T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

EVALUATION OF PRECAST SLABS (HOLLOW CORE) COMPARED TO-SITE CASTING IN COST AND TIME MANAGEMENT OF PUBLIC BUILDINGS IN IRAQ

MASTER'S THESIS

Saleem AL HAMEED

Engineering Management Department

Engineering Management Master in English Program

AUGUST 2022

T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

EVALUATION OF PRECAST SLABS (HOLLOW CORE) COMPARED TO SITE CASTING IN COST AND TIME MANAGEMENT OF PUBLIC BUILDINGS IN IRAQ

MASTER'S THESIS

Saleem AL HAMEED
(201281012)

Engineering Management Department

Engineering Management Master in English Program

Thesis Advisor: Prof. Dr. Gözde ULUTAGAY

AUGUST 2022

T.C.
İSTANBUL GEDİK ÜNİVERSİTESİ
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

Yüksek Lisans Tez Onay Belgesi

Enstitümüz, Engineering Management Department İngilizce Tezli Yüksek Lisans Programı (201281012) numaralı öğrencisi Saleem AL HAMEED'in "Evaluation of Precast Slabs (Hollow Core) Compared to Site Casting in Cost and Time Management of Public Buildings in Iraq" adlı tez çalışması Enstitümüz Yönetim Kurulunun 12/08/2022 tarihinde oluşturulan jüri tarafından *Oy Birliği* ile Yüksek Lisans tezi olarak *Kabul* edilmiştir.

Öğretim Üyesi Adı Soyadı

Tez SavunmaTarihi: 12/08/2022

1) Tez Danışmanı: Prof. Dr. Gözde ULUTAGAY

2) Jüri Üyesi: Dr. Öğr. Üyesi Tuğbay Burçin GÜMÜŞ

3) Jüri Üyesi: Dr. Öğr. Üyesi Ayşe Övgü KINAY

DECLARATION

I, Saleem AL HAMEED, do hereby declare that this thesis titled as "Evaluation of Precast Slabs (Hollow Core) Compared to Site Casting in Cost and Time Management of Public Buildings in Iraq" was an original academic work done by me for the award of the master's degree in the Engineering Management faculty. I also declare that this thesis or any part of it has not been submitted or presented for any other degree or research paper in any other university or institution. (12.08.2022)

Saleem AL HAMEED

DEDICATION

To you, my father and mother, for your pure soul.
My family, thank you for being with me.
Brothers and friends, thank you for your support.
To everyone who taught me even a single letter in my life.

PREFACE

First, I would thank my supervisor Prof. Dr. Gözde ULUTAGAY for all support and guidance throughout my research work.

It was all fruitful advice during my academic career.

I would like to thank all my teachers at Istanbul Gedik Unıversıty Instıtute of Graduate Studıes.

Finally, I would like to thank all participants who took part in the study and enabled this research to be possible.

August 2022 Saleem ALHAMEED

TABLE OF CONTENT

Page

ABBREVIATIONS

CSO	**:** Central Statistical Organization Iraq
db	**:** Decibel
DL	**:** Dead Load
EXT.	**:** Exterior
F_P	**:** Minimum Tensile Strength
F_pA_P	**:** Minimum Breaking Force
F_{PU}	**:** Tensile Strength of Prestressing Tendons
Fy	**:** Yield Strength
HCS	**:** Hollow Core Slab
ID	**:** Iraqi Dinar
INT.	**:** Interior
LL	**:** Live Load
Ls	**:** Stirrup Length
NO.	**:** Number
Qu	**:** Allowable Stress
R_c	**:** Thermal Resistance
R_w	**:** Acoustic Insulation
VAT	**:** Value Added Tax
Vol.	**:** Volume

LIST OF TABLES

Page

LIST OF FIGURES

Page

EVALUATION OF PRECAST SLABS (HOLLOW CORE) COMPARED TO - SITE CASTING IN COST AND TIME MANAGEMENT OF PUBLIC BUILDINGS IN IRAQ

ABSTRACT

The importance of project management is manifested in reducing costs and project completion times and choosing the type of system that suits the construction, as the construction method is one of the most important factors that contribute to determining the time and cost of the project.

The method of implementing slabs using precast hollow core panels has many advantages, including speed in implementation to save time and an appropriate cost, this method reduces the use of molds and manpower, which means an increase in productivity and a cleaner environment, in addition to many advantages, including the presence of cavities that reduce the weight of these panels and thus reduce the load on the building.

In this study, the implementation of slabs by the traditional method (casting on-site) in projects and buildings in Iraq was compared, then the traditional system was changed to precast hollow core panels, and the cost and time were compared between the two methods.

Field tours of these projects were taken, a search was conducted for cost and time information for the implementation of these projects from the relevant stakeholders, and secondary and primary data were obtained about the projects, price analysis, and time of completion.

By comparing the two methods, it was found that the implementation of slabs by the method of hollow core panels takes 38 days less time than the traditional method (in-site casting), as it took 121 days to cast the slabs traditionally, while the hollow core method took only 83 days, which is 31.4% faster.

As for the cost, the secondary data results indicated that the method of implementing the slabs with precast panels is 17% less expensive than the slabs implemented traditionally.

Also, the preliminary data showed that the precast method in the building closest to the factory for the production of hollow core panels was the lowest cost by 16.8%, and in the farthest building, it was lower by 13.9%.

Keywords: *Hollow core, Precast, Management, Traditional*

IRAK'TA KAMU BİNALARININ MALİYET VE ZAMAN YÖNETİMİNDE YER DÖKÜMÜ İLE KARŞILAŞTIRILMIŞ PREKAST DÖŞEMELERİN (HOLLOW CORE) DEĞERLENDİRİLMESİ

ÖZET

İnşaat yöntemi, projenin zamanını ve maliyetini belirlemeye katkıda bulunan en önemli faktörlerden biri olduğu için, maliyetlerin ve proje tamamlanma sürelerinin azaltılmasında ve inşaata uygun sistem türünün seçilmesinde proje yönetiminin önemi ortaya çıkmaktadır.

Prekast boşluklu paneller kullanılarak döşeme uygulama yöntemi, zamandan tasarruf için uygulama hızı ve uygun maliyet gibi birçok avantaja sahiptir, bu yöntem kalıp kullanımını ve insan gücünü azaltır, bu da verimlilikte artış ve daha temiz bir çevre anlamına gelir. Bu panellerin ağırlığını azaltan ve böylece bina üzerindeki yükü azaltan boşlukların varlığı da dahil olmak üzere birçok avantaj.

Bu çalışmada, Irak'taki proje ve binalarda geleneksel yöntemle (yerinde döküm) döşeme uygulamaları karşılaştırılmış, daha sonra geleneksel sistem prekast boşluklu panellere dönüştürülmüş ve iki yöntem arasında maliyet ve zaman karşılaştırılmıştır.

Bu projelere saha gezileri yapılmış, ilgili paydaşlardan bu projelerin uygulanması için maliyet ve süre bilgisi araştırması yapılmış, projeler, fiyat analizleri ve tamamlanma süreleri hakkında ikincil ve birincil veriler elde edilmiştir.

İki yöntem karşılaştırıldığında, plakaların geleneksel yöntemle dökümünün 121 gün sürdüğü için, boşluklu panel yöntemiyle döşeme uygulamasının geleneksel yönteme (yerinde döküm) göre 38 gün daha az zaman aldığı bulundu. , hollow core yöntemi sadece 83 gün sürdü, bu da %31.4 daha hızlıdır.

Maliyete gelince, ikincil veri sonuçları, prekast panellerle döşeme uygulama yönteminin, geleneksel şekilde uygulanan döşemelerden %17 daha ucuz olduğunu göstermiştir.

Ayrıca ön veriler, içi boş panel üretimi için fabrikaya en yakın binadaki prekast yönteminin %16,8 ile en düşük maliyet olduğunu, en uzak binada ise %13,9 ile daha düşük maliyet olduğunu göstermiştir.

Anahtar Kelimeler: *Hollow core, Prekast, Yönetim, Geleneksel*

1. INTRODUCTION

1.1 Overview

A country like Iraq has gone through many crises that led to the collapse of its facilities and infrastructure, and it desperately needs to reduce costs and the time factor to rise again and as soon as possible to keep pace with the urban development taking place.

Therefore, it was necessary to prepare such a study to take advantage of the difference in cost and time to take advantage of the maximum limits of precast concrete technology.

The development of the construction world from year to year is getting more advanced, with the presence of innovations related to design modifications or methods in the implementation of the construction.

With the presence of these innovations, it is hoped that it will make it easier for consultants to plan, and make it easier for contractors to implement them. Therefore, many studies have been carried out on how to realize infrastructure and buildings that are more economical, efficient, and faster without forgetting the aspects of quality and work safety.

In the implementation of building work, there are several methods used in the project. The most frequent method used is the normal method, namely the method with the execution of casting in place (in site), then there is also the precast concrete method, hollow core slab (HCS) is a precast, prestressed or non-prestressed concrete containing a group of hollow cores stretched through the length of the slab, this leads to a reduction in the weight and cost. HCS systems can be used in floor and roof systems.

The main utilization of the HCS system is the slab of the buildings and parking, wall panels, and deck slabs for bridges. It is possible to get the span length to reach up to 18m without any support by using the HCS system. It supplies high structural performance when using high-strength concrete and at the same time, this system is economical in the amount of concrete (Stephen, 2013) as shown in Figure 1.1.

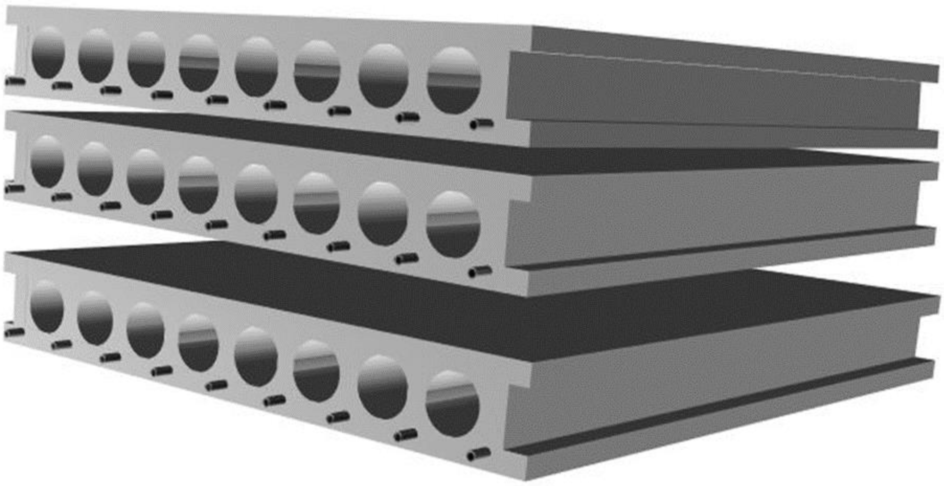


Figure 1.1: Hollow Core Slab System

This precast method has many advantages including, faster execution time because the concrete has hardened, the quality of the concrete is more guaranteed due to better quality control, reduction in the use of labor on the project, making the workplace cleaner, and more productive.

Since it is necessary, before starting an engineering project, to study the cost of the project and the duration of completion, the importance of engineering management for any project is evident. The project management triangle is the most influential section in project management (quality, cost, time) and they control the course of the project and complete it see Figure 1.2.

Figure 1.2: Time- Cost- Quality Triangle Concept

Scheduling in construction projects is a tool for determining the activities required to complete a task project in a specific order and timeframe, every activity must be carried out so that the project is completed on time at an economical cost (Widiasanti, Irika & Lenggogeni, 2013).

In this study, a review was carried out on the implementation of building construction projects, this project uses normal methods in the implementation of construction. In this final project, the slab structure will be modified, from site casting slabs to hollow core slabs.

An Iraqi factory will also be approved for the production of hollow core slabs (Darin Group precast factory).

1.2 Research Problem

Problems that will be discussed in this final project are how the site casting slab method compares with hollow core slab on Iraqi buildings in terms of cost and time.

1.3 Research Aims

The objectives to be achieved in this project are to show the importance of the engineering management of the project by knowing the comparison of the site casting slab compared to the hollow core slab on the Iraqi building in terms of cost and time.

1.4 Problem Limitations

In this final project, the problem is limited to the main subject matter as follows:

1. The structural modification only on the plate structure, from the plate conventional into hollow core slab precast plates.
2. Scope of calculation of construction cost and time only beams, and slab's structure work.
3. The costs reviewed are only direct and indirect costs review indirect costs.
4. Does not take into account the strength of precast joints.

1.5 Research Importance

The benefits that can be given by this research are:

1. The importance of engineering management for the project and preparing the necessary plan to reduce costs and time for engineering projects.
2. Adding insight for readers and as one of the references for alternative implementation methods using precast concrete.
3. Provide insight to contractors regarding the comparison of conventional methods with precast methods in terms of cost and time.
4. Can be used as a reference for the development of science and technology in future research.

2. LITERATURE REVIEW

2.1 Overview

One of the most important tasks of the engineering management of projects is to save costs, time, and quality, and because there are many options available in concrete buildings, especially slabs, the issue of choosing the type of slab was one of the important things that would save many important things, including cost and time.

The topic of slab type testing for buildings has occupied many specialists, designers, and researchers to meet the requirements of quality, cost and time, here we will get acquainted with some of the studies that have been researched on this topic.

(Sarhan, Raslan, & Tallawi, 2021) conducted a study on the use of a hollow core slab compared to a two-way solid slab in terms of cost and time, the study concluded that the implementation of the hollow core slab was much faster compared to the cast slab on-site, as the site casting took 43 days in total and 31 actual days after deducting holidays, while the implementation of the hollow core slab took approximately 13 total days and 9 actual working days. In terms of cost, the HCS took precedence as well, where the cost of on-site casting was 3.76 times higher than the cost of precast, and the period was 3.31 times longer, because the HCS needless activities than cast-in-place slabs, such as framing, curing steelwork, and concrete pouring.

(Vyas, 2015), he surveyed the method of on-site casting compared to precast concrete in general in India and found some important results below for the use of precast concrete (as shown in Figure 2.1): -

1. 20% less concrete.
2. 30% less steel.
3. 50% less manpower.
4. 50% less wastage.

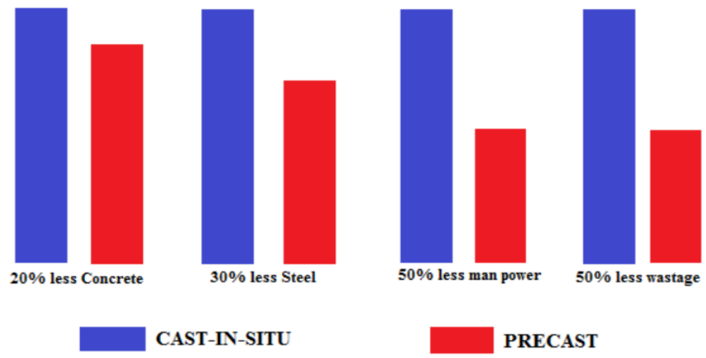


Figure 2.1: Some Benefits of Precast

Source: Vyas, (2015)

(Turai, & Waghmare, 2015) they compared the precast concrete pouring with on-site casting in terms of recovering the project's investment costs, and they found that the on-site casting takes a longer time to recover the costs, reaching (3.8) years, while the pre-casting did not take more than (2.5) years.

(Adenuga, & Sotunbo, 2014) made a questionnaire to assess the temporal change for the construction of solid and hollow roofs in Nigeria, Lagos State.

The respondents' most familiar slab construction technologies or processes were determined to be cast in situ, precast, and semi-precast.

The most popular approach was cast-in-situ beam and slab construction, which was followed by flat slab, hollow clay pot, and waffle slab construction. In terms of construction time, placing reinforcement and constructing formwork take longer than other processes in solid slab construction, whereas in the reinforced cast in situ concrete hollow slab construction, constructing formwork, placing hollow bricks, blocks, or molds on formwork, and curing concrete takes longer than other processes.

In the case (Alsheikh, 2020), he compared the post-tension system and the HCS for a commercial building in Amman, discovering that the hollow panels are installed at a rate of (300-500) square meters per day and that both systems achieve safety in design, but the post-tension system is characterized by flexibility in design and height the net for the floor, whereas the HCS is characterized by its lightweight and quick completion time. In terms of cost, the researchers discovered that the two methods are relatively similar.

(Asamoah, Ankrah, Offei-Nyako & Tutu, 2016), they made an analysis showing the cost of precast concrete and the cost of cast concrete for some public buildings in

Ghana and they found that precast concrete is cheaper by (23.33%) on average than the cost of in situ cast.

The choice of the type of slab is one of the matters that depend on many factors, taking into account the construction economy to a fundamental degree, but this consideration comes after discussing many things, including the design loads, the spaces between the supports & service requirements and strength.

According to (Park & Gamble, 1999), For slabs built without beams, when the choice is made between flat slabs and flat plates, it depends on the loads and distances of spaces (spans), usually determined by the shear strength at the columns, as well as the live loads that reach more than (4.8 KN/m^2), as well as when spans are greater than (7-8m), choosing a flat slab is the preferred option.

If the architectural requirements refuse the work of drop panels or column capitals, then consideration must be given to taking into account the shear strength by using a metal shear load or by adding more steel that increases the bearing of the shear strength, but this will be at the expense of costs that may be high.

Depending on the design, the deflection and shear stress may limit the addition of beams instead of the drop panel system or column capitals system, When the deflection is severe, it will be appropriate to choose a two-way slab system.

The issue of choosing between beamless slab systems and two-way slabs is rather complicated. From an economic point of view, the two-way system is usually less expensive for rebar, but it is uneconomic in terms of formwork and labor, in this case, flat slabs are cheaper as well as easier and less complicated.

Another thing that can be noted is that the flat slab system provides more distance in the height of the floor compared to the two-way slab system in which beams are used.

The actual cost is the ratio between labor and material costs, based on this, in areas where the cost of labor is high, the two-way slab system is not preferred if there is no urgent need, on the contrary, this system is used when rebar is the most expensive element.

Also, the best solution for all of this may be to use precast slabs (Hollow core) will also be very useful when the cost of steel, cement, and labor is very high.

According to (Ervianto, 2006), precast is a process of production of building structural elements at a place or location different from the place or location where the structural elements will be used. For example, the concrete production process Precast can be done in the factory or the workshop.

2.2 Types of Concrete Slabs (Cast in Site)

Slabs are available in a wide variety of shapes and sizes. A concrete slab is a fundamental structural element. It's designed to be flat, having top and bottom sides that are parallel. Ceilings, floors, and roof decks are examples of such surfaces.

The kinds of concrete slabs that use in the projects are determined by several factors. Cost-effectiveness and restrictions are two examples.

Slabs provide unrivaled advantages to your development. Foundation slabs, for example, have thermal qualities, are long-lasting, and keep moisture out of your living area.

The thickness of a slab is generally rather tiny in comparison to its breadth or length. In structures, slabs primarily support their weight as well as live loads. This weight might be shifted to the beam.

The support system of concrete slabs may be classed. There are various slab kinds to choose from.

We will discuss here the in-situ cast slabs, which are the most common in Iraq:

2.2.1 Solid slabs

It is a slab of a constant thickness throughout, and it is often linked to beams and is armed with upper and lower steel according to the direction of the moment, always be in both directions.

The solid slab working mechanism depends on the aspect ratio, where the slab behaves as a slab in one direction in case the aspect ratio is greater than or equal to 2, and behaves as a slab in two directions if the mentioned ratio is less than 2.

The slab thickness is minimal, but the beam depth is great, and the load is passed to the beams and subsequently to the columns of this kind. When opposed to a flat slab, it requires additional formwork (Clarke & Cope, 1984).

Depending on the length and breadth of solid Slab is classified into two types:

2.2.1.1 On-way slabs

To bear the weight in one direction, a one-way slab is supported by beams on both sides. One-way slabs have a ratio of longer spans to shorter spans that is equal to or higher than 2, the slab will bend in one way in this case, namely in the direction of its shorter span.

However, distribution steel is used as a minimum reinforcement over the longer span above the primary reinforcement to evenly distribute the load and withstand temperature and shrinkage stresses.

Figure 2.2 shows a one-way slab system, when the bays are lengthy and the superimposed loads are significant, a one-way slab system is the most cost-effective option.

When the structure is subjected to substantial line loads, such as hefty partitions, the method is extremely cost-effective.

Large perforations in the slab may be made almost anywhere on the floor. The structural depth of beam and one-way slab systems is greater than that of other floor systems, and their forming costs are often higher. These drawbacks are somewhat offset by cost reductions in concrete and reinforcing. This sort of technology also ensures that moments are transferred between beams and columns clearly and unambiguously. In high-wind or seismic zones, where the structural frame resists lateral stresses on the structure, this is a significant benefit. (Setareh & Darvas, 2016).

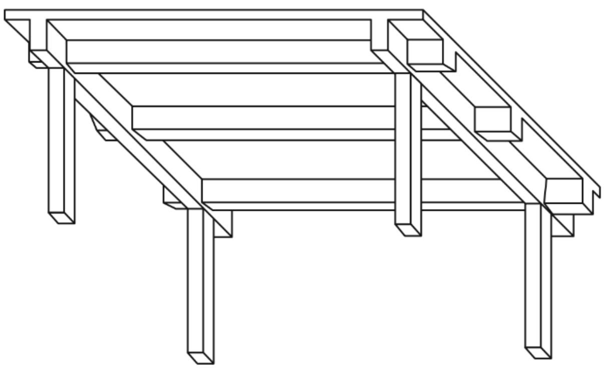


Figure 2.2: One-Way Slabs on Beams and Girders

Source: Setareh & Darvas, (2016)

2.2.1.2 Two-way slabs

It is known as a two-way slab because it is supported by beams on all four sides and the loads are carried by the supports in both directions.

Figure 2.3 shows a two-way slab system. The ratio of longer span to shorter span in a two-way slab is less than 2, due to the likelihood of the slabs bending in both directions to the four supporting edges, distribution reinforcement is provided in both directions.

In a two-way slab, the length and width of the slab oppose the creation of stress distribution bars, which are given at both ends. These slabs usually are utilized in the construction of multi-story building levels. (Setareh & Darvas, 2016).

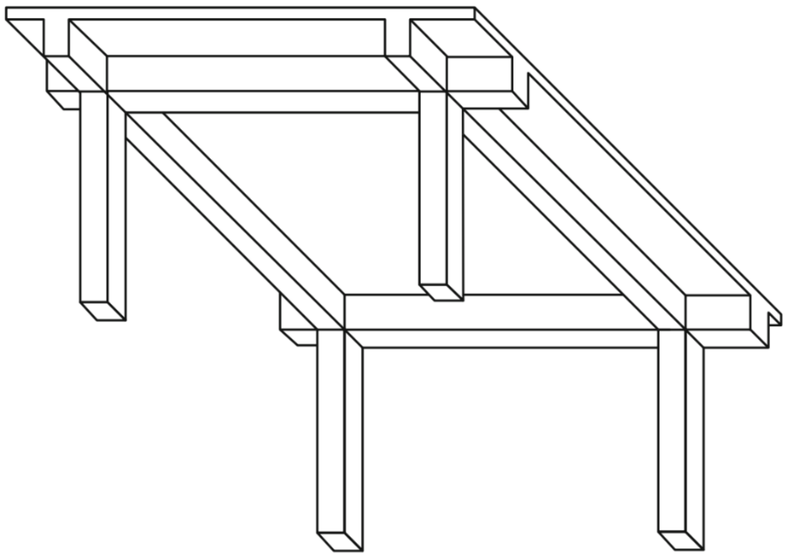


Figure 2.3: Two-Way Slabs on Beams

Source: Setareh & Darvas, (2016)

2.2.2 Flat slabs and flat plate slabs

A flat slab is a reinforced concrete slab that rests directly on columns. There will be no need for a beam or other support. In most situations, additional reinforcing is only added near columns to prevent punching shear. A flat plate slab is another sort of comparable slab.

There is no column capital or drop panel in a flat plate slab. At the intersection of the columns and the slab, a column capital flares up. This gives additional support along the column's perimeter. In the event of a drop panel, a thicker slab is given every few meters along the column's perimeter.

If the span is less than 8 meters and the live load is less than 5 kN/m^2, a flat slab with no column capital or drop panel may be used. In other circumstances, however, a flat slab with column capital or a drop panel may be required.

A flat plate is a uniformly thick slab that rests on column supports. It is the most cost-effective system to construct because it only requires a wood deck on adequate shoring. It also allows for the shortest structural depth and thus the shortest floor-to-floor height, which is an important cost consideration in a multistory building's overall economy.

Figure 2.4 shows a high-rise structure under construction using a flat plate floor system.

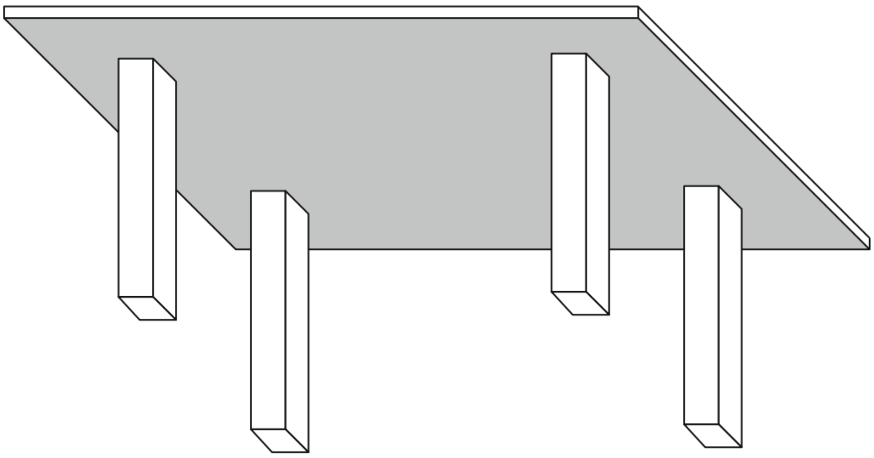


Figure 2.4: Flat Plate Floor System

Source: Setareh & Darvas, (2016)

A flat slab floor system is similar to a flat plate floor system, except the flat slab contains enlarged parts surrounding the columns known as drop panels see Figure 2.5.

The major goal of the drop panels is to boost the concrete's nominal two-way shear strength in the vital area surrounding the columns. The flat slab system offers the benefits of easy construction and formwork, low floor-to-floor heights, and a reasonably level ceiling, allowing an architectural finish to be applied directly to the slab's underside. Buildings with moderate to high weights, such as office buildings, hospitals, and warehouses, are the most common applications for this system. (Fanella, 2016).

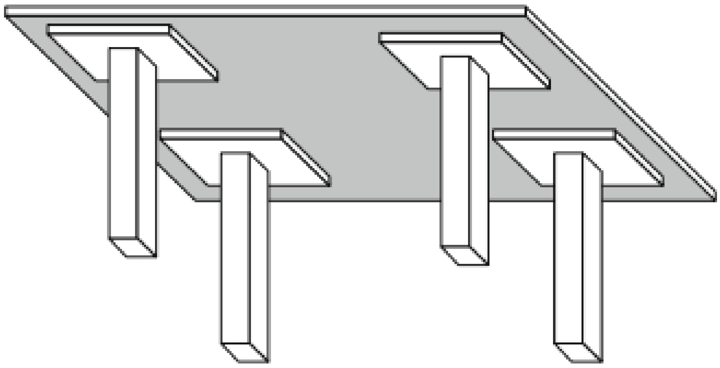


Figure 2.5: Flat Slab with Drop Panels

Source: Setareh & Darvas, (2016)

A column head is a local extension of the top of the column that provides more support to the slab than the column section alone.

Depending on the depth of the head, the dimensions of a column head may be considered effective. If the head is flared, the angle of slope should not be less than 45 degrees from the horizontal. If the head is uniform, the angle of the theoretical slope should not be less than 45 degrees from the horizontal. The dimension should be taken 40 mm below the underside of the slab or drop if one is available.

If the actual head dimensions are less than those obtained from the 45° requirement, those measurements should be used. (Allen, 2017).

See Figure 2.6 shows a flat slab with drop panels and column capitals.

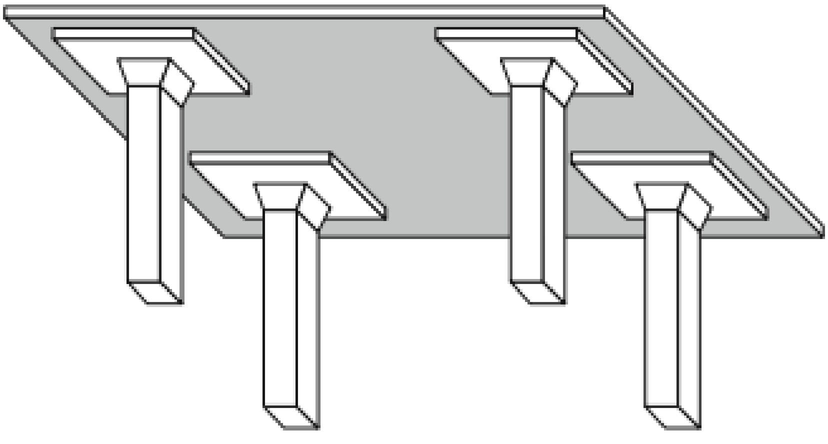


Figure 2.6: Flat Slab with Drop Panels and Column Capitals

Source: Setareh & Darvas, (2016)

So, for a summary of the flat plate and flat slab, there are four main kinds see (Figure 2.7):

1. Slab without drop and column without column head (capital).

2. Slab with drop and column without column head.

3. Slab without drop and column with column head.

4. Slab with drop and column with column head.

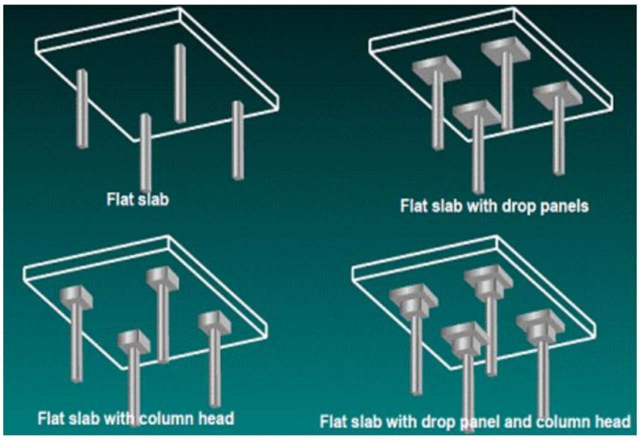


Figure 2.7: Different Types of Concrete Flat Slabs

Source: ESE Soedarsono, (2002)

And flat Slabs can be used following applications:

1. To give a simple ceiling surface that allows for improved light dispersion.

2. Constructability is simple, and the formwork is cost-effective.

3. More headroom or a lower story height with a more appealing look.

4. Parking slabs of this kind are available.

5. Flat slabs are often utilized in parking garages, commercial buildings, hotels, and other locations where beam projections are undesirable.

The benefits of a flat slab system:

1. When a deep fake ceiling is not required, it reduces floor-to-floor heights. The height of a building may be decreased.

2. Using an automatic sprinkler is more convenient.

3. Construction time is reduced.

4. It improves the slab's shear strength.

5. Reduce the clear or effective span to reduce the moment in the slab.

However, there are weaknesses in this system as:

1. In a flat plate system, it is not possible to have a large span.

2. Increased slab thickness.

3. Not recommended for fragile (masonry) partitions.

2.2.3 Ribbed and hollow block slabs

Ribbed slabs are slabs constructed in situ by one of the methods below:

1. When considering that the upper class contributes to structural strength:

- Comprises a series of concrete ribs cast in place between blocks that remain part of the finished construction; the ribs' tops are joined by a topping of concrete of the same strength as the ribs see (Figure 2.8).

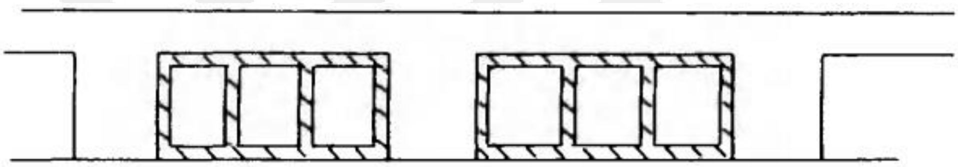


Figure 2.8: Ribbed Slab with Permanent Blocks

Source: Allen, (2017)

- A group of sequential concrete ribs is accompanied by pouring a top layer on temporary molds that are removed after the concrete has hardened see (Figure 2.9).

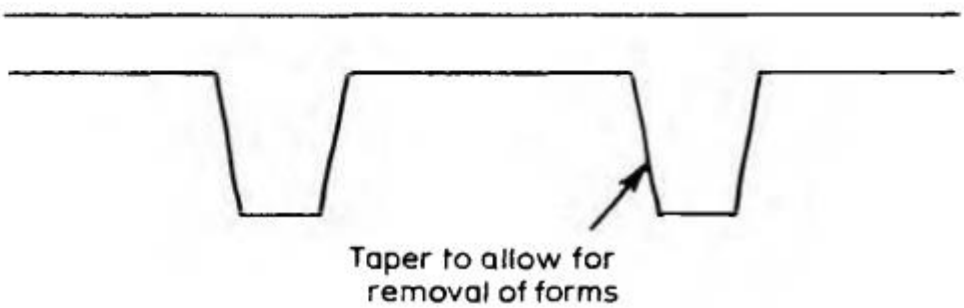


Figure 2.9: Ribbed Slab without Permanent Blocks.

Source: Allen, (2017)

- Contain voids of rectangular or other shapes, permanent or removable; with the upper and lower sides being continuous see (Figure 2.10).

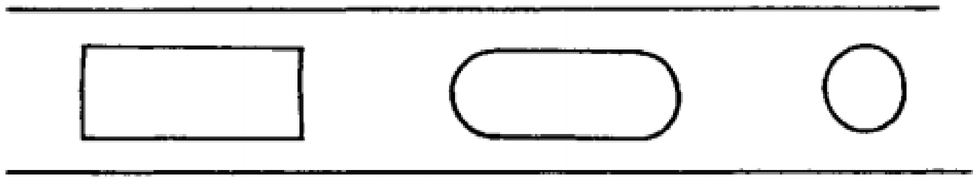


Figure 2.10: Ribbed with Voids

Source: Allen, (2017)

2. When the top layer does not contribute to the structural strength. As a series of concrete ribs cast in place between blocks that remain part of the finished construction; the ribs' tops may be joined by a concrete topping. (Allen, 2017).

Ribbed and Hollow block slabs are divided into two parts:

2.2.3.1 One-way ribbed slabs

consists of a series of tiny, closely spaced reinforced concrete T beams that frame monolithically cast concrete girders that are borne by the building columns.

The ribs, or T beams, are created by creating vacuum areas in what would otherwise be a solid slab.

As seen in Figure 2.11, these voids are usually created using specific steel pans or hollow blocks. A hollow Block Slab is a ribbed slab made from permanent hollow blocks.

To construct ribs, concrete is cast between the forms and then poured to a depth over the top of the forms to make a thin monolithic slab that serves as the T beam flange.

The arrangement of blocks in a one-way hollow block slab is shown in Figure 2.12.

The joists and supporting girders are installed in a single piece. The girders, like the joists, are built as T beams (Darwin, Dolan, C. W., & Nilson, 2016).

As illustrated in Figure 2.13, the shape of the girder cross-section is determined by the shape of the end pans that form the joists.

The pictures in the Figure 2.14 show the site implementation for a one-way ribbed slab.

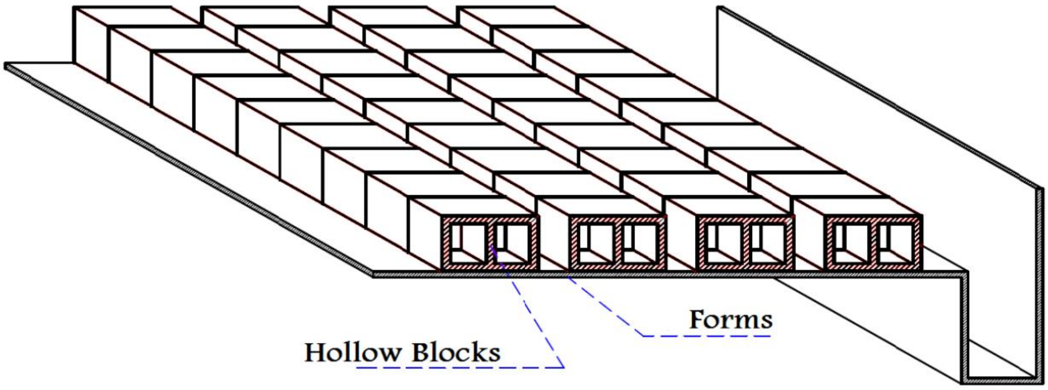


Figure 2.11: One-Way Ribbed Slab Formed Using Blocks.

Source: Muhammad. N.J, (2016)

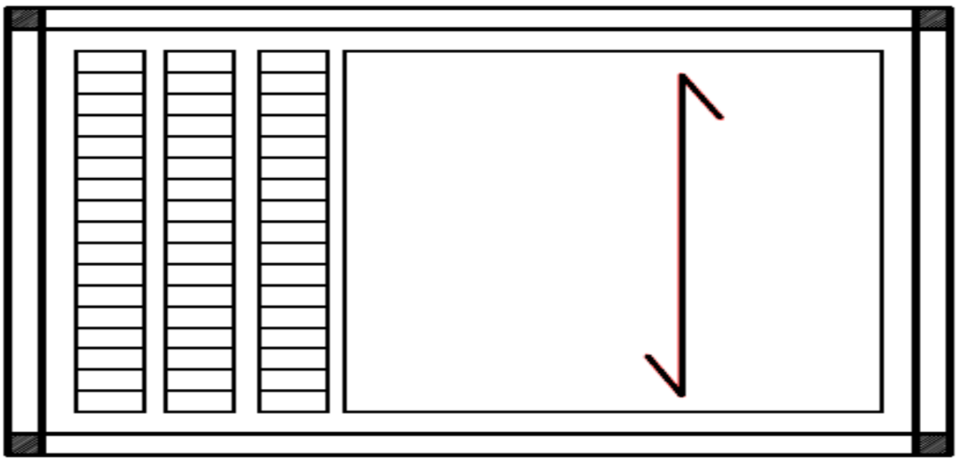


Figure 2.12: Arrangement of Block in One-Way Hollow Blocks

Source: Muhammad. N.J, (2016)

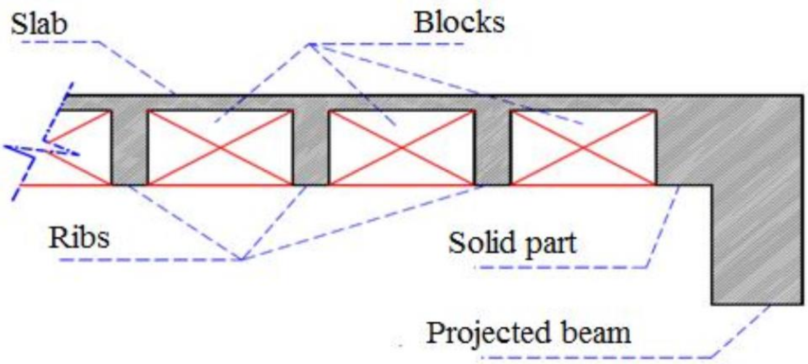


Figure 2.13: One-Way Hollow Block Slab Cross Section

Source: Muhammad. N.J, (2016)

Figure 2.14: Site Implementation for One-Way Ribbed Slab

Source: Muhammad. N.J, (2016)

2.2.3.2 Two-way ribbed slabs (waffle slabs)

Solid slab version that supports a thin top slab and may be viewed as a collection of crossing ribs arranged at tiny spacings relative to the span.

A waffle slab is a concrete slab with square grids running in opposite directions. It has a lot of depth to it. A hollow hole appears on the slab when concrete is struck.

Shuttering, laying pods, placing reinforcement between pods and mesh above the pods, and finally casting concrete are all steps in the construction of waffle slabs.

A two-way joist slab is also known as a waffle slab. Due to its architectural appeal, this type of slab is commonly found in malls and hotel entrances (Darwin, Dolan, C. W., & Nilson, 2016).

Depending on the configuration of voids, a waffle slab may be built as a flat slab or a solid slab. The potential Waffle slab layouts are shown in Figure 2.15.

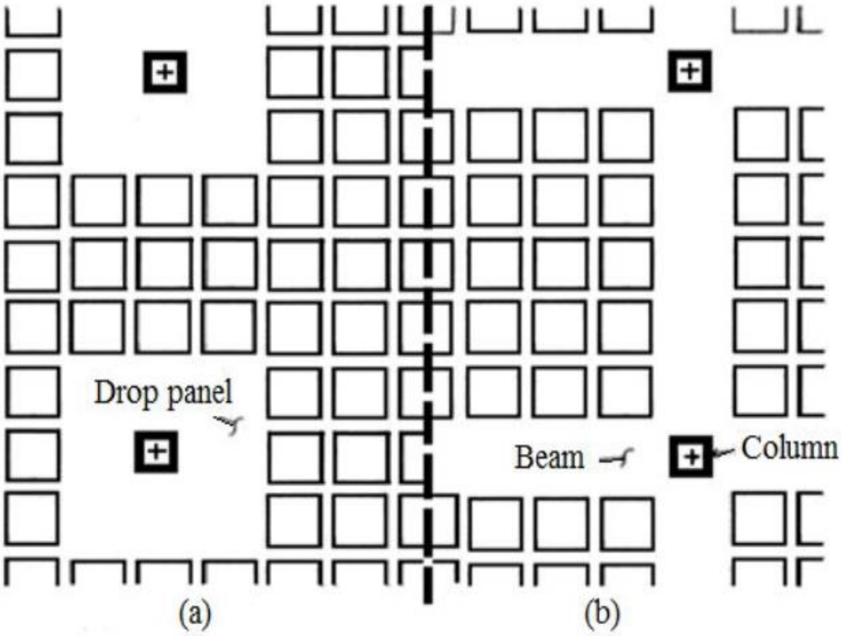


Figure 2.15: Arrangements of Waffle Slab. (a) as a Flat Slab (b) as a Solid Slab

Source: Muhammad. N.J, (2016)

As shown in Figures 2.16 and 2.17, the bottom voids are usually created by placing dome-shaped steel pans or hollow blocks on a plywood platform.

The pictures in the Figure 2.18 show the site implementation for the Two-way ribbed slab.

Figure 2.16: Waffle Slab Formed Using Steel Pans

Source: Muhammad. N.J, (2016)

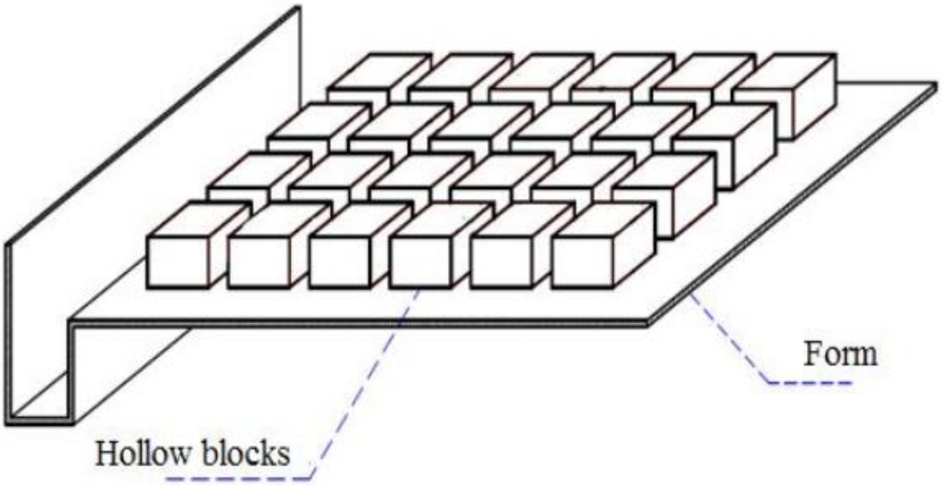


Figure 2.17: Waffle Slab Formed Using Hollow Blocks.

Source: Muhammad. N.J, (2016)

Figure 2.18: Site Implementation for Two-Way Ribbed Slab.

Source: Muhammad. N.J, (2016)

A waffle slab is a slab with holes below that resembles waffles. When vast spans are necessary (e.g., auditoriums, movie halls), it is often employed to eliminate numerous columns interfering with space, see (Figure 2.19).

As a result, thick slabs spanning between large beams are necessary (to prevent the beams from intruding below for aesthetic reasons). The major reason for using this technique is because of its great foundation fracture and sagging resistance. In comparison to normal concrete slabs, waffle slabs can bear more weight. (Darwin, Dolan, C. W., & Nilson, 2016).

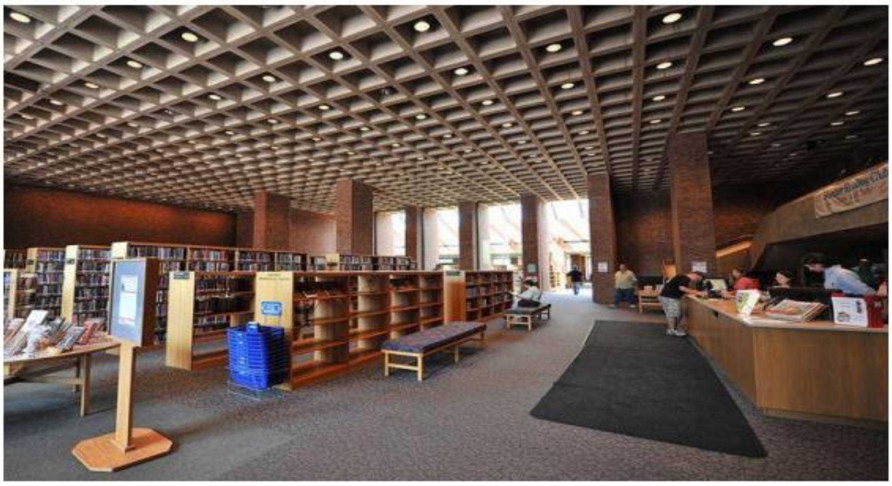


Figure 2.19: Waffle Slab Appearance

Source: Muhammad. N.J, (2016)

Deduce the ribbed floors are cost-effective in facilities like apartment complexes, hotels, and hospitals, where the live loads are low and the spans are long. They are unsuitable for heavy-duty construction, such as warehouses, printing factories, and heavy-duty industrial structures.

When temperatures are high, this method is employed. The thickness of the slab is raised to withstand the heat from the top. The heat from the walls is resisted by utilizing special bricks with solar insulators.

Disadvantages of this type are not correctly handled, the hollow core ribbed brick units may be destroyed during shipping, are not economic for short spans, difficult to repair and strengthen.

2.3 Hollow Core Slabs (Precast Slabs)

According to (Stephen,2013), a hollow core slab (HCS) is a precast, prestressed or non-prestressed concrete containing a group of hollow cores stretched through the length of the slab, this leads to a reduction in the weight and cost. HCS systems can be used in floor and roof systems. The main utilization of the HCS system is the slab of the buildings and parking, wall panels, and deck slabs for bridges. It is possible to get a span length reaches up to 18m without any support by using the HCS system.

It supplies high structural performance when using high-strength concrete and at the same time, this system is economical in the amount of concrete as shown in Figure 2.20.

Figure 2.20: Hollow Core Slab System

Source: Matthews, (2004)

The benefits of the HCS system are:

1. Reduction in the dead loads and use it in different locations.
2. This system has wide applications and serves humans such as buildings residential, teaching, hospitals, and factories in addition to bridges.
3. This system provides a long span without any support in the middle region with high carrying capacity.
4. This system provides fire resistance.
5. This system has good insulation from heat and noise.
6. This system is considered to be economical for weak soil and reduction in the number of site workforce.
7. Use of hollow cores for air circulation for cooling and heating purposes.
8. In this system, benefit from hollow cores can be utilized to conduct electrical wiring, water tap, and sewage pipes (IPHA, 2016).
9. In this system, it is possible to save the consumption of reinforcing steel (due to the use of the strands), as well as we do not need wooden or metal molds that are used in the method of casting slabs on the site.
10. Production of HCS can be done in bulk.
11. Facilitate monitoring.

12. Better quality concrete is produced because its quality is more secure.
13. Construction implementation is almost unaffected by weather (Ervianto, 2006).

Here are the disadvantages of precast concrete when compared with cast in situ concrete:

1. Transportation factor, because the precast concrete production process is carried out at the factory, then after finishing the results must be transferred production to the site.
2. Elements Unification Stage, the use of precast concrete technology always passes the process of uniting precast concrete elements into a unified whole to form a building.
3. Jointing of concrete structures to unite the concrete elements precast requires an additional construction capable of transmitting all the forces acting in every element (Ervianto, 2006).

2.3.1 Historical development of hollow core slabs

The concept of inserting voids in the middle of a cross-section to minimize the self-weight of concrete slabs goes back to the turn of the century. Several inventors from various nations filed patent applications for various systems.

Hollow core slabs were made either at a facility or on-site in the beginning. Individual molds and even extended line beds were often employed, although in a disjointed manner.

The majority of the concrete compaction was done by tamping the new concrete.

We can differentiate three primary approaches to hollow core slab fabrication based on patent filings.

- Wet cast.
- Slip forming.
- Extrusion.

In general, these manufacturing technologies may be utilized to produce both reinforced and pre-stressed slabs. They are typically found in regular thick concrete; however structural lightweight concrete is sometimes used.

The prestressed and reinforced hollow-core floor slabs of today are the product of much research and development. New hollow core slab versions are continually being introduced to the market.

The manufacturing procedures, more than the hollow core slab itself, are constantly being improved.

The following sections classify historical developments according to the three production systems outlined above (Van Acker & Mass, 2021).

1. Wet cast:

(Siegler, 1906) is often credited as being the first to use longitudinal void formers in concrete slabs.

Prefabricated short molding tubes in a hardened mortar or similar substance were positioned on scaffolding to create cores in his technique (Figure 2.21).

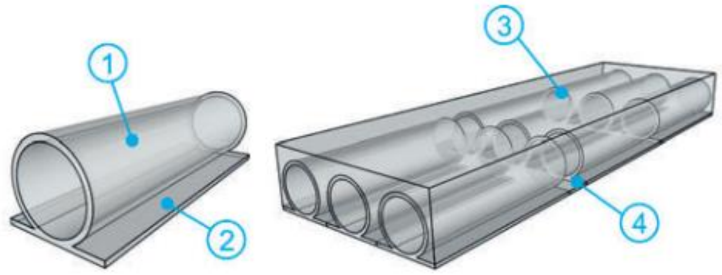


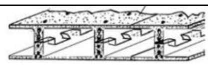
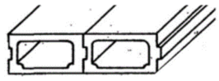
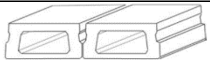
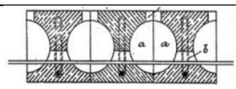
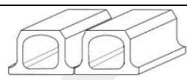
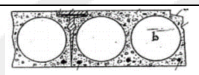
Figure 2.21: Basic Core Unit and Application into a Floor Slab

(1) Short molding tube. (2) Lateral lugs. (3) Tubes positioned longitudinally in contact with each other, and (4) Tubes positioned at a short distance to form transversal ribs
Source: Van Acker & Mass (2021).

The slabs' lengths were chosen at random. The bottom of the tubes contained lateral lugs that served as a mold for the webs. To produce transverse ribs, they were either inserted constantly in the longitudinal direction or with short inter-distances at certain locations. The longitudinal and transverse webs were traditionally strengthened.

Several ways for creating longitudinal holes in flat floor slabs were developed throughout the next two decades. Table 2.1 gives an overview of the situation.

Table 2.1: Historical Developments For Variant Shapes to Form Hollow-Core Units

The Date	Country	Variant HCS Shapes	The Source
1914	Belgium		(Martens,1914)
1916	Russia		(Molotiloff,1916)
1919	Belgium		(Moyse,1919)
1921	Great Britain		(Rings,1921)
1926	France		(Chaumeny,1927)
1927	France		(Societe,1927)

2. Slip forming

In March 1931, the German Wilhelm Schafer filed for a patent for precast reinforced and prestressed hollow core slabs stacked one line above the other on long line beds. His goal was to develop an already-in-use manufacturing system based on a kind of slip-form technology with moveable cores and side plates, in which the various production phases were carried out one after the other. It might be thought of as a forerunner to the slip form method. In 1933, patents were awarded in Germany, the United Kingdom, the United States, and Switzerland (Schafer, 1933).

The Schafer patent was bought by Spancrete (an American company), which began producing prestressed hollow core components in 1950, using a procedure in which a succession of long lines was cast in stacks, one on top of the other. A diamond disk sawing machine was put on the pile of slabs once the higher slab had been set, and hollow core units were cut and removed, see (Figure 2.22).

In 1951, Wilhelm Schafer was granted a patent for prestressed hollow core flooring with large spans (Schafer, 1951). The pieces featured a specific longitudinal edge profile with a dovetail groove and could be made with a soffit thermal insulation layer, see (Figure 2.23).

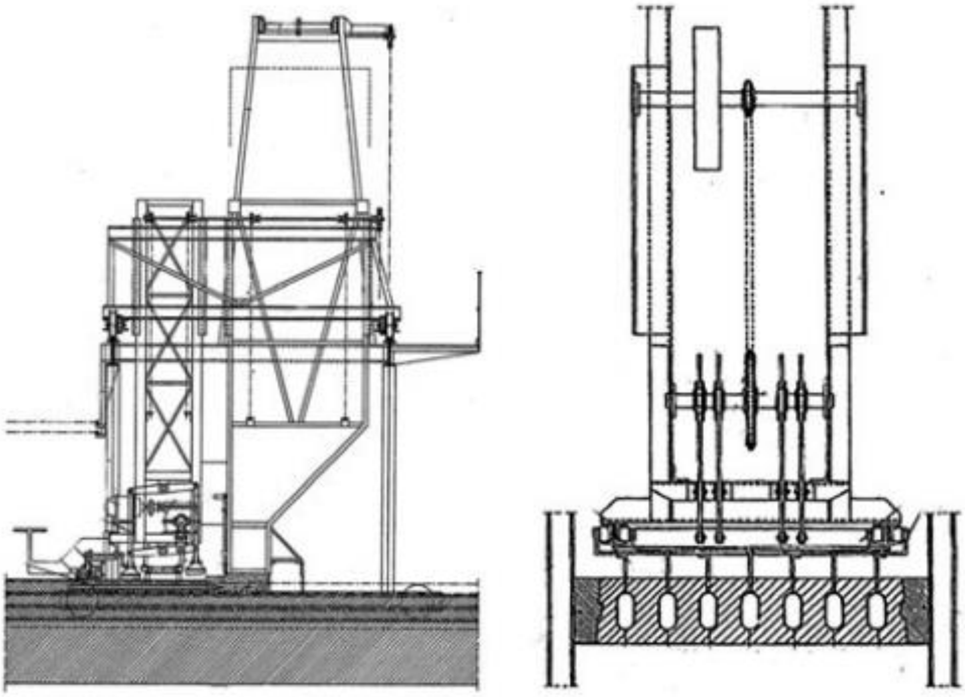


Figure 2.22: Casting Machine Hanging in a Movable Portal Frame Invented by Schafer

Source: Schafer (1933)

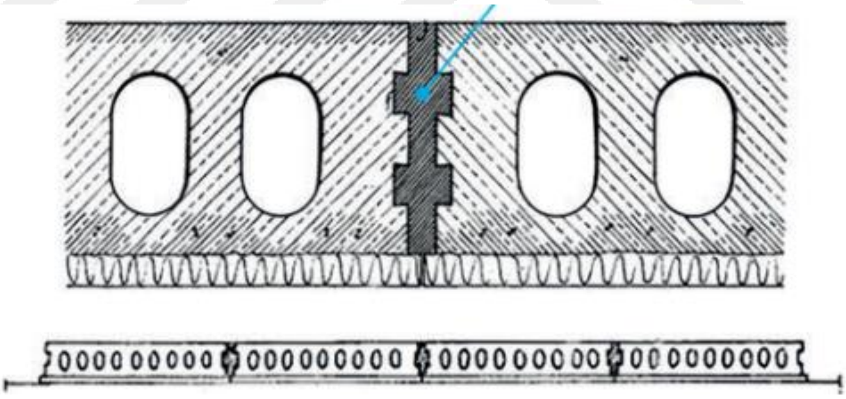


Figure 2.23: Prestressed Hollow Core Elements with Profiled Longitudinal Edges.

Source: Schafer (1951)

The Wacker Brothers were awarded a patent in 1952 (Wacker G.,1952). This business devised a way to shape and compress concrete in moving molds, which was inspired by a 1938 patent outlining a method and equipment for constructing pipes, vibrating the concrete achieves compaction.

In 1953, Max Gessner of Locham filed a patent application (Gessner, 1957) for compaction machinery for producing prestressed concrete beams or structural parts. This invention, which was issued in 1957, shows how to operate the vibrating slip-the-form machine on a single casting bed, which is the most typical design nowadays.

David Dodd received a US patent in 1965 for a single-hopper slip-form machine that cast the whole slab in one step (Dodd, 1965). He defined it as a self-propelled extrusion slip forming machine that may be used with moderately dry concrete mixtures. The Tensyland flow former machine (Prensoland a, 2017) which has just one hopper, is another variation of the basic slip form machine. The flow former relies only on the self-weight of a concrete column within the casting machine, as well as the vibration necessary to settle the particles, to flow concrete through a static mold.

3. Extrusion

With the extrusion process, a very low slump concrete is forced into a molding chamber by screws (augers), which molds the concrete into the desired cross-section. Vibration and pressure work together to compress the concrete. The pressure exerted by the augers causes the extruder to go ahead.

Already in 1912, the Italian inventor Achille Gaiba filed a patent for his machine to make continuously reinforced items, in which the product was shaped and compacted only by the pressure of a plastic concrete mix into a molding compartment, with no additional vibration (Gaiba, 1913).

John Murray of the United States used pressure without vibration to crush concrete in 1928 (Murray 1932). The technique and equipment might be utilized to create continuous conduits by forcing plastic concrete into a progressively moveable mold under pressure. His idea was focused on the construction of subterranean conduits with many ducts for transporting electric lines. Glenn Booth of Spiroll Corporation referred to this paper in his patent of 1966 (Booth, 1965), which was issued 40 years later.

Ellis and Thorsteinson were awarded a patent in Canada in July 1961 for a Machine for extruding hollow cored concrete pieces (Ellis & Thorsteinson, 1961).

The extruder was marketed as a better version of the most popular method at the time, which was molds with inflated cores. The process calls for compressing concrete through a molding section with an auger to make longitudinally cored concrete slabs on an extended pallet. A vibrator is used to compress the concrete on top of the molding.

TTV, a private construction business in Finland, invented the Variax version of extrusion machines for prestressed hollow core parts in 1969.

Elematic Engineering Ltd. became the worldwide Finnish market leader in the marketing and design of Variax technology after multiple mergers and acquisitions.

Other extrusion machine firms were afterward established in Finland.

Elematic bought Dy-Core and Roth in 1984 and 1996, respectively. The original extrusion machines were very loud (up to 85 decibels in the neighborhood). Elematic invented the so-called shear compaction technology in 1984, in which the concrete is compacted by a tamping movement of augers and side formers rather than high-frequency vibrators within the augers. The machines are quieter and generate a high-quality product profile. Figure 2.24 shows several kinds of prestressed hollow core slab cross-sections that were employed in Sweden in 1984. (Van Acker & Mass, 2021).

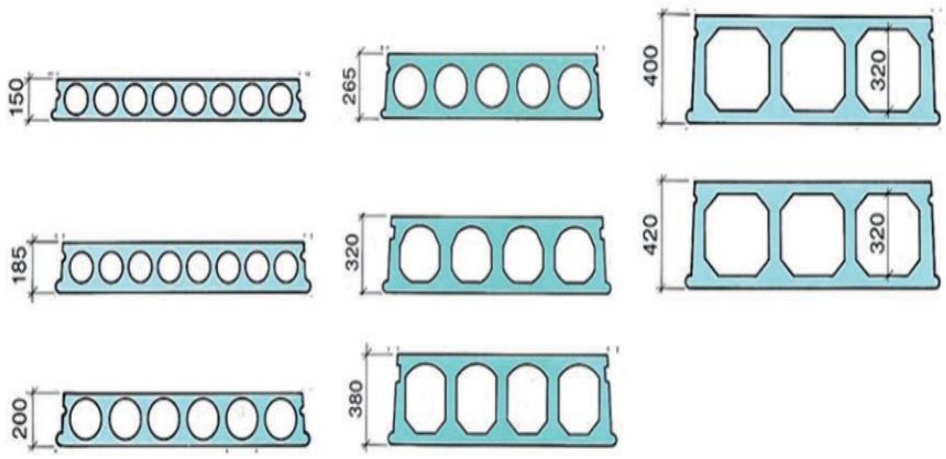


Figure 2.24: Extruded Slabs in Sweden in 1984

Source: Van Acker & Mass (2021)

2.3.2 Production and manufacture of hollow core in the factories

According to (PCFOG Committee, 2009) on a lengthy flatbed, a machine-produced hollow-core is constructed. The machine moves along the bed, making a continuous completed concrete profile out of extremely dry zero slump concrete that has been subjected to high compaction stresses. When the topping is applied, the final slab, which was made in a single pass of the machine, will have shaped sides that will connect neighboring slabs when they are filled with concrete. It will have three to six layers, depending on slab thickness and manufacturer, as well as a roughened top surface to bind with the in-situ topping.

Different machines and procedures have relative strengths (typically linked to machine noise), but variations in final product performance are small from the consumer's perspective.

The prestressing tendons are tensioned and run out along a bed in all circumstances. Except for minor curves to form the completed slab's bottom borders, the bed is flat.

The machine moves along the bed, sculpting the concrete into the desired shape. The machine compacts the concrete around the prestressing tendons and produces the completed slab's shape, complete with continuous voids, in a single pass.

Hollow-core manufacture requires an extremely dry concrete mix. The concrete must be workable enough for the machine to shape and compress it properly while maintaining its profile directly next to the strongly vibrating machine.

When a minimum of 30 Map is generally needed for release (at 16 hours), the critical strength is used. Although the 28-day strength isn't a production factor, it commonly ranges from 50 to well over 60 Mpa.

According to (Albero, Saura, Hospitaler, Montalva, & Romero, 2018), the machines are operated on steel beds up to 200 meters long, with stressing abutments where tendons are originally positioned and prestressed, as shown in Figure 2.25.a. The location, number, and cross-section of these tendons may all alter. Concrete casting is continuous, and there are three different techniques on the market, slip former, extruder, and flow former.

The finishing mold, a specialized and replaceable element of the casting process, determines the final shape of the slab hollows see (Figure 2.25.b). This core mold may be swapped out to make slabs with varying cross-sections or heights. Using the same machine but a different finishing mold, the form, amount, and location of the slab holes may all be altered. As a result, new hollow core slab design suggestions may cause modifications in the manufacturing finishing mold.

The units are cast in one continuous pour on a long bed (up to 100 meters) and then trimmed to length after they have hardened.

A sequence of prestressing strands is tensioned along the casting bed before the units are extruded, and the extruded travels along the bed creating the units, see Figure 2.26. Hollow core units come in a variety of depths, the most typical depths are 200, 300, and 400 mm, and the depth of the units is frequently used to identify them (Matthews, 2004).

(a) Casting beds.

(b) Finishing molds.

Figure 2.25: Hollow Core Slab, Manufacturing Process

Source: (Manufacturer pictures: Horviten S.L & Hermo S.L)

The building should be dimensioned to fit the 1200 or 2400-mm modular plank width for economic reasons.

A concrete topping may be added to raise the fire rating, and insulating material can be applied to the soffit to increase the cover.

Wire for pre-tensioning cold drawing is used to create wires from high carbon steel. Straightening and low-temperature heat treatments are often used to reduce tension and promote ductility in this wire. To increase the steel's stress relaxation qualities, a further stabilizing steps including stretching and heat treatment are often performed.

Figure 2.26: Extrusion of a Hollow Core Floor Unit

(a) Prestressing strands in place for unit extruded. (b) Hollow-core unit being extruded
Source: *(Matthews, 2004)*

Table 2.2 lists the minimum breaking loads as well as other characteristics. The most frequent diameters for 7-wire, stress-relieved strands are 9.5, 12.7, and 15.2 mm in diameter (C & CAA, 2003).

Table 2.2: Properties and other Characteristics of Strands

Property	Size designation 9.5	12.7	15.2	15.2 EHT
Minimum tensile strength, f_p (MPa)	1850	1870	1750	1830
Nominal diameter (mm)	9.5	12.7	15.2	15.2
Nominal linear mass (kg/m)	0.43	0.77	1.12	1.12
Nominal area (mm^2)	55.0	98.6	143.0	143.0
Minimum breaking force, $f_p A_p$ (kN)	102	184	250	261
0.1% proof force (kN)	83.6	151.0	205.0	214.0
0.2% proof force (kN)	86.6	156.0	212.0	222.0

Source: C & CAA, (2003)

The stages of hollow core board production can be summarized, (Figures 2.27a &b).

1. Cleaning and oiling the bed.
2. Strand pulling.
3. Tensioning strands.
4. Lifting extruder on the bed.
5. Concrete mixing.
6. Concrete transportation.
7. Concrete dosing to the extruder.

8. Extruding.
9. Draw openings by plotter.
10. Making openings.
11. Covering of slab.
12. Curing of the slab.
13. Recovering the slab.
14. Cutting of slab.
15. Lifting of the slab.
16. Drilling of drainage holes.
17. Transportation to storage.
18. Handling of slabs in storage.
19. Transportation to site.

Figure 2.27: Some Stages of Hollow Core Production

(a) A realistic picture of a hollow core productionfactory (b) realistic picture showing the Covering of the slab

2.3.3 Transferring the hollow core slab to the worksite

Coordination between suppliers with contractors is very necessary at this stage, the coordination is related to the number of precast elements, shape, and size.

Delivery of precast materials to the location using a trailer truck. Before shipping the supplier survey to see the road access that will be traversed related to the carrying capacity and maximum load allowed. Chains or webbing straps may be used as load restraints. The maximum economical distance for transportation by truck is from 150 to 350 kilometers, but this also depends on the type of product. Whereas for sea transportation, the maximum transportation distance can reach 1000 km (Orry, 2008).

During travel, restraints should be checked and adjusted as needed, they tend to relax owing to weight settling and stretch in the restraints, some states have extremely strict constraint laws, however, Figure 2.28 provides broad parameters.

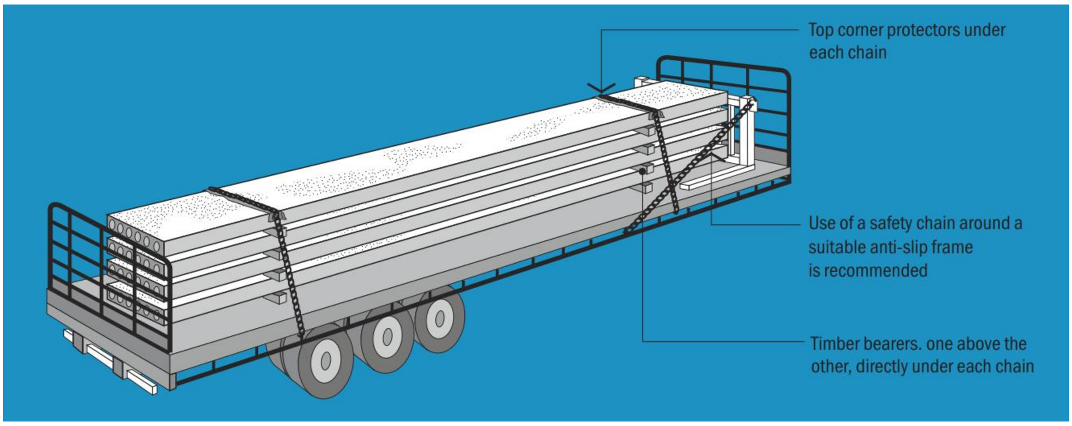


Figure 2.28: Employing a Flat-Top Trailer, Horizontal Panels Must be Restrained

Source: *(NPCAA, 2002).*

2.3.4 The storage

The storage area is normally an open area located at the end of the production hall. There are gantry cranes, overhead bridges, or A-frame loading systems. The cranes lift single slabs or bundles of slabs onto transport wagons, this is about storage in the factory. Because the number of precast is very large and impossible to install simultaneously, the precast concrete must be accommodated in the stockyard first.

Before delivery, storage should be organized to minimize handling. Every time a unit is moved, there is a chance of harm, see (Figure 2.29).

Figure 2.29: Storage in the Precast Production Plant

Source: (Darin Precast catalog)

2.3.5 Site erection

Hollow core panels are installed using equipment that must be available at the site, including the clamps, shown in (Figure 2.30) for holding the slab, as well as choosing a suitable crane for the site, which may be a mobile crane or a tower crane.

The installation must be done by a specialized party, and it is often the manufacturer of the panels that do the installation, see (Figure 2.31).

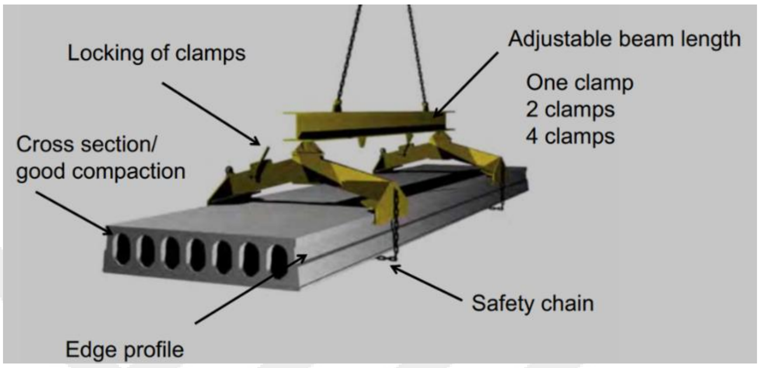


Figure 2.30: Clamps for Hollow Core Slabs Installation

Source: IPHA, (2016)

To guarantee excellent installation, proper planning and preparation work must be completed before the actual installation of precast concrete pieces. The following things must be scheduled ahead of time (NPCAA, 2002):

1. HCS panels should be recognized by their location number and marked in the order in which they should be assembled and installed.
2. Temporary support method: Elements should be briefly supported before they are stabilized. Securing the panels is usually done using structural components with movable ends. To maintain dimensional accuracy, shims should be used to modify the panels.
3. Installation tolerances: Installation tolerances should be based on cod provisions, with design concerns explicitly expressed.
4. Handling and rigging requirements: Before lifting, elements should be examined for handling stresses, and cranes should be capable of handling the precast panels.

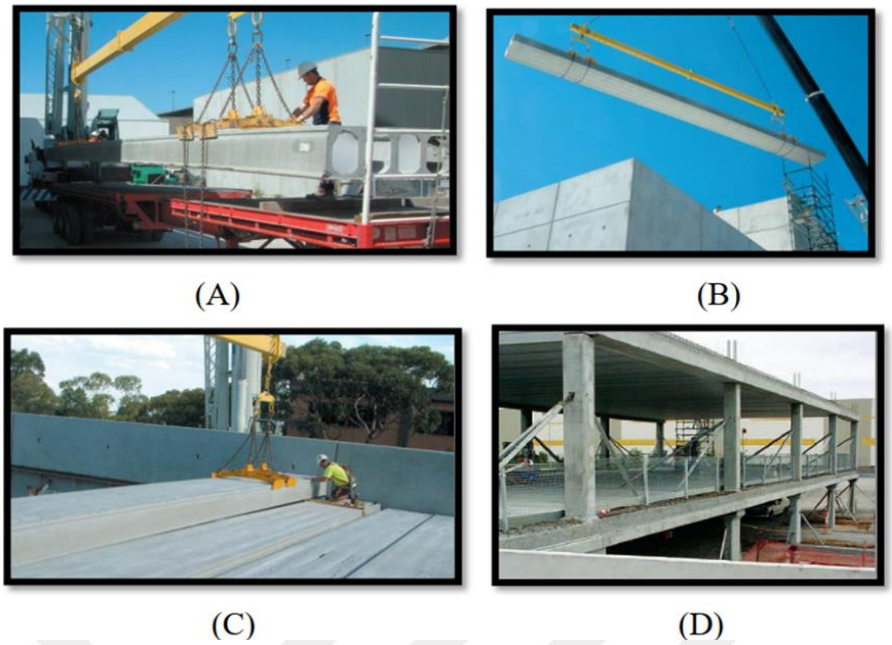


Figure 2.31: Installation Stages of Hollow Core Slabs in Site

Source: Stephen, (2013)

2.3.6 Connections

Hollow core slab systems will need connections for several reasons. Internal connections and connections to the lateral force resisting parts will be necessary if the slabs are to function as a diaphragm. Localized stresses may also need connections, such as a bracing and interior or external wall, laterally bracing the top flange of a beam, or hanging mechanical equipment or a ceiling. Tie-backs to the structure, shear wall connections, and gravity support of floors or roofs are all possibilities for hollow-core wall panels.

A link is often built to withstand pressures in many directions. Other connections are intended to give resistance solely in one direction to prevent causing unanticipated loads to the panel or the structure.

Connections are a project expenditure that, if employed incorrectly, may have negative consequences by failing to accommodate volume change movements in a precast structure. As these motions are restrained, forces may emerge in connections. The real forces in the connection must be considered while setting connection criteria.

The link should not be utilized if no force can be shown to exist. When a connection is judged to be essential, the force in the connection should be defined, especially when the hollow core is in contact with another material. (Donald & Roger, 1998).

2.3.7 Topping concrete

The top surface of the Hollow core units shall be clean and free of all dust, oil, or any deleterious substances which may adversely affect the wet topping bond to the Hollow core units. The HCS surfaces before placing the topping concrete.

Free water shall be broomed away before the topping is applied, and topping concrete shall have a minimum 28-day cube strength of 25 MPa and be well compacted with mechanical vibrators.

In-situ concrete shall be cured by the application of an approved curing membrane or by being kept continuously wet for not less than seven days.

Because of the upward bending caused by pre-stressing, Hollow core floor planks are cambered. This camber should be taken into account when detailing planks and joints at abutting walls, doorways, and other areas. A site-cast topping screed unites the boards into a monolithic floor, eliminates differences in unit levels, and creates a level working surface. At the plank's highest point, the minimal thickness of topping is found. For practical reasons, 60mm of average topping is utilized for units 200 - 220mm deep, and 80mm for units 300mm deep and above (Figure 2.32).

Screed reinforcement is usually specified at a minimum of SL72 mesh, if the topping concrete is to be used to grout the keyways, it should be a low shrinkage mix with a superplasticizer if required to aid placement. If the topping concrete is to be used to grout the keyways, the maximum aggregate size should be 10mm (Detailing Manual, 2004).

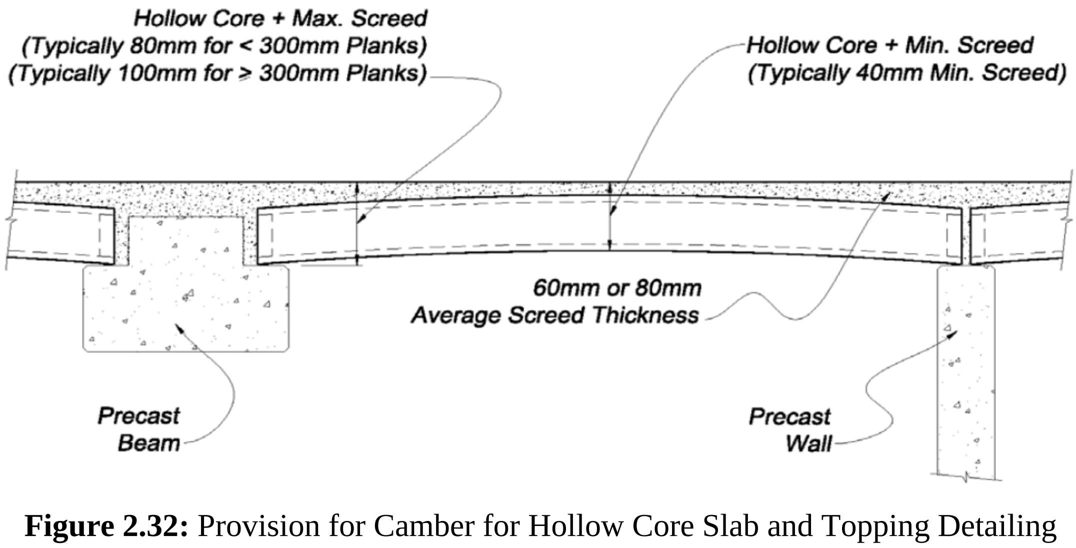


Figure 2.32: Provision for Camber for Hollow Core Slab and Topping Detailing

Source: Detailing Manual, (2004)

2.4 Engineering Management of Project Costs

The capacity of construction projects to objectively estimate project costs and respond to changes in the external environment, which is influenced by numerous variables and needs of the competitive market, is a critical factor in their success.

To fulfill their objectives, these initiatives must overcome several challenges.

To address these issues, research has been conducted during the last two decades, with the emphasis shifting to the function of project cost management in giving information and supporting management in planning and regulating the balance between the project's primary aspects (time - cost - quality).

In recent years, the area of cost accounting has seen significant changes as a consequence of technological advancements combined with greater competition and the creation of high-quality products and services at the lowest feasible cost while meeting client needs. Costs and decision-making by management (Hilton & Platt, 2011).

The phrase "cost management" is often used in business institutions to define the techniques and actions used to manage short and long-term planning and control choices that improve customer satisfaction while also rationalizing product and service costs (Horngren. et. Al., 2009).

The term cost management does not have a unified, agreed-upon definition, according to Hilton it's a collection of tools and processes that provide value for customers at the cheapest feasible cost (Hilton & Platt, 2011).

Horngren, defined it as they are the ways and actions that managers use to give value to customers and accomplish corporate objectives by using resources (Horngren. et. Al., 2015).

As well as Bhimani defined it as the procedures taken by the managers to satisfy the customer with continuous rationalization and cost control (Bhimani. et. Al.,2008).

So, before a construction project begins, first carefully estimated the costs to be incurred for work on the project, hereinafter referred to as the Plan budget. The cost budget plan is a calculation of the number of costs required for materials and wages, as well as other costs associated with the implementation of the building or project (Ibrahim, 2001).

The cost budget plan is calculated based on the volume of each type of work multiplied by the unit price of each job and calculated for all types of work that are carried out on a construction project so that can be obtained the total budget plan. Unit price work consists of material costs, labor costs, and labor costs equipment where these costs include direct costs in a project.

2.4.1 Volume of work

The volume of work is the calculation of the number of volumes of work in one unit. So, the volume (cubic) of a work, is not a volume (actual content) but rather the sum of the volume of parts of the work in one unit.

Volume calculation in construction work is the process of measuring/calculating the quantity of items work based on drawings of work in the field.

By knowing the amount of work volume, it will be known how much cost is required in the implementation of the construction (Ibrahim, 2001).

2.4.2 Unit price of work

The unit price of work is the sum of prices, materials, and labor wages based on analytical calculations. The price of materials obtained in the market is collected in a list called the unit price list of materials. Wages for labor obtained at the location are collected and recorded in a list called the unit price list of wages. The unit prices of materials and labor wages vary in each region. So, in calculating and compiling the budget for a project, it must be guided by the unit price of materials and labor wages on the market and at the job site.

Usually, the executor or contractor makes the unit price separate work that is adjusted to market prices where the project is implemented. (Ibrahim, 2001).

2.4.3 Direct costs

Direct costs are cost elements that are related directly to the volume of work listed in the item payment or become a permanent component of the final project result.

Included in the direct cost category are all costs that are within the control of the subcontractor. Direct costs are all costs that are directly related to the implementation of construction work in the field (Sudarsana, 2008).

1. Material/material costs: The price or materials used for the process construction execution.
2. Labor costs: Costs paid to workers to complete a type of construction work.
3. Equipment cost: Costs required for rental activities, transportation, equipment installation, and operating costs can be also included wages from machine operators.

2.4.4 Indirect Costs

Indirect costs are all project costs that are not directly related to construction in the field but this cost must exist and cannot be separated from the project. Indirect costs consist of from (Lafiza, 2017): -

1. General overhead costs: Office rental costs, office equipment, stationery, water, electricity, and others.
2. Project overhead costs: Costs such as telephones installed on the project, measurements (surveys), permits, and others. The amount of overhead can range from12 %-30%.
3. Profit: Profit earned by project implementers (contractor). In general, the advantages of contractors range from 10% -12% depending on the contractor's wishes.
4. Taxes: Various kinds of taxes such as VAT, and others on the results of the company's operations.

2.5 Engineering Management of Project Times

Scheduling in construction projects is a tool for determining the activities needed to complete a project in a certain sequence and time frame, in which each activity must be carried out so that the project is completed on time at an economical cost (Widiasanti, Irika & Lenggogeni, 2013). From the schedule, we will get an idea of the length of work that can be completed. Scheduling is done by determining the sequence in which activities are started, postponed, and completed so that the cost and resource usage needs are adjusted according to the needs and time of implementation. One example of a scheduling method is PDM.

According to (Suharto,1999), PDM (Precedence Diagram Method) is known for its constraints, one constraint can only connect two nodes because each node has two ends, namely the start or start = (S) and end or end = (F). So here are four kinds the constraints are:

1. Finish-to-start (FS); An activity cannot be started as long as the previous activity has not ended.
2. Start-to-start (SS); An activity cannot be started as long as other activities have not started.
3. Finish-to-finish (FF); An activity cannot be terminated while other activities are over.
4. Start-to-Finish (SF); An activity cannot be terminated as long as activity A has not started.

2.5.1 Productivity and work duration

To determine the duration of the work, the things that are needed are the volume of work and the productivity of the tool. Product productivity depends on capacity and time tool cycle which is done by time analysis. Productivity workers are usually obtained by dividing the coefficient of labor contained in the unit price analysis by the volume of work.

2.5.2 Relationship between activities

Relationships between activities include reviewing activities to be carried out and determining dependence on one another. Dependencies or relationships between activities are related to the sequencing of project activities and tasks. It is necessary to determine dependencies between activities for critical path analysis (Rismanto, 2013).

Dependency types in the project:

1. Mandatory dependence (Hard Logic): in line with the nature of the work to be done in the project.
2. Discretionary dependencies (Soft Logic): determined by the project team and should be used with care because it will likely limit the options next schedule.
3. External dependencies: include the relationship between project activities and non-project activities.

3. METHODOLOGY

3.1 Research Steps

In this methodology chapter, we will explain the steps to be taken in preparation for the assignment final about in situ casting slab comparison with precast slabs (hollow core) to be used as a frame of reference. The steps in this research are as shown below:

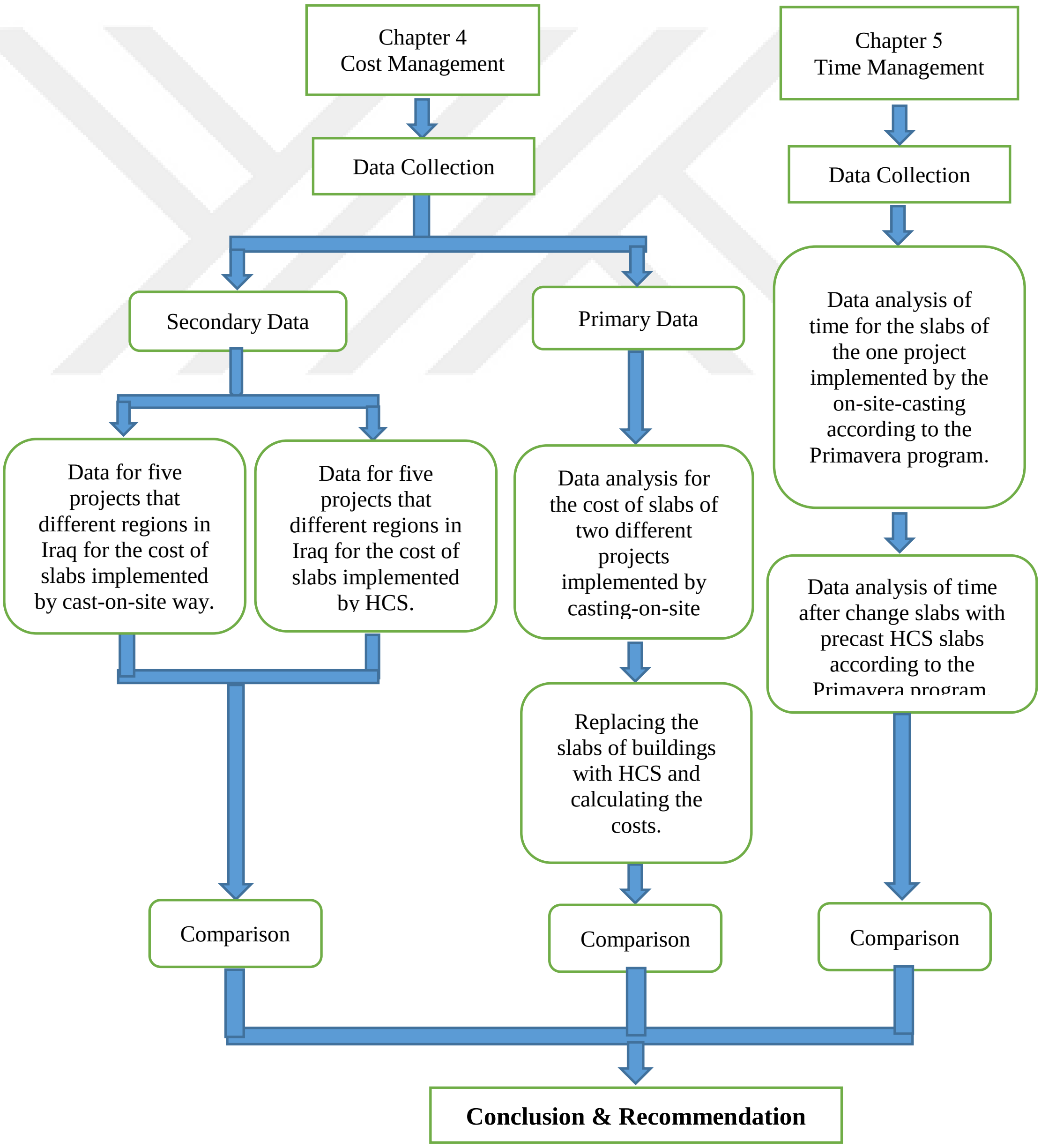


Figure 3.1: Research Flowchart

3.2 Data Collection

3.2.1 Data collection of cost

Data costs will be collected in the form of data secondary and Primary.

3.2.1.1 Secondary data

Was obtained by government departments for five projects in different regions of Iraq, whose slabs are implemented by the method of on-site casting, also data for five projects that were obtained by (Darin precast factory) for projects whose slabs have been implemented using the precast HCS method.

The comparison is done to find out the average price difference between the two methods and compare them.

3.2.1.2 Primary data

The primary data will be obtained from a study of buildings under construction by the on-site casting method. Their drawings will be obtained from government agencies, companies, contractors, and implementers.

After that, the implementation method is changed from on-site casting to hollow core, changing it with drawings, and taking detailed data from the hollow core production plant (Darin precast factory).

Then the results of the analysis are compared to find out the difference in cost between the two methods.

3.2.2 Data collection of time

Data collection of times will be collected for the duration of the completion of the slabs of one building, that was completed by the on-site casting method, through the Primavera program, the data of which was obtained through the executing company, which was known from the observation of taking work time data using a stop watch, video camera, interviews with workers or engineers, and from books or literature that already has a research basis.

As for the periods related to the completion of the slabs of the same building in hollow core, the data of the manufacturer (Darin precast factory) will be based.

3.3 Comparison of the conventional method with hollow core slab precast system

3.3.1 Conventional slab

3.3.1.1 Conventional slab design

Slab design drawings are the basis for calculating the volume of work per floor.

The shop drawings obtained from the contractor's implementation are the reference for these accounts.

3.3.1.2 Conventional working method

Analysis of work methods becomes the basis for calculating cost and implementation time for each method, by a brief explanation of the conventional slab working method begins with the installation of a work floor in the slab area, and the columns that have been installed, then the scaffolding is installed as formwork holder plates and beams after that adjust the height of the scaffold with predetermined height, then install the beam formwork and plates together, then beam reinforcement and plate reinforcement according to shop drawing plans, then a checklist is carried out to check the required reinforcement and dimensions installed, to make sure it's true, after that the casting is done together between the slab and beam.

3.3.1.3 Conventional implementation cost analyses

Cost analysis is needed to find out the number of costs required in every method of construction work.

Unit price should be considered in cost analysis, to calculate the cost of conventional slabs, prices obtained from Iraqi government sources and related companies are used.

Then the cost budget plan is calculated based on the volume of each type of work multiplied by the unit price per unit profession.

3.3.1.4 Conventional implementation time analyses

The implementation time will be calculated traditionally by obtaining the Primavera program prepared by the executing company to find out the real-time period that was used to complete the work, which is obtained from the experience of technicians and contractors, following the camera at the work site, as well as magazines related to related works.

3.3.2 Precast slab (hollow core slab)

3.3.2.1 Design of hollow core slab

In this final project, we will use a precast plate (HCS) that has been made by a precast concrete factory, then the type of slab to be implemented will be selected, after that make a precast slab plan drawing as volume reference for cost calculation required.

3.3.2.2 Hollow core slab working method

For the precast hollow core slab work, the method will be carried out observations on projects using the precast method, studies of research that has been done, and product brochures.

3.3.2.3 Cost analyses of a precast slab (HCS)

Cost analysis is needed to find out the number of costs required in every method of construction work.

One of the most important things to keep in mind in cost analysis is the analysis of unit price, the unit price will be based on the production plant for precast slabs.

3.3.2.4 Time analyses of a precast slab (HCS)

The duration of the work is highly dependent on then the volume of work, the number of workers, and the tools used on the job. The data will be taken from the factory producing the precast plates.

3.4 Comparative Analyses

After analysis of methods, costs, and time for both the construction method obtained, the results will then be compared to how much it costs, and the time it takes for both methods are based on the results of the analysis of the implementation method, and the most cost-effective and time-effective of the two methods.

4. COST ANALYSIS AND MANAGEMENT IN THE TRADITIONAL WAY AND PRECAST (HOLLOW CORE) SLABS OF PUBLIC BUILDINGS IN IRAQ

4.1 Introduction

In Iraq, costs are greatly affected by several variables, the most important of which are two main factors that affect the cost of on-site casting and the cost of producing hollow cores as below:

1. Casting on site:

The cost is affected in this way by the decrease and rise in the prices of materials such as rebar, concrete, and labor, which are unstable in different Iraqi places and governorates.

Therefore, we will try to collect secondary data on the cost of casting slabs on site for buildings that were completed in different periods and in different Iraqi governorates to find out the average cost of one cubic meter in this way. This data was collected for five different projects from the statements and contracts implemented in these governorates, its cost will be compared with five other projects that slabs implemented in the hollow core method.

Then we will take two buildings and analyze the cost of casting their slabs in detail as basic data that we rely on in comparison with the precast way (hollow core) slabs. This way is not affected much by transportation.

2. Hollow core slabs (HCS):

This way is greatly affected by transportation and the distance of the project from the production plant of these panels, and less affected by changes in rebar prices (considering that we use less rebar in the presence of strands).

Therefore, we will take the same data for the two buildings that are far from the HCS plate production plant for different distances, one of them is close (about 30 km) and the other is far (about 120 km), to find out the effect of transportation. We will refer to data obtained from the Darin precast factory in the Erbil governorate.

4.2 Secondary Data

Data from five projects implemented for the period from 2018 - 2022 were taken and different regions of Iraq to compare the average price of the cubic meter, both ways, as follows:

4.2.1 Projects implemented in the traditional way (casting on site)

Table 4.1 can be noted the projects implemented in various regions of Iraq for on-site casting slabs of buildings, at an average price per cubic meter, 381,000 ID, and noted there are no significant differences in the prices of the cubic meter for the different governorates, and this indicates that the transport factor does not have a significant impact on the method of on-site casting of slabs.

Bills of quantities and prices for projects implemented in the traditional way can be viewed, and obtained from official bodies and contractors, see (Appendix A, p.88).

It can also be noted that the higher the quantity, the lower the execution price per cubic meter and vice versa.

Table 4.1: Projects Implemented in Various Regions of Iraq for On-Site Casting Slabs

S.	**Project Name**	**Governorate**	**Quantity** (m^3)	**Price** (ID/m^3)	**The Cost** (ID)
1	Project of establishing directorate of the Municipality of Chabayish.	Dhiqar	160	400,000	64,000,000
2	18 Classrooms School in Erbil.	Erbil	276	350,000	96,600,000
3	Projects Authority Building Al Faw General Engineering company.	Baghdad	75	400,000	30,000,000
4	Building of the Directorate of Civil Status and National Card in Ramadi.	Anbar	1650	370,000	610,500,000
5	The Great Imam College building in Mosul.	Nineveh	1733	385,000	667,205,000

4.2.2 Projects implemented by precast (hollow core) slabs

Table 4.2 can note the projects implemented in various regions of Iraq for precast (hollow core) slabs of buildings, at an average price per cubic meter, 291,000 ID this price taken without topping concrete which is the cost per cubic meter of about 25,000 ID, the thickness of the layer should be 60 mm and according to the specifications mentioned in Darin Group precast factory bruchure (Appendix C, p.103).

That means the average price is up to about 316.000 ID with a topping concrete layer.

It is noted that the effect of transportation is very important in this method and the extent of the distance from the factory for the production of precast panels.

This data was obtained from a hollow core production factory in Erbil (Darin precast factory), see (Appendix A, p.89), since the distance between Erbil and Dohuk is the closest, and between Erbil and Basra is the farthest, which led to the difference in the cost of transportation and thus the difference in the price of one cubic meter.

The preparation of a factory in Erbil for hollow core panels for these distant provinces, one of which (such as Basra) reaches a distance of about 900 km, is evidence of the lack of these factories in Iraq or the lack of capacity of these factories due to the large demand for them, and the reason for the lack of these factories is due to many reasons, including the spread of culture Traditional construction and lack of culture towards prefabricated construction, in addition to political factors and internal problems in Iraqi society.

Table 4.2: Projects Implemented in Various Regions of Iraq for Precast Slabs (HCS)

S	Project Name	Governorate	Quan. (m^3)	Price (ID)	Cost (ID)
1	Implementation of slabs for buildings of a Lebanese village in Erbil.	Erbil	17,200	245,000	4,214,000,000
2	Section building of the Family Mall project in Dohuk.	Dohuk	14,500	265,000	3,842,500,000
3	School project in Baghdad for Jeckor company.	Baghdad	6,250	298,000	1,862,500,000
4	School project in Hella for Babylon company.	Babel	3,000	305,000	915,000,000
5	School project 18 classroom in Basra.	Basra	12,500	342,000	4,275,000,000

4.2.3 Comparison

According to the comparison of secondary data for projects implemented in several governorates by the traditional method (casting on site) and the precast method (hollow core), the percentage of costs by the precast method is less by approximately (17%) per cubic meter, which is a very good percentage if compared to the quantities of cubic meters for huge projects.

One of the most important reasons for this increase in implementation in the traditional way may be the high prices of labor and materials in Iraq, especially since building in the traditional way requires much more workers than the other method.

Although the indicator in the cost ratio (17%) is a good indicator for working with the precast method, it cannot be definitively confirmed because it is based on secondary data collected in a narrow range, on the one hand, and on the other hand, it can be noted that the data taken in the traditional It included quantities ranging from a little to a lot, and we find that there is a quantity (75 m^3) which is the lowest and the highest is (1733 m^3). As for the precast method, the quantities were much more and the disparity is less, the lowest quantity was (3000 m^3), and the largest amount was (17200 m^3), and this gives an indication that it is not feasible to work in the precast method for small quantities of cubic meters, due to the high costs of operating the plant in addition to the cost of transportation and other costs.

From the graph (Figure 4.1) it can be seen that the prices per cubic meter by the method of casting in the site are close despite the different places.

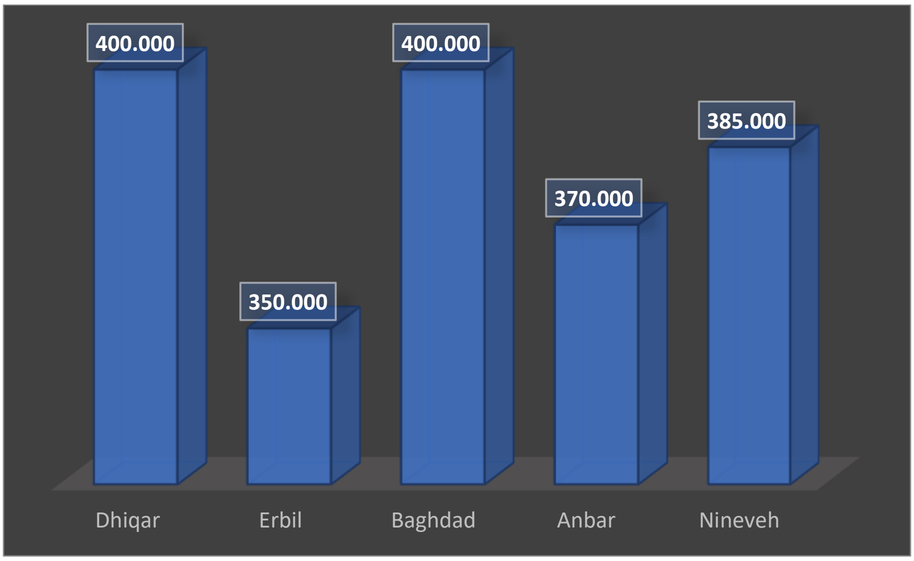


Figure 4.1: On-Site Casting Price per Cubic Meter is Relative to the Governorate

The graph (Figure 4.2) shows the extent of the increase in the prices of the cubic meter executed by the precast method the further away from the production city (Erbil), and this is evidence of the effect of the transportation price the further away from the factory.

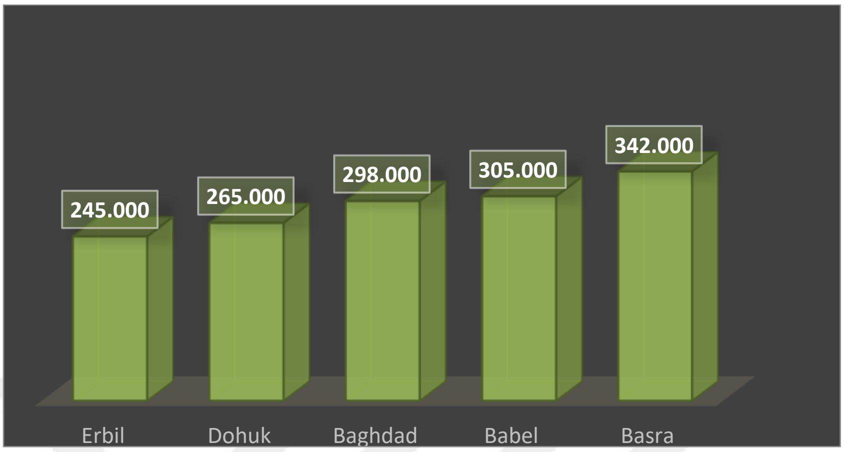


Figure 4.2: Hollow core Slab Price per Cubic Meter is Relative to the Governorate

4.3 Primary Data

Two buildings implemented in the traditional way will be studied, and their data and drawings will be obtained from the executing company and contractors, after that, the slabs are changed to precast panels (hollow core), and the two methods are compared.

For the cost, the pricing process in a country like Iraq is not an easy task, as it is subject to several internal and external factors and influences that occur from time to time.

To achieve accuracy in determining the prices of materials and labor prices, we have taken several sources to determine the price, including:-

- Keeping up with and inquiring from the local market.
- Inquiries about company owners and contractors.
- The approved official statistical electronic portals and sources.
- Professionals and Experienced.

To determine the labor prices, it was reported to make a bill of quantities for the outputs of one of the two buildings and send them to the owners of companies and contractors for pricing to reach an acceptable average and closer to the accuracy of the prices of the works of the items required in the research as shown in the

(Appendix A, p.91), Table 4.3 shows the labor prices after taking the arithmetic average for each paragraph of the bills:

Table 4.3: Labor prices Schedule in the Iraqi Market

S.	Items	Unit	The price (I.D)
1	**Wooden formwork works:** The work includes preparing and transporting wood to the work site, installing and removing it after completing the work, and moving it outside with all the work required of scaffolding, cranes, nails, and any other materials, noting that the building consists of three floors.		
A	For beams	m^2	12300
B	For slabs	m^2	10700
2	**Reinforcement works:** The work includes lifting the reinforcing steel to the three floors using a crane with installation work with all the work required of connecting wires, cutting and bending tools, noting that the diameter of the steel bar used is D16 and the stirrups D10 are done in a cut-bar method.		
A	For beams	Kg	189
B	For slabs	Kg	178
3	**In-site concrete works:** The work includes casting reinforced concrete C35 with polishing works and everything needed to work from curing with water and laboratory tests.		
A	For beams	m^3	13100
B	For slabs	m^3	11600

As for the prices of materials, we obtained from websites and electronic portals that publish prices daily, as well as inquiries from nearby factories, to ensure that the price matches the materials and as in Table 4.4 with the sources of prices:

Table 4.4: Building Materials Prices According to the Iraqi Market

S.	Items	Unit	The price (I.D)	The source
1	Steel Reinforcement	Kg	1200	CSO or https://cosit.gov.iq/ar/constr-stat/constr-pr
2	Concrete (C35)	m^3	85000	Factories and https://www.askans.net
3	Concrete (C25)	m^3	74000	Factories and https://www.askans.net
3	6mm steel mesh	m^2	16000	CSO or https://cosit.gov.iq/ar/constr-stat/constr-pr

We deduce from Tables (4.3) and (4.4) the price Table (4.5) for each unit of items executed in the traditional way.

Table 4.5: Total Price for Each Unit of Items Executed in the Traditional Way

For Beams				
Items	**Material price**	**Work price**	**Additional**	**Total price**
Formwork (ID/m^2)	0	12300	0	**12,300**
Steel reinforcement (I.Q/kg)	1200	189	(transfer)	**1,395**
Concrete (ID/ m^3)	85000	13100	0	**98,100**
For Slabs				
Formwork (ID/m^2)	0	10700	0	**10,700**
Steel reinforcement (ID/kg)	1200	178	6 (transfer)	**1,384**
Concrete (ID/m^3)	85000	11600	0	**96,600**

As for the prices of hollow core panels, they were obtained from the Darin Group precast factory in Erbil.

4.3.1 Construction of slabs in the traditional way (casting on site)

In conventional construction methods, implementation of slab works begins after the completion of the columns for the floor with installation beam and slab formwork, rebar beams and slabs, and ends with castings of beams and slabs.

Scaffolding serves to support and hold the formwork beams and slabs to keep them at the desired elevation. The order of implementation is to install the jack base, main frame, cross brace, ladder frame, and U-head jack. To determine the height of the scaffold by adjusting the height of the jack base and U head jack (Figure 4.3).

For slab formwork the brackets (U head jack) are installed to carry the pieces of secondary wood, which are erected crosswise to carry the main wood (plywood) with a thickness of 9 mm and are fixed with the secondary wood by nails, then, before the casting process, the molds are lubricated with concrete pouring oil.

In the same way, beam formworks are made in the places designated for the beams, as it works in the form of a box with supports from the sides.

It is necessary to note the coverage of the holes between the columns and beams also, in the slab molds, there should be no voids that can cause concrete leakage, (Figure 4.4).

Figure 4.3: Scaffolding for Slabs and Beams

Then the engineer will follow up and receive the wooden mold work, where the following must be taken into account:

- Integrity.
- Dimensions.
- Orthogonality.
- Center to center for columns.
- Sheathing (the mold is well sealed) using restriction in the beams and traps in the columns and filling the voids in the wooden mold with formic.
- Elevation of the casting must be fixed with the level survey device.
- Mold cleaner
- The electrical engineer receives the electrical works according to the drawings.

Figure 4.4: Slab and Beam Formwork Installation

After that reinforcement stage begins, arming is not started until the engineer approves that placing the mold is correct in terms of shape, durability, and level, the blacksmith first reinforces the beams in a suspended manner that is connected to the columns and puts (wood) below them and does not go down to its place until after receiving it by the engineer, after that placing the reinforcing net slightly raised (2 cm from the mold to secure the concrete cover) on plastic seats or small concrete pieces, the lower layer is separated from the upper layer by iron chairs (corrugated iron) according to the plans and the thickness of the slab.

It is important that the chairs rest on the rebar of the lower layer and not the mold so that it is confined between the two layers (the two grids).

The rebar is sawn in the short span direction and rebar sawn in the long span direction is carried, and tighten the rebar in the form of squares in two directions positive moment region except for the sides, the negative moment region, because half of it will be swept, and deploy the additional rebar cover at the top, along the length of one-third of the space, L/3, from the face of the column or beams, and it also exceeds the scavenging area of the negative moment as well, In the case of deployment to more than one space, the rebar can be deployed differently with the other space, so that it is bent rebar and it is additional rebar at the same time.

Each intersection point between two bars is connected with a connecting wire, and at least half of the intersections should be connected, i.e., between one bar and another (Figure 4.5). (ACI 318, 95).

Figure 4.5: Reinforcement of Slabs and Beams

Then the engineer will follow up and receive the armament work:

- Match the rebar used with the drawings (diameter, number, length).
- Spacing between rebars.
- Leave the cover space between the rebar and the mold.
- Overlap for joint works with other floors.
- The rebar must be clean from rust.

Casting concrete slab begins, preferably in moderate, non-rainy weather, good quality ordinary cement, checked sand and crushed gravel, washed and tested in the laboratory. The casting is homogeneous, neither too strong nor too soft.

It is preferable in mild weather that is not rainy, where the beams are cast first and the slab together, as well as the stairs, and the casting is once for the slab to avoid resorting to the structural joints that are placed in the middle where there is the maximum bending moment, i.e., at the lowest shear forces.

It is preferable to use the vibrator for 3 seconds per point, taking care to avoid the occurrence of concrete decay (Segregation).

It is also preferable that the casting be ready from the central mixer and not a pot mixer.

After casting, the upper surface is smoothed and leveled by skilled workers, (Figure 4.6).

Figure 4.6: Casting of Slabs and Beams with a Concrete Pump

During casting, a slump test is performed and a compressive strength test (cubes) is tested, cube samples were taken to test the compressive strength at the age of 7 and 28 days, generally, 12 cubes are checked for every 80 m^3, with the addition of 3 cubes for every additional 20 m^3.

The concrete mixture must conform to the specifications (mixing ratio) mentioned in the table of quantities and drawings when casting and achieve the required compressive strength (for example, 25 MPa) at the age of 28 days.

Concrete is treated after hardening, where the slab is immersed in water for not less than seven days.

Removal of scaffolding and formwork from the elements of origin if the tests of the cubes prove it concrete treated under the same conditions as the treatment of the elements of origin.

The components have achieved at least (70%) of the required design tolerances or that the ratio of the resistance of the test cubes to the design resistance is equal to or greater than the ratio of the total dead load and the construction load to the total design load, in contrast, the molds remain in their positions for the period specified in Table 4.6.

Table 4.6: Mold Removal Time (in Days)

Concrete element	**Active space (m)**	**Average Temperature** (°C)			
		More than 20	10--20	5--10	Less than 5
Walls, columns and beams sides		1 day	2 days	3 days	5 days
Slabs	less than 3.0	5 days	7 days	10 days	14 days
	3	7 days	10 days	14 days	21 days
	more than 6.0	10 days	14 days	21 days	28 days
Beams	less than 3.0	7	10	14	21
	3	10	14	21	28
	6	14	21	28	28

Source: Iraqi Ministry of Construction and Housing (2014)

We will analyze the costs of two buildings in detail and by the method of on-site casting once, and in a precast again, the first building is close to the precast factory (about 30 km), and the other is far from the hollow core production factory (about 120 km).

The first building will be a building inside the city of Erbil, which is the (Hemophilia center of Nanakaly hospital in Erbil). It will consist of a basement and two upper floors, and the slab will have a solid slab.

The second building will be in the city of Mosul, which is the (housing building for the professors at the Amam Azam College), and it is under construction, it consists of a ground floor and two upper floors and the drawings obtained from the executing company will be relied upon.

We will calculate the quantities involved in the work of the slabs, including the beams on the three floors, and know the costs in the traditional way, and then replace them with the precasting method and compare the results.

4.3.1.1 Near building (Hemophilia center of Nanakaly hospital in Erbil)

It is a governmental hospital in Erbil city, the building consists of a basement floor and two upper floors and the slabs are executed in a solid slab.

The area of one slab is about 520 m^2, all drawings related to this building can be found in (Appendix B, p.92-93).

General notes for design building:

1. ACI Code 318M-08 is used in the design.
2. Concrete compressive strength: C35 for beams and slabs.
3. Minimum yield stress, fy should be at least 420 Mpa. (Grade 60).
4. Deformed reinforced bars shall conform to the requirements of ACI code section 3.5.3.1 (ASTM A615 or A706).
5. Compaction test results should be submitted before foundation concrete work.
6. The minimum concrete cover was provided for the reinforcement according to ACI.

a. For Concrete exposed to earth (foundation on soil) = 75 mm.

b. For Slab, (foundations on lean concrete) and walls = 20 mm.

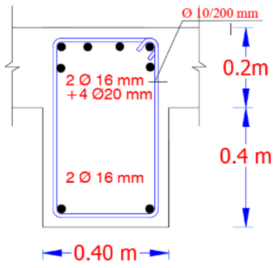
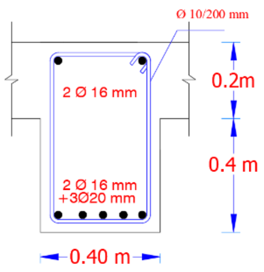
c. For Beams and columns = 40 mm.

We can start by calculating the quantities for beams and slabs, for the building as below:

4.3.1.1.1 Calculation of work volume for beams

The volume of each profession, formwork, rebar, and concrete is calculated and these calculations are made based on the drawings, following is an example of a B2 type beam with volume calculation:

Table 4.7: Beam Reinforcement Details

Type of Beam	**B2**	
	At the support	**At the midspan**
Section		
B x H	400 x 600	400 x 600
Top Reinforcement	2 D16 + 4 D20	2 D16
Bottom Reinforcement	2 D16	2 D16 + 3D20
Stirrup	D10-200	D10-200

- **Calculation of Concrete Beam Volume:**

To calculate the volume of concrete is by calculating the surface area of the beam, then multiplied by length, and the volume of the beam itself, it is used as units per meter of length making calculations easier.

<u>Calculation of Concrete Beam B2 Volume:</u>

Dimensions: h= 0.60 m, b= 0.40 m, L=1 m.

Volume of concrete for 1m = b x (h – 0.20) x L

= 0.40 m x 0.40 m x 1 m = 0.16 m^3.

So, for 1m. length of beam B2 we need 0.16 m^3 concrete.

- **Calculation of Beam Formwork Volume:**

Dimensions: h= 0.60 m, b= 0.40 m, L=1 m.

Volume of formwork for 1 m length = (b + (h - 0.20) x 2) x L

= (0.4 + (0.60 – 0.20) x 2) x 1= 1.20 m^2

So, for every 1m of beam B2, required formwork with an area of 1.20 m^2.

- **Calculation of Reinforcement Beam Volume:**

The weight of the rebar will be calculated for the entire length of the beam, then we divide the weight by the length to find out the total weight per meter of the length of the beam. Reinforcement is used according to Table 4.7 and Figure 4.7.

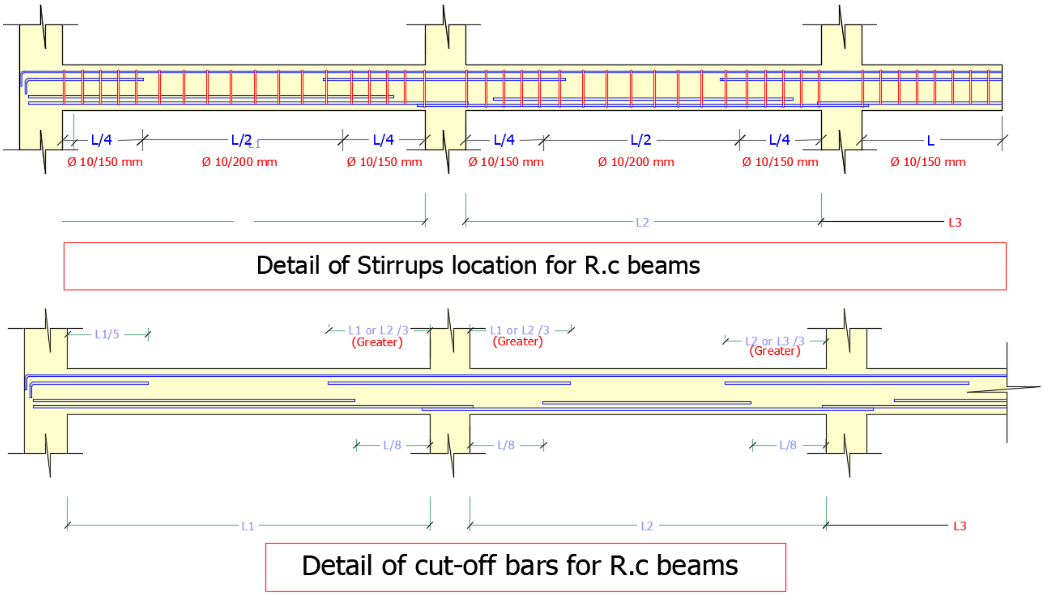


Figure 4.7: Cross Section of Beam Reinforcement

Dimensions: b = 0.40 m, h = 0.60 m, L_{beam} = 8.30m.

<u>At Support Reinforcement:</u>

Top reinforcement continuous = 2D 16

Bottom reinforcement continuous = 2D 16

Top reinforcement cut = 4 D20

<u>At midspan Reinforcement:</u>

Top reinforcement continuous = 2D 16

Bottom reinforcement = 2D 16

Bottom reinforcement cut = 3D 20

Weight of D16 = ¼ x π x D^2 x steel density.

= ¼ x π x $(0.016)^2$x 7850 kg/m^3 = 1.579

Weight of D20 = ¼ x π x D^2 x steel density.

= ¼ x π x $(0.020)^2$ x 7850 kg/m^3 = 2.467 kg/m.

Reinforcement length for continuous bar (D16) = (2+2) x 8.3 = 33.2 m

Reinforcement length for support cut bar (D20) = 4 x (8.3/3) x 2 = 22.133 m.

Reinforcement length for midspan cut bar(D20) = 3 x{8.3- (8.3/8) x 2} = 18.675 m.

Weight of D16 = 1.579 kg/m x 33.2 m = 52.423 kg.

Weight of D20 = 2.467 kg/m x (22.133 + 18.675) m = 100.673 kg.

Total weight of (D16 & D20) = 52.423 + 100.673 = **153.096 kg.**

All these accounts are shown in Table 4.8.

Table 4.8: Rebar Calculations of Cut-off Bars for Beam B2

Beam	Height (m)	Width (m)	Length c/c (m)	No. of Bars Continuous		No. of Bars Cut at Sup.t	No. of Bars Cut at Mid.	Reinforcement Length (m)				Steel Type		Steel Weight (kg)		Total Weight (Kg)
				Top	Bottom	Top	Bottom	Top Cont.	Bot. Cont.	Supp. Cut	Mid. Cut	D16	D20	W.16mm	W.20mm	
	H	B	L	16mm	16mm	20 mm	20mm	L*2	L*2	(L/3)*2*No.	L-{(L/8)*2}*No.	kg/m	kg/m	W*(top cont.+Bot. cont.)	W*(supp. cut+mid. cut)	W16 +W20
B2	0.6	0.4	8.3	2	2	4	3	16.6	16.6	22.133	18.675	1.579	2.467	52.4228	100.674	153.10

<u>Stirrup's weight:</u>

No. of stirrups at support = (L/ 4) x 2 /0.15 + 2

= (8.3 / 4) x 2 / 0.15 + 2 = 29.7 ~ 30 No.

No. of stirrups at midspan = (L /2) / 0.20

= (8.3/2) /0.20 = 20.75 ~ 21 No.

Stirrup Length (L_s) = (2H +2B) – (4 x beam cover) + 0.1

= (2x0.6 + 2x0.4) – (4x0.04) + 0.1 = 1.94 m.

Weight of (D10) = ¼ x π x D^2 x steel density.

= ¼ x π x $(0.010)^2$x 7850 kg/m = 0.617 kg/m.

Weight of stirrups = L_S x $W._{D10}$ x No.

= 1.94m x 0.617 kg/m x (30+21) = 61.046 kg.

All these accounts are shown in Table 4.9.

Table 4.9: Calculations of the Weight of Stirrups for Beam B2

Beam	Height	Width	length c/c	No. Cont. Rein.		No. Cut Supp.		No. Cut Mid.		Reinforcement Length (m)				Steel Type	Tota Weight (Kg)
				Top	Bottom	Top	Bottom	Top	Bottom	Top Cont.	Bottom Cont.	Supp. Cut	Mid cut	D16	
Interior	H	B	L	16mm	16mm	16mm	16mm	16mm	16mm	L*No.	L*No.	(L/3)*2*No.	L-{L/8)*2}*NO.	kg/m	W*(top cont.+Bot. cont.+supp. Cut+mid.cut)
B1	0.6	0.4	4.7	2	2	4	0	0	3	9.4	9.4	12.5	10.58	1.579	66.173

Total weight of reinforcement for 8.3m of B2 = Weight of $_{(D16\ \&\ D20)}$ + Weight of $_{tirrups}$

= 153.096 + 61.046 = 214.142 kg.

So, the weight of reinforcement for 1 meter of B2 = 214.142 kg/8.3m = 25.8 kg/m.

The tables below show all the calculations related to calculating the different types of beams for rebar weight.

Table 4.10: Rebar Calculations of Total Steel Weight for B1 Interior

Beam	Height (m)	Width (m)	Length c/c (m)	Total Weight of Stirrups				
				Length of Stirrups (Ls) m.	No. of Stirrups at Supp.	No. of Stirrups at Mid.	W. D10	Total Weight (kg)
	H	B	L	((H-.04) + (B-0.04) *2 +0.1)	((L/4)*2) /0.15+2	(L/2)/0.20	kg/m	Ls*W_{D10}* (No.Supp. +No.Mid.)
B2	0.6	0.4	8.3	1.94	30	21	0.617	61.0459

Table 4.11: Rebar Calculations of Total Steel Weight for B1 Exterior

Beam	Height	Width	length c/c	No. Conti. Rein.		No. Cut Supp.			No. Cut Mid.		Reinforcement Length (m)					Steel Type	Total Weight (Kg)
				Top	Bottom	Top Ext.	Top Int.	Bottom Ext.	Top	Bottom	Top Cont.	Bottom Cont.	Supp. Ext. Cut	Supp. Int. Cut	Bottom cut	D16	
Exterior	H	B	L	16mm	16mm	16mm	16mm	16mm	16mm	16mm	L*No.	L*No.	L/5*NO.	L/3*NO.	L-(L/8)*NO.	kg/m	W*(top cont.+Bot. cont.+supp.Ex. Cut+Supp. Int. cut+Bot.cut)
B1	0.6	0.4	5.8	2	2	2	4	3	0	3	11.6	11.6	2.32	7.73	15.23	1.579	76.55

Table 4.12: Rebar Calculations of Total Steel Weight for B2,3,4

Beam	Height (m)	Width (m)	Length c/c (m)	No. of Bars Continuous		No. of Bars Cut at Supp.	No. of Bars Cut at Mids.	Reinforcement Length (m)				Steel Type		Steel Weight (kg)		Total Weight (Kg)
				Top	Bottom	Top	Bottom	Top Cont.	Bott. Cont.	Supp. Cut	Mid. Cut	D16	D20	W. 16mm	W. 20mm	
	H	B	L	16mm	16mm	20 mm	20mm	L*2	L*2	(L/3) *2*No.	L-{(L/8) *2}*No.	kg/m	kg/m	W*(top cont.+Bot. cont.)	W*(supp. cut+mid. cut)	W16 +W20
B2	0.6	0.4	8.3	2	2	4	3	16.6	16.6	22.13	18.68	1.579	2.467	52.423	100.674	153.10
B3	0.6	0.4	5.8	2	2	4	2	11.6	11.6	15.47	8.7	1.579	2.467	36.633	59.619	96.2520
B4	0.6	0.4	1.47	4	4	0	0	5.88	5.88	0	0	1.579	0	18.569	0	18.569

Table 4.13: Total Weight of Stirrups for all Beams

Beam	Height (m)	Width (m)	Length c/c (m)	Total Weight of Stirrups				
				Length of Stirrups (Ls) m.	No. of Stirrups at Supp.	No. of Stirrups at Mid.	W. D10	Total Weight (kg)
	H	B	L	{(H-0.04)+(B-0.04)}*2+0.1}	((L/4)*2)/.15+2	(L/2)/0.20	kg/m	Ls*W. D10*(Supp.no.+Mid no.)
B1 Ext.	0.6	0.4	5.8	1.94	21	15	0.617	43.091
B1 Int.	0.6	0.4	4.7	1.94	18	12	0.617	35.91
B2	0.6	0.4	8.3	1.94	30	21	0.617	61.046
B3	0.6	0.4	5.8	1.94	21	15	0.617	43.091
B4	0.6	0.4	1.47	1.94	7	4	0.617	13.167

We can now find the volume of the reinforcement per 1 meter of the beam for each type as follows:

Weight Beam(kg/m) = (Total weight of rebar +Total weight of stirrups) / L of beam

Weight of $B1_{INT.}$ = (66.173 + 35.91) / 4.7 = 21.72 kg/m

Weight of $B1_{EXT.}$ = (76.55 + 43.09) / 5.8 = 20.63 kg/m

So, the average weight For B1 kg /m = (21.72 + 20.63) = 21.17 kg/m.

Weight of B2 (kg/m) = (153.097 + 61.046) / 8.3 = 25.80 kg/m.

Weight of B3 (kg/m) = (96.252 + 43.091) / 5.8 = 24.025 kg/m.

Weight of B4 (kg/m) = (18.57 + 13.167) / 1.47 = 21.589 kg/m

Table 4.14 shows the calculation of all quantities of concrete, formwork, and steel reinforcement required for all beams of the building.

Table 4.14: All Quantities for all beams in the Building

Beam	Length of Beam (m)				Total Length (m)	Volume Concrete m^3/m	Volume Formwork m^2/m	Volume Reinforcement kg/m	Total Concrete (m3)	Total Formwork (m2)	Total Reinforcement (Kg)
	B.F.	G.F.	F.F	PEN.							
B1	203.5	203	203	25.1	634.78	0.16	1.2	21.17	101.56	761.74	13438.29
B2	8.3	8.3	8.3	0	24.9	0.16	1.2	25.8	3.984	29.88	642.42
B3	0	5.8	5.8	0	11.6	0.16	1.2	24.025	1.856	13.92	278.69
B4	0	4.17	4.17	4.17	12.51	0.16	1.2	21.589	2.002	15.012	270.078
Total Quantity for all Beams in Building									109.4064	820.548	14629.481

4.3.1.1.2 Calculation of work volume for slabs

Calculation of the volume on the floor slab will be calculated per m^2.

The details of the floor slab reinforcement can be seen in Figure 4.8.

Slab thickness = 200 mm.

Top reinforcement = D12 @ 20 cm.

Bottom reinforcement = D12 @ 20 cm.

- **Calculation of Concrete Slab Volume:**

= Floor slab area x Slab thickness

= 1m x1m x 0.20 m = 0.20 m^3

So, for all 1 m^2 of the slab, we need 0.2 m^3 of casting concrete.

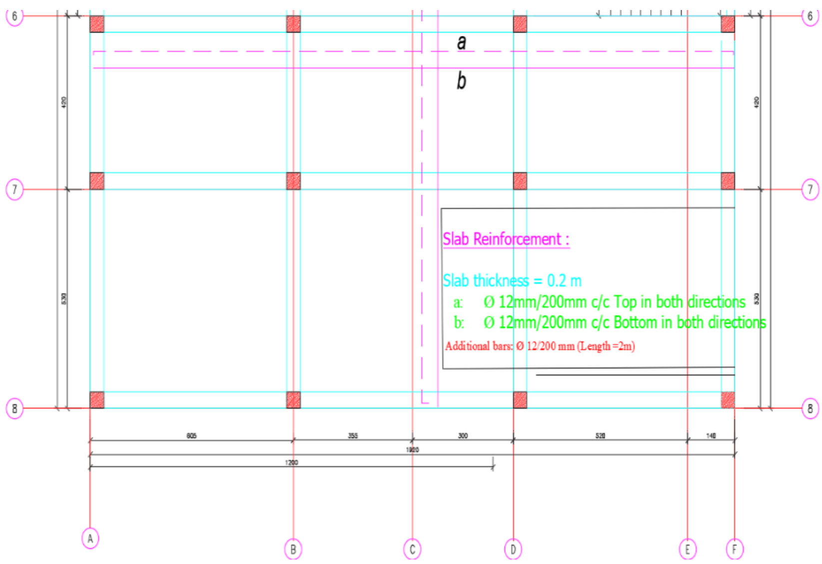


Figure 4.8: Slab Reinforcement Details

- **Calculation of Formwork Volume for Slab:**

= 1m x 1m = 1 m^2

So, for all 1 m^2 of the slab, we need 1 m^2 of formwork.

- **Calculation of Reinforcement Volume of Slab:**

Reinforcement weight D12 = ¼ x π x D2 x steel density

= ¼ x π x $(0.012)^2$ x 7850 kg/m^3 = 0.888 kg/m

Number of reinforcement/m = 1000/200 + 1 = 6 No. x 2 (both directions) = 12 No.

Reinforcement length/m = 1 m

Top reinforcement /m^2 = 12 x 1 x 0.888 = 10.656 kg/m^2

Bottom reinforcement /m^2 = 12 x 1 x 0.888 = 10.656 kg/m^2

Total slab reinforcement /1m^2 = 10.656 + 10.656 = 21.312 kg/m^2

So, for all 1 m^2, we need 21.312 kg reinforcement.

Table 4.15 shows the calculation of all quantities of concrete, formwork, and steel reinforcement required for all slabs of the building.

Table 4.15: Recapitulation of Total Slab Volume for Each Floor

Floor	Floor Area (m^2)	Volume Concrete (m^3)	Volume Formwork (m^2)	Volume Reinforcement (kg)
B. F	508.14	101.628	508.14	10829
G. F	462.12	92.424	462.12	9849
F. F	462.12	92.424	462.12	9849
PEN. F	40.92	8.184	40.92	872
Additional	0	0	0	60
Total Quantities		**294.66**	**1473.3**	**31459**

Here is a summary of what the building needs from quantities of concrete, formwork, and steel reinforcement for the total sum of beams and slabs for the Erbil Hemophilia Center building: -

Total quantities = Beams + Slabs

Total Concrete (m^3) = 109.40 + 294.66 = 404 m^3.

Total Formwork (m^2) = 820.55 + 1473.3 = 2,294 m^2.

Total Reinforcement (kg) = 14629 + 31459 = 46,088 kg.

- **Total cost:**

Refer to Table 4.5, beams cost for all buildings:

Table 4.16: Total Cost of Beams for Erbil Building.

Items	**Quantity**	**Price / unit**	**Cost** (I.D)
Formwork	820.55	12,300	10,092,765
Steel Reinforcement	14629	1,395	20,407,455
Concrete	109.4	98,100	10,732,140
Total cost for beams (ID)			**41,232,360**

20% added administrative fees and profits.

So, total cost beams for building 41,232,360+ 8,246,472 = **49,478,832 ID.**

Slab cost for all buildings:

Table 4.17: Total Cost of Slabs for Erbil Building

Items	**Quantity**	**Price / unit**	**Cost** (I.D)
Formwork	1473.3	10,700	15,764,310
Steel Reinforcement	31459	1,384	43,539,256
Concrete	249.66	96,600	24,117,156
Total cost for beams (ID)			**83,420,722**

20% added administrative fees and profits.

So, total cost slabs for building = 83,420,722+ 16,684,144 = **100,104,866 ID.**

Total cost for the building (beams and slabs) = 49,478,832 + 100,104,866

= **149,583,698 ID.**

Total concrete of building = 404 m^3.

For 1 cubic meter = 149,583,698/404 = ~370,000 ID/m^3.

Therefore, the results are close between the secondary data (381,000 ID/m^3) and the main results after analysis, per cubic meter by the traditional method.

1.3.1.2 Far building (professors' residence building at Amam Azam college in Mosul)

The building consists of a ground floor and two upper floors and the slabs are executed in a tow-way slab, the area of one slab is about 300 m^2, all drawings related to this building can be found in (Appendix B, p.94-95).

General note about the design of the building:

1. ACI Code 318M-08 is used in the design.
2. Concrete compressive strength: C35 for beams and slabs.
3. Steel reinforcement: Shall be of deformed type conform to ASTM A615M (Fy 420 Mpa).
4. The following minimum concrete cover shall be provided for reinforcement:

a. Concrete cast against and permanently exposed to earth 75 mm.

b. Beams and columns 25 mm.

c. Slabs 20 mm.

4.3.1.2.1 Calculation of work volume for beams

The volume of each profession, formwork, rebar, and concrete is calculated and these calculations are made based on the drawings, following is an example of a B14 type beam with volume calculation:(Table 4.18)

- **Calculation of Concrete Beam Volume:**

To calculate the volume of concrete is by calculating the surface area of the beam, then multiplied by length, and the volume of the beam itself, it is used as units per meter of length making calculations easier.

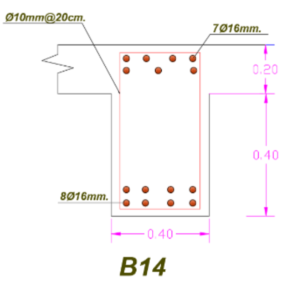
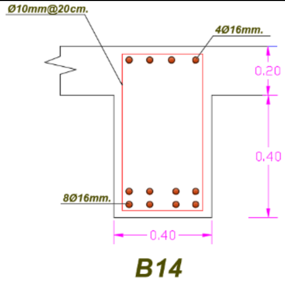
<u>Calculation of Concrete Beam14 Volume:</u>

Dimensions: h= 0.60 m, b= 0.40 m, L=1 m.

Volume of concrete for 1m = b x (h-0.2) x L

= 0.40 m x 0.40 m x 1 m = 0.16 m^3.

Table 4.18: Beam Reinforcement Details

Type of Beam	**B14**	
	at the support	**at the midspan**
Section		
B x H	400 x 600	400 x 600
Top Reinforcement	7 D16	4 D16
Bottom Reinforcement	8 D16	8 D16
Stirrup	D10-200	D10-200

- **Calculation of Concrete Beam Volume:**

To calculate the volume of concrete is by calculating the surface area of the beam, then multiplied by length, and the volume of the beam itself, it is used as units per meter of length making calculations easier.

Calculation of Concrete Beam14 Volume:

Dimensions: h= 0.60 m, b= 0.40 m, L=1 m.

Volume of concrete for 1m = b x (h-0.2) x L

= 0.40 m x 0.40 m x 1 m = 0.16 m^3.

So, for 1m. length of beam B14 we need 0.16 m^3 casting concrete.

- **Calculation of Beam 14 Formwork Volume:**

Dimensions: h= 0.60 m, b = 0.40 m, L=1 m.

Volume of formwork for 1 m length = (b + (h - 0.20) x 2) x L

= (0.4 + (0.60 – 0.20) x 2) x 1 = 1.20 m^2

So, for every 1 m of beam B14 required formwork with an area of 1.20 m^2.

- **Calculation of Reinforcement Beam 14 Volume:**

Dimensions: b = 0.40 m, h = 0.60 m, L_{beam} = 7.22m.

At Support Reinforcement:

Top reinforcement continuous = 4D 16

Bottom reinforcement continuous = 8D 16

Top reinforcement cut = 3 D16

At midspan Reinforcement:

Top reinforcement continuous = 4D 16

Bottom reinforcement continuous = 8D 16

Weight of D16 = 1.579 kg/m

Reinforcement length for continuous bar (D16) = (4+8) x 7.22 = 86.64 m.

Reinforcement length for interior support cut bar (D16) = 3 x (7.22/3) = 7.22 m.

Reinforcement length for exterior support cut bar (D16) = 3 x (7.22/5) = 4.332

Total weight of $_{\text{bars}}$ = (86.64 + 7.22 + 4.332) m x 1.579 kg/m = **155.045 kg.**

All these accounts are shown in Table 4.19.

Table 4.19: Rebar Calculations of Cut-off Bars for Beam B14

Beam	Height	Width	length c/c	Conti. Rein.		Cut Supp. No.			Cut Mid. No.		Rein. Length					Steel Type	Total Weight (Kg)
				Top No.	Bottom No.	Top Ext.	Top Int.	Bottom Ext.	Top	Bottom	Top Cont.	Bott.Cont.	Supp. Ext. Cut	Supp. Int. Cut	Bottom Cut	D16	
	H	B	L	16mm	16mm	16mm	16mm	16mm	16mm	16mm	L*No.	L*No.	L/5*No.	L/3*No.	L-(L/8)*NO.	kg/m	W*(Top cont.+Bot. cont.+supp.Ex. Cut+Supp. Int. Cut+Bot..cut)
B14	0.6	0.4	7.22	4	8	3	3	0	0	0	28.88	57.76	4.332	7.22	0	1.579	155.045

Stirrup’s weight:

No. of stirrups at support = (L/ 4) x 2 /0.15 + 2 = (7.22 / 4) x 2 / 0.15 + 2 = 26 No.

No. of stirrups at midspan = (L /2) / 0.20 = (7.22 / 2) /0.20 = 18 No.

Stirrup Length (L_s) = (2H +2B) – (4 x beam cover) + 0.1

= (2x0.6 + 2x0.4) – (4x0.04) + 0.1 = 1.94 m.

Weight of (D10) = 0.617 kg/m.

Weight of $_{\text{stirrups}}$ = L_s x $W._{D10}$ x No. = 1.94 m x 0.617 kg/m x (26+18) = **52.667 kg.**

All these accounts are shown in Table 4.20.

Table 4.20: Calculations of the Weight of Stirrups for Beam B14

Beam	Height (m)	Width (m)	Length c/c (m)	Total Weight of Stirrups				
				Length of Stirrups (Ls) m.	No. of Stirrups at Support	No. of Stirrups at Midspan	W. D10	Total Weight (kg)
	H	B	L	{(H-0.04)+(B-0.04)}*2+0.1}	((L/4)*2)/.15+2	(L/2)/0.20	kg/m	Ls*W. D10*(Supp.no.+Mid no.)
B14	0.6	0.4	7.22	1.94	26	18	0.617	52.667

Total weight of reinforcement for 7.22 m of B14 =Total weight of $_{\text{bars}}$ + Total weight of $_{\text{stirrups}}$ = 155.045 + 52.667 **= 207.712 kg.**

The weight of reinforcement for 1meter of B14 = 207.712 kg/7.22 m = **28.769 kg/m.**

The tables below show all the calculations related to calculating the different types of beams for rebar weight.

Table 4.21: Rebar Calculations of Total Steel Weight for all Types of Beams

Beam	Height	Width	Length c/c	Conti. Rein.		Cut Support NO.			Cut Midspan No.		Rein. Length					Steel Type	Total Weight (Kg)
				Top No.	Bottom No.	Top Ext.	Top Int.	Bottom Ext.	Top	Bottom	Top Cont.	Bottom Cont.	Supp. Ext. Cut	Supp. Int. Cut	Bottom Cut	D16	
	H	B	L	16mm	16mm	16mm	16mm	16mm	16mm	16mm	L*No.	L*No.	L/5*No.	L/3*No.	L-(L/8)*NO.	kg/m	W*(top cont.+Bot. cont.+supp.Ex. Cut+Supp. Int. cut+Bottom.cut)
B14	0.6	0.4	7.22	4	8	3	3	0	0	0	28.88	57.76	4.332	7.22	0	1.579	155.045
B13	0.6	0.4	5.14	4	5	2	3	0	0	0	20.56	25.7	2.056	5.14	0	1.579	84.407
B15	0.6	0.25	1.93	4	4	0	0	0	0	0	7.72	7.72	0	0	0	1.579	24.380
B26	0.6	0.4	1.6	6	4	0	0	0	0	0	9.6	6.4	0	0	0	1.579	25.264
B29	0.5	0.15	9.71	2	1	0	0	0	0	0	19.42	9.71	0	0	0	1.579	45.996
B30	0.7	0.15	9.35	4	4	0	0	0	0	0	37.4	37.4	0	0	0	1.579	118.109
H.B3	0.2	0.3	4.7	4	5	0	0	0	0	0	18.8	23.5	0	0	0	1.579	66.792

Table 4.22: Total Weight of Stirrups for all Beams

Beam	Height (m)	Width (m)	Length c/c (m)	Total Weight of Stirrups				
				Length of Stirrups (Ls) m.	No. of Stirrups at Support	No. of Stirrups at Midspan	W. D10	Total Weight (kg)
	H	B	L	{(H-0.04)+(B-0.04)}*2+0.1}	((L/4)*2)/.15+2	(L/2)/0.20	kg/m	Ls*W. D10*(Supp.no.+Mid no.)
B13	0.6	0.4	5.14	1.94	19	13	0.617	38.303
B14	0.6	0.4	7.22	1.94	26	18	0.617	52.667
B15	0.6	0.25	1.93	1.64	8	5	0.617	13.154
B26	0.6	0.4	1.6	1.94	7	4	0.617	13.167
B29	0.5	0.15	9.71	1.24	34	24	0.617	44.375
B30	0.7	0.15	9.35	1.64	33	23	0.617	56.665
H.B3	0.2	0.3	4.7	0.94	18	12	0.617	17.399

We can now find the volume of the reinforcement per 1 meter of the beam for each type as follows:

Weight Beam(kg/m) = (Total weight of rebar +Total weight of stirrups) / L of beam

Weight of B13 = (84.407 + 38.303) / 5.14 = 23.87 kg/m

Weight of B14 = (155.045 + 52.667) / 7.22 = 28.77 kg/m

Weight of B15 (kg/m) = (24.380 + 13.154) / 1.93 = 19.45 kg/m.

Weight of B26 (kg/m) = (25.264 + 13.167) / 1.6 = 24.02 kg/m.

Weight of B29 (kg/m) = (45.996 + 44.375) / 9.71 = 9.31 kg/m

Weight of B30 (kg/m) = (118.11 + 56.665) / 9.35 = 18.69 kg/m.

Weight of H.B3 (kg/m) = (66.792 + 17.399) / 4.7 = 17.91 kg/m.

Table 4.17 shows the calculation of all quantities of concrete, formwork, and steel reinforcement required for all beams of the building.

Table 4.23: All Quantities for all Beams in the Building.

Beam	Length of Beam (m)				Total Length (m)	Volume Concrete m^3/m	Volume Formwork m^2/m	Volume Reinforcement kg/m	Total Concrete (m3)	Total Formwork (m2)	Total Reinforcement (Kg)
	G.F.	F.F	S.F	PEN.							
B13	84.2	84.2	84.2	14.3	267	0.16	1.2	23.87	42.72	320.4	6373.29
B14	28	28.2	28.2	0	84.52	0.16	1.2	28.77	13.523	101.424	2431.640
B15	11.4	11.4	11.4	0	34.2	0.1	1.05	19.45	3.42	35.91	665.19
B26	3.8	3.8	3.8	0	11.4	0.16	1.2	24.02	1.824	13.68	273.828
B29	9.71	9.71	9.71	0	29.13	0.045	0.75	9.31	1.3109	21.848	271.200
B30	53.6	60.7	60.7	0	175.08	0.075	1.15	18.69	13.131	201.342	3272.245
H.B3	36.4	36.4	23.5	0	96.34	0	0	17.91	0	0	1725.449
Total Quantity for all Beams in Building									**75.929**	**694.604**	**15012.843**

4.3.1.2.2 Calculation of work volume for slabs

Calculation of the volume for the floor slab will be calculated per m^2.

The details of the floor slab reinforcement can be seen in Figure 4.9.

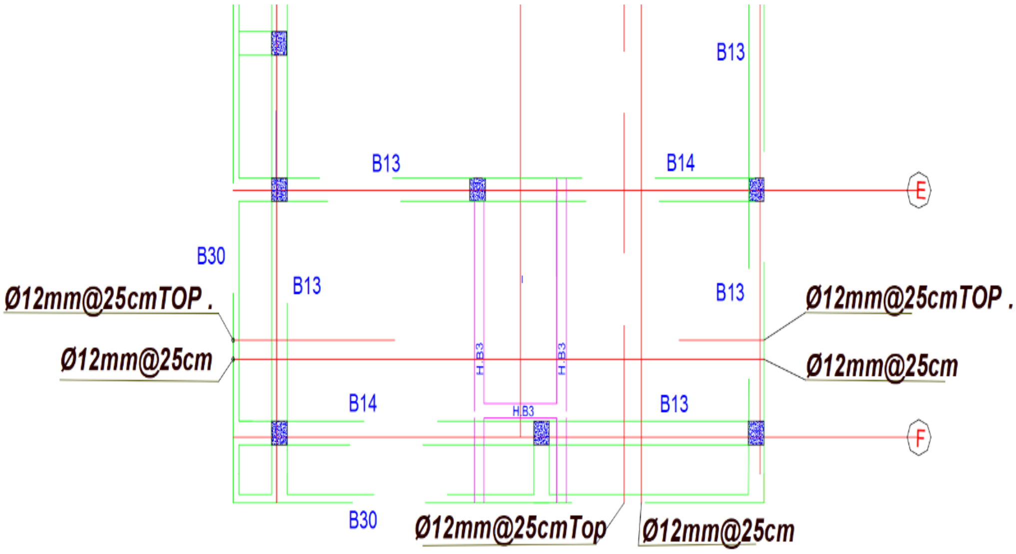


Figure 4.9: Slab Reinforcement Details

Slab thickness = 200 mm.

Top reinforcement = D12 @25 cm.

Bottom reinforcement = D12 @25 cm

Calculation of Concrete Slab Volume:

= Floor slab area x Slab thickness

= 1m x1m x 0.20 m = 0.20 m^3

So, for all 1 m^2, we need 0.2 m^3 casting concrete.

- **Calculation of Formwork Volume for Slab:**

= 1m x 1m = 1 m^2

So, for all 1 m^2 of the slab, we need 1 m^2 of formwork.

- **Calculation of Reinforcement Volume of Slab:**

Reinforcement weight D12 = 0.888 kg/m

Number of reinforcement/m =1000/250 +1 =5 No. for (both directions)

=10 No./m^2.

Reinforcement length/m = 1 m

For top and bottom layers =10 x 2 = 20 No. / m^2

Weight of reinforcement /m^2 = 20 x 1 x 0.888 = 17.76 kg/m^2

So, for all 1 m^2, we need 17.76 kg reinforcement.

Shows The Calculation of All Quantities of Concrete, Formwork, and Steel Reinforcement Required For All Slabs of the Building

Table 4.24: Recapitulation of Total Slab Volume for Each Floor

Floor	Area Floor (m^2)	Vol. Concrete (m^3)	Vol. Formwork (m^2)	Vol. Reinforcement (kg)
G. F	298.125	59.625	298.125	5294.7
F. F	323.125	64.625	323.125	5738.7
S. F	323.125	64.625	323.125	5738.7
PEN.F	12.87	2.574	12.87	228.57
Total		**191.449**	**957.245**	**17000**

Here is a summary of what the building needs from quantities of concrete, formwork, and steel reinforcement for the total sum of beams and slabs for the professors' residence building at Imam Azam college in Mosel building: -

Total quantities = Beams + Slabs

Total Concrete (m^3) = 75.93 + 191.449 = 267.379 m^3.

Total Formwork (m^2) = 694.6035 + 957.245 = 1651.85 m^2.

Total Reinforcement (kg) = 15012.8433 + 17000 = 32013 kg.

- **Total cost:**

Refer to Table 4.25, beams cost for all building:

Table 4.25: Total Cost of Beams for Mosel Building

Items	Quantity	Price / unit	**Cost** (I.D)
Formwork	694.60	12,300	8,543,580
Steel Reinforcement	15012.84	1,395	20,942,911
Concrete	75.93	98,100	7,448,733
Total cost for beams (ID)			**36,935,224**

20% added administrative fees and profits.

So, total cost beams for building 36,935,224+ 7,387,044 = **44,322,268 ID.**

Slab cost for all building:

Table 4.26: Total Cost of Slabs for Mosel Building

Items	Quantity	Price / unit	Cost (I.D)
Formwork	957.245	10,700	10,242,522
Steel Reinforcement	17000	1,384	23,528,000
Concrete	191.449	96,600	18,498,803
Total cost for beams (ID)			**52,269,325**

20% added administrative fees and profits.

So, total cost slabs for building = 52,269,325+ 10,453,865 = **62,723,190 ID.**

Total cost for the building (beams and slabs) = 44,322,268 + 62,723,190

= **107,045,458 ID.**

Total concrete of building = 267.379 m^3.

For 1 cubic meter = 107,045,458 /267.379 = ~ 400,000 ID/m^3.

Therefore, the results are close between the secondary data (381,000 ID/m^3) and the main results after analysis, per cubic meter by the traditional method.

The approximation of the cost of one cubic meter of buildings is a guide to the accuracy of the calculations and results, in preparation for the next paragraph, which is replacing the slabs of buildings that were molded in the traditional way with precast slabs (hollow core slabs).

4.3.2 Construction of slabs in a precast way (hollow core slab)

Here, work will be done on replacing the casting slabs in a conventional way with precast slabs for the two projects that were analyzed to find out the cost difference between the two ways.

The beams and the rest of the vertebrae, will remain as in the traditional method, and only the slabs will change.

The flow chart of the precast slab way can be done as below:

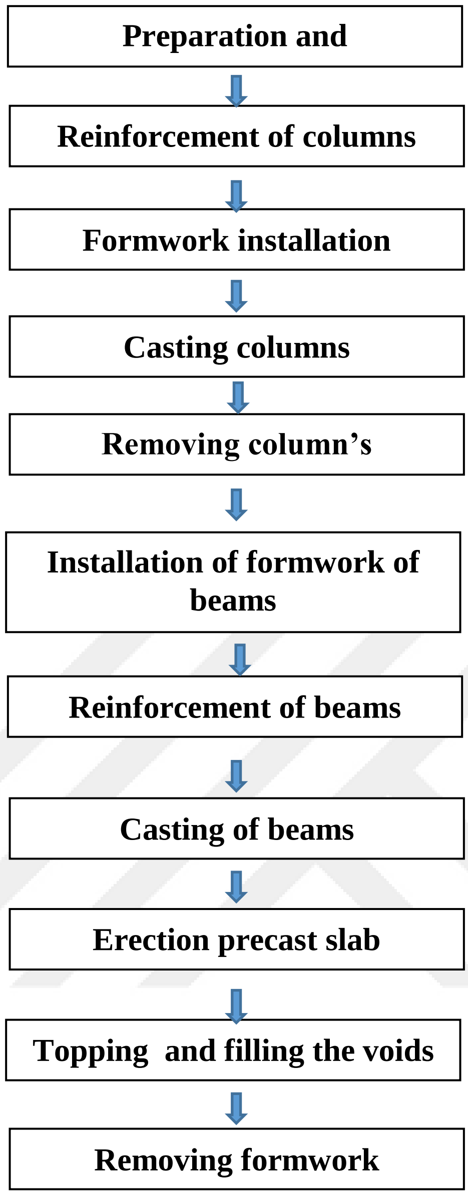


Figure 4.10: Flowchart of the Implementation of the Precast Slab Method

Only the slab panels will be replaced and the beams will remain the same as in the traditional method.

The production of precast hollow core panels differs from the production of other pre-cast building components because in the production of these hollow panels a special machine is used called a Hollow core slab machine as shown in Figure 4.11.

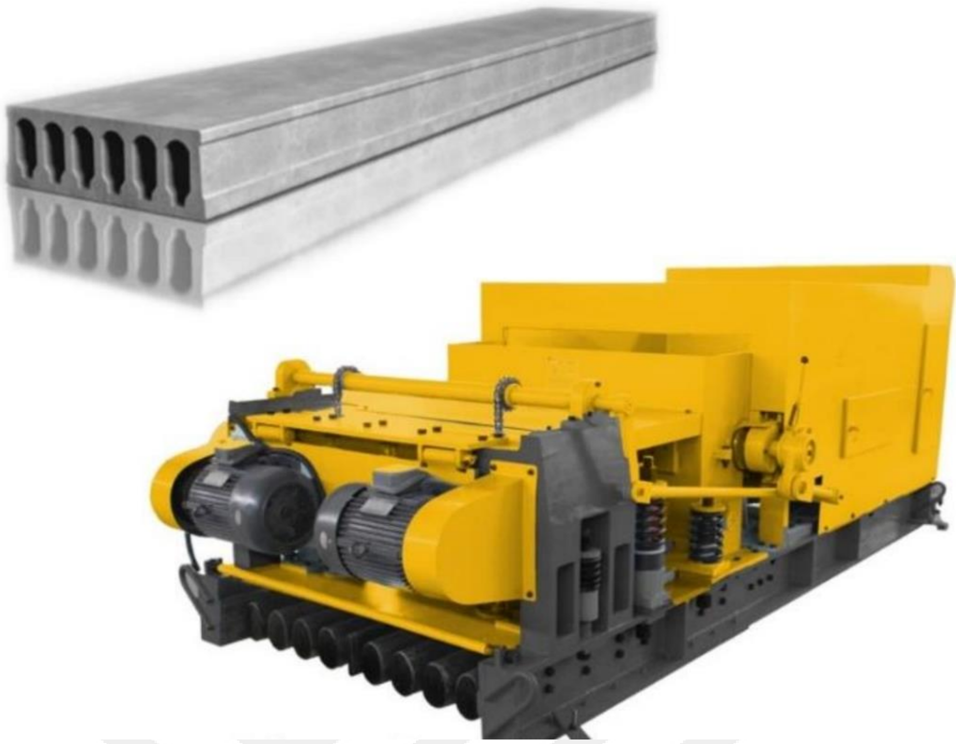


Figure 4.11: Hollow Core Slab Machine

Source: www.alibaba.com

The production process of hollow core panels according to the Darin Group factory goes through several stages, including:

1. Mixing and blending.
2. The manufacture of concrete is done in many ways, and in the case of large quantities, a batching plant must be established.
3. Strand tension (prestressing) tendon attachment for prestressing, and erection prestressed.
4. Concrete casting.
5. Cutting process: after hardening the concrete, the panels are cut to the required lengths.
6. Storing.
7. Loading and transporting to the work site.

Hollow core panels can be installed in different ways, we will use the method used by the Darin Group precast factory on the beams as shown in Figure 4.12.

Figure 4.12: Precast Hollow Core Slab Panels Installation Works

Source: Darin Group Precast Brochure

The seating distance of the pre-cast panels on the beam must be not less than 75 mm.

These panels can be installed by using a heavy equipment hoist, a mobile crane, or a tower crane, according to the height and needs of the building.

We will start replacing the slabs of the traditional on-site casting of the building near Darin Group factory (Hemophilia center of Nanakaly hospital in Erbil) with the precast panels and changing the plans according to the dimensions and design of these panels and for all the slabs of the building and calculating the costs in this way, then we will change slabs of a far building (professors' residence building at Imam Azam college in Mosul) and calculate the costs and then compare with the costs resulting from cost analysis of two buildings in the traditional way.

Below are some specifications of the Darin Group factory, see(Appendix C, p.102) for the production of precast in Erbil: -

1. The number of Beds 8 No. length=120 meter and width 1.2 meter.
2. Hollow core slab production capacity is 1500 m^2 per day.
3. Strands are of 2 types diameters 9.53 mm &12.7 mm (f_{pu} not less than 1800 Mpa).
4. Hollow core slabs are produced in thicknesses (150, 200, 250, and 300) mm.

4.3.2.1 Replacing the slabs of the nearby building (Hemophilia center of Nanakaly hospital in Erbil) with precast slabs (HCS)

The dimensions, quantities, and calculations for the beams will remain unchanged, we'll just change the slabs and the used area must remain the same with the distribution of hollow core panels over the area in proportion to the distribution of beams.

To reach the final cost of this type of slab, the following must be done: -

1. Choosing the dimensions of the hollow core panels according to the building drawings: After receiving the plans, the hollow core panels are distributed according to the dimensions of the building and in proportion to the length and width of the produced panel.

The hollow core panels produced in the Darin Group factory are 120 cm wide, and the length is cut according to distribution.

Figure 4.13 the regular distribution of hollow core panels for the basement floor of the building, and the (Appendix B, p.96) includes the distribution of hollow core panels for the rest of the floors.

Figure 4.13: Distribution of HCS Panels for Basement Floor of Erbil Building

2. Hollow core panels design:

The thickness of the slab designed in the traditional way will not change from the thickness of the hollow core panels, which will be 20 cm, according to the panels produced by Darin Group, they are produced in a controlled factory condition using very high strength of concrete and under strict quality control 28 days cylindrical strength not less than 40 Mpa.

The self-weight of panels with a thickness of 20 cm is 303.6 kg/m2 (2.98 KN/m2), as shown in Figure 4.13, the diameter of strand 12.7mm, and their number 8 No. and according to the distribution, the longest HCS panel is a measurement 6.85 m, and referring to the brochure tables in (Appendix C, p.106), we find that the length (6.9 m) bears 9 KN/m^2 of dead load and 5 KN/m^2 of live load, so the total load is 14 KN/m^2.

The slab is designed to accept dead and live loads according to (ASCE, 2019): -

Dead load (DL):

- HCS Panel = 2.98 KN/m^2
- Ceramic + Mortar = 1.75 KN/m^2
- Plumbing + Ducting = 0.75 KN/m^2
- False ceiling = 0.50 KN/m^2
- Lighting and other services = 0.25 KN/m^2

DL = 6.23 KN/m^2

Live load (LL): Same source as above

- Hospital building = 2.87 KN/m2

Qu = 1.4 DL + 1.7 LL = 1.4 (6.23) + 1.7 (2.87) = 13.60 KN/m^2 < 14 KN/m^2 …...**OK.**

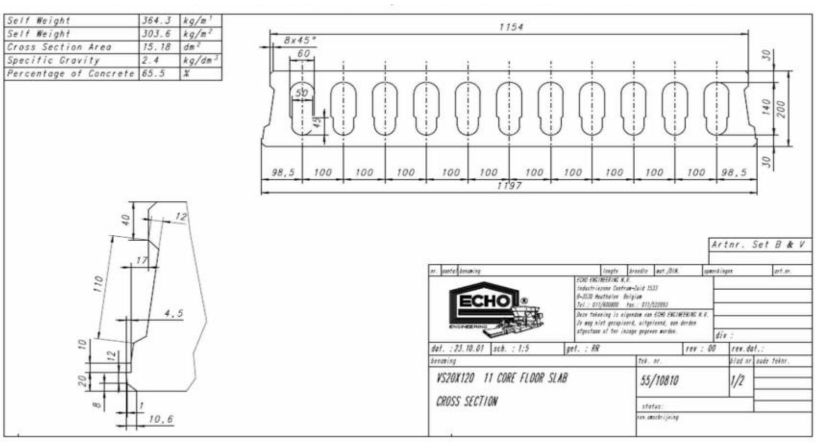


Figure 4.14: Hollow Core Slab 200 mm Thick. with Standard Width of 1.2 m.

Source: Darin Group Precast Catalog

3. Calculation of quantities:

Calculations related to the quantities and cost of the beams will be taken from the traditional method, only we will calculate the quantities and cost of hollow core slab works for all floors, as follows:

- **Hollow core quantity and cost:**

The number of panels can be calculated from the prepared drawings and is summarized in Table 4.27.

Table 4.27: Quantity of HCS Panels Used in Erbil Building

Floor	Type of HCS		NO.	Quantity (m^2)
	W. (m)	L. (m)		
Basement	1.2	6.1	39	285.48
	1.2	6.85	22	180.84
	1.2	5.4	3	19.44
	0.6	6.1	2	7.32
	0.6	6.85	1	4.11
Ground	1.2	6.1	21	153.72
	1.2	6.7	21	168.84
	1.2	6.2	8	59.52
	1.2	5	8	48
	1	6.7	1	6.7
	1	6.2	1	6.2
	1	6.1	1	6.1
First	1.2	6.1	21	153.72
	1.2	6.7	21	168.84
	1.2	6.2	8	59.52
	1.2	5	8	48
	1	6.7	1	6.7
	1	6.2	1	6.2
	1	6.1	1	6.1
PENTHOUSE	1.2	6.2	5	37.2
Total HCS Quantity (m^2)				**1432.55**

The price of one square meter in the factory according to Darin group precast factory for HCS 20 cm thickness is 42,000 ID/m^2, this price includes manufacturing and installation supervision, see (Appendix A, p.90), so the cost of all quantities is:

1432.55 m^2 x 42,000 ID/m^2 = **60,167,100 ID.**

- **Transfer panels:**

The quantities of the hollow core are transported to the work site by special trucks that may carry 25 tons or 40 tons, depending on the lengths of the pieces, long pieces (12 meters for example) are transported by special trucks with a long cart and a high load, but small pieces are often transported with trucks carrying 25 tons. Erbil hospital building is about 30 km away from the production plant, which is a relatively close distance, the transportation price for a trip is estimated, according to (Appendix A, p.90) and about the local market, about 150,000 ID for one trip. The number of transfers for a transport truck with a load of 25 tons is calculated as follows: -

Weight 1m^2 20 cm HCS = 304 kg/m^2

So, the total weight = 304 kg/m^2 x 1432 m^2 = 435,495 kg ~ 435.5 tons.

No. of trips = 435.5 tons / 25 tons = 17.5~ 18 trips

The total cost of transfer = 18 x 150,000 = **2,700,000 ID.**

- **Installation works for hollow core panels:**

Hollow core panels are installed over the beams using cranes, and different cranes are used depending on the height and capacity of the building.

Tower cranes may be used in high and spacious buildings, and heavy, large or small mobile cranes may be used as needed. Erbil hospital building is not high in that it contains a basement and two floors in addition to the penthouse, so we do not need a large crane, and the weight of the largest penal to be lifted can be calculated as follows:

Largest panel 1.2 x 6.85 = 8.22 m^2

Weight of 1 m^2 HCS 20 cm = 304 kg/ m^2

So, total weight for bigger load = 8.22 x 304 = 2499 kg. ~ 2.5 tons.

According to the experience of technicians of the Darin Group plant, a medium-sized crane can lift and install about 30 panels or more, at a price of 300,000 ID/day. from Table 4.27, No. of panels = 194.

So, installation cost = (No. of Panels / 30) x 300,000 ID

= (194 / 30) x 300,000 = **1,940,000 ID.**

- **Topping concrete and filling the voids:**

After installing the hollow core panels over the beams, these panels must be covered with a screed layer on the last floor and the penthouse, given that the floors at the bottom will be covered with finishes such as ceramics and others.

This layer is implemented according to the specifications of the Darin Group plant (Appendix C, p.103).

The top surface of the hollow core units shall be clean and free of all dust, oil, or any deleterious substances which may adversely affect the wet topping bond to the hollow core units, and the pre-wet precast hollow core concrete surfaces before placing the topping concrete.

Topping concrete shall have a minimum 28-day cube strength of 25 Mpa and be well compacted with mechanical vibrators.

Topping concrete shall be poured to a true surface so that the specified thickness of (usually 60 mm but not less than 50 mm) is achieved at the center of the span and screed reinforcement is usually specified at a minimum of steel mesh 6 mm. The key-ways between each hollow core unit must also be filled with well-compacted topping concrete (or other specified non- shrink grout). L

In-situ concrete shall be cured by the application of an approved curing membrane or by being kept continuously wet for not less than seven days.

So, the area that should be covered with topping concrete including the rooftop with the penthouse is 486.28 m^2.

The cost of this paragraph can be found as follows- :

Concrete quantity = 486.28 m^2 x 0.06 m = 29.17 m^3.

6 mm steel mesh = 486.28 m2.

Refer to Table 4.4, concrete (C25) = 74000 ID/m^3, steel mesh = 16000 ID/m^2.

So, cost of concrete (C25) = 29.17 x 74000 =2,158,580 ID

Cost of 6 mm steel mesh = 486.28 x 16000 = 7,764,480 ID

According to the (CSO), the wages of work can be calculated where we need a skilled worker number (75,000 ID) and a semi-skilled worker number 2 (25,000 ID), so the price of the total wages of work is 125000 ID, other transportation expenses are added, and curing is 100000 ID, so the total wages for work are 225000 ID.

Total cost of topping concrete = 2,158,580 + 7,764,480 + 225,000

= **10,148,060 ID**

- **The total cost of the entire slab of the building:**

Total cost includes the following:

- Cost of the works before the slab (beams) = **49,478,832 ID**.
- Cost of the production (HCS 20 cm) panels = **60,167,100 ID**.
- Cost of the transfer for all panels = **2,700,000 ID.**
- Cost of installation works for HCS panels = **1,940,000 ID.**
- Cost topping concrete and filling the voids = **10,148,060 ID.**

The total cost of precast slabs (hollow core) way = 124,433,992 ID.

Here we can know the difference in the cost for the slab of the building (Hemophilia center of Nanakaly hospital in Erbil) between the two ways, where the cost of the traditional way (149,583,698) ID, and the cost of the precast way (124,433,992) ID, where the precast way was less by:

149,583,698 – 124,433,992 = **25,149,706 ID**

This means that the (HCS) way is less by the difference percentage = 16.8%

It is very close to the percentage of secondary data (17%).

4.3.2.2 Replacing the slabs of the far building (professors' residence building at Amam Azam college in Mosul) with precast slabs (HCS)

The dimensions, quantities, and calculations for the beams will remain unchanged, we'll just change the slabs and the used area must remain the same with the distribution of hollow core panels over the area in proportion to the distribution of beams.

We will go through the same steps that were taken on the Erbil hospital building to find the cost of the Mosul building using the precast method as below:

1. Choosing the dimensions of the HCS panels according to the building drawings: Figure 4.15 shows the regular distribution of hollow core panels for the ground floor of the building, and (Appendix B, p.97) includes the distribution of hollow core panels for the rest of the floors.

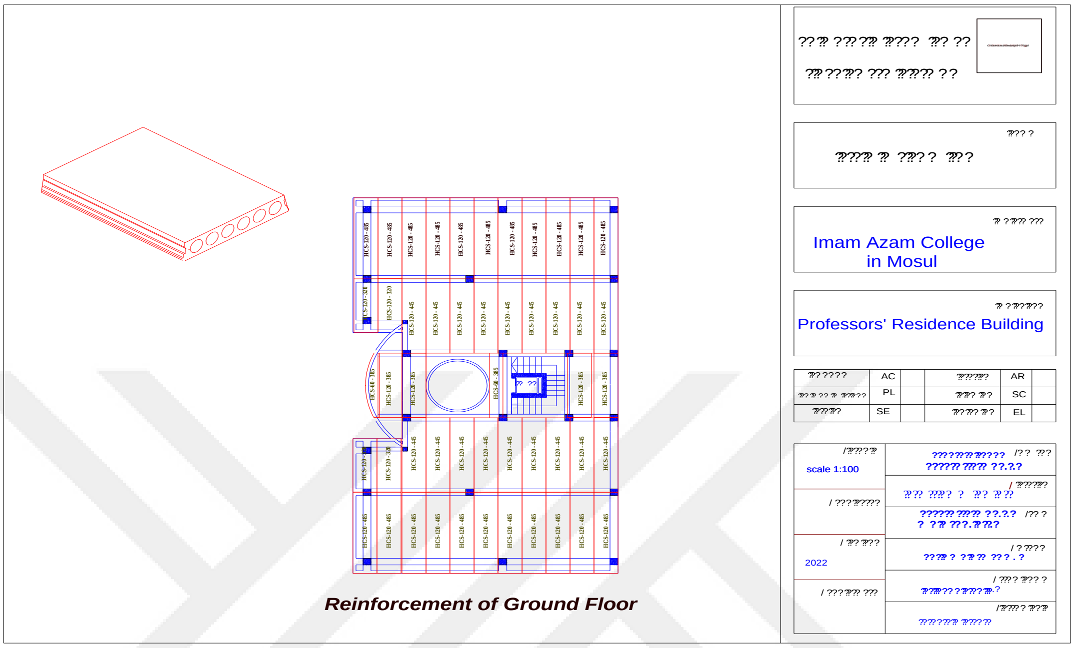


Figure 4.15: Distribution of HCS Panels for Ground Floor of Mosel Building.

2. Hollow core panels design: The thickness of the slab designed in the traditional way will not change from the thickness of the hollow core panels, which will be 20 cm, according to the panels produced by Darin Group, they are produced in a controlled factory condition using very high strength of concrete and under strict quality control 28 days cylindrical strength not less than 40 Mpa.

The self-weight of panels with a thickness of 20 cm is 303.6 kg/m2 (2.98 KN/m2), as shown in Figure 4.13, the diameter of strand 12.7mm, and their number 8 No. and according to the distribution, the longest HCS panel is a measurement 5.35 m, and referring to the brochure tables in (Appendix C, p.106) we find that the length (5.4 m) bears 20 KN/m2 of dead load and 5 KN/m2 of live load, so the total load is 25 KN/m2.

The slab is designed to accept dead and live loads according to (ASCE, 2019):

Dead load (DL):

- HCS Panel = 2.98 KN/m^2
- Ceramic + Mortar = 1.75 KN/m^2
- Plumbing + Ducting = 0.75 KN/m^2
- False ceiling = 0.50 KN/m^2
- Lighting and other services = 0.25 KN/m^2

DL = 6.23 KN/m^2

Live load (LL): Same source as above

- Residential building = 4.79 KN/m^2

Qu = 1.4 DL + 1.7 LL = 1.4 (6.23) + 1.7 (4.79) = 16.87 KN/m^2 < 25 KN/m^2 …...**OK.**

3. Calculation of quantities: Calculations related to the quantities and cost of the beams will be taken from the traditional method, only we will calculate the quantities and cost of hollow core slab works for all floors, as follows:

- **Hollow core quantity and cost:**

The number of panels can be calculated from the prepared drawings and is summarized in Table 4.28.

Table 4.28: Quantity of HCS Panels Used in Mosel Building

Floor	**Type of HCS**		**NO.**	**Quantity** (m^2)
	W. (m)	**L.** (m)		
Ground	1.2	4.85	22	128.04
	1.2	4.45	18	96.12
	1.2	3.85	4	18.48
	1.2	3.2	4	15.36
	0.6	3.85	2	4.62
First	1.2	5.35	22	141.24
	1.2	4.45	20	106.8
	1.2	3.85	4	18.48
	1.2	3.62	2	8.688
	0.6	3.85	2	4.62
Second	1.2	5.35	22	141.24
	1.2	4.45	20	106.8
	1.2	3.85	4	18.48
	1.2	3.62	2	8.688
	0.6	3.85	2	4.62
PENTHOUSE	1.2	3.85	7	32.34
Total HCS Quantity (m^2)				**854.616**

The price of one square meter in the factory according to Darin Group precast factory for HCS 20 cm thickness is 42,000 ID/m^2, this price includes manufacturing and installation supervision, so the cost of all quantities is:

854.616 m^2 x 42,000 ID/m^2 = **35,893,872 ID.**

- **Transfer panels:**

The building is far from the factory production of hollow panels building is far from the factory for the production of hollow panels about 120 km, which is a relatively far distance, the transportation price for a trip is estimated, according to the Darin Group factory (Appendix A, P.90), and local market, about 350,000 ID for one trip, The number of transfers for a transport truck with a load of 25 tons is calculated as follows: -

Weight 1m^2 20 cm HCS = 304 kg/m^2

So, the total weight = 304 kg/m^2 x 854.616 m^2 = 259,803 ~ 260 tons.

No. of trips = 260 tons / 25 tons = 10.4~ 11trips

The total cost of transfer = 11 x 350,000 = **3,850,000 ID.**

- **Installation works for hollow core panels:**

The weight of the largest penal to be lifted can be calculated as follows:

Largest panel 1.2 x 5.35 = 6.42 m2

Weight of 1 m2 HCS 20 cm = 304 kg/ m2

So, total weight for bigger load = 6.42 x 304 = 1951kg ~ 2 tons.

a medium-sized crane can lift and install about 30 panels or more, at a price of 300,000 ID/day, from table 4.28, No. of panels = 157.

So, installation cost = (No. of Panels / 30) x 300,000 ID

= (157 / 30) x 300,000 = **1,570,000 ID.**

- **Topping concrete and filling the voids:**

The area that should be covered with topping concrete including the rooftop with the penthouse is 312.168 m^2.

The cost of this paragraph can be found as follows- :

Concrete quantity = 312.168 x 0.06 m = 18.73 m^3.

6 mm steel mesh = 312.168 m^2.

Refer to Table 4.4, concrete (C25) = 74000 ID/m^3, steel mesh = 16000 ID/m^2.

So, cost of concrete (C25) = 18.73 x 74000 =1,386,020 ID

Cost of 6 mm steel mesh = 312.168 x 16000 = 4,994,688 ID

According to the (CSO), the wages of work can be calculated where we need a skilled worker number (75,000 ID) and a semi-skilled worker number 1 (25,000 ID), so the price of the total wages of work is 100,000 ID, other transportation expenses are added, and curing is 75000 ID, so the total wages for work are 175,000 ID.

Total cost of topping concrete =1,386,020 + 4,994,688 + 175,000 = **6,555,708 ID.**

- **The total cost of the entire slab of the building:** Total cost includes the following:

- Cost of the works before the slab (beams) = **44,322,268 ID.**
- Cost of the production (HCS 20 cm) panels = **35,893,872 ID.**
- Cost of the transfer for all panels = **3,850,000 ID.**
- Cost of installation works for HCS panels = **1,570,000 ID.**
- Cost topping concrete and filling the voids = **6,555,708 ID.**

The total cost of precast slabs (hollow core) way **= 92,191,848 ID.**

Here we can know the difference in the cost for the slab of the building (professors' residence building at Amam Azam college in Mosul)) between the two ways, where the cost of the traditional way = 107,045,458 ID, and the cost of the precast way = 92,191,848 ID, where the precast way was less by:107,045,458 – 92,191,848 = **14,853,610 ID**

This means that the (HCS) way is less by the difference percentage = 13.9%

4.3.3 Comparison

It is evident from the results that working with precast slabs (hollow core) is less costly than working with slabs using on-site casting.

By comparing the results, it is clear that in the Erbil building near the factory, which has a larger area, the results of the cost difference were greater (25,149,706 ID), as shown in the diagram of the difference in the cost of the construction structure implementation in the two ways for Erbil building, Figure 4.16.

That is, it saved costs by 16.8%, which is a good percentage and indicates that the larger the project area, the greater of cost savings results when using precast panels for slabs, as well as whenever a factory is available close to the project.

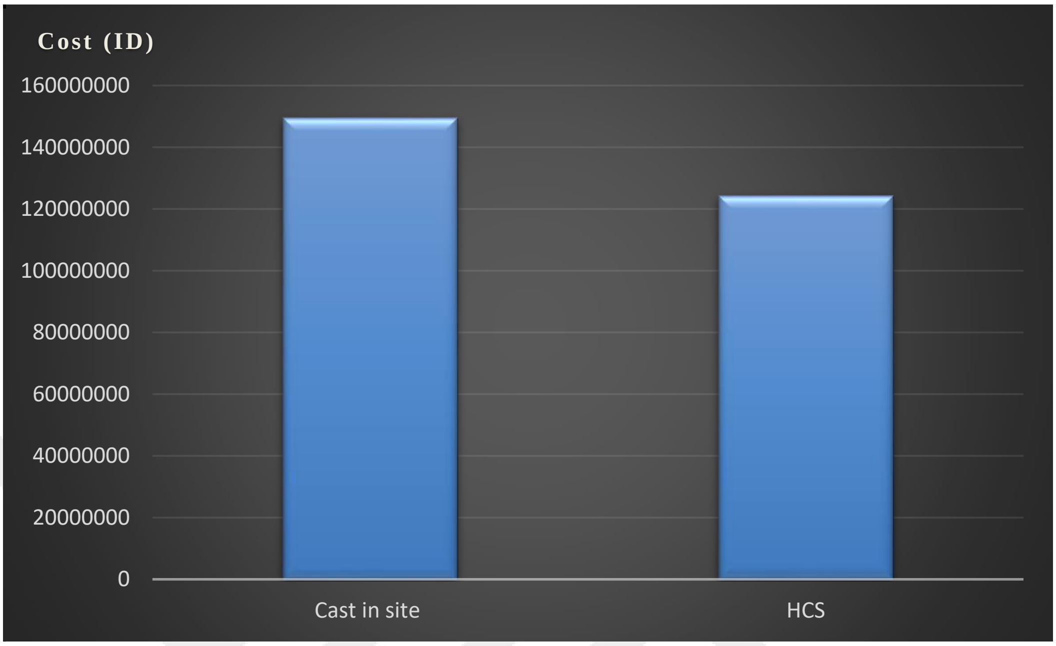


Figure 4.16: Diagram Showing the Difference in the Cost of the Construction Structure Implementation in the Two Ways for Erbil Building

As for the smallest and farthest building (Mosul building), the results were also in favor of precast slabs, and the cost was less by an amount (14,853610 ID), as shown in the diagram of the difference in the cost of the construction structure implementation in the two ways for Mosel building, Figure 4.17.

That is, it saved costs by 13.9%, and this indicates that working with precast panels is feasible, effective, and more, whenever it is a large project and is close to the panel production factory.

It is also noted that working with precast panels reduces the number of materials used as well as the labor force, and thus reduces the amount of waste

It is noted that the percentages of the difference in the primary data are very close to the percentages of the difference in the secondary data (17%), and this indicates the accuracy of the calculations and the results extracted from the project.

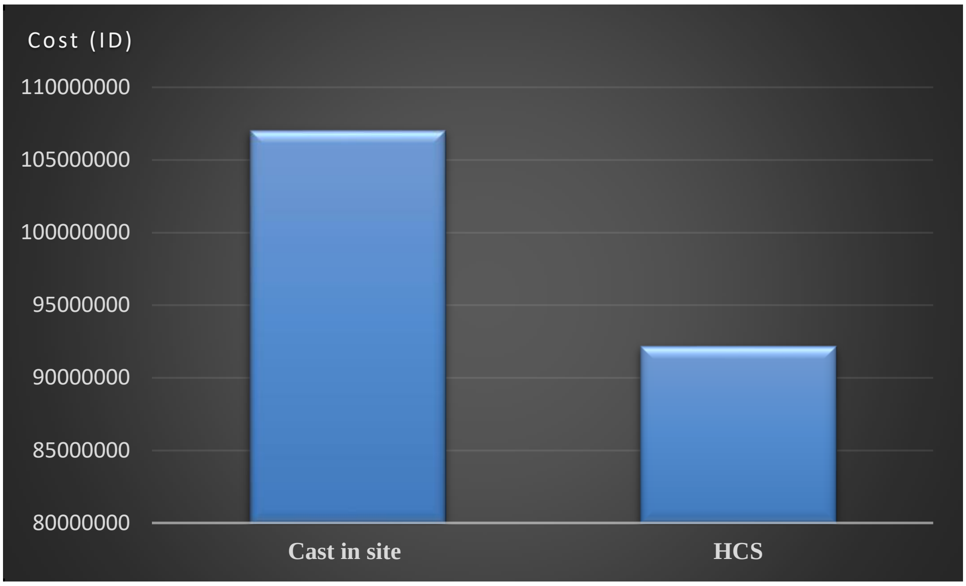


Figure 4.17: Diagram Showing the Difference in the Cost of the Construction Structure Implementation in the Two Ways for Mosel Building

5. TIME ANALYSIS AND MANAGEMENT IN THE TRADITIONAL WAY AND PRECAST (HOLLOWCORE) SLABS OF PUBLIC BUILDINGS IN IRAQ

5.1 Introduction

Importance of time management for the project is a major priority for the project because time is also a cost, the longer of project duration, the higher of costs, and the shorter the duration and the delay time is exceeded, the costs will be reduced.

In investment projects, project owners work on the speed of recovery and turnover of capital, so it is necessary to speed up the completion of projects, and here is the importance of time management.

It is clear that every project needs a scheduled time, and every project manager needs to manage that scheduled time.

There are many project schedule programs and the prevailing ones, including two programs that simplify project management, but there are major differences between them, and they have different features, solutions, prices, pros, and cons, but they are necessary for success of any project.

The first program is (Primavera), which is an advanced program for managing and simplifying the schedule, while the second is (Microsoft Project) and enables to display of the necessary project information quickly, some projects use both programs to evaluate the time progress activities in their projects.

We will use the Primavera program to find out the work progress tables for the traditional and precast methods and the building away from the panel manufacturing plant (Mosul building) whose costs were analyzed by the two methods in the last chapter.

5.2 Data Collection

The project duration data is collected in both ways by referring to the work site to find out the real conditions to analyze the time of completion of the actual work.

The data will be collected from the Mosul city building project (professors' residence building at Amam Azam college in Mosul), in both ways, as follows: -

1. The traditional way (cast in site): The time for implementing the work will be calculated in the traditional way by obtaining the Primavera program prepared by the executing company to determine the realistic period that was used to complete the work, which was extracted through project control, the experience of technicians and contractors, and the follow-up of the site cameras.
2. Precast way: The time data will be collected using the hollow core slab method, using the data collected from the Darin Group precast factory in Erbil.

The same previous paragraphs will be taken for the process of preparing and installing the panels in the primavera program and will be changed according to the data provided by the plant for the duration of the project after installing these panels.

5.2.1 The duration of the completion of the project is implemented in a traditional way

What concerns us at this stage is the logical sequence of work on all floors of the building, so we will take into consideration the construction of columns in addition to the beams and slabs, as follows:

1. Column completion period: The process begins with preparing the necessary rebar and wood panels that can be used again on the recurring floors.

To avoid wasting time, the quantities of reinforcing steel for the project must be fully calculated (as was done in the previous chapter), with the addition of the percentage of losses and their processing to the site.

As well as preparing the wood needed to complete the columns, beams and slabs, and where it can be used again on all floors.

One floor contains 29 columns with dimensions (40x40) cm, as is noted in Table 5.1 for the Primavera program, the time taken to complete this paragraph is 17 days, three days are not within the critical path.

From monitoring the project, the work personnel was one carpenter and with him 4 workers, since this paragraph took the longest period in completing the paragraph, it was possible to use more than one carpenter or to make an overlap in the activities, as it is possible to start carpentry work whenever the arming work of ten columns is completed, given that the completion of the blacksmithing work for the columns was completed in three days for 29 columns, so the arming of ten columns is finished in one day.

2. Beams and slabs period: The process begins with preparing the scaffolding and supports and installing them on the work site and installing the main and secondary wood in preparation for the installation of the beams and slabs template, and then raising the amount of rebar using a mobile crane and placing it on the slab mold to start the work of reinforcing the beams and then the slabs.

After receiving the supervising engineer and making sure of the stability of the mold and reviewing the reinforcing steel, the concrete casting work begins.

as it is noted from Table 5.1for the primavera program, the time taken to complete this paragraph is 35 days, four days are not within the critical path.

It was also possible to increase the number of carpenters and blacksmiths and to overlap the activities after casting to start with the columns of the first floor to reduce this period.

Referring to Table 5.1 of the primavera program, it is clear that the total period for traditionally completing the project structure according to the critical path was 121days.

Table 5.1: Primavera Program for Schedule Time of Traditional Way for Mosel Building

Al-Furkan Company
For General Contracts
Ltd.

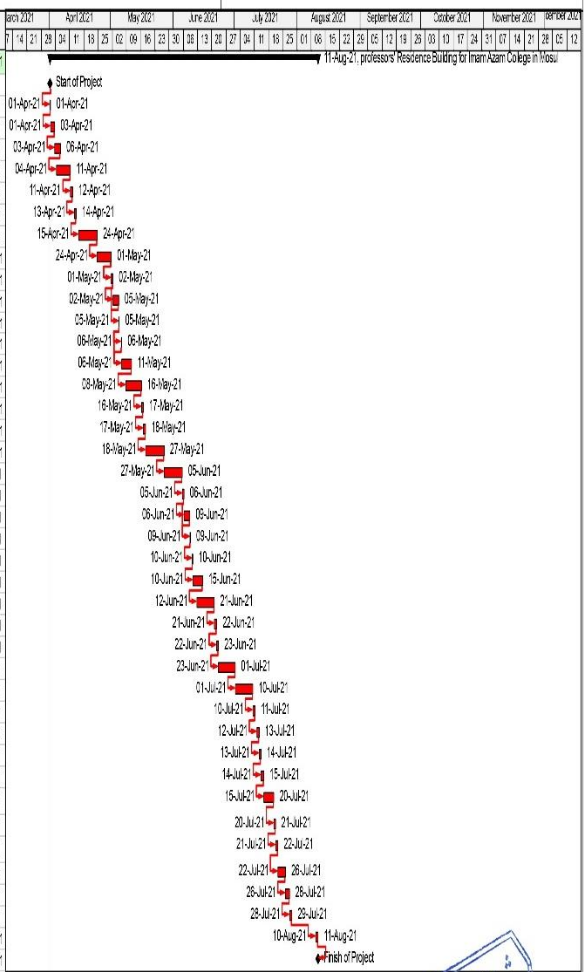
AL-FURKAN
General Contracts

شركــــة
الفــــرقان
للمقاولات العامة
المحدودة

professors' Residence Building for Imam Azam College in Mosul

ديوان الوقف السني

Activity ID	Activity Name	Original Duration	Start	Finish
	professors' Residence Building for Imam Azam College in Mosul	121	01-Apr-21	11-Aug-21
A1000	Start of Project	0	01-Apr-21	
A1020	Supplying of Wooden Form Wood	1	01-Apr-21	01-Apr-21
A1021	Marking and concrete kickers for Columns of ground foor	1	01-Apr-21	03-Apr-21
A1030	Reinforcement works for Columns of Ground Floor	3	03-Apr-21	06-Apr-21
A1040	Wooden Form Works for Columns of Ground Floor	6	04-Apr-21	11-Apr-21
A1050	Concrete Works for Columns of Ground Floor	1	11-Apr-21	12-Apr-21
A1060	Removing Wooden Form for Columns of Ground Floor	1	13-Apr-21	14-Apr-21
A1080	Wooden Form Works for Beams, slab & stairs of Ground Floor	8	15-Apr-21	24-Apr-21
A1100	Reinforcement works for Beams, slab & stairs of Ground Floor	6	24-Apr-21	01-May-21
A1120	Concrete Works for Beams, slab & stairs of Ground Floor	1	01-May-21	02-May-21
A1150	Curing Works for Beams, slab & stairs of Ground Floor	3	02-May-21	05-May-21
A1160	Marking and concrete kickers for Columns of 1st floor	1	05-May-21	05-May-21
A1161	Supplying Crane for Reinforcement Bars Lifting to slab of 1st Floor	1	06-May-21	06-May-21
A1170	Reinforcement works for Columns of 1st Floor	4	06-May-21	11-May-21
A1180	Wooden Form Works for Columns of 1st Floor	7	08-May-21	16-May-21
A1190	Concrete Works for Columns of 1st Floor	1	16-May-21	17-May-21
A1200	Removing Wooden Form for Columns of 1st Floor	1	17-May-21	18-May-21
A1220	Wooden Form Works for Beams, slab & stairs of 1st Floor	9	18-May-21	27-May-21
A1250	Reinforcement works for Beams, slab & stairs of 1st Floor	7	27-May-21	05-Jun-21
A1270	Concrete Works for Beams, slab & stairs of 1st Floor	1	05-Jun-21	06-Jun-21
A1300	Curing Works for Beams, slab & stairs of 1st Floor	3	06-Jun-21	09-Jun-21
A1310	Marking and concrete kickers for Columns of 2nd floor	1	09-Jun-21	09-Jun-21
A1311	Supplying Crane for Reinforcement Bars Lifting to slab of 2nd Floor	1	10-Jun-21	10-Jun-21
A1320	Reinforcement works for Columns of 2nd Floor	4	10-Jun-21	15-Jun-21
A1330	Wooden Form Works for Columns of 2nd Floor	8	12-Jun-21	21-Jun-21
A1340	Concrete Works for Columns of 2nd Floor	1	21-Jun-21	22-Jun-21
A1350	Removing Wooden Form for Columns of 2nd Floor	1	22-Jun-21	23-Jun-21
A1370	Wooden Form Works for Beams, slab & stairs of 2nd Floor	8	23-Jun-21	01-Jul-21
A1400	Reinforcement works for Beams, slab & stairs of 2nd Floor	7	01-Jul-21	10-Jul-21
A1420	Concrete Works for Beams, slab & stairs of 2nd Floor	1	10-Jul-21	11-Jul-21
A1460	Marking and concrete kickers for Columns of penthouse	1	12-Jul-21	13-Jul-21
A1470	Supplying Crane for Reinforcement Bars Lifting to penthouse	1	13-Jul-21	14-Jul-21
A1480	Reinforcement works for Columns of penthouse	2	14-Jul-21	15-Jul-21
A1490	Wooden Form Works for Columns of penthouse	4	15-Jul-21	20-Jul-21
A1500	Concrete Works for Columns of penthouse	1	20-Jul-21	21-Jul-21
A1510	Removing Wooden Form for Columns of penthouse	1	21-Jul-21	22-Jul-21
A1530	Wooden Form Works for Beams & slab of penthouse	3	22-Jul-21	26-Jul-21
A1540	Reinforcement works for Beams & slab of penthouse	2	26-Jul-21	28-Jul-21
A1541	Concrete Works for Beams & slab of penthouse	1	28-Jul-21	29-Jul-21
A1550	Removing Wooden Form for Beams & slab of penthouse	1	10-Aug-21	11-Aug-21
A1570	Finish of Project	0		11-Aug-21



شركة الفرقان للمقاولات العامة المحدودة

Remaining Level of Effort | Actual Work | Critical Remaining ... | Actual Level of Effort | Remaining Work | ◆ Milestone

Page 1 of 1

Prepared By: Omar Ismail

5.2.2 The duration of the completion of the project is implemented in a precast way

At this stage, the same period of completion of the columns and beams will be maintained, and the slab paragraph of the project executed in the traditional way will be changed to the method of preparing and installing precast panels (hollow core), and according to the data of the precast processing plant, the installation is as follows:

3. After the columns are prepared and cast, the beams are approved and cast and the hollow core panels are processed. Referring to the brochure of the Darin Group factory (Appendix C, p.102), the plant's production capacity is 1500 m^2/day, and because the thickness of the panels used in the project is 20 cm, the production capacity of the daily of the plant is 300 m^3/day, which is enough for all the slabs of the project, so there is no need to calculate the period of manufacturing the panels within the work schedule, as it can be contracted to manufacture the panels and store them in the plant during the period of completion of the columns and beams.
4. The choice of the Mosul building project for calculating the duration was first of all because it is the furthest from the production plant located in Erbil, to take into account, the duration of transportation of the panels to the work site where that needs special trucks to transport these panels.

Transport is usually carried out in trucks with a maximum load capacity of 25 tons and the area of one floor is 320m^2, and the weight of 1m^2 hollow core 20cm is 304 kg/m^2, so the number of trips per floor can be calculated as follows: -

Capacity of one truck: 25000 kg/304 kg/m^2 = 82 m^2

Area of one floor: 320 m^2/82 m^2 = 4 trip for one floor.

Therefore, the processing period was calculated as 3 days as in Table 5.2 for the Primavera program, considering that every day it is possible to transfer two trips and consider an additional day in anticipation of traffic congestion problems.

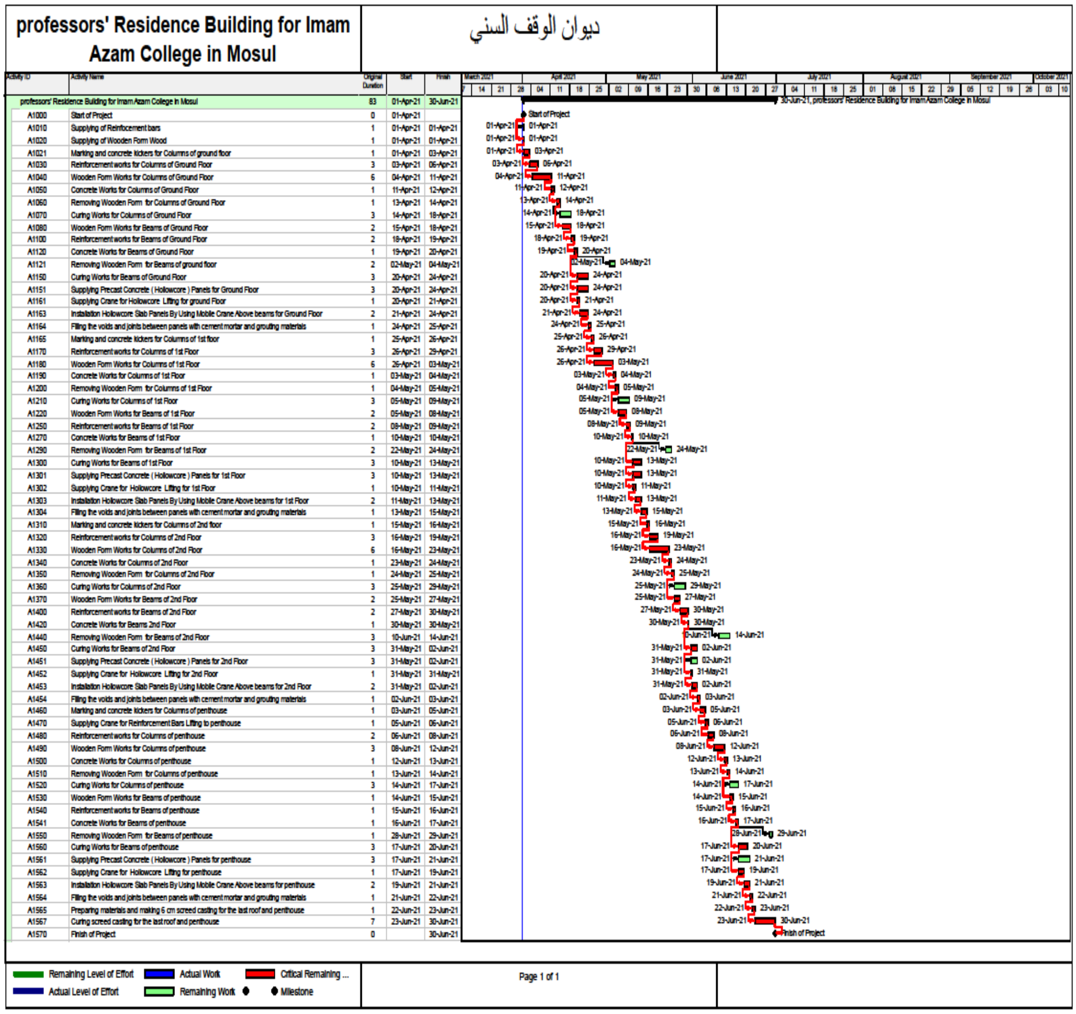
5. The process of installing panels over beams begins with a mobile crane, and according to the Darin Group factory, the daily capacity for installing panels is 30 panels per day, so one floor can finish the installation process of panels

in only two days. After that we need one day for filling the voids and joints between panels with cement mortar and grouting materials, Thus, the floor is finished, and the work on the other floors continues in the same way.

6. In the final surface, we need to make a screed with a thickness of 6 cm over the hollow core panels, which is simple work that requires only one day.

Referring to Table 5.2 of the primavera program, it is clear that the total period for completing the project structure in a precast way according to the critical path was only 83 days.

Table 5.2: Primavera Program for Schedule Time of Precast Way for Mosel Building



Activity ID	Activity Name	Original Duration	Start	Finish
	professors' Residence Building for Imam Azam College in Mosul	83	01-Apr-21	30-Jun-21
A1000	Start of Project	0	01-Apr-21	
A1010	Supplying of Reinforcement bars	1	01-Apr-21	01-Apr-21
A1020	Supplying of Wooden Form Wood	1	01-Apr-21	01-Apr-21
A1021	Marking and concrete kickers for Columns of ground floor	1	01-Apr-21	03-Apr-21
A1030	Reinforcement works for Columns of Ground Floor	3	03-Apr-21	06-Apr-21
A1040	Wooden Form Works for Columns of Ground Floor	6	04-Apr-21	11-Apr-21
A1050	Concrete Works for Columns of Ground Floor	1	11-Apr-21	12-Apr-21
A1060	Removing Wooden Form for Columns of Ground Floor	1	13-Apr-21	14-Apr-21
A1070	Curing Works for Columns of Ground Floor	3	14-Apr-21	18-Apr-21
A1080	Wooden Form Works for Beams of Ground Floor	2	15-Apr-21	18-Apr-21
A1100	Reinforcement works for Beams of Ground Floor	2	18-Apr-21	19-Apr-21
A1120	Concrete Works for Beams of Ground Floor	1	19-Apr-21	20-Apr-21
A1121	Removing Wooden Form for Beams of ground floor	2	02-May-21	04-May-21
A1150	Curing Works for Beams of Ground Floor	3	20-Apr-21	24-Apr-21
A1151	Supplying Precast Concrete (Hollowcore) Panels for Ground Floor	3	20-Apr-21	24-Apr-21
A1161	Supplying Crane for Hollowcore Lifting for ground Floor	1	20-Apr-21	21-Apr-21
A1163	Installation Hollowcore Slab Panels By Using Mobile Crane Above beams for Ground Floor	2	21-Apr-21	24-Apr-21
A1164	Filling the voids and joints between panels with cement mortar and grouting materials	1	24-Apr-21	25-Apr-21
A1165	Marking and concrete kickers for Columns of 1st floor	1	25-Apr-21	26-Apr-21
A1170	Reinforcement works for Columns of 1st Floor	3	26-Apr-21	29-Apr-21
A1180	Wooden Form Works for Columns of 1st Floor	6	26-Apr-21	03-May-21
A1190	Concrete Works for Columns of 1st Floor	1	03-May-21	04-May-21
A1200	Removing Wooden Form for Columns of 1st Floor	1	04-May-21	05-May-21
A1210	Curing Works for Columns of 1st Floor	3	05-May-21	09-May-21
A1220	Wooden Form Works for Beams of 1st Floor	2	05-May-21	08-May-21
A1250	Reinforcement works for Beams of 1st Floor	2	08-May-21	09-May-21
A1270	Concrete Works for Beams of 1st Floor	1	10-May-21	10-May-21
A1290	Removing Wooden Form for Beams of 1st Floor	2	22-May-21	24-May-21
A1300	Curing Works for Beams of 1st Floor	3	10-May-21	13-May-21
A1301	Supplying Precast Concrete (Hollowcore) Panels for 1st Floor	3	10-May-21	13-May-21
A1302	Supplying Crane for Hollowcore Lifting for 1st Floor	1	10-May-21	11-May-21
A1303	Installation Hollowcore Slab Panels By Using Mobile Crane Above beams for 1st Floor	2	11-May-21	13-May-21
A1304	Filling the voids and joints between panels with cement mortar and grouting materials	1	13-May-21	15-May-21
A1310	Marking and concrete kickers for Columns of 2nd floor	1	15-May-21	16-May-21
A1320	Reinforcement works for Columns of 2nd Floor	3	16-May-21	19-May-21
A1330	Wooden Form Works for Columns of 2nd Floor	6	16-May-21	23-May-21
A1340	Concrete Works for Columns of 2nd Floor	1	23-May-21	24-May-21
A1350	Removing Wooden Form for Columns of 2nd Floor	1	24-May-21	25-May-21
A1360	Curing Works for Columns of 2nd Floor	3	25-May-21	29-May-21
A1370	Wooden Form Works for Beams of 2nd Floor	2	25-May-21	27-May-21
A1400	Reinforcement works for Beams of 2nd Floor	2	27-May-21	30-May-21
A1420	Concrete Works for Beams 2nd Floor	1	30-May-21	30-May-21
A1440	Removing Wooden Form for Beams of 2nd Floor	3	10-Jun-21	14-Jun-21
A1450	Curing Works for Beams of 2nd Floor	3	31-May-21	02-Jun-21
A1451	Supplying Precast Concrete (Hollowcore) Panels for 2nd Floor	3	31-May-21	02-Jun-21
A1452	Supplying Crane for Hollowcore Lifting for 2nd Floor	1	31-May-21	31-May-21
A1453	Installation Hollowcore Slab Panels By Using Mobile Crane Above beams for 2nd Floor	2	31-May-21	02-Jun-21
A1454	Filling the voids and joints between panels with cement mortar and grouting materials	1	02-Jun-21	03-Jun-21
A1460	Marking and concrete kickers for Columns of penthouse	1	03-Jun-21	05-Jun-21
A1470	Supplying Crane for Reinforcement Bars Lifting to penthouse	1	05-Jun-21	06-Jun-21
A1480	Reinforcement works for Columns of penthouse	2	06-Jun-21	08-Jun-21
A1490	Wooden Form Works for Columns of penthouse	3	08-Jun-21	12-Jun-21
A1500	Concrete Works for Columns of penthouse	1	12-Jun-21	13-Jun-21
A1510	Removing Wooden Form for Columns of penthouse	1	13-Jun-21	14-Jun-21
A1520	Curing Works for Columns of penthouse	3	14-Jun-21	17-Jun-21
A1530	Wooden Form Works for Beams of penthouse	1	14-Jun-21	15-Jun-21
A1540	Reinforcement works for Beams of penthouse	1	15-Jun-21	16-Jun-21
A1541	Concrete Works for Beams of penthouse	1	16-Jun-21	17-Jun-21
A1550	Removing Wooden Form for Beams of penthouse	1	28-Jun-21	29-Jun-21
A1560	Curing Works for Beams of penthouse	3	17-Jun-21	20-Jun-21
A1561	Supplying Precast Concrete (Hollowcore) Panels for penthouse	3	17-Jun-21	21-Jun-21
A1562	Supplying Crane for Hollowcore Lifting for penthouse	1	17-Jun-21	19-Jun-21
A1563	Installation Hollowcore Slab Panels By Using Mobile Crane Above beams for penthouse	2	19-Jun-21	21-Jun-21
A1564	Filling the voids and joints between panels with cement mortar and grouting materials	1	21-Jun-21	22-Jun-21
A1565	Preparing materials and making 6 cm screed casting for the last roof and penthouse	1	22-Jun-21	23-Jun-21
A1567	Curing screed casting for the last roof and penthouse	7	23-Jun-21	30-Jun-21
A1570	Finish of Project	0		30-Jun-21

Remaining Level of Effort · Actual Work · Critical Remaining ... · Actual Level of Effort · Remaining Work · Milestone

Page 1 of 1

5.3 Comparison

By researching the actual period of completion of the structure of the professors' residence building at Imam Azam college in Mosul, it was found that the actual period of completion of the structure in the traditional way is 121 days, as for the precast slab method, the total period for the completion of the same structure is only 83 days.

Thus, the difference between the two periods is 38 days, that is, the percentage of time saved for the precast slab way is 31.5%.

This ratio is considered good for saving time and therefore costs, and it is considered a high time-earning period when compared to huge investment projects, where the difference in duration will increase as the project size grows, and the time-earning period may reach several months, and this, in turn, will provide large financial returns as it will accelerate the turnover of the capital for investment projects and the speed of completion of these projects.

The technology of using the precast is less time-consuming and is very useful, especially for a country like Iraq which suffers a lot from the destruction and destruction of infrastructure, housing, and construction due to wars in large areas of it.

Therefore, it is better to use technologies that speed up the construction process as an alternative to the buildings that were demolished due to wars and to avoid the occurrence of migration to other areas.

There is no doubt that one of the biggest problems of this technology is that it needs to establish factories to produce precast, and this is very few in Iraq, as the number of factories in it is counted on fingers, and this is due to several reasons, including internal and external factors, in addition to the lack of awareness and culture of investors in this country.

Here is the importance of project management in choosing the type of slab for the facility, where it is possible to express the opinion of the owners of capital in the use of this technology to save time and effort, reduce losses, and speed up the turnover of capital.

Figure 5.3 shows the graph of the time difference in the implementation of the traditional method and the method of precast panels, where it was faster by 38 days, which is more practical, requires less energy, and reduces the use of materials and equipment.

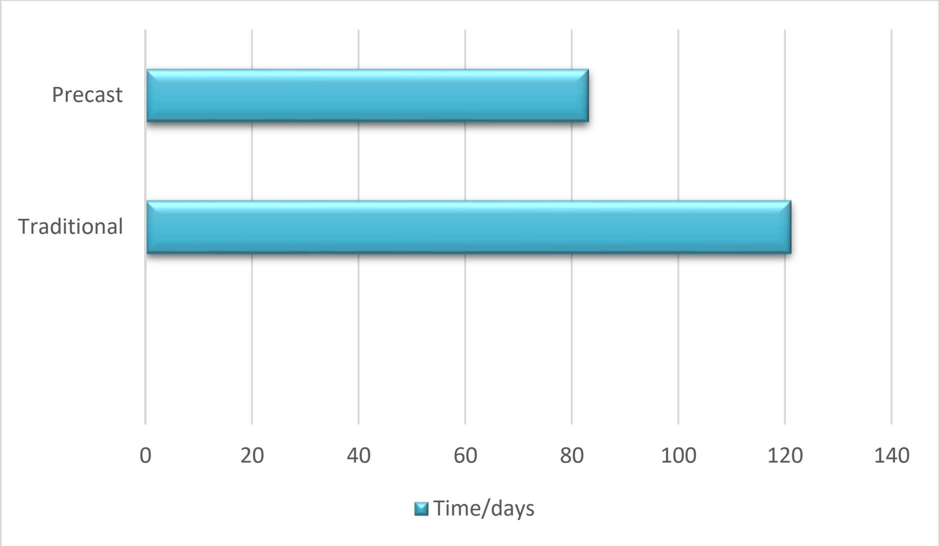


Figure 5.1: Diagram Showing the Difference in the Duration of the Construction Structure Implementation in the Two Ways

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Although the use of the precast concrete system offers many advantages, the share of these systems in the construction market in Iraq is very little.

One of the objectives of this thesis is to show the importance of using this technology in many circumstances, especially when time is the most important part of the project.

The research focused on several projects implemented in different regions of Iraq in two ways, the method of casting slabs on site and the method of precast slabs (hollow core panels), and the results of the secondary data regarding the costs of implementing slabs with hollow core panels were the least expensive for one cubic meter if compared to the percentage of the cubic meter in the traditional method.

The results of the secondary data regarding the costs of implementing slabs with hollow core panels were the least expensive for one cubic meter if compared to the percentage of the cubic meter in the traditional way, where the average price per cubic meter for five projects implemented in the traditional way was (381,000) ID, while the average cost of five Projects executed by the pre-cast method is (316,000) ID, i.e., less than (65,000) ID per cubic meter, which is 17% less.

As for the results of the primary data, which studied and analyzed two buildings, one of which is close to the factory for the production of hollow core panels in Erbil, the cost of the building using the pre-cast method was reduced by (25,149,706 ID), which is lower by a similar percentage to the secondary data, where it was 16.8%.

As for the farthest and smallest building, it was in the city of Mosel. It was found that the cost of the precast panels is also lower than the traditional casting method, but with a lower percentage, which is 13.9%, with a difference of (14,853,610 ID).

We conclude from this that the economic feasibility of using precast panels is achieved in large projects, and the closer the panel production plant is, reduce transportation costs.

As for time, the use of the precast slab method (hollow core) is very successful in saving time for the project, and s it is known, saving time is also cost saving and is very important in the speed of capital turnover, as many investors resort to using modern technology in order to speed up the completion of projects so that the capital spent on projects returns as quickly as possible.

By comparing the two ways, it was found that the on-site casting method consumed (121) days, while the precast method consumed only (83) days, and this means that the savings were (38) days, as the time-saving rate was 31.4%, which is a high percentage, especially when the project is large, as the savings rate doubles whenever the project was bigger.

From that we conclude the following:

1. The use of hollow core panels in constructing slabs is faster in implementation time and lower in cost than the method of constructing slabs in the traditional way.
2. Hollow precast slabs are lighter in weight, which saves a lot of weight on the building and reduces the loads on the foundations.
3. The precast slab method saves effort, energy, and cost, especially in large projects, as it reduces the use of materials and labor.
4. The presence of cavities in hollow core panels is an advantage in addition to reducing weight, as it works to hide electrical and mechanical extensions through these cavities in addition to their importance in thermal insulation.
5. The use of hollow core slabs technology is an important factor in the rapid turnover of capital and achieves the goal of completing the project faster.
6. The manufacture of these panels in the factory reduces the percentage of waste and preserves the environment and it is possible to control the quality.
7. The lengths of hollow core panels that may reach (15-18) meters and are based on beams can be used to reduce the number of columns and make large halls to exploit the spaces.

8. The percentage of cost gain decreases in small projects and increases in large projects if the hollow slabs precast method is used.
9. One of the downsides of the hollow core method is that it requires factories in the regions, and the process of transporting these panels also requires special transport trucks.

6.2 Recommendations and suggestions

After doing the research, there are some recommendations and suggestions that may be needed when conducting further research, among them are:

1. Increasing the education and awareness of contractors, investors, and capital owners in Iraq towards the use of precast panel construction by publishing such research to know the economic feasibility and the importance of speedy completion of projects using such technology.
2. Increasing the number of precast factories in Iraq, given that the current stage requires speedy completion of projects and institutions instead of those that were destroyed due to disasters and wars.
3. Conducting a wider study in the design of all parts of the building to take advantage of the lighter weight and thus using a smaller number of columns and different dimensions of the beams as well as the foundations where the load is reduced due to the reduction of weight.
4. We need a broader study on creating an integrated structure using precast walls and slabs and comparing it with traditional methods.
5. In the end, the result of this study encourages the use of precast hollow panels to save time and cost.

REFERENCES

ACI Committee 318. (1995). Building code requirements for structural concrete: (ACI 318-95) ; and commentary (ACI 318R-95). Farmington Hills, MI: American Concrete Institute, Adenuga, O. A., & Sotunbo, G. (2014). An Assessment of Time Variation in Solid and Hollow Floor Construction in Lagos State. Organization, Technology and Managementin Construction (June 2014), 984-993.

Albero, V., Saura, H., Hospitaler, A., Montalva, J. M., & Romero, M. L. (2018). Optimal design of prestressed concrete hollow core slabs taking into account its fire resistance. Advances in Engineering Software, 122, 81-92.

Allen, A. (2017). Reinforced Concrete Design to BS 8110 simply explained. CRC Press.

Alsheikh, A. (2020) Comparison between Post Tension and Hollow Core Slabs systems (Case Study)-Commercial Building in Amman.

American Society of Civil Engineers. (2000, February). Minimum design loads for buildings and other structures. American Society of Civil Engineers.

Asamoah, R. O., Ankrah, J. S., Offei-Nyako, K., & Tutu, E. O. (2016). Cost analysis of precast and cast-in-place concrete construction for selected public buildings in Ghana. Journal of Construction Engineering, 2016.

Bhimani, Alnoor, Horngren, Charles T, Datar, Srikant M, & Foster, George. (2008). Management and Cost Accounting, Pearson Education, Inc. 4th ed., New Jersey.

Booth. G. (1965). “A machine for extruding a hollow cored concrete product”, Great- Britain Patent GB994578A, Jun. 10, Canada.

C & CAA. (2003). Guide to long-span concrete floors. Cement and Concrete Aggregates Australia 73b, Second Edition, (August), ISBN1- 877023–09– 4.

Chaumeny. E. (1927), “Plancher en ciment armé”, France Patent FR618750A, Mar. 18. France.

Clarke, L. A., & Cope, R. J. (1984). Concrete slabs: analysis and design. CRCPress.concrete sections”, Canada Patent CA623476A, Jul. 11.

Darwin, Dolan, C. W., & Nilson, A. H. (2016). Design of concrete structures (Fifteenth edition.). McGraw-Hill Education.

Detailing Manual. (2004). Hollow Core Concrete Detailing Manual. P.O.BOX, Altona North, VIC3025, Australia.

Dodd. D. H. (1965). “Conduit forming apparatus and process: Method of forming concrete articles and slip forming machine therefor”, United States Patent US3200177A, Aug. 10. US.

Donald R. Buettner and Roger J. Becker, S.C., (1998). “PCI Manual for the Design of Hollow Core Slabs,” 2nd Edition, PCI Precast/Prestressed Concrete Institute,175 West Jackson Blvd, Chicago, IL. ISBN 0-937040-57-6, 141 pp.

Ellis. F.G. Thorsteinson. M.A. (1961). “Machine for extruding hollow cored.

Ervianto, I.W. (2006). “Eksplorasi Teknologi dalam Proyek Konstruksi ". Publisher: Andi. Yogyakarta.

Ese Soedarsono HS, (2002) Design and Detailing of Flat Slab, 27 February 2002.

Fanella, D.A. (2016). Design Guide for Economical Reinforced Concrete Structures. First Edition., U.S.A.

Gaiba. A. (1913). “Machine pour construire des corps longs, tels que tuyaux, poteaux, etc., en matériaux à l‘état pâteux, et pour les armer avec des fils métalliques”, France Patent FR449553A, Mar. 3, Italy.

Gessner. M. (1957). “Verdichtungsgerät zum Herstellen von vorgespannten Trägern oder Bauelementen aus Stahlbeton”, Germany Patent DE1008180B, May 9.Germany.

Hilton, Ronald. W & Platt, David. E. (2011). Managerial Accounting. McGraw-Hill Professional Inc. 9 th Ed, New York.

Horngren , Charles T, Datar, Srikant M, Foster, George, Rahan, Madhav, & Ittner, Christopger. (2009). Cost Accounting A Managerial Emphasis, Person, Prentice-Hall, 13 th Ed, New Jersey.

Horngren, Charles T, Datar, Srikant M, & Rajan, Madhav V. (2015). Cost Accounting A Managerial Emphasis, Pearson Education, Inc. 15th Ed.,Ne Jersey.

Ibrahim, Bachtiar. (2001). Plan and estimate Real of Cost. Jakarta: Earth. Script.

IPHA (2016). International Prestressed Hollow core Association. www.hollowcore.org.

Iraqi Ministry of Construction and Housing. (2014). Technical Specifications for Civil Works, The General Authority for Buildings and the Ministry of Planning / Central Agency for Standardization and Quality Control, first edition.

Lafiza, A. (2017). Analisa Perbandingan Metode Top-Down dan Bottom-Up Pada Proyek Fave Hotel Ketintang Ditinjau dari Segi Biaya dan Waktu (Doctoral dissertation, Institut Teknologi Sepuluh Nopember).

Martens. A. (1914). “Planchers, poutres et plafonds en béton armé, placés sans échafaudages”, France Patent FR468929A, Jul.20. Belgium.

Matthews, J. (2004). Hollow-core floor slab performance following a severe earthquake

Molotiloff. N. (1916). “Detachable Reinforced Concrete Flooring”, Great-Britain Patent GB191513497A, Apr. 13. Russia.

Moyse. S. (1919), “Improvements in Reinforced Concrete Beams, Floors, Walls and the like”, Great-Britain Patent GB120394A, Oct. 2. Belgium.

Muhammad. N. J. (2016). Civil Engineer Building Series 5, “the slabs, implemented, types, and everything related to them.

Murray J. (1932). “Conduit forming apparatus and process”, United States Patent US1887244A, Nov. 8, US.

NPCAA. (2002). National Precast Concrete Association Australia, Precast Concrete Handbook, North Parramatta.

Orry, G. (2008). Analisa dan Perencanaan Pelat Beton Pracetak Sistem Hollow Core Slab (HCS) Untuk Pelat Satu Arah. Tugas Akhir. Tidak dipublikasikan. Medan. Universitas Sumatera Utara**.**

Park, R., & Gamble, W. L. (1999). Reinforced concrete slabs. John Wiley & Sons.

PCFOG Committee. (2009). Seismic Performance of hollow-core floor systems. Preliminary Draft, Department of Building and Housing, Wellington, NZ

Prensoland sa. (2017). “100.000 m² of hollowcore slabs produced with flow former machines”, Archives of CPI, no. 3, pp. 236-237.

Rings. F.C.C. (1921). “Improvements in reinforced concrete beam floors”, Great-Britain Patent GB156973A, Jan. 20. GB.

Rismanto, Ade. (2013). https://aderismanto01.wordpress.com/2013/11/16/ manajemen- proyek-4/ .Diakses pada tanggal 22 Desember 2016.

Sarhan, O., Raslan, M., & Tallawi, G. (2021). Hollow-core precast and two-way solid slabs: Cost estimation and time duration comparison. International Journal of Advanced Engineering, Sciences and Applications, 2(1), 29-35.

Schafer. W. (1933). “Vorrichtung zum Herstellen von Betonplatten aller Art Germany Patent DE581572C, Sep. 16. Germany.

Schafer. W. (1951). “Plattendecke aus großformatigen Hohlplatten”, Germany Patent DE813198C, Sep. 10. Germany.

Setareh, M., & Darvas, R. (2016). Concrete structures. Springer.

Siegler. W. (1906). “Plafond en ciment armé sans enduit”, France Patent FR365548A, Sep.10. France.

Société Des Applications Mécaniques Du Ciment Armé. (1927). “Poutres en béton armé et dispositif d‘assemblage de ces poutres entre elles pour former un ensemble monolithe”,France Patent FR619622A, Apr. 6. France.

Stephen, C. (2013). "Hollow Core Manufacture and Factory Design", theIndian Concrete Journal 2013.pp 20-25.

Sudarsana, Dewa Ketut. (2008). “Integrated Cost and Schedule Control in Construction Projects”: Scientific Journal of Civil Engineering Vol. 12, No. 2:118.

Suharto, I. (1999). “Manajemen Proyek”. Penerbit: Erlangga. Jakarta**.**

Turai, V., & Waghmare, A. (2015). A Study of Cost comparison of precast concrete vs. Cast-in-Place. International Journal on Recent and Innovation Trends in Computing and Communication.

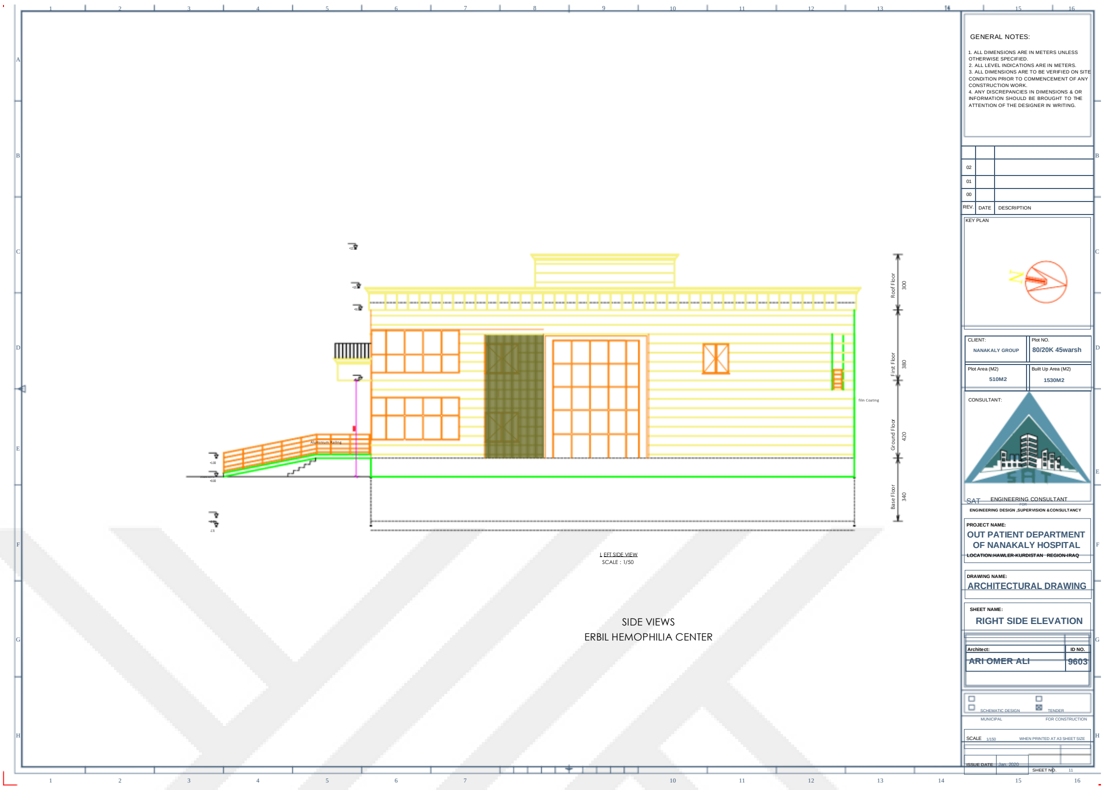
Van Acker, A., Maas S. (2021). Historical development of Hollow Core slabs, BMA/MKT 84/006, September. CPI – Concrete Plant International – 2.

Vyas, V. S. (2015). Survey of Precast Concrete Method and Cast-in-Situ Concrete Method. International Journal of Engineering and Technical Research (IJETR), 869(11), 70-73.

Wacker Gebrüder. (1952). "Verfahren und Vorrichtung zur Herstellung von Formstücken aus Beton und ähnlichen Massen", Germany Patent DE859724C, Dec. 15. Germany.

Widiasanti, Irika dan Lenggogeni. (2013). "Manajemen Proyek Dari Konseptual Sampai Operasional". Jakarta: Erlangga.

Appendix B: Drawings



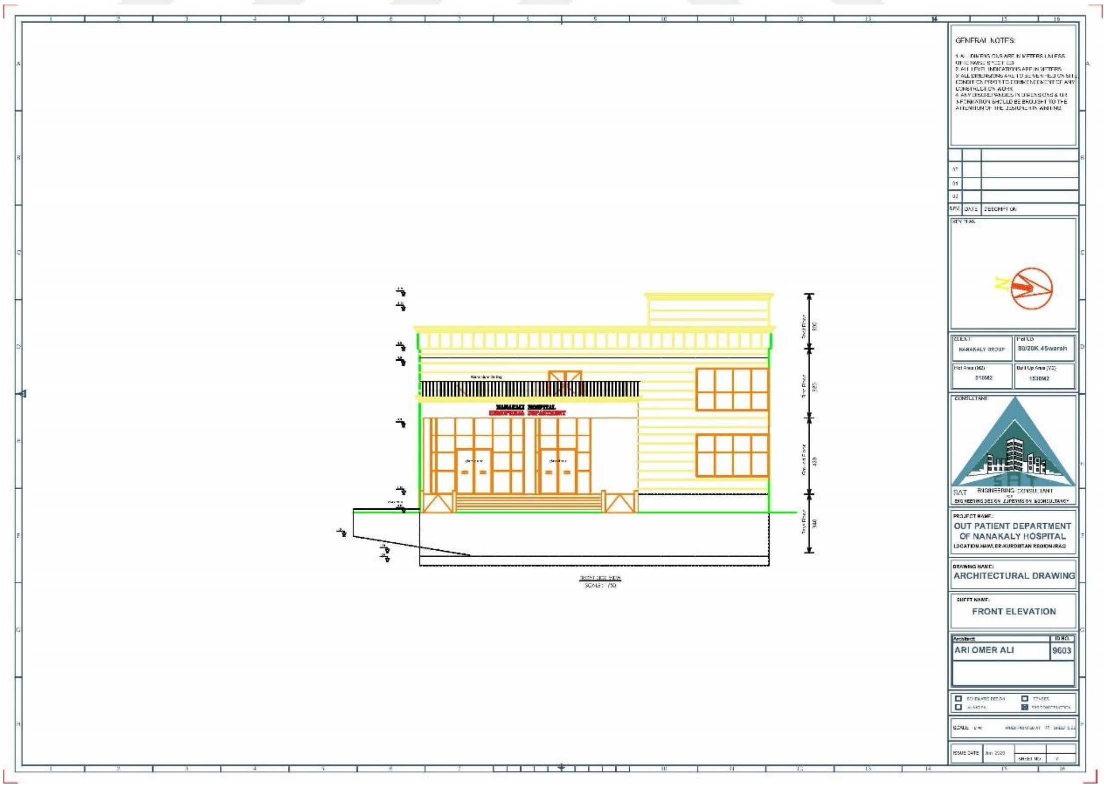


Figure B.1: Architectural Drawings for Nanakaly Hospital in Erbil

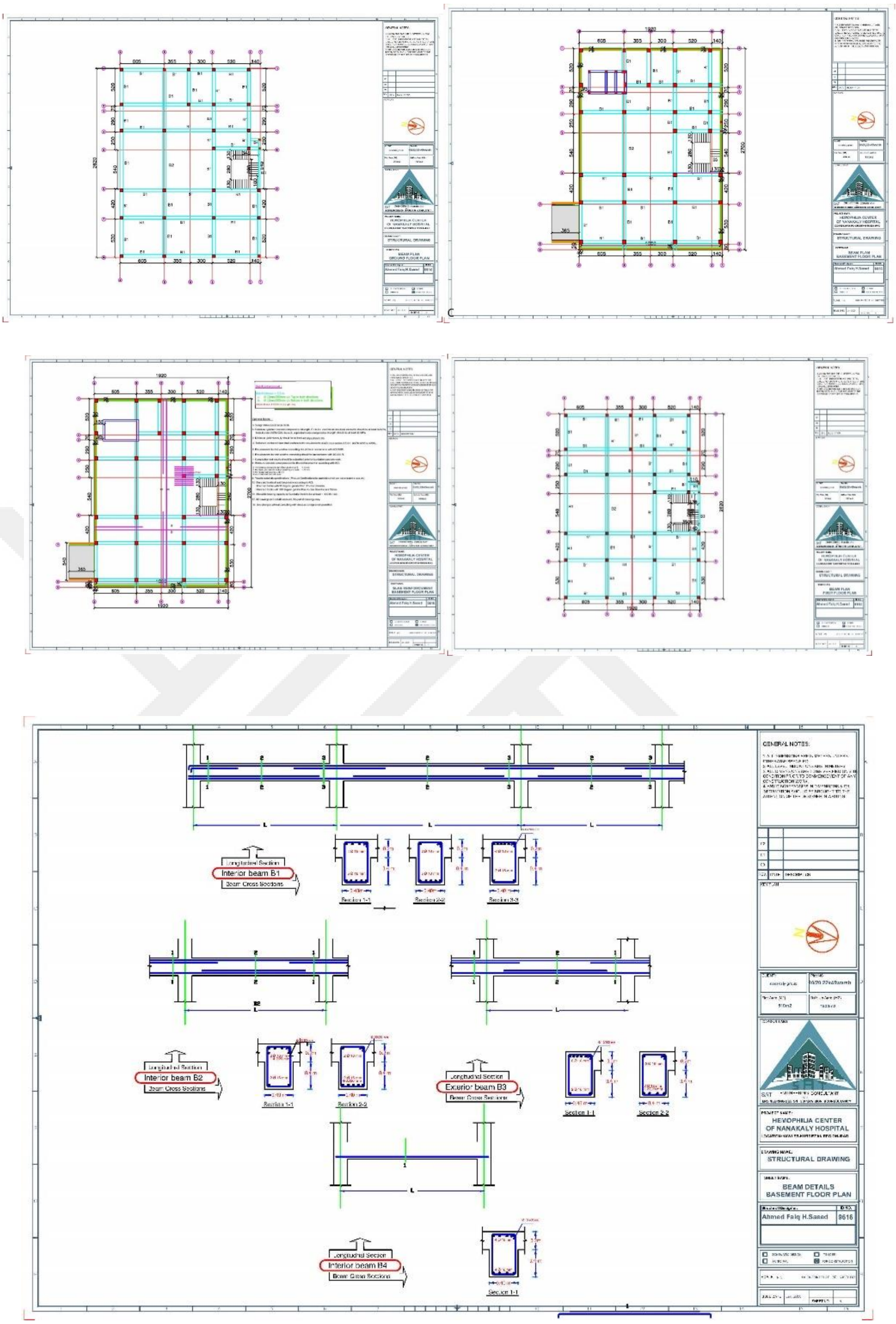


Figure B.2: Structural Drawings for Nanakaly Hospital in Erbil

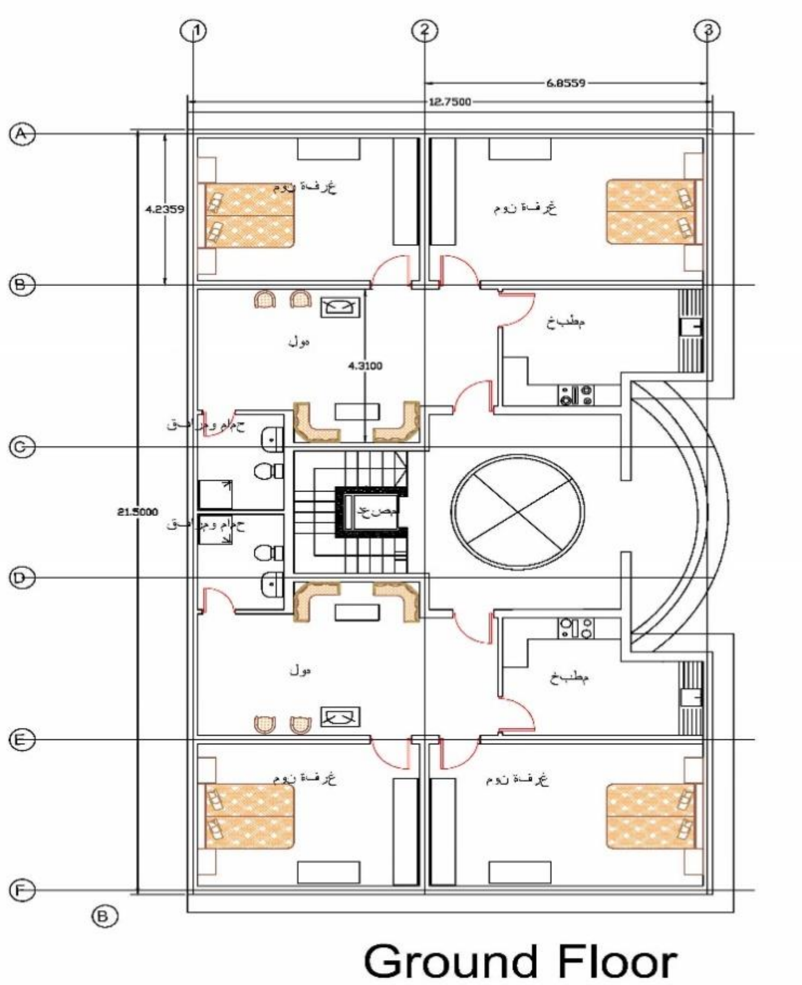
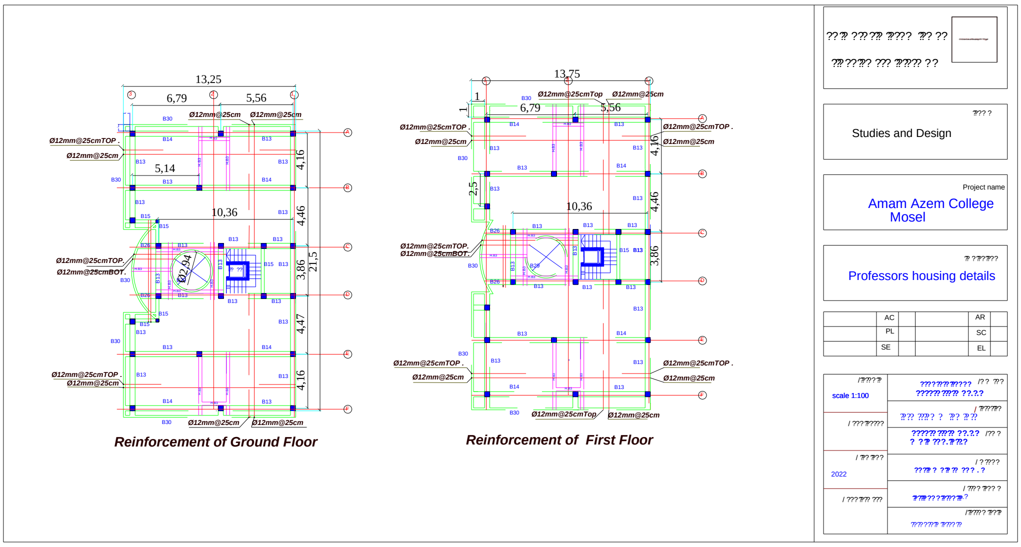


Figure B.3: Architectural Drawings for Imam Al-Azham Residential in Mosel



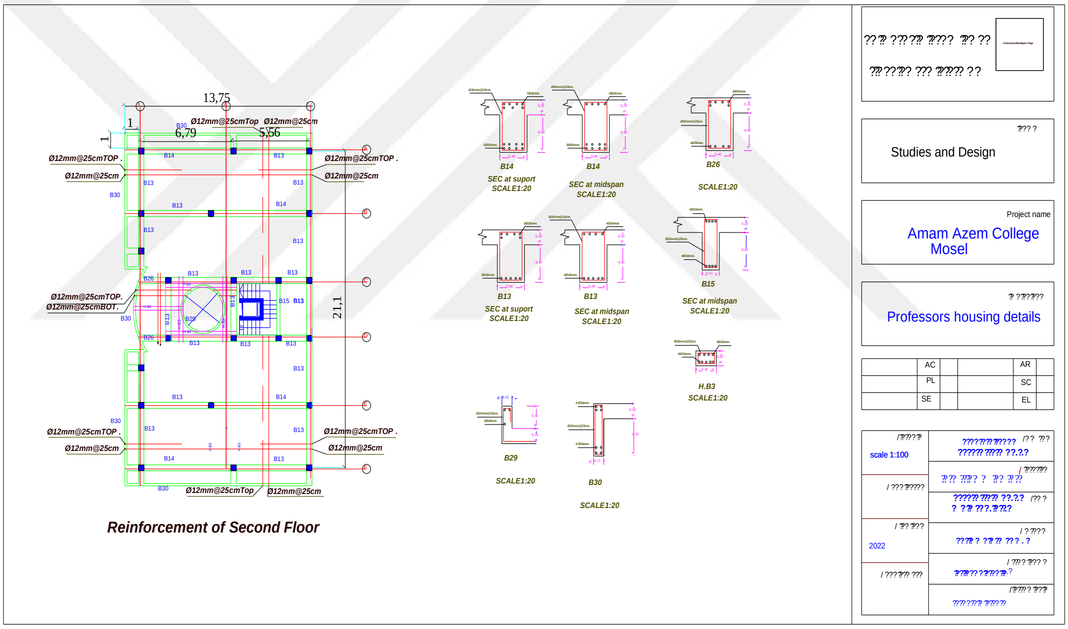
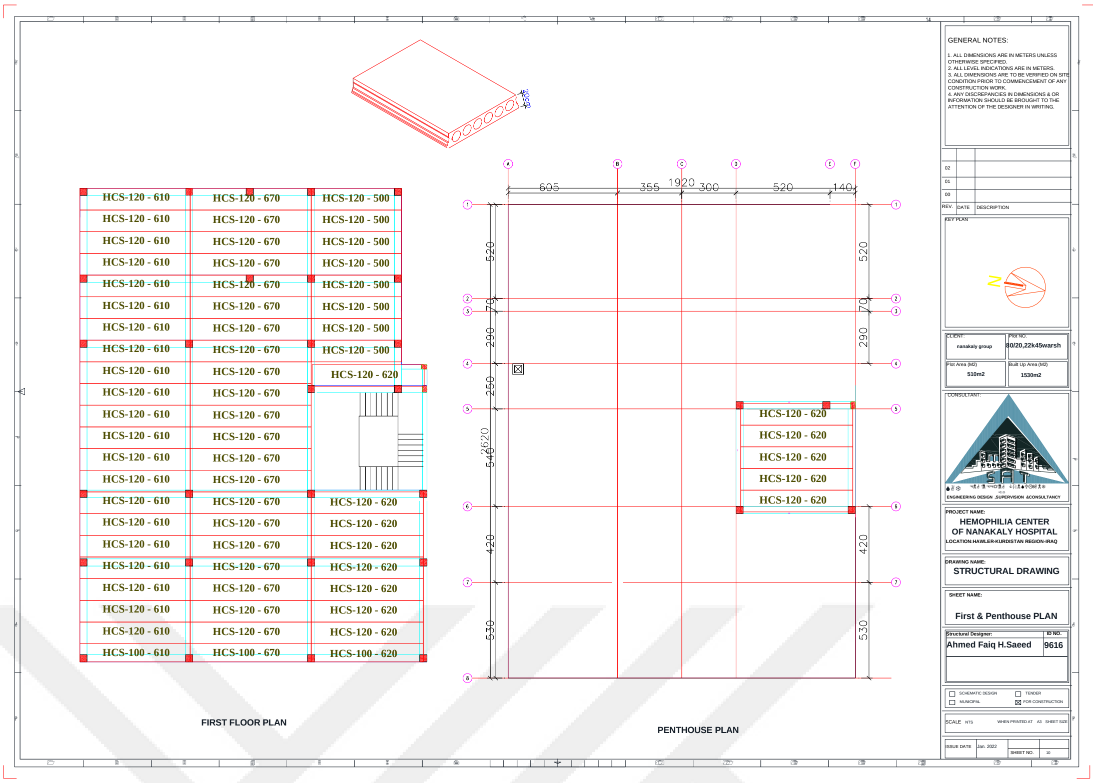


Figure B.4: Structural Drawings for Amam Azem Residential in Mosel



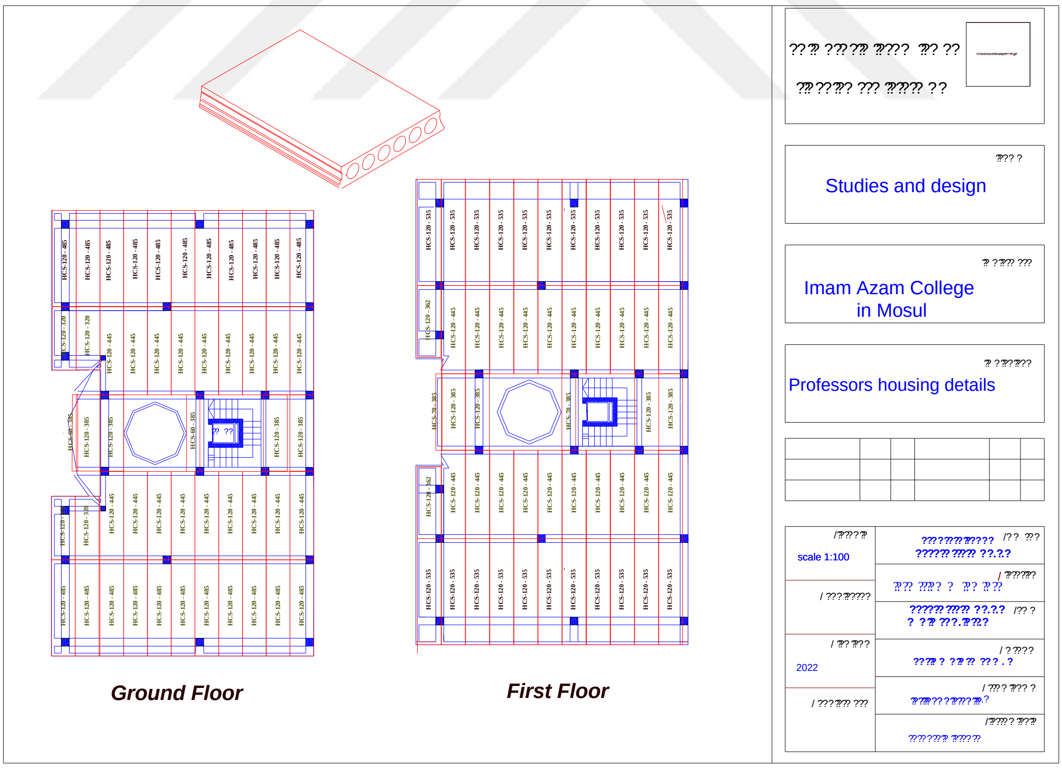


Figure B.5: Structural Drawing for Distribution of HCS Panels for Nanakaly Hospital, in Erbil

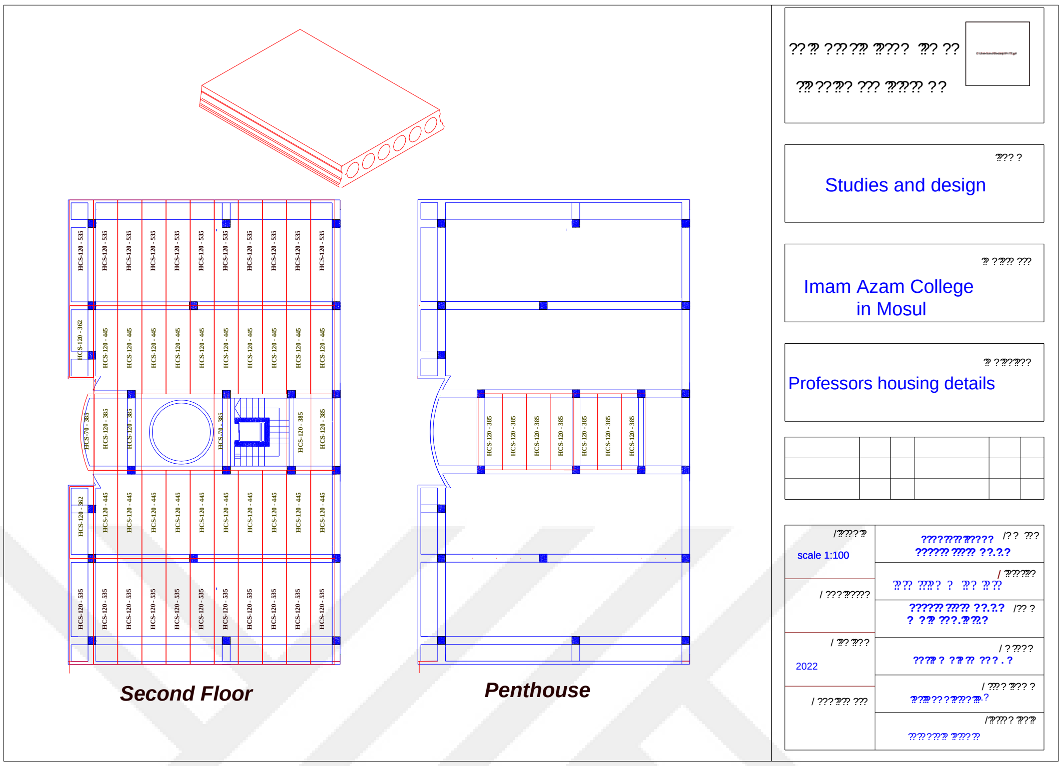


Figure B.6: Structural Drawing for Distribution of HCS Panels Amam Azam Residential in Mosel

Appendix C: Darin Group Precast Factory Brochure

DARIN GROUP
LEADING THE WAY

HOLLOWCORE SLABS STORAGE

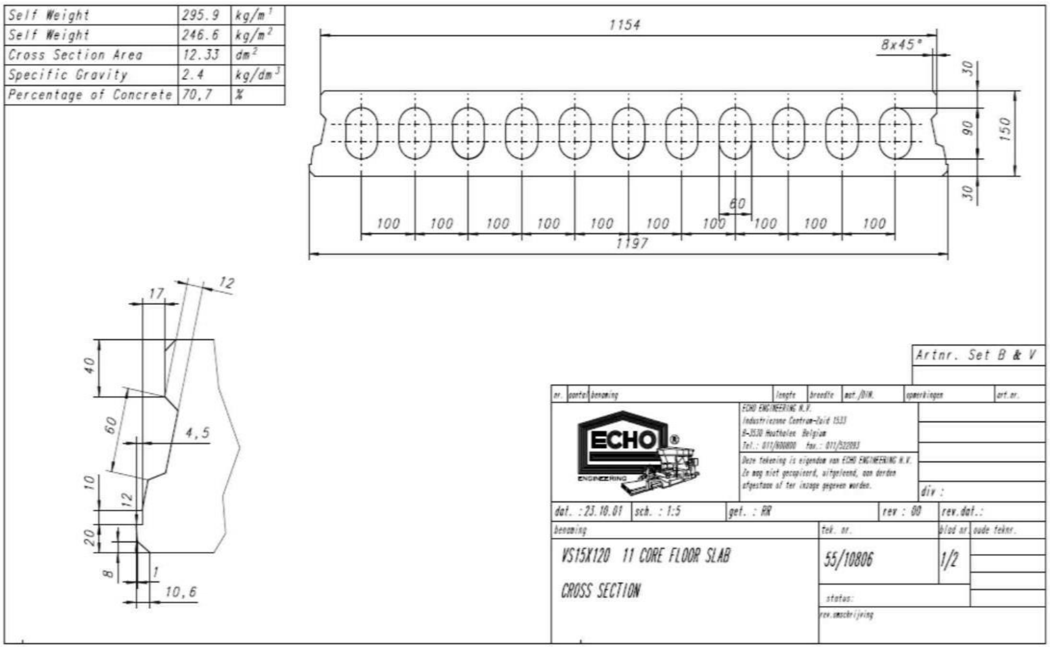

HOLLOWCORE SLABS STORED IN STOCKYARD

AVAILABLE THICKNESSES OF HOLLOWCORE SLABS: 15 cm, 20 cm, 25 cm & 30

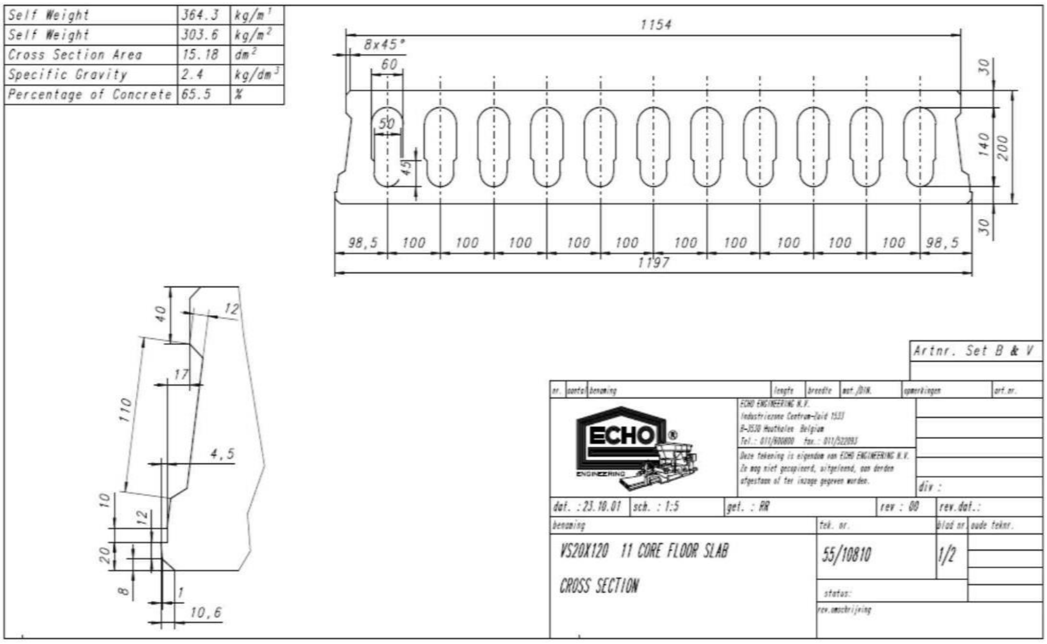
HOLLOWCORE BEING ERECTED / INSTALLED

DARIN GROUP HOLLOWCORE SLABS THICKNESSES:

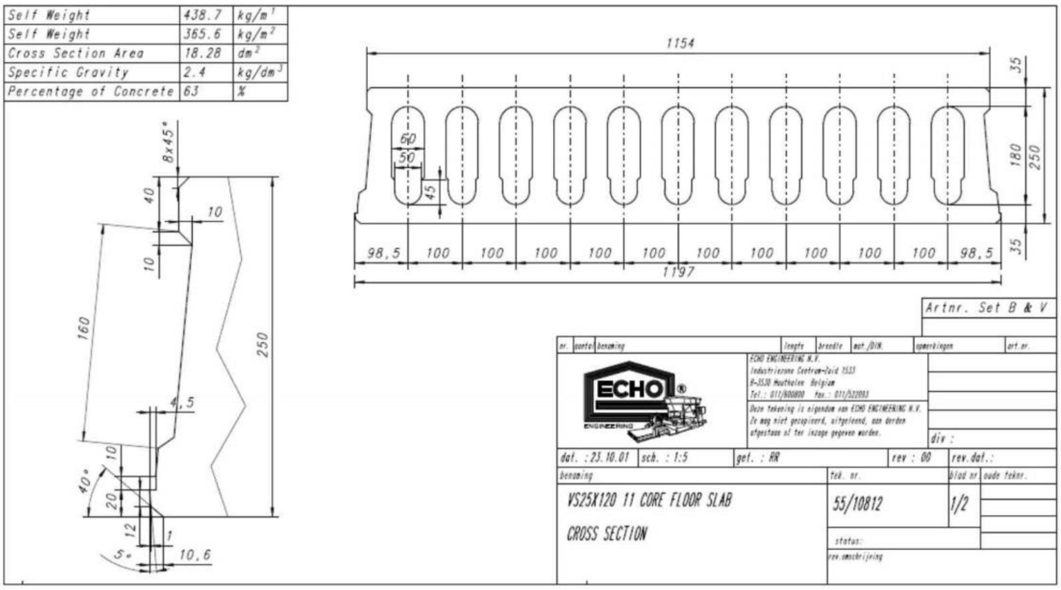
HOLLOWCORE SLAB 150 mm THICK, WITH STANDARD WIDTH 1.2 m



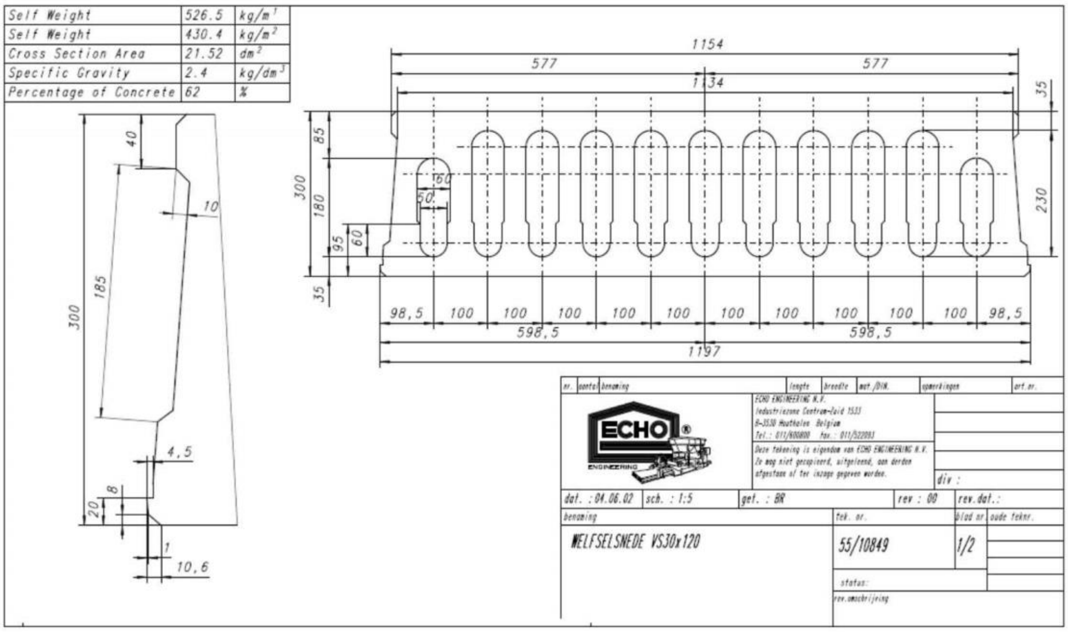
HOLLOWCORE SLAB 200 mm THICK, WITH STANDARD WIDTH 1.2 m



HOLLOWCORE SLAB 250 mm THICK, WITH STANDARD WIDTH 1.2 m



HOLLOWCORE SLAB 300 mm THICK, WITH STANDARD WIDTH 1.2 m



Darin Group has its Hollowcore Slabs Factory located at Bnaslawa. Factory's Hollowcore related information is as given below:

1. Number of Beds 8 Nos. Length=120 meter and width 1.2 meter
2. Hollowcore Slabs 'Production Capacity' is ***1500 m^2 per day***
3. Strands are of 2 types Diameter 9.53 mm and 12.7 mm (f_{pu} not less than 1800 Mpa)
4. Hollowcore Slabs are produced in thicknesses **150/200/250/ 300 mm**

Darin Group hollowcore slabs offer a fast and economical solution for suspended floors and roof construction, both for concrete structures and steel structures on steel beams. The slabs can be used as part of a full frame system in precast construction or in cast-in-situ frame construction.

Special Advantages of using Darin Group Hollowcore slabs:

1. Wide range of applications including walls, floors and roofs.
2. Plane and even surfaces, ready to receive putty and paints, avoiding the need for false ceilings.
3. Advantageous load-span characteristics due to low dead weight, pre-stressing high strength concrete
4. Early project completion date adding to the fast process of erection without the use of any propping or scaffolding.
5. They are produced in a controlled factory condition using very high strength of concrete and under strict quality control (**28 Days Cylindrical Strength NOT LESS than 40 Mpa**).
6. They can be cut to any length and used in a various locations.
7. Using Darin Group Hollow Slabs is the right solution to control the cost construction.

HANDLING, PROTECTION & ERECTION OF DARIN GROUP HOLLOWCORE SLABS :

1. The Darin Group Hollowcore units as well as Precast Concrete Panels are designed by our well-experienced and qualified Structural Engineer to sustain all lifting stresses.

2. The Hollowcores as well as Precast Concrete Panels shall be lifted only at the lifting position as specified on our drawings.

3. Hollowcore units shall be handled using scissor clamps or metal woven strops. Strops must not exceed 30 degrees to the vertical and must be checked regularly for wear and tear.

4. Dunnage (timbers) used for storing the Hollowcore units needs to be of suitable quality and placed on 'good' ground at the correct points in from the end of the units.

5. Where units are stacked one above the other, bearing dunnage (timbers) shall be positioned in vertical lines.

6. Hollowcore Slabs and Precast Panels shall be handled and placed according to references contained in various A.C.I. / B.S. standards.

TOPPING CONCRETE:

1. The top surface of the Hollowcore units shall be clean and free of all dust, oil or any deleterious substances which may adversely affect the wet topping bond to the Hollowcore units.

2. Pre-wet precast Hollowcore concrete surfaces prior to placing the topping concrete.

3. Free water shall be broomed away before the topping is applied.

4. Topping reinforcement shall be laid and would be as indicated in Darin Group's Structural Engineer's Drawings and shall be well supported to prevent displacement during concreting.

5. Topping concrete shall have a minimum 28 day Cube strength of 25 MPa and be well compacted with mechanical vibrators.

6. Topping concrete shall be poured to a true surface so that the specified thickness of (Usually 60 mm but NOT LESS THAN 50 mm) is achieved at the centre of the span. The key-ways between each Hollowcore unit must also be filled with well-compacted topping concrete (or other specified Non- Shrink Grout).

7. In-situ concrete shall be cured by the application of an approved curing membrane or by being kept continuously wet for not less than seven days.

FIXINGS & PENETRATIONS:

1. Fixing to the Hollowcore units (as well as Precast Panels) shall be in accordance with the approved details by Darin Group's Structural Engineer only.

2. Documentation of tested fixings proposed for the project shall be submitted to the Darin Group's Structural Engineer prior to installation.

3. Penetrations, set-downs or chases to the Hollowcore unit or topping concrete shall be in accordance with the details agreed by the Darin Group's Structural Engineer prior to any work being undertaken / carried out on site.

DARIN GROUP

LEADING THE WAY

HOLLOWCORE SLAB 200 mm THICK, LOAD SPAN TABLE (For guidance ONLY)

VS 20x120 - 11 cores (Without Structural Screed): Consult Darin Group's Structural Engineer for Actual and correct spans

Reinforcement type		Strands	Strands	Strands
Upper reinforcement				
LOWER reinforcement		8 Nos. Dia. 12.7 mm	10 Nos. Dia. 12.7 mm	12 Nos. Dia. 12.7 mm
Live load	*Dead load*	ALLOWABLE SPAN	ALLOWABLE SPAN	ALLOWABLE SPAN
kN/m²	*kN/m²*	(Meter)	(Meter)	(Meter)
1	0.5	13.5	13.7	13.9
1.5	1.0	11.6	11.7	11.9
1.5	1.5	11.4	11.5	11.7
1.5	2.0	11.1	11.2	11.4
1.5	2.5	10.9	11	11.2
1.5	3.0	10.5	10.7	10.9
1.5	3.5	10.2	10.5	10.7
1.5	4.0	9.9	10.2	10.4
1.5	4.5	9.7	10	10.2
1.5	5.0	9.4	9.7	9.9
1.5	5.5	9.2	9.5	9.7
1.5	6.0	8.9	9.2	9.4
1.5	6.5	8.7	9	9.2
1.5	7.0	8.4	8.7	8.9
1.5	8.0	8.2	8.5	8.7
1.5	9.0	7.9	8.2	8.4
1.5	10.0	7.7	8	8.2
1.5	12.5	7.1	7.4	7.6
1.5	15.0	6.6	6.9	7.1
1.5	20.0	5.9	6.2	6.3

MENTIONED ALLOWABLE SPANS ARE CLEAR SPANS.

For a normal office / apartment building, deflections are in order of 10 mm to 20 mm for 6 m to 9 m simply supported spans. Deflections are limited to Span / 500 where brittle finishes are to be applied or Span / 350 for non-brittle finishes. The usual requirements of limiting the span to effective depth ratio to control deflection is not applicable to pre-stressed concrete because of major influence of the pre-stressing.

DARIN GROUP CAN DESIGN THE HOLLOWCORE SLABS FOR A LIMITED DEFLECTION AS PER REQUIREMENT

Self weight of hollow core slab + joint filling : 3.16 + 0.16 = 3.32 kN/m²

Exposure class : 1 (dry environment)

Fire resistance : 2 hours

Acoustic insulation : Rw=52.6 Db, Thermal resistance Rc : 0.166 m²K/W

HOLLOWCORE SLAB 200 mm THICK, LOAD SPAN TABLE (For guidance ONLY)

VS 20x120 - 11 cores (Without Structural Screed): Consult Darin Group's Structural Engineer for Actual and correct spans

Reinforcement type		Strands	Strands	Strands
Upper reinforcement				
LOWER reinforcement		8 Nos. Dia. 12.7 mm	10 Nos. Dia. 12.7 mm	12 Nos. Dia. 12.7 mm
Live load	*Dead load*	ALLOWABLE SPAN	ALLOWABLE SPAN	ALLOWABLE SPAN
kN/m²	*kN/m²*	(Meter)	(Meter)	(Meter)
7.5	0.5	8.2	8.8	8.9
7.5	1.0	8.1	8.7	8.8
7.5	1.5	7.9	8.5	8.6
7.5	2.0	7.8	8.4	8.5
7.5	2.5	7.7	8.3	8.4
7.5	3.0	7.5	8.1	8.2
7.5	3.5	7.4	8.0	8.1
7.5	4.0	7.3	7.9	8.0
7.5	4.5	7.2	7.8	7.9
7.5	5.0	7.1	7.6	7.7
7.5	5.5	7.0	7.5	7.6
7.5	6.0	6.9	7.4	7.5
7.5	6.5	6.8	7.2	7.3
7.5	7.0	6.7	7.1	7.2
7.5	8.0	6.5	6.9	7.0
7.5	9.0	6.4	6.8	6.9
7.5	10.0	6.3	6.6	6.7
7.5	12.5	5.9	6.2	6.3
7.5	15.0	5.6	5.9	6.0
7.5	20.0	5.2	5.4	5.5

MENTIONED ALLOWABLE SPANS ARE CLEAR SPANS.

For a normal office / apartment building, deflections are in order of 10 mm to 20 mm for 6 m to 9 m simply supported spans. Deflections are limited to Span / 500 where brittle finishes are to be applied or Span / 350 for non-brittle finishes. The usual requirements of limiting the span to effective depth ratio to control deflection is not applicable to pre-stressed concrete because of major influence of the pre-stressing.

DARIN GROUP CAN DESIGN THE HOLLOWCORE SLABS FOR A LIMITED DEFLECTION AS PER REQUIREMENT

Self weight of hollow core slab + joint filling : 3.16 + 0.16 = 3.32 kN/m²

Exposure class : 1 (dry environment)

Fire resistance : 2 hours

Acoustic insulation : Rw=52.6 Db, Thermal resistance Rc : 0.166 m²K/W

DARIN GROUP
LEADING THE WAY

HOLLOWCORE SLAB 200 mm THICK, LOAD SPAN TABLE (For guidance ONLY)

VS 20x120 - 11 cores (Without Structural Screed): Consult Darin Group's Structural Engineer for Actual and correct spans

Reinforcement type		Strands	Strands	Strands
Upper reinforcement				
LOWER reinforcement		8 Nos. Dia. 12.7 mm	10 Nos. Dia. 12.7 mm	12 Nos. Dia. 12.7 mm
Live load	*Dead load*	ALLOWABLE SPAN	ALLOWABLE SPAN	ALLOWABLE SPAN
kN/m^2	*kN/m^2*	(Meter)	(Meter)	(Meter)
5.0	0.5	9.5	10.1	10.2
5.0	1.0	9.2	9.9	10.0
5.0	1.5	9.0	9.8	9.8
5.0	2.0	8.8	9.6	9.7
5.0	2.5	8.6	9.4	9.5
5.0	3.0	8.5	9.3	9.3
5.0	3.5	8.3	9.1	9.1
5.0	4.0	8.2	8.9	9.0
5.0	4.5	8.0	8.7	8.8
5.0	5.0	7.9	8.6	8.6
5.0	5.5	7.7	8.4	8.4
5.0	6.0	7.6	8.2	8.3
5.0	6.5	7.5	8.1	8.1
5.0	7.0	7.3	7.9	7.9
5.0	8.0	7.1	7.6	7.7
5.0	9.0	6.9	7.4	7.4
5.0	10.0	6.7	7.1	7.2
5.0	12.5	6.2	6.6	6.8
5.0	15.0	5.9	6.3	6.4
5.0	20.0	5.4	5.9	5.9

MENTIONED ALLOWABLE SPANS ARE CLEAR SPANS.

For a normal office / apartment building, deflections are in order of 10 mm to 20 mm for 6 m to 9 m simply supported spans. Deflections are limited to Span / 500 where brittle finishes are to be applied or Span / 350 for non-brittle finishes. The usual requirements of limiting the span to effective depth ratio to control deflection is not applicable to pre-stressed concrete because of major influence of the pre-stressing.

DARIN GROUP CAN DESIGN THE HOLLOWCORE SLABS FOR A LIMITED DEFLECTION AS PER REQUIREMENT

Self weight of hollow core slab + joint filling : 3.16 + 0.16 = 3.32 kN/m^2

Exposure class : 1 (dry environment)

Fire resistance : 2 hours

Acoustic insulation : Rw=52.6 Db, Thermal resistance Rc : 0.166 m^{2}K/W

RESUME

Saleem Mohammed Yaseen Alhameed

EDUCATION:

- **High School:** 1991graduated from Al-Ramady High School.
- **Bachelor:** 1997 graduated from Al-Anbar University, Engineering Department, Civil Engineer

PROFESSIONAL EXPERIENCE AND REWARDS:

General civil consultancy, project manager in the private sector, experience in commercial malls, hospitals, and amusement parks.