 2 phases.

Phase 1: The scaffolding should be designed to support the weight of the 3 longitudinal main PT beams. Once these beams are cast and stressed, it will be able to carry itself plus some of the service load. Thus, the scaffolding can be released under these beams. The PT beams can carry the full load once the concrete reaches its design strength (at 28 days). However, the PT beams will be designed to carry the loads applied at construction phase in order not to delay the next phase.

Phase 2: The scaffolding are no more needed to support the PT beams. However, it will be used in this phase to support the PT slab along with the construction loads. Thus, effectively, the props are now to support the wet weight of the concrete PT slab plus the wood platform and the live load due to workmanship on site.

- Casting of PT Beams

Once the former activities are completed, the platform will be laid and the work on the 3 main longitudinal PT beams starts. The activities involved for casting and stressing the PT beams are the following.

- PT Beams Formwork Installation
- Rebar Cutting and Installation
- PT Materials Fabrication
- PT Tendons Installation
- Casting of Concrete
- Stressing of PT Tendons
- Grouting of PT Tendons

#### **3.2.2.2 Phase II**

Once phase 1 is completed, phase 2 can take place.

- Casting of PT Slab

This phase is related to the PT slab execution. The PT Slab is designed to have an equivalent thickness less than 24cm. The total depth of the slab is 30cm. However, 20cm ducts are introduced inside the slab with 2 ducts every 1m spaced at 400mm cc in order to reduce the total concrete volume and the total weight applied on the steel props.

- PT Beams Formwork Installation
- Rebar Cutting and Rebar Installation
- PT Materials Fabrication
- PT Tendons Installation
- Casting of Concrete
- Stressing of PT Tendons

## CHAPTER FOUR

### RESEARCH METHODS AND METHDOLOGY

#### 4.1 Research methods

This chapter explains the methods employed in conducting this study, which is first identifying the problems of the IMS system when it comes to the finishing stages of building construction works and then try to quantify these problems in terms of cost, time and quality.

##### 4.1.1 Study Area

The study area for this specific research is bound around Addis Ababa the political, economic and social center of Ethiopia. Also the IMS system factory is found only in this city which is 10 kms away from the city municipality.

The research will only focus on challenges of finishing works of IMS building system projects under construction in Addis Ababa.

##### 4.1.2 Study Design

As mentioned in the beginning of this research, the necessity of conducting this research came from the need to solve the practical problem that the researcher came across by working with the IMS system This makes this study to fall under applied research category as applied research is designed to solve practical problems of the modern world, rather than to acquire knowledge for knowledge's sake. One might say that the goal of the applied scientist is to improve the human condition. It is undertaken to solve immediate practical problem [6].

The research is also both explanatory and experimental as it tries to answer or explain to the question why and as it compares two groups on one outcome measure to test some hypothesis.

##### 4.1.3 Sample Size Determination & Sampling Technique

As this research focuses on the challenges of finishing works on IMS building system under construction in Addis Ababa, the sample size will be 100% because all three projects under

construction by this system are under consideration namely.

- ICT B+G+7 Incubation Center, Addis Ababa Meles Zenawi Leadership Academy and Kotebe Metropolitan University Administration Building.

#### **4.1.4 Method of Data Collection**

This research uses both primary and secondary data in conducting the research. Primary data is obtained from the site on which the actual construction work is done and secondary data is obtained from previously conducted researches.

#### **4.1.5 Research Variables**

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 [4].

Accordingly, the independent variables of this research are indirect costs. Consequently, the dependent variables will be finishing work; Cost, Time and Quality.

#### **4.1.6 Plan of Data Analysis**

The approach taken for data analysis in preparing this research starts with first by identifying the challenges or difficulties on finishing works with the IMS system and then, by further developing this challenges in a tangible manner for the reader.

### **4.2 Research Methodology**

The methodology used for this research includes a critical literature review of prefabrication construction in general and an in depth literature review specifically into the Integrated Modular System IMS.

Also IMS building construction system with regards to its applicability during the construction finishing stages of the construction industry in our country particularly to Addis Ababa will be the focal point.

All the necessary data will be gathered in order to tangibly quantify and proof or disproof the initial hypothesis put at the beginning of this research. Then the collected data and information will analyzed by using different techniques. Finally after analyzing the data, conclusions and recommendations will be forwarded.

## CHAPTER FIVE

### DATA ANALYSIS AND DISCUSSION

#### 5.1 Analysis;

As discussed earlier in the literature review part of this study, the lack of integration of the vertical utility system has caused inconveniences on the progress of the work on site. These inconveniences create unnecessary or additional costs, extended time and poor Quality.

Here under the challenges are discussed thoroughly with the help of photographs which were taken by the researcher.

#### 5.2 Cost Implication;

The cost implication can be seen mainly with the unpleasing aesthetics of utility lines lying horizontally on the bottom of the slab soffit running from one corner to the other and vertically for top to bottom.

Horizontally, all the utility lines have to be covered as a result there is a necessity or need to cover the unpleasing view of all the wiring and piping from sight, these calls for the use of ceilings.

All the projects under this study have used Armstrong ceilings to cover up all the utility lines.



Figure 5.1a



Figure 5.1a

Figure 5.1a: Ventilation ducts, conduits and electrical wiring to be covered by ceiling at ICT

Figure 5.1b: Conduits and electrical wiring to be covered by ceiling at AAMZLA/MCH

Vertically, in order to connect the utility lines from top to bottom we had to drill or chisel the slab, which in turn led to the additional cost of labor and material to drill the holes on the surface of the slab.

Utility lines that run vertically include sanitary lines, water supply lines for toilet (kitchen and fire suppressing systems), air conditioning ducts, electrical lines and communication lines. As compared to the sanitary, water supply lines and air conditioning ducts, the electrical and communication lines requires less drilling therefore, the impact of these utility lines on the negative impact on the structure is negligible.



Figure 5.2a



Figure 5.2b

Figure 5.2a: Vertical ventilation ducts

Figure 5.2b: Vertical sanitary system, conduits and electrical wiring

Cost of labor for chiseling per hole = 20 Birr

Additional Cost per Floor of Addis Ababa Meles Zenawi Leadership Academy with a Built up Area of 882 m<sup>2</sup>

Item	Unit	Quantity	Rate	Cost in Birr
Ceiling	m <sup>2</sup>	882	350	308,700 Birr
Chiseling	Point	16	20	320 Birr
Total Cost				309,020 Birr

Table 5.1: Additional cost per floor for Armstrong ceiling at AAMZLA/MCH administration block

The other cost implication is related with the piping system of the fire suppression system on each floor of the building/



Figure 5.3a;



Figure 5.3b;

Figure 5.3a: Fire suppressing system piping.

Figure 5.3b: Fire suppressing system piping as it connects from one floor to the other.

Cost of labor for chiseling per hole = 20 Birr

Additional Cost per Floor of Addis Ababa Meles Zenawi Leadership Academy

Item	Unit	Quantity	Rate	Cost in Birr
Chiseling	Point	2	2	40 Birr
Elbow	No.	2	250	500
Cutting & threading	No.	4	150	600
Total Cost				1140 Birr

Table 5.2: Additional cost per floor for piping at AAMZLA/MCH administration block

The above analysis shows that there is an additional cost of 1140 birr per floor for the fore mentioned activities.

### 5.3 Time;

It is the additional time that is needed for the extra work that is required to execute the above activities.

Extended Hour per Floor of Addis Ababa Meles Zenawi Leadership Academy University with a Built up Area of 882 m<sup>2</sup>

Item	Unit	Quantity	Productivity per Hour	Time in Hour
Ceiling	m <sup>2</sup>	882	5	176.4 Hour
Chiseling	Point	16	0.5	32 Hour
Cutting & threading	No.	4	0.5	8 Hour
Fixing in position of the additional accessories i.e. elbow joints	No.	4	2	2 Hour
Total Time				218.40 Hour

Table 5.3: Prefab extended hour per floor of AAMZLA/MCH administration block

As the table indicates there is an additional 218.40 labor hour per floor.

#### **5.4 Quality;**

Quality is a tricky word to either define or measure, but ISO 9000 puts it as a degree to which a commodity meets the requirements of as customer at the start of its life. It can simply be defined as also quality is to fit for a purpose.

In the sense of the above definition, the IMS system is a prefabricated system that uses a production facility to produce the individual elements in a controlled environment. This helps to assure the quality of the product better than the conventional cast in situ construction method.

By chiseling the prefab elements on site one is altering negatively the standard of the individual elements from the manufactured standard leading to degradation in the quality of the material in the first place. The diminished in quality can be seen by its esthetic value and structural integration in being monolithically casted at the origin of production.

#### **5.5 Discussion;**

Even though literatures show that there is a significant amount of cost saving when it comes during the erection of the structure, the loss that comes with the finishing part of the construction has become significant according to the above analysis.

## CHAPTER SIX

### CONCLUSIONS AND RECOMMENDATIONS

#### 6.1 Conclusions

In this research the challenges of the problems that was presented at the beginning has taken shape through an exciting journey of enlightenment towards the realization of what had faded away and take as a step back rather than going forward. Here are some points to incorporate in the conclusion part of this research.

- The precast construction industry in our country with regards to the IMS system has regressed in to oblivion rather than moving forward and developing. This is because of the lack of adaption of new technologies or developments in this particular industry since the erection of the plant in 1984.
- The knowledge in both design and construction of this system is fading away with time without passing from the first generations of the early 1980s to this generation. As knowledge is a perishable commodity if we as individuals or as a group should nurture it to grow or else it will be lost through gradual decline.
- There are only a number of consulting firms specifically there are two, that would dare to pursue the challenge of working with the IMS building system according to the stake holders of the industry.
- Availability of design and construction documents is scarce because of all the documents were first brought in in 1984 by a hard copy, due to an old age and improper storing of these documents have led to degradation and loss or miss-placement. Un availability of a soft copy is also a challenge for this digital era.
- The level of detailed construction and working drawings that the international practice employs even at that time is not to the level that we are experiencing right now,
- Documents are hard to access because of the old age of the hard copies in which the system drawings and specification are found on; most of the rest of the documents are also misplaced or lost as the company abandons the system through the years.
- There is a fixed span length of 4.2 meters (c/c) distance between the structural columns,

which makes it difficult to work freely and express ones interest with this system with respect to design and construction.

- There are no codes or standards that are used for evaluation when it comes to design approval and construction method in this country. This makes it difficult to get approval from municipalities and expand the system.

## 6.2 Recommendations

- There is a dire need to achieve flexibility in structural, spatial and system aspects of the IMS system in order to develop and work on the system further more.
- As to the knowledge aspects of the system, there must be a transfer of knowledge from the former to the current generation before the loss of all or what it's left of it.
- The knowledge transfer should also be conducted in pair, i.e. in terms of design and erection/construction aspects of the system, as both determine the crucial and integral effectiveness functionality of the whole system. One cannot stand alone without the other.
- The corporation should devise a way to incorporate the Complementary elements (facade and inner walls, sanitary walls, sanitary cabins, non-standard staircases etc.) for better performance of the system.
- There should also be an effort to communicate with the developers of the IMS system to share the knowledge in both design and construction and check new developments if there are any.
- The available IMS modules should be incorporated to the National Design Codes after a thorough evaluation, if necessary; and the details be made available for utilization by design offices as per requirement. This includes the, demonstration of its safety, simplicity in erection and economic benefits.
- In general, the IMS building system should be updated in every aspect of its phases, starting from inception and design to the production of individual elements and to the transportation mechanisms and erection techniques up to final stage of hand over and throughout its operational life.

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## **APPENDIX**

The following appendix was a pilot assay conducted by Prefabricated Building Parts Production Enterprise PBPPE before joining the Ethiopian Construction Works Corporation and became Building Technology and Construction Sector. ECWC BTCS in October 2016.

# 1. የድርጅቱ ነባራዊ ሁኔታ ዳሰሳ

## 2.1 የድርጅቱ ዋና ዋና መልካም ልምዶች፣

### ህንፃ ግንባታ ቴክኖሎጂ ሽግግር

የተገጣጠሟ ህንፃ አካላት ማረጋገጫ ድርጅት /ተሀኦሙ/ በቀደሞው የዩጎዝላቪያ መንግሥትና በኢትዮጵያ መንግሥት መካከል በተፈረመ የኢኮኖሚ ትብብር ስምምነት መሠረት እንደ ኢትዮጵያ ዘመን አቆጣጠር በ1978 ዓ.ም በቀደሞው የኢትዮጵያ ሕንፃ ኮንስትራክሽን ባለሥልጣን (EBCA) ሥር የተገጣጠሟ ሕንፃ አካላት ማረጋገጫ ፋብሪካ በመሆኑ ስያሜ ተቋቋመ፡ በዚህ አደረጃጀት የተገጣጠሟ ህንፃ ግንባታ ቴክኖሎጂን በመጠቀም የተለያዩ የህንፃ ግንባታዎችን ሲያከናውን ከቆየ በኋላ በ1985 ዓ.ም ተገቢነቱ ለመንግሥት የልማት ድርጅቶች ተቆጣጣሪ ባለሥልጣን ሆኖ በመንግሥት የልማት ድርጅትነት በሚስትሮች ምክር ቤት ደንብ ቁጥር 118/1985 በድጋሚ ተቋቋመ፡፡

በእነዚህ ጊዜያት ድርጅቱ በዋናነት ፔትሮቭ በመባል ዩጎዝላቪያዊው አርክቴክት የተፈለሰፈውና ኢትዮጵያን ጩሮ ወደ ተለያዩ የዓለም ሀገራት የተሰራጩ አይ.ኤም.ኤስ የግንባታ ቴክኖሎጂ (IMS Prestressed Concrete Building Technology) ተገቢ የሚሆኑ የግንባታ ቴክኖሎጂ በመጠቀም በርካታ የመሆኑ፣ የመንግሥት ቢሮዎች፣ ማሪያ ቤቶችና የንግድ ሕንፃዎችን በመገንባት ቴክኖሎጂው በአገር ውስጥ እንዲተዋወቅ አድርጓል፡፡

### ሠነደኛ 1፣ የተገጣጠሟ ሕንፃ አካላት ግንባታ ቴክኖሎጂ ወጭ የሆኑ ሕንፃዎች ዝርዝር

ተ.ቁ	የፕሮጀክት ስም	የህንፃ ከፍታ	የሕንፃው ባለቤት	ፕሮጀክቱ የሚኝበት ቦታ
1	የገንዘብ ኢኮኖሚ ልማት ሚስቴር የቢሮ ሕንፃ	G+8	ፌዴራል መንግስት	አዲስ አበባ (5 ኪሎ)
2	የአዲስ አበባ ወና ፍሳሽ ባለስልጣን ዋና ማህበት የቢሮ ሕንፃ	G+5	አ/አ/ው/ፍ/ባ	አዲስ አበባ (ማናኛ አካባቢ)
3	የአይሲቲ ቢዝነስ ኢንኮፎስት ሜካል /አይቲ ፓርክ/	G+2	ማኢ/ቴ/ሚስቴር	አዲስ አበባ (አይቲ ፓርክ)
4	የገቢዎችና ጉዳዩን ባለስልጣን ህንፃ	G+4	የመንግስት ቤቶች ኤጀንሲ	አዲስ አበባ (በቅሎ ቤት አካባቢ)
5	የሚስትሮች ምክር ቤት ህንፃ	G+4	የሚስትሮች ምክር ቤት	አዲስ አበባ (አራት ኪሎ)
6	የፌዴራል ጉዳዮች ሚስቴር የቢሮ ህንፃ	G+2	ፌዴራል መንግስት	አዲስ አበባ (ሜሲኮ)
7	የሳይንስና ቴክኖሎጂ ሜካል	G+4	ሳ/ቴ/ ሚስቴር	አዲስ አበባ (ኮተቤ)
8	ኮንስትራክሽን ዲዛይን አ/ሚበር ቢሮ ህንፃ	G+3	ኮ/ዲ/አ/ሚበር	ጎተራ (ቅ/የሴፍ ቤ/ክ)
9	የኢትዮጵያ ባለስትራ ፋብሪካ ህንፃ	G+5	ባለስትራ ፋብሪካ	አዲስ አበባ (ሳሪስ)
10	መከላከያ ኢንጂነሪንግ ኮሌጅ	G+7	መከላከያ ኮሌጅ	ቢሾፍቱ
11	ሀዋሳ ዩኒቨርሲቲ ቢሮ ህንፃ	G+0	ሀዋሳ ዩኒቨርሲቲ	ሀዋሳ
12	ቦሌ መንገድ 6 ብሔራዊ አፓርትመንቶች	G+9	የመንግስት ቤቶች ኤጀንሲ	አዲስ አበባ (ቦሌ መንገድ)

ተ. ቁ	የፕሮጀክት ስም	የሀንፃ ከፍታ	የሕንፃው ባለቤት	ፕሮጀክቱ የሚኝበት ቦታ
13	ቦሌ መንገድ 100 ቤቶች አፈጻጸም	G+5	የመንግሥት ቤቶች ኤጀንሲ	አዲስ አበባ (ቦሌ መንገድ)
14	አሳይ ትምህርት ቤት	G+4	የህዝብ ት/ቤት	አዲስ አበባ (አላማርያ)
15	የፍትህ አካላት መዝገብ መከፈል	G+4	የመንግሥት ቤቶች ኤጀንሲ	አዲስ አበባ (መከፈል ፍላጎት)
16	ዋራት ህንፃ	G+4	የግል	አዲስ አበባ (22 አካባቢ)
17	የቢሮ ህንፃ	G+2	የግል	ቦሌ ኤርፖርት አካባቢ
18	SGA ህንፃ	G+1	የግል	ቦሌ ኤርፖርት አካባቢ
19	እምህጫት ህንፃ	G+4	የግል	ሳር ቤት አካባቢ
20	አዩ ሸሌ ህንፃ	G+8	የግል	አዲስ አበባ (ጥቁር አንበሳ ት/ቤት)
21	ኢሞድ የእንግዳ ማረፊያ	G+5	የግል	አዲስ አበባ (ገርጂ)
22	ሄለን ህንፃ	G+7	የግል	አዲስ አበባ (ልደታ)
23	ቢዮካራ ህንፃ	G+4	የግል	አዲስ አበባ (በቅሎ ቤት)
24	ሜ ህንፃ	G+9	የግል	አዲስ አበባ (ወሎ ሰፈር)
25	ብስራት ህንፃ	G+3	የግል	አዲስ አበባ (ለም ሆኑል)
26	ዳን ቴክኖሎጂ ሞድ ማቤት	G+3	የግል	አዲስ አበባ (ቃሊቲ)
27	ካዲስ ህንፃ	G+4	የግል	አዲስ አበባ (ቃሊቲ)
28	መብሉ ህንፃ	G+2	የግል	አዲስ አበባ (ቦሌ)
29	ጣና የጭጭ ሰል ፋብሪካ	G+3	የግል	አዲስ አበባ (ኮልፊ)
30	ሀጂ ናስር ህንፃ	G+3	የግል	አዲስ አበባ (ጦር ሀይሎች)
31	ራፍት ቫሊ ሆቴል	G+4	የግል	አዳማ
32	ባቦጋያ ሆቴል	G+5	የግል	ቢሾፍቱ
33	ራስ አምባ ሆቴል	G+2	የግል	አዲስ አበባ (አባሬ)
34	ጃጂ ሮያል ሆቴል	G+4	የግል	አዲስ አበባ (ገርጂ)
35	ወንዝ ዳር ህንፃ	G+4	የግል	አዲስ አበባ (ቦሌ)
36	የእስልምና ጉዳዮች ህንፃ	G+5	የእስልምና ጉዳዮች ማቤት	አዲስ አበባ (ጦር ሀይሎች)
37	የግል ማረፊያ ህንፃ	G+1	የግል	እንግሊዝ ኤምባሲ አካባቢ
38	የግል ማረፊያ ህንፃ	G+1	የግል	አዲስ አበባ (ገርጂ)
39	አህመድ ኑርሁኔን የግል ማረፊያ ህንፃ	G+1	የግል	አዲስ አበባ (ጦር ሀይሎች)
40	ገርጂ የመሀበር ማረፊያ ህንፃ	G+1	የመሀበር መሀበር	አዲስ አበባ (ጦር ሀይሎች)
41	የግል ማረፊያ ህንፃ	G+2	የግል	አዲስ አበባ (ላፍቶ)
42	የጋንብር ምድግ መከፈል	G+0	ጋንብር ኢንስቲትዩት	አዲስ አበባ (ጋንብር)
43	ጋላሬ ጉምዳክ መቆጣጠሪያ ጣቢያ	G+0	ገቢዎችና ጉምዳክ	ጋላሬ
44	ደወሌ ጉምዳክ መቆጣጠሪያ ጣቢያ	G+0	ገቢዎችና ጉምዳክ	ደወሌ
45	የቂርቆስ ክ/ከተማ ቢሮ ህንፃ	G+0	ቂርቆስ ክ/ከተማ	አዲስ አበባ (ካዳማ ቤት)

**2.1.2 በሚከተለው ህንጻ ግንባታ ዘርፍ የደርጅቱ ማና አፈጻጸም ዳሰሳ፣**

ደርጅቱ እንዲሁ በህንጻ ግንባታ ዘርፍ በርካታ ሀገር በቀል ስራ ተቋራጭ ባልፈረሰት ወቅት በሚከተለው የህንጻ ግንባታ ዘዴ ገበያው ውስጥ የነበረው ተሳትፎ ሰፊ ሲሆን ይህንን የግንባታ አሜሪካዊ ዘዴ በሚጠቀም ለህንጻ ገንባታ አገልግሎትን በሚሰጡት በተለይም ደግሞ በአዲስ አበባ ከተማ በርካታ ግንባታዎችን አከናውኗል፡፡ በሚገኝበት በከፊ በቀጥታ የተሰጠው የሚገኝበት ቢሮዎች የግንባታ ሥራ የግብርና ሚስቴር፣ የወጪ ጉዳይ ሚስቴር፣ የፍትህ ሚስቴር እና የሳይንስና ቴክኖሎጂ ሚስቴር ህንጻ ግንባታዎችን አከናውኗል፡፡

**ሠንጠረዥ 2፣ በሚከተለው ግንባታ ዘርፍ የተከናወኑ ግንባታዎች ዝርዝር ሚጃ**

ተ. ቁ	የፕሮጀክት ስም	የህንጻ ከፍታ	የሕንጻው ባለቤት	ፕሮጀክቱ የሚኝበት ቦታ
1	የግብርና ሚስቴር	G+7	ግብርና ሚስቴር	አዲስ አበባ (ጉርድ ሾላ)
2	የወጪ ጉዳይ ሚስቴር	G+7	ወጪ ጉዳይ ሚስቴር	አዲስ አበባ (ቤተሚናር ገንባታ አካባቢ)
3	የፍትሕ ሚስቴር	G+7	ፍትሕ ሚስቴር	አዲስ አበባ (ልደታ)
4	ሀንገር ህንጻ	G+0	ሲቪል አቪዬሽን	አዲስ አበባ (ቦሌ ኤርፖርት)
5	የውሃ ሀብት ሚስቴር ፕሮጀክት	G+0	የውሃ ሀብት ሚስቴር	አዲስ አበባ (ቃሊት)
6	የሳይንስና ቴክኖሎጂ ሚስቴር	G+8	ሳይንስና ቴ/ሚስቴር	አዲስ አበባ (ጥቁር አንበሳ ት/ቤት ጀርባ)

**2.1.2.1 የአዲስ አበባ ከተማ ቤቶች ግንባታ ፕሮጀክቶች ተሳትፎ፣**

ደርጅቱ በሚከተለው ቤቶች ልማት ፕሮጀክት በተለይም ደግሞ ወጪ ቆጣቢ የሆኑ ዘዴዎችን እና ቴክኖሎጂዎችን በሚጠቀምበት ቀዳሚ ማኅበር የነበረው ሲሆን የቤቶች ልማት ፕሮጀክት ሲጀምሩ በሚከተሉት ዘርፍ የተጀመሩ የጋራ ማሪያ ቤቶች ግንባታ ላይ በሚጠቀሙ 142 ብዛትን ገንብቶ ያስረከበ ደርጅት ነው፡፡ በዚህ ተሳትፎው ደርጅቱ ለግንባታ የሚሆኑ ግብዓቶችን ራሱ አግዶ በሚከተለው የቤቶችን የግንባታ ዋጋ ማህበረሰብ ሆኖ በተጨማሪ በሚከተለው በዚህ ሂደት የተገኙ የተግባር ጥንካሬዎች፣ ልምዶችና ተግባራዊነት በአሁኑ ወቅት በቤት ልማት ስራዎች ማሻ ለማሻ በሚከተለው በማልገል ሰፊ አስተዋጽኦ አበርክቷል፡፡

**ሠንጠረዥ 3፣ በአዲስ አበባ ማሪያ ቤቶች ልማት ግንባታ ዘርፍ የተከናወኑ ግንባታዎች ፣**

ተ. ቁ	የፕሮጀክት ስም	የህንጻ ከፍታ	የሕንጻው ባለቤት	ፕሮጀክቱ የሚኝበት ቦታ
1	ኮልፌ ፕሮጀክት	G+4	አዲስ አበባ ቤቶች	አዲስ አበባ (ቤቴል አካባቢ)
2	ልደታ ማሪያ ፕሮጀክት	G+4	አዲስ አበባ ቤቶች	አዲስ አበባ (ቶታል አካባቢ)
3	ቂርቆስ ፕሮጀክት	G+4	አዲስ አበባ ቤቶች	አዲስ አበባ (ቂርቆስ)
4	የካ ቁጥር 2 ፕሮጀክት	G+4	አዲስ አበባ ቤቶች	አዲስ አበባ (አድዋ ድልድይ)
5	ገርጂ ቁጥር 3 ፕሮጀክት	G+4	አዲስ አበባ ቤቶች	አዲስ አበባ (ገርጂ)