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Assessment of Key Imperatives for Enhancing Precast Adoptability in Egypt

Mostafa Sameh
mo90@aucegypt.edu

The American University in Cairo

School of Sciences and Engineering

ASSESSMENT OF KEY IMPERATIVES FOR ENHANCING PRECAST ADOPTABILITY IN EGYPT

BY

Mostafa Ahmed Sameh Abdelatty

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Under the supervision of

Dr. Mohamed Nagib Abou-Zeid

Professor, Construction Engineering Department

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“I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.”

– Albert Einstein

DEDICATION

I would like to dedicate this paper to my family

My father for going over and beyond in giving me exclusive access to top management level data amongst some of the biggest developers within Egypt and in KSA.

Finally, to the loving memory of My Uncle Talaat El Mahala who did not get the chance to see me publish this paper, He was always in my thoughts and prayers during the study of this thesis.

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My thesis has finally been completed. It has been a bumpy road with many swerves and breakdowns, but the road also was insightful, full of knowledge and provided exposure to various barely touched corners of the very wide construction industry.

This long journey couldn't have been completed firstly without God, with all His grace, guidance and the ease of way created during strenuous times and for blessing me with the select few I mention below who are constantly showing me undying support, and love, accepting me at my lows, cheering me on at my highs.

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I would also like to thank the Board Members of Modern Precast for sharing their experiences, trials, and expertise for greater knowledge of the precast field from a contractor's perspective.

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ABSTRACT

Precast Concrete's modular application concept is a major construction method that has been used historically seen in various shapes, forms and with a wide range of constituents. Examples include Ancient Egypt and China among several impressive structures in old civilizations. The major advantages of precast concrete lies in its adaptability, resilience, and versatility which makes precast concrete one of the most agile building materials. Precast concrete as we know it today has been introduced to our markets over the past several decades. Having similar advantages to that of old precast building methods, the road has been paved for a wider use of modern precast concrete into the construction industry. However, this use has been somewhat limited in Egypt despite the booming and ever-growing construction industry. As such, questions arise as to why precast has not sufficiently penetrated the Egyptian market and what could be the barriers or disadvantages that limit its use. Answering those questions could illuminate a protocol guide for precast concrete to be more commonly used within Egypt.

The main objective of this study is to assess the status of precast concrete in Egypt in an attempt to pinpoint both the advantages and the disadvantages as well as the barriers associated with its use. To meet this objective, aspects related to precast concrete are discussed including its adaptability to the ever-booming Egyptian construction industry, its capabilities, as well as the value added that it can render. The Egyptian market is taken as an example for an emerging market where a full set of material products are considered. To cope with recent advances, modern methods of using precast concrete are taken into consideration with increased aesthetic and performance capabilities are covered by this work. Data analysis as well as surveys are used to adequately incorporate actual market conditions and concern into the findings of this work. Sites were also visited where accessible while taking face to face surveys and alignment interviews.

The study rendered a summary of major trends of precast concrete in the Egyptian construction industry with analysis of their impact into its market strength and value added. Recommendations are provided for the concrete society and the construction industry by in large towards a better utilization of precast concrete in Egypt.

Keywords: Precast, Egypt, Construction, Market, Concrete

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LIST OF ABBREVIATIONS

Abbreviation	Meaning	Page
PCC	Precast Concrete Construction	1
CAGR	Compound Annual Growth Rate	1
USD	United States Dollar	1
GDP	Gross Domestic Product	46,47,49
MENA	Middle East and North Africa	49
MEED	Middle East Economic Digest	49
LEED	Leadership in Energy and Environmental Design	27,28,29
VOC	Volatile Organic Compound	29
SANS	South African National Standard	7,9
PCCP	Pre-stressed concrete cylinder pipes	15
RFP	Request for Proposal	51
BOQ	Bill Of Quantities	80,81,85,86
H.C	Hollow Core	83
CIS	Cast in Situ	60

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND HISTORY OF THE PRECAST INDUSTRY

Precast Concrete has been a prominent part of the ready-made construction industry for over decades. With regards to Precast Concrete, the worldwide Precast Concrete Construction (PCC) Market is expected to reach USD 985.80 billion by 2024, from USD 782.77 billion recorded in 2017 with a 2.6% CAGR over 2017-2024, according to market research reports scripted by certified Precast Concrete Market researcher Payal Agrawal (Agrawal., 2018).

World War 2 destroyed nearly 30% of France's urban infrastructure, and despite this economic downfall, the usage of modular construction methods replenished and redeemed the loss inquired in the war. This leaves a gap to identify why, despite the lack of funding and human resources, France could hail up its infrastructure quickly. It was through using ready-made units fixed via modular construction. In such strenuous times, precast does suffice in delivering quick ready-to-use units. It should then be more beneficial to developing countries that have a lack of resources and financial funding (Diefendorf, 1989).

Precast Concrete is usually composed of a specific mixture comprising cement, water, admixtures and aggregates that is then cast into particular figures in a well-managed environment. The precise concrete is initially poured into a modeling form, and it is cured before it is being stripped from its real form. These features are further transferred to the construction site to make use of them for building and erection into the workplace. Precast Concrete is engaged with reinforcement processes with either conventional reinforcement bars, or a combination of reinforcing bars and high

strength steel with high tensile strength or with single high-tensile strength steel only, without the combination of reinforcing bars. For the reinforcement of bars, the specific method utilized namely is the prestressing method where the strands of steel are pre-tensioned in the real form before the casting of Precast Concrete. The compressive force exerted by the strands allocates the elements of Precast Concrete for spanning wider distances and carrying great amounts of load (Xie et al., 2021).

In the last few years, various changes and advancements have taken place in the construction industry in Egypt, as well as with regard to the manufacturing of Precast Concrete: (a) quality control, (b) assurance of the slab floor, and (c) other products assembled with concrete floor. There are several changes that have taken place in the structural designs as well as the building codes in recent times and insurance adherence is kept necessary and compulsory. With continuous advancement of such an Industry, the inspection of materials and products manufactured from Precast Concrete is kept necessary before mixing and after mixing. This is needed for checking the strength of concrete and ensuring the accuracy of building works at the construction site. Typical testing cylinders are used in the young, booming markets of Egypt, having about 160 mm of cubic strength, utilized for inspecting the changes and working performances of Precast Concrete. Precast Concrete composed of moderative and high levels of strength are utilized in some great and long-term projects such as in the construction of big buildings, long bridges, and high-rise offices. In the Egyptian market, the recent trend is to manufacture moderative and high strength Precast Concrete and this trend is increasing periodically in the Egyptian markets. No doubt that it is not an easier task to

produce high-quality concrete with high strength, but it should still be moderated depending on the needs of construction. (Weng et al., 2021).

The fundamental guideline of prestressing was applied to construction, hundreds of years prior when ropes or metal groups were twisted around the wooden staves to frame a barrel as shown in Figure 1.1. At the point when the groups were fixed, they were under tensile prestress, which thusly created compressive prestress between the fights and empowered them to oppose hoop tension delivered by internal fluid pressure. As such, the groups and the fights were prestressed before they were exposed to any service loads. This is not precast as we know today but some form of precast prestressing that paved the way for modern precast applications.

Figure 1.1 Prestressed barrel in the early ages and the general principle of prestressing applied to barrel construction (Neupane ,2020)

1.1.1 FUNDAMENTAL COMPONENTS OF PCC

While the latest techniques and modern methods have increased aesthetic and working capabilities, they have also affected the preservation of realistic attributes of concrete. Precast Concrete is considered an environmentally sound material formed by natural materials. Nontoxic materials are formed and utilized by the production of concrete or from its usage. The controlled manufacturing of Precast Concrete increases the sundress of the environment by optimizing materials used on the construction site, decreasing the wastage of materials when the panels are created and minimizing interrelated wastage on the job site.

Precast Concrete is made up of slabs of prestressed concrete; it is developed in the solid form or in the form of longitudinal hollow cores. The floor units are approachable at various depths to meet different capabilities and performances essential for loading and span. The main purpose behind the excessive usage of Precast Concrete is that it offers a number of potential benefits over onsite casting. Increased production of Precast Concrete can be completed at ground level which assists with reliability and safety throughout the construction project. Precast Concrete plays a major role in enhancing the material quality and workmanship on precast plants in comparison with construction sites (Sun et al., 2021).

In Egypt's young, booming markets, the panel of Precast Concrete particularly ranges from almost $400 to $700 per cubic meter, and this is considered a broad range of cost because there is a wide range of options and causes impacting the overall cost of Precast Concrete. The panels of Precast Concrete also have different edging treatments and finishes based on the final usage of the products. Precast Concrete is

classified into different types such as PCC slabs, slabs of prestressed hollow, slabs of prestressed solid, slabs in double tee, and waffle slabs. Precast Concrete is usually composed of a specific mixture comprising cement, water, admixtures; an aggregate that is then cast into figures in a well-managed environment. The precise concrete is initially poured into a modeling form and is cured before being stripped from its real form. These features are further transferred to the construction site to make use in building and the erection into the workplace (Petkovic et al., 2020).

Precast Concrete is engaged with the reinforcement processes with either conventional reinforcement bars, a combination of reinforcing bars and high-tensile strength steel, or with single high-tensile strength steel without the combination of reinforcing bars. For the reinforcement of bars, the specific method utilized is the prestressing method where the strands of steel are pre-tensioned in the real form before the casting of Precast Concrete. The compressive force exerted by the strands, again, gives the elements of Precast Concrete the capability to span wider distances and to carry greater amounts of load. The prestressing method also decreases cracks until reaching the state when the members are still in compression. The parts of precast element joints binding elements together can be better perceived as shown in Figure 1.2 below.

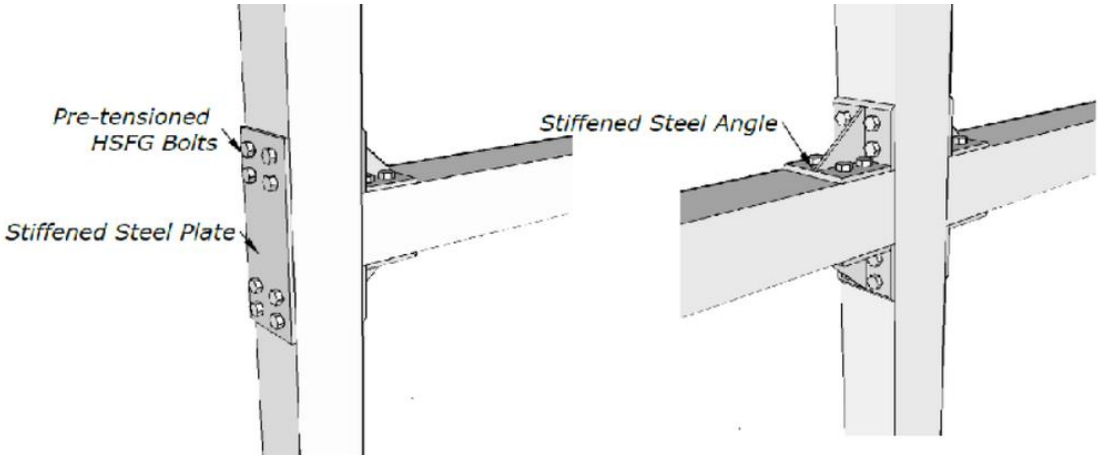

Figure 1.2: Precast Concrete and rigid joints (Sun et al., 2021)

Regarding the perception of concrete adaptability and performance, the thermal mass of Precast Concrete secures the energy, being a non-combustible material with maximum fire-resistant capability. Precast Concrete creates a secure platform that assists in protecting tools, personal equipment, and the integrity of the entire structure itself. When used for structural elements, the Precast Concrete excretes or reveals the requirements and costs of extra fire-proofing measures. The higher albedo or total ratio of light reflection has the additional capability and quality of reflecting sunlight as well as solar heat, increasing the impact of maintaining cold closed places naturally suitable for warmer urban or commercial developments. The temperature benefit results in cost savings in electricity. It also minimizes pollution and smog formation by improving the quality of air in more developed areas. Additionally, capabilities of preventing noise are protected because of the overall mass of Precast Concrete. This also provides added cost-saving benefits, diminishing the need for extra interior or exterior noise penetration insulation. The option of Precast Concrete also offers lifetime benefits to occupants due to its high durability and not needing maintenance for prolonged periods of time.

Further pictorial representations showing more durable demoldable precast components are shown in Figure 1.3.

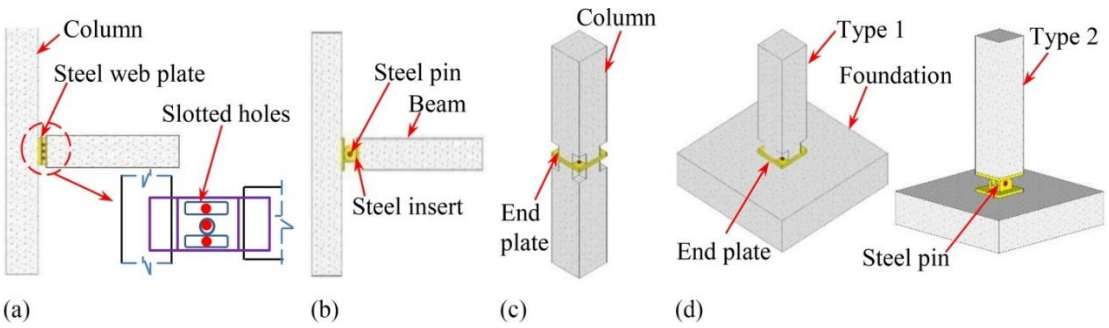

Figure 1.3: Demoldable Precast Concrete (Morgen et al., 2018).

1.1.2 MATERIALS CONCRETE MIX DESIGN

An economically successful precast member should avoid surface breakages and damages (Abdullah et al., 2016, 213-224). The concrete should have a robust strength that develops quickly after casting. The minimum stone size should conform to the smallest precast element dimension.

1.1.3 CEMENT

The cement should conform to SANS 50197 standards. The preferable class is 32.5 R or more which develop strength quickly. A 32.5 N class cement is useable and may require a higher cement proportion than the one indicated in Table 1.1 to assure sufficient early strength.

1.1.4 AGGREGATES

The desirable sand should be coarse, either natural sand from pits or rivers, or crushed. The fresh concrete becomes less cohesive and harsher when almost a quarter is substituted with plaster sand. Natural or crushed stone is usable. The stone size is

essential since the most oversized particles must not surpass a quarter of the Precast Concrete thickness.

Table 1.1: The least concrete thickness for several stone sizes.

Nominal size (mm)	**6 .7**	**9.5**	**13.2**	**19.0**
Least thickness of concrete, mm	3	40	50	80

1.1.5 WATER

Drinking water is usable and, if it is not suitable for drinking, it requires component laboratory testing and approval.

1.1.6 PIGMENTS

The synthetic pigment should be of the best quality best with use of metallic oxides and usually iron.

1.1.7 MIX PROPORTIONS

The cement, sand, and stone mix ratio vary depending on stone size, as shown in Table 1.2.

Table 1.2: Mix proportions attempt by volume for Precast Concrete

Stone Size in mm								
	6.7		9.5		13.2		19	
Batch	Large	Small	Large	Small	Large	Small	Large	Small
Cement	One bag	1	One bag	1	One bag	1	One bag	1
Stone	40L	1	50L	$1^1/_4$	55L	$1^1/_2$	75L	2
Sand	75L	2	75L	2	75L	2	75L	2

The above mix ratio calculation is achieved by using 32, 5R cement. The mixture should have sufficient water to offer a plastic mix compatible with any available means. The obtained slump measurement follows the SANS 5862-1:2006. Suitable slumps are shown in Table 1.3. Small batches can use small containers to establish mix ratios.

Table 1.3: Workability and Slump Sizes

Slump	Compaction (mm)
25-50	Thorough mechanical palpitation
50-100	Restrained mechanical palpitation
100- 150	Human hand

Machine mixing is suitable, although smaller quantities are mixable by hand. The most appropriate mixer is a pan-type mixer with a forced mixing mechanism.

Concrete workability needs to be compatible with compaction means. High-energy mechanical vibrators are suitable for unworkable, stiff mixes. If the vibrator is not available, use workable mixes as in the above Table 1.3.

1.1.8 EQUIPMENT USED

Precast Concrete element production comprises various intermediate phases, and each phase requires dedicated equipment. A de-tensioning pump unit retains steel wires in the first phase. The de-tensioning then occurs as the response beams on the holding side discharge tension on the steel wires in a controlled manner via hydraulic cylinders. The regulation is done by a de-tensioning pump for single or multiple stressing. The precast elements production is continuous in the cast machine and has diamond blades for cutting desired points. Special clamps transport the Precast Concrete from the production unit to the stocking location using the pulleying system (Hegarty et al., 2020)

Figure 1.4: Molds used for Precast Concrete walls (Catalogue molds, accessed 28th July, 2021)

The pulling system uses radio-controlled drive motors; hence, the transport line offers a flexible and economical solution across a considerable distance. The production bed requires cleaning due to the concrete residues that remain. A sample crane lifting mold for precast panels is shown in Figure 1.5. Molds are also made for precast load-bearing walls, as shown in sample Figure 1.4.

Figure 1.5: Crane lifting precast panel mold (Hegart et al., 2020)

Manual cleaning using a wheelbarrow, brooms, and shovels consumes a lot of production time. Utilizing a multi-function cleaning machine is an efficient and time-saving solution. Multi-function cleaning machines also lay wires in the production area; a bucket attached to overhead cranes moves concrete to the casting machine. Once the production area is clean, oiled, and equipped with tensional pre-stressing wires, the casting machine begins the element casting as shown in Figure 1.6.

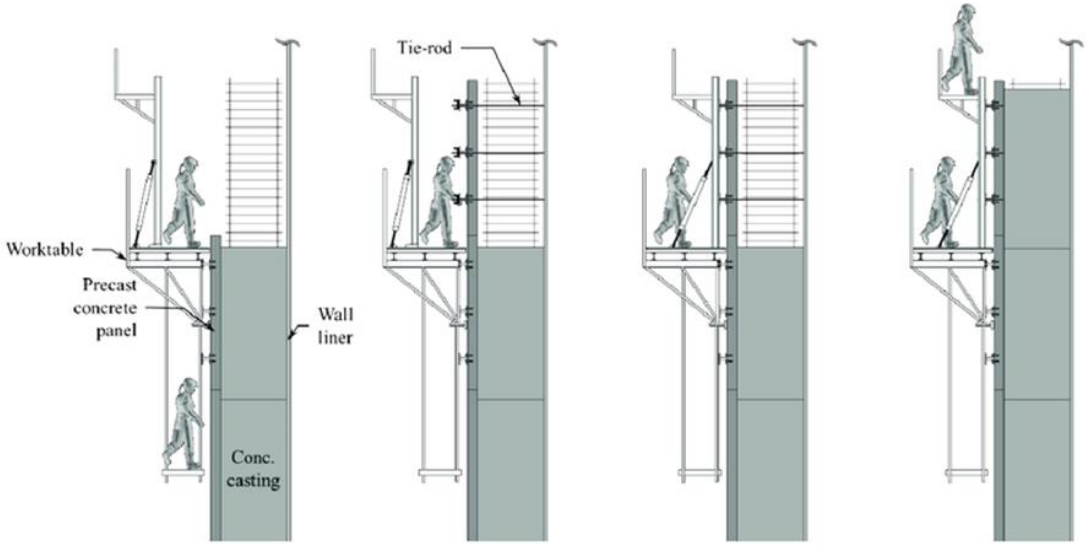

Figure 1.6: Conceptual construction procedure using Precast Concrete (Hossieni et al., 2020)

Products formed with Precast Concrete are already reinforced with steeling rebar, but the overall managed processes also make sure that the concrete does this settlement appropriately and, under some ideal consequences, for maximum strength. The greatest aspect of Precast Concrete is that it saves a lot of time in construction processes and reduces risks associated with delays in construction projects. Moreover, it is the most cost-effective element in the construction industry and simplified construction processes decrease time constraints and enhance productivity and growth, security, quality, and, hence, costs. Precast Concrete is utilized due to its special aspects such as versatility and is most commonly utilized for parking garages, the construction of office buildings, stadiums, bridges, housing societies, and shops; moreover, precise concrete is excessively utilized in modular structures and modular elements. If brick is considered in the construction of these buildings, then according to estimates, bricks are far away cheaper in cost when compared to Precast Concrete. The curing of low

pressure and conventional steam are the two most basic methods for the curing of Precast Concrete elements. Another method for the curing of Precast Concrete is the method of membrane curing which is directly engaged with the method of conventional curing by utilizing polyethylene sheets, similar materials, and curing compounds. With the membrane curing method, external water is not utilized in the curing operations (Hossieni et al., 2020).

Fresh concrete works include making rain drainage weep holes, surface grooving, side indenting, longitudinal cutting, making cutouts, and notches. Element marking draws a mark representing production lines or product-related information. Plotter machines furnished with inkjet printers are used in element marking. A heating plant shortens the curing time and thus ensures maximum utilization of the production bed (Wilden, 2014).

1.1.9 WORKMANSHIP USED AND LEVEL OF SKILL

Structural precast and pre-stressed concrete elements require knowledge and skill. Operators need the competency to mold, cure, and strip the element, control the quality, and resolve issues within their area of responsibility. A Precast Concrete producer should have the ability to read and interpret steel drawings, element specifications, test outcomes, job sheets, casting schedules, procedures, safety information, and material labels (Eastman, 2011). Precast Concrete production requires checking and positioning of materials, fittings, formwork, molds, reinforcement, and equipment according to the specifications provided. Production teams will need the knowledge to apply tension to the strands, cast the product, test the raw materials, and collect samples. Finally,

finishing handle curing, stripping, destressing, and storage of the elements also need to be part of the team's skillset.

Workers in Precast Concrete should monitor critical variables such as mold condition, concrete cover, amount, and consistency of the concrete mix, compaction, reinforcement tension, placement, stripping strength, reinforcement anchorage, curing time, rate, voids placement, product integrity, and conformance to specifications. Operators should be able to make adjustments to meet production output specifications and product quality. Safety procedures apply to precast production, so the team should identify hazards and implement relevant hazard control measures.

Production staff should furthermore have the ability to identify routine and non-routine problems and apply rectification measures. Workers should have the skill to distinguish among potential causes of routine problems such as process errors, mix variations, reinforcement abnormalities, mold anomalies, and casting conditions. Record-keeping and communication skills to communicate effectively among their workgroups are also required (Cao et al., 2021).

1.2 TYPES OF PRECAST MODULAR UNITS

Precast usually involves a variant of modular units produced within production plants and, at times, also onsite. Commonly known identifications of these units are as shown and explained below.

- Slabs:

Also called planks, it a construction system that is composed of mainly precast structural elements that lie on modules between walls and joins through a tight connection with rebars.

- Beams:

  The precast beam is also called joist and supports the precast slab. It is used to hold the weight of slab and make a connection with the slab.

- Wall panels:

  Precast walls are utilized in various shapes and sizes depending on the wall type needed. There are three distinct categories such as thin shale, sandwich panels, and solid walls.

- Double tees:

  The double tee is used for parking lots, floors, and roof systems. It is also used for heavy loads and long spans.

- Pre-stressed concrete cylinder pipes:

  Abbreviated as PCCP, is an ideal structural element when combined with high compressive strength and the high tensile strength of steel which are used in water-retaining and hydraulic structures.

- Reinforced concrete cylinder pipes:

The steel pipe is enclosed in concrete which provides better durability and water tightness.

- Segmental tunnels and shafts:

  These are used for ventilation, water retaining structures, sewers, and tunnel launching. This is a significant method used in both permanent and temporary construction.

- House connection chambers:

  These are built for inspection purposes. The main difference between utility access holes and connection chambers is that you cannot physically inspect the inside of the chamber.

- Precast decorative panels:

  These are precast elements used in different shapes and varieties. Apart from their strength, these panels are used as decorative pieces as well.

- Reinforced concrete utility access holes:

  These are composites made from concrete and steel which are used in sewers and sewerage systems.

- Pre-stressed structural elements:

These include all kinds of beams, columns, slabs, load-bearing walls, and arches as well. Bridge decks are often made precast with longer spans, extra durability, and rapid speed.

- Reinforced concrete pipes:

  These are reinforced with steel and then used for various purposes such as water retaining structures, cause ways, ventilations, and bridges.

1.3 MARKETING SKILLS

Any good marketing strategy requires Precast Concrete awareness and a placing of oneself as a leading Precast Concrete producer and distributor in the construction industry. An overall marketing tactic is to delineate primary clients and prospects. The Precast Concrete manufacturer engages in commercial promotion through sharing Precast Concrete concepts and manufacturing approaches. It is also crucial to develop an understanding relationship with clients. This strategy ensures a personal assembly with clients, informing them on new and custom-made precast solutions that suit their needs (Caspin, 2007).

Marketing skills and strategy are crucial factors for precast construction firms in obtaining sustainable development alongside low costs and durability. Precast contractors need to identify and sell themselves in an appealing form, emphasizing the long-term benefits of precast whilst accentuating how it succeeds over other, more traditional methods of construction. Marketing is considered a key part of any precast firm, mainly due to the strong marketing capabilities needed in promoting precast not just as a product but as a concept. Precast Concrete promoters and marketeers need to

firstly create precast awareness and then promote and advertise the product with regard to its advantages (Aldani and Arboro, 2015).

The common Egyptian marketing practice is to create awareness of the brand firstly by shining light on the ease of construction and how capable the precast contractor is at delivering the product at an unprecedented lead time. Further to this, the long-term capabilities are highlighted with the general notion emphasized that Precast Concrete is generically a high-quality product.

1.4 MARKETING OPPORTUNITIES

Approaching contractors, interior designers, and remodelers requires networking via local referrals, builder’s associations, and the arrangement of appointments to discuss the needs of the project. This is often done by way of before and after pictures on online platforms such as company websites or social media pages, demonstrating the various kinds of outdoor products and concrete flooring to new clients. Using local publications to issue informative articles that demonstrate the company's expertise on available solutions to swiftly deliver a ready-made precast home is another common practice [34].

The increasing population and emerging economy in Egypt necessitate a heightened demand for Precast Concrete. As an emerging country, the Egyptian government actively invests and centers on developing industrial and commercial infrastructures by enacting several projects expanding the Precast Concrete market. The increase in renovation and remodeling operations within non-residentials like resorts and hotels also boosts Precast Concrete demand. Increasing investments by industrial players within industrial construction further propel Precast Concrete adaptation and generate

new market opportunities. Elements like roofs, floors, columns, and beams are projected to be the largest sector within the Precast Concrete sector. Their use is extensive within both the non-residential and residential segment and enable application within non-building and building structures.

The growth and demand arise as a result of keen interest from builders and contractors to employ individual precast constituents to build a whole structure across non-residential and residential construction and to increase private and public investment in Egyptian infrastructural developments. The main factors that raise heightened marketing opportunities are durability, cost-effectiveness, less construction time, and low maintenance. Marketing cannot be dealt with as a separate function, like in any industry. Precast construction needs a proper strategy involving strategic marketing skills and focused on creating new opportunities and introducing new customers to the market. It is obvious that new products create innovative marketing opportunities as well (Dikmen et al., 2005).

Prominent benefactors such as governmental establishments and environmentally friendly communities require green marketing which plays a vital role and cannot be ignored. Green marketing is a key sustainable approach promoting low-life cycle cost and alternatives to similar properties in non-sustainable traditional construction (Khoshbakht et al., 2017).

1.5 EGYPTIAN SUPPLIERS AND PRODUCERS OF PRECAST CONCRETE

The Egyptian Market has seen an increase in the establishment of Precast Contracting Plants across the region with the majority being on the outskirts of Cairo in the 6th of October Area and around Madinet El Saadat. While collecting data on Modern

Concrete, owners explained that most Precast contractors rely on precast beds for the production of precast slabs. More sophisticated production, such as hollow core slabs, would usually be produced at the plant and transported to the site in sections. The main units produced by most contractors are fences and utility access holes. Further to this, if a contractor is offered a project of a larger scale, contractor would pause the production of utility access holes and fences in order to begin working on other, more customized components such as beams, slabs, and hollow core slabs. Precast Columns are rarely requested due to their long lead times and high price.

Below in Table 1.4 is a summary of Contracting companies and the precast components they provide and have delivered

Table 1.4: Company details with precast elements products

Company	Products
1) Ceramics Structural Elements	• Columns • Foundations • Wall Systems • Precast Concrete fences • Pre-stressed slab system • Cladding panels
2) Osman Group (SCIC Precast Concrete)	• Pre-stressed concrete cylinder pipes • Reinforced concrete cylinder pipes • Segmental tunnels and shafts • House connection chambers • Precast decorative panels • Reinforced concrete manholes • Pre-stressed structural elements • Reinforced concrete pipes
3) Modern Concrete	• Block and inter-lock • Slabs • Beams • Wall panels • Double tees • Hollow core
4) Premco Precast	• Bathroom pods • Guard towers • Floor beam systems • Electric panels • Car stoppers and barriers • Retaining wall panels

5) Sam Crete (Samy Saad)	• Hollow Core Slabs • Structural Elements • Portable Fences & Road Barriers • Building Blocks • Interlocking Pavers • Interlocking Retainers • Curbstones

1.6 FIXATION OF PRECAST COMPONENTS ON SITE

When covering customary practice and market norms with Modern Concrete stakeholders, it was explained that most contractors would rely on two means of fixation. Either this is done by the Precast Contractor themselves – if they are well equipped and have the resources to provide this service of transport and erection – or a larger, more equipped contractor would be approached to fixate the precast units on site, if the Precast Contract themselves is not equipped or would experience high costs during Precast erection.

Typical components of bridges at off site includes precast piers, box girders, caps, piers, beams boxes, or W-shapes, as well as components of parapets and deck wearing surfaces. While the footing is cast in situ most of the time, precast footing can also be used in short span bridges, but, in general, onsite fabrication is more common for super structures rather than sub-structures. Other parts include full and partial depth precast girders (Khan, 2015).

There are two options available at site for an engineer to make a decision: (a) the elements are manufactured in factory and then brought back to site, (b) prefabrication of elements at the site adjacent to the building if space is not constrained. A typical sequence of a bridge with prefabrication components are (Khan et al., 2015):

- Designing and planning
- Fabrication of components
- Accelerated testing
- Benching and shoring
- Issues raised in erection
- Site visits
- Grouting and closures

Figure 1.7: Prefabricated Girders being lifted with two cranes at bridge (NPCA)

1.7 OBJECTIVE

This study aims to formulate the basis for the selection and adoption of Precast Concrete, looking at the socio-economic environment of Egypt while pinpointing the advantages, opportunities, and challenges that face such an industry.

1.8 SCOPE

Considering literature concerning market penetration of Precast Concrete construction (PCC), the study will majorly collect data from field professionals and market leaders in Egypt.

The industrial leaders ought to have experience with the Precast Trade and where precast demand and supply lie within a developing region of Egypt. It will utilize Egypt's market, field data, field alignment interviews, and previous literature to study precast implementation within the Egyptian market and socio-economic factors. The study of these market trends is to pinpoint the leading derivatives hindering or promoting the penetration of offsite precast technology in Egypt's market compared to the country's more developed socio-economic ecosystem.

Upon pinpointing market trend barriers and catalysts, the study further signifies the main constituents of Precast Concrete products, such as detailed mix designs, required labor, contractor qualifications, related equipment used in manufacturing, and marketing tools used to penetrate the market. The study will further explore the possibility of using Precast Technology within Egypt to address the sudden boom in vast middle-income housing, taken into consideration Precast Concrete 's speed of production and delivery of modular units in particular that may be used to feed the growing demand of vast residential projects.

Egypt, a quickly developing country, raises the same questions highlighted above to question the barriers in precast penetrating the Egyptian market and even become the majority construction method used. This thesis study confers on developing countries'

national barriers, such as those in Egypt, preventing the full potential of this quick construction delivery method.

1.9 CHALLENGES FACED BY PRECAST TECHNOLOGY IN PENETRATING THE MARKET

At first sight, when assessing market trends and perceptions, a majority of professionals believe poor infrastructure including (a) limited road access to many settlements and (b) rural remote areas that are incapable of providing suitable environments to deliver precast at a reasonably competitive market price constitute the key problems facing the Precast Concrete construction industry in Egypt today. Other general findings, considering comparison with other developing countries with similar socioeconomic environments, indicate a lack of standardization, certification, and available testing facilities aimed at optimizing precast production. Contractual issues and the lack of properly regulated taxation policies, the non-availability of tools, technology and equipment, limited knowledge, lack of government incentives and promotion, are some additional major challenges faced by Precast Concrete construction industries within these developing third-world countries. A deeper focus on these challenges both relatable to Egypt and abroad will be investigated further in more detail through this paper (Prakash, 2013).

1.10 PROMOTING PRECAST TECHNOLOGY STRENGTHS IN EGYPT

With the recent exponential development in national Egyptian infrastructure, especially seen in the homogeneous development of roadworks and related services supporting trucking to remote areas within the capital city and reaching further rural areas, we can conclude that the sudden upgrade in infrastructure has created a more capable, efficient,

and realistic environment for promoting precast. Precast can now achieve more competitive pricing in comparison to more traditional construction techniques. The Arab Republic of Egypt has one of the fastest-growing construction industries within Africa, with a recent initiative created by the new government set to create more cities and newly developed megacities such as the New Capital. The demand for rapid construction has never been more than current market trends. Further development of these mega-urban centers has pulled in more developers to build housing and establishments, creating a market gap for Precast Concrete contractors to flow in easily. Given the country's direction and rising demand for rapid, large-scale projects, precast technology is the answer to this prominent requirement of quick and large-scaled construction practices.

1.11 PRECAST CAPABILITY AND BENEFITS FROM ENVIRONMENTAL SUSTAINABILITY (LEED) PERSPECTIVE

Current LEED ("Leadership in Energy and Environmental Design") trends are immensely popular and highly encouraged for making new buildings sustainable. LEED is an international certifier that certifies the building with respect to its ecological footprint in order to promote its green building program. The LEED program is an internationally accepted certification for green buildings, and it has been utilized by many countries including the USA, Brazil, and many more.

The LEED certification uses a136 point-based criterion for every building and checks the sustainability of the building according to those criteria. Figure 1.9 below shows the point criteria distribution for LEED-certified buildings as of 2009. These point-based criteria are updated every year for designers applying for LEED

certifications within their designs. A criterion level of LEED gold and LEED platinum is awarded depending upon the overall performance of the building with respect to sustainability and green building. The certification covers various types of building such as houses, health care facilities, hospital buildings, new construction, and mid-rise buildings. The criterion is of two types, one has to be selected by the applicant and the other criterion is mandatory and has to be fulfilled by the applicant. For instance, version 4 for new construction concludes that following state regulations for indoor facilities is mandatory while protecting wildlife and natural habitats at the building site is termed as optional (Basu and Bindada, 2014).

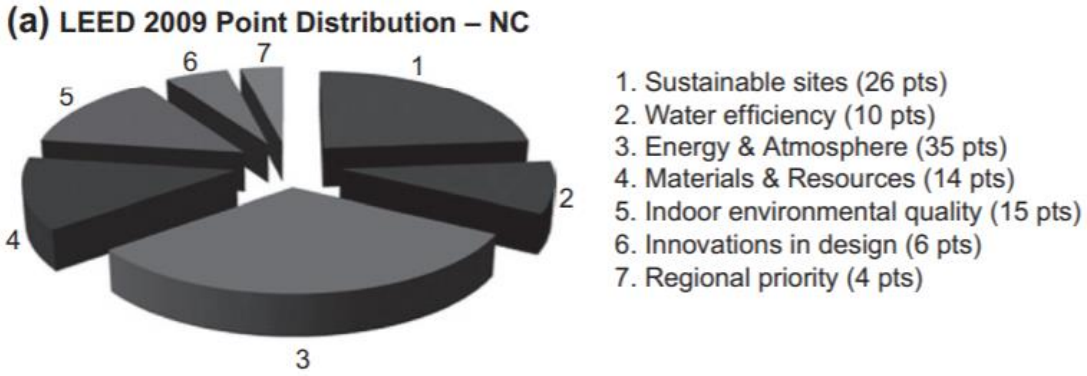

Figure 1.8: LEED point distribution criteria (Kubba, 2017)

The new LEED criteria define the new set of rules for commercial, educational institutes, and other publicly and privately owned buildings with the main motto being to promote sustainability and a healthy and environmentally friendly culture. The people involved in the certification include owners, engineers, land scrapers, architects, contractors, and property dealers (Kubba, 2017). Precast Concrete touches on all these pillars individually, leading to a homogeneous approach for delivering LEED-certified

buildings. Precast Concrete is the most used approach by architects and designers in reaching a LEED-certified building standard. This is easily achieved using precast in comparison to in situ methods. Precast compliments LEED certifications by contributing to the main pillars used to score and qualify for a LEED-certified building. The pillars supported by precast means include but are not limited to location and transport efficiency, the fact that they are used to develop sustainability-oriented sites, low water to cement ratio utilizing limited water in comparison to traditional methods, not to mention the large reduction in wastage of water during production. Thermal mass provided by Precast Concrete allows for buildings to maintain internal temperatures longer, thereby reducing the energy consumption typically needed for heating and cooling. Precast Concrete is very welcoming when it comes to versatility in the use of recyclable materials such as fly ash or slag during production. Precast Concrete can also be crushed and reused as aggregates in cases where buildings are being demolished or renovated. Precast Concrete shows long-lasting durability, highly limiting the need for repair or replacement. Precast Concrete doesn't emit any harmful VOCs ("Volatile Organic Compounds "), it can therefore be used without the need for any additional materials being added to the interior, considering it also has high-grade finishing properties. The prominent durability of Precast Concrete places it at the forefront of optimum serviceability, requiring minimum upkeep and thus elongating service lifetime. This longer lifespan and the reduction of service requirements over its lifetime reduces the operational costs of structures, not to mention the reduction of demolition volume. This waste reduction measure is very much needed in addressing today's ample by-product creation from construction waste which continues to increase with the exponential growth witnessed in infrastructure execution volume (Cole et al., 2013).

CHAPTER 2

LITERATURE REVIEW

2.1 PREAMBLE

In the present world, the paneled building constructed using Precast Concrete was initially pioneered in Liverpool, England in 1955. This process was developed by an engineer, John Alexander Boride. Precast Concrete is mostly utilized in low and mid-rise hotels, apartments, buildings, and nursing homes. Precast Concrete provides excellent fire resistance and soundproofing for buildings. Precast Concrete has also been known to decrease the costs of fire insurance. Precast Concrete is considered an immensely popular material for the construction of large buildings and offices. The person who invented the idea of constructing paneled buildings made of Precast Concrete was Joseph Monier. He was a gardener, and his main aim was to undertake permanent planters at a low rate, for which he then planted various products manufactured of Precast Concrete in 1867. Precast Concrete has a rebar present within it for the provision of reinforcement, specifically when it translates tensile strength. With regard to stress measurement, there are two main types: tensile strength and compressive strength. Precast Concrete is considered to be one of the strongest building systems within the construction industry. For this reason, it has shown popularity in the market of Egypt as well as at the global level. In Egypt, engineers utilize Precast Concrete as a replacement for concrete due to its resilience, shine performance, and adaptability. However, challenges are still faced as a majority of engineers often do not consider precast as a primary building option.

Figure 2.1: Paneled Office Building of Precast Concrete (Thai et al., 2020)

2.2 CONCEPTUAL CONSTRUCTION PROCEDURE USING PRECAST CONCRETE

The major aspect of Precast Concrete is that it saves a lot of time in the construction processes and also reduces risks associated with delays in construction projects.

Moreover, it is the most cost-effective element in the construction industry; simplified construction processes decrease time constraints and enhance productivity, growth, security, and quality. All these enhancement and savings lead to a conceptual decrease in cost. Precast Concrete is also utilized due to its special aspects such as versatility, most commonly being utilized for parking garages, office buildings (refer to Figure 2.1), stadiums, bridges, housing societies, and shops, etc. Moreover, Precast Concrete is excessively utilized in modular structures and modular elements. According to estimates, bricks are far away cheaper in cost when compared to Precast Concrete. The process of curing using low pressure and conventional steam are the two most basic methods in the curing of Precast Concrete elements. Another method for the curing of Precast Concrete is the method of membrane curing and it is directly engaged with the method of conventional curing by utilizing polyethylene sheets, similar materials, and curing compounds. With the membrane curing method, external water is not utilized in the curing operations.

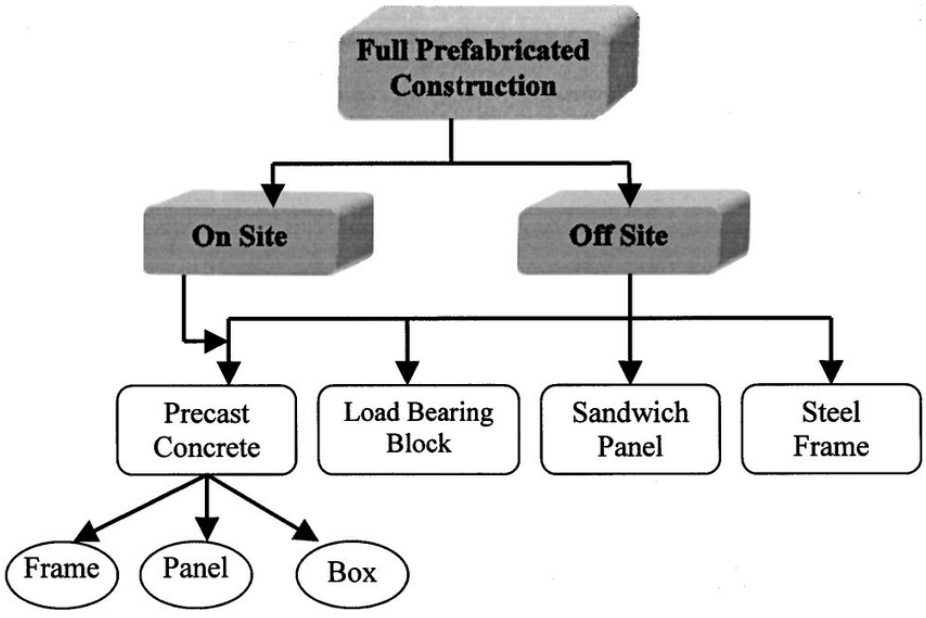

Figure 2.2: Techniques of Precast Concrete Fabrication (Badar et al., 2002)

A construction product produced in summary as per Figure 2.2 involves concrete casting in specific molds, cured in control conditions. The product is then transported to the desired construction sites and placed according to architectural designs, this is known as Precast Concrete. The whole building envelope is obtained by combining both architectural and structural precast members. A pictorial view of Precast Concrete members in building systems has been given in Figure 2.3 below.

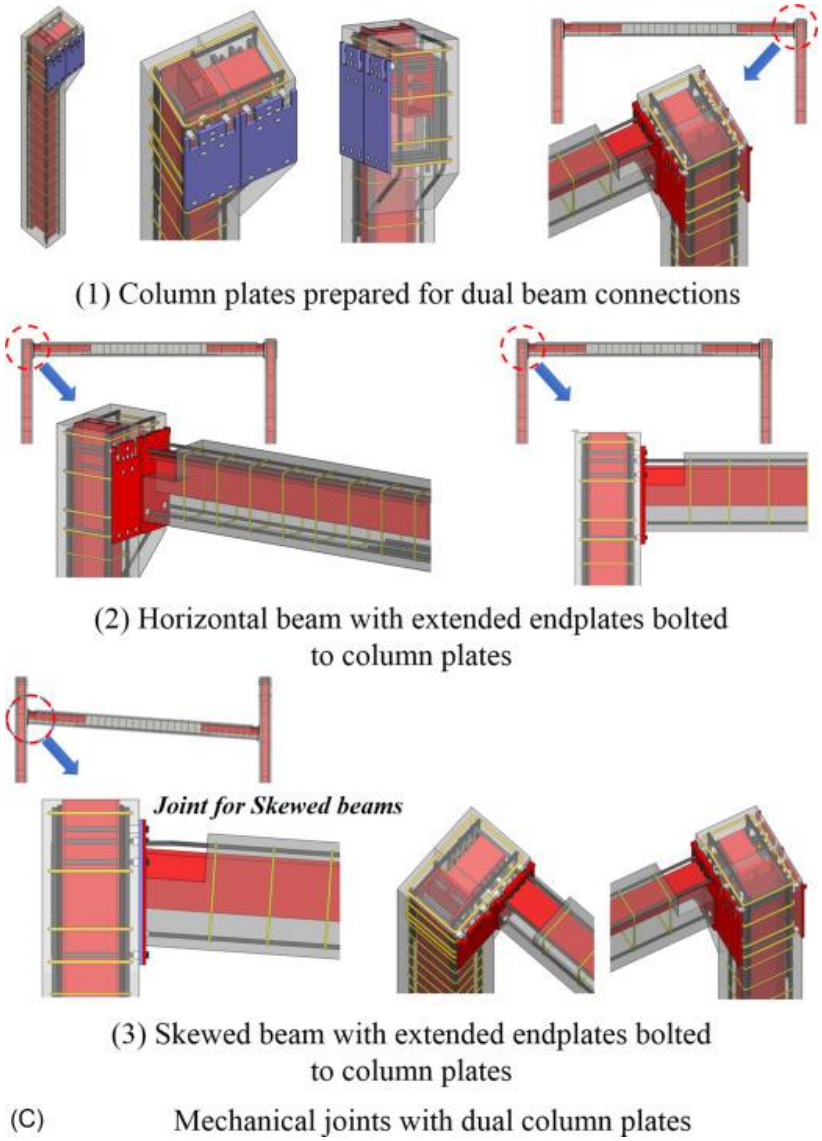

Figure 2.3: Pictorial view of Precast Concrete members in building system (Hong, 2020)

Generically, Precast Building Systems are commonly divided into Structural and Non-Structural Components, that is, components that are load-bearing or non-load bearing

There are a variety of types of Precast Concrete that is used in most concrete structures. They can be identified further as listed below:

i) Precast Beams

There are two types of precast beams, i.e., internal beams and external beams. Internal beams are used for variable symmetrical loading while external beams are used predominantly for symmetrical loading.

ii) Precast Floor Slab

This consists of two types, hollow cored block and double tee block.

iii) Precast Walls

Precast walls serve two functions, i.e., stability and as a shaft in close staircases. Walls are classified into two categories: infill walls and cantilever walls.

iv) Staircases

Three choices are considered for precast staircases:

a) Single formwork (consists of all flights landings)

b) Individual

c) Components (consists of some parts of landing and flights in one piece)

v) Precast columns

Precast columns are divided into three categories, i.e., edge columns (one direction symmetrical, internal (altogether), and corner columns (non-symmetrical).

2.3 ADVANTAGES OF PRECAST CONCRETE

Precast Concrete increases the completion rate of construction projects. According to different surveys, Precast Concrete saves around 30 to 40 percent of time to the steel structural systems and more in comparison with cast-in-place concrete. Designers feel ease in designing Precast Concrete members for their modular nature. Designers also prefer precast to traditional works due to the ease of fireproofing as precast does not require extra fire proofing measures. Moreover, Precast Concrete requires low maintenance and is high quality, effectively priced, safe, provides interior design flexibility and a green design, all in one components, lateral design flexibility, comprehensive drawings, and low cost options' variability.

2.4 PRECAST CONCRETE PRODUCTS

Precast involves a variety of components to create wholly concrete structures. Precast Concrete becomes interconnected through the help of welding connections, and these connections are mostly utilized for erecting Precast Concrete components on site. These connections are very dependable and extremely strong and can therefore withstand longevity alongside the precast members. The welded connections are created by putting loose plates among the structural steel plates that are erected together by welded connections. These steel plates may be in the form of cast in place or built-in to the Precast Concrete panel. Precast Concrete is directly associated with prefabricated concrete, it has the same adaptability and resilience but the major difference between them is that the latter is manufactured in a factory rather than on a construction site.

Hence pre-cast concrete is applicable to any material that could be found in a mold. Moreover, the tensile strength of prefabricated concrete is exceptionally low and is less ductile. The weight of fabricated tensile strength is composed of soluble salts, which can lead to efflorescence.

In perspectives of studies and surveys on modern Egyptian markets, the cost of concrete floors ranges from $50 to $60 per square meter; normally, these costs are for 200 or 300 square meters respectively, but these prices can get lower based on their sizes and depending on the amounts ordered. Batch Plant for Prestressed Slabs showing allocation crane moving molds slab units is shown in Figure 2.5.

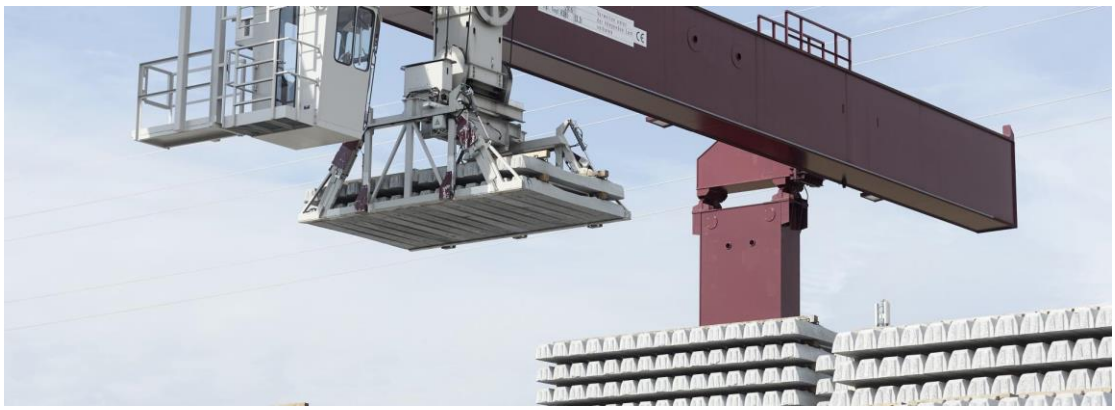

Figure 2.5: Precast Concrete Products being moved around by allocation crane (Vicat accesses 3 August 2021)

The materials utilized for making Precast Concrete and further products that are manufactured using Precast Concrete are gained from recycling and natural sources, majorly inorganic. Precast Concrete is sustainable and that sustainability means that there is going to be improvements from a resource efficiency perspective, decreasing wastage and making sure that in case of any disorder the environmental management systems will submit complain to EMAS or ISO 14001. In opposition with situ concrete,

Precast Concrete is much better as it can be molded if it is poured and can be cured on the construction site. The Precast Concrete is produced in a mold form and then lifted onto the construction site. On the other hand, one of the main benefits interrelated with precast slabs is that they do not require to be moved forward to be lifted into the construction site. Precast Concrete panels are particularly thick, having a typical width of almost 4 to 15 ft. and typical height of almost 10 to 50 ft. with a typical thickness of about 4 to 12 inches. Moreover, Precast Concrete panels are casted in a flat-oriented form side, and it is particularly that side which will be revealed for viewing the finalized construction on site. The classifications of precast floors are totally based upon their assembling into entire precast slabs and floors. Entire volumes of precast floors are made up of units and these units are entirely cased at the construction site. The walling saws of Precast Concrete seem to be most typical than tracking saws, but these saws are utilized to manufacture precise cuts placed on the vertical surfaces such as concrete walls, pre-cast concrete, and masonry structures. If there is a need to have the openings on the horizontal walls and steeping inclines or at any typical angles sawing techniques and equipment other than concrete will not perform. There are many types of concrete, but Precast Concrete has some specific types according to their classifications, such as precast beams that are utilized in the precast construction of building and offices. Other classes of Precast Concrete comprise precast floor slabs, precast walls, precast staircases, precast columns, thermal insulation, long term viability, and being aesthetically pleasing. In comparison with hollow blocks, Precast Concrete is much better and effective, although the Precast Concrete is more solid than hollow blocks. In the case of hollow blocks, these blocks are only reliable and suitable for concrete walls because they can be easily poured into an expected form and size. Precast concrete

products and materials are delivered by different sources of transportation like trucks, carries, and buses and transferred directly to the construction site or workplace. Precast Concrete is composed of efficient building components that make the Precast Concrete much more sustainable when compared to other building materials. Even replacement of damaged or worn-out members can be done in case of repair or replacement, see Figure 2.6 below.

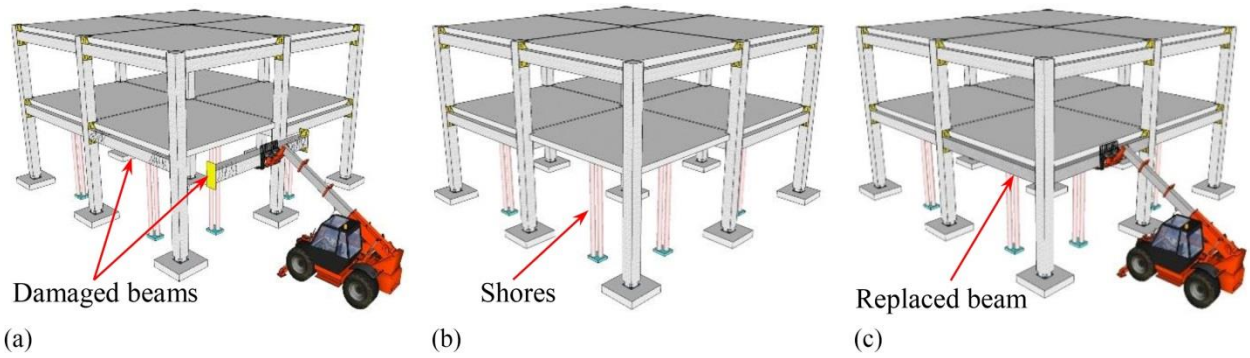

Figure 2.6: Precast Beams (Aninthenani and Dhakal, 2017)

2.5 DEMOUNTABLE PRECAST CONCRETE FRAME

In the last few years, various changes and advancements have taken place in the construction industry in Egypt as well as the manufacturing of Precast Concrete in perspectives of quality control and assurance of the slab floor and other products assembled with concrete floor. There are several alterations taking place in the structural designs as well as building codes in recent years and insurance adherence is kept necessary and compulsory. Interval inspections are required multiple times during the fabrication and installation of Precast Concrete. The inspection of materials and products manufactured from Precast Concrete are kept necessary before mixing, and

after mixing. This is needed for checking the strength of concrete and accurateness of building work at the construction site. The typical cylinder that is bought in the young, booming markets of Egypt has almost about 160 mm of cubic strength and is utilized for inserting the changes and working performances of Precast Concrete. Precast Concrete is composed of moderate and high level of strengths and is utilized in some great and long-term projects such as the construction of big building, construction of long bridges and high-rise offices. In the Egyptian markets, the recent trend is to manufacture moderate and high strength Precast Concrete and this trend is increasing periodically across the Egyptian market. No doubt that it is not an easier task to produce high quality concrete with high strength nevertheless it should be moderated. Figure 2.7 below shows general modern-day Precast Structure components combined with steel bracing.

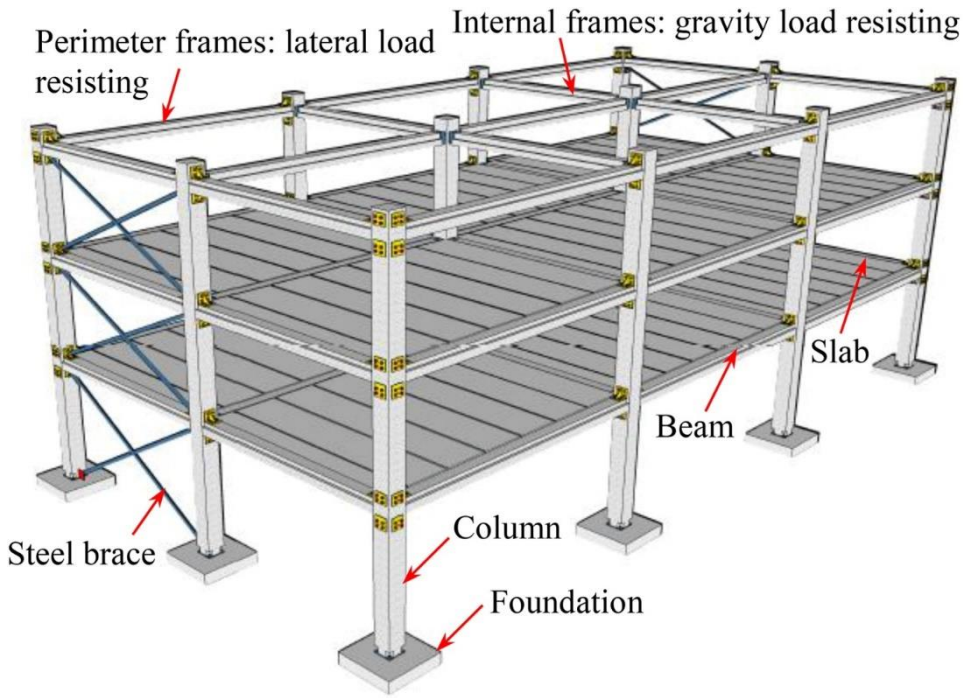

Figure 2.7: Components of Precast Structure (Elliot, 2014)

Precast Concrete is made up of slabs of prestressed concrete and it is developed in the solid form or in the form of longitudinal hollow cores. The floor units are approachable in various depths for meeting the different capabilities and performances essential for loading and span. The main purpose behind the excessive usage of Precast Concrete is that it offers several potential benefits over onsite casting. Production of Precast Concrete can be completed at the ground level which assists with reliability and safety throughout the construction project. Precast Concrete plays a major role in enhancing the materialistic quality and workmanship in precast plants when compared with a construction site. In Egypt's young, booming markets, the panel of Precast Concrete particularly ranges from almost $400 to $700 as per cubic meter and this is considered as broad range of cost considering there are a broad range of options and causes impacting the overall cost of Precast Concrete. The panels of Precast Concrete also have several edging treatments and finishes based on the final usage of the products.

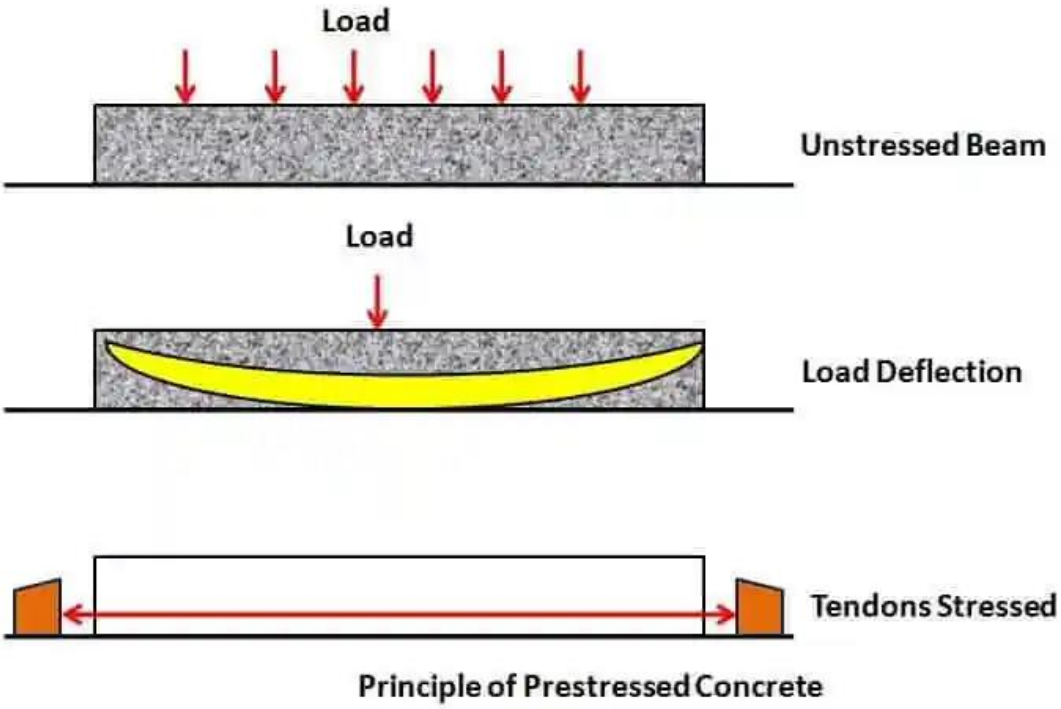

Figure 2.8: Prestressed Concrete Structure Load Effect (Civil Concepts)

Precast concrete slabs are divided into PCC slabs, prestressed hollow slabs, prestressed solid slabs in double tee slabs, and waffle slabs. Precast concrete is often made up of a precise mix of cement, water, admixtures, and aggregate that is cast into specific shapes in a controlled environment. Initially, the perfect concrete is poured into a molding machine, and it is cured before being stripped from its real form. These characteristics are then transported to the construction site for use in the construction and erection of the workplace. Precast Concrete uses a mixture of reinforcement bars, and high tensile strength steel, or single high tensile strength steel without the need of reinforcing bars in its reinforcement procedures. The specific method used for bar reinforcement is prestressing, in which steel strands are pretensioned in the genuine form before the casting of Precast Concrete. The compressive force imparted by the strands allows the Precast Concrete pieces to span greater distances and carry a greater

load. The pre-stressing procedure also reduces cracks until they reach a point where they are no longer visible. Figure 2.8 above shows prestressing methods and load deflection effect.

While the latest techniques and modern methods have increased aesthetic and working capabilities, they have also gone over the preservation of realistic attributes of concrete. Precast Concrete is considered to be an environmentally sound material formed by natural materials. Nontoxic materials are formed and utilized by the production of concrete or from its usage. The controlled manufacturing of Precast Concrete increases the sundress of the environment by optimizing materials used in the construction site, decreasing the wastage of materials when the panels are created and interrelated wastage on the jobsite.

In perception of concrete adaptability and performance shine, the thermal mass of Precast Concrete secures the energy and it is a non-combustible material with maximum fire-resistant ability. Precast Concrete creates a secure platform that assists with protecting tools, personal equipment, and integration of the entire structure itself. In the usage for structural elements, Precast Concrete reveals requirements and costs of extra fire-proofing measures. The overall temperature consequences result in low capability for making a pretty difference regarding electrical energy consumed in an air-conditioned environment and decreased smog formation by bettering the quality of air in developed areas. Additionally, there are capabilities of inherent sound; because of the overall mass of Precast Concrete, they serve as a barrier to interior noise penetration and exterior noise penetration. The securing and tenant advantages do the provision of potent marketing assets while accessing long-term occupants.

It is well-known that Egypt is the most populated state in the Middle East, and the second most populated region in Africa. The materials associated with construction are found in abundance on the markets of Egypt. Materials such as aggregates, grave limestone, pink limestone, sand, small aggregates, Precast Concrete, and the admixtures are prepared on the local level by undertaking their license. Precast Concrete and its slabs are imported, manufactured, and utilized in the construction industry and sometimes the Precast Concrete is exported. Egypt is engaged with various coastal areas such as Alexandra, red sea areas, Cairo, other rural areas and Aswan's dry areas. In summer, the temperatures in these regions are much higher and the areas become humid near the coast. So, these environmental consequences are hazardous for Precast Concrete materials and are particularly structured with aggressive conditions to the moisture, salt, and sulphate attacking in coastal regions. Most of the constructed buildings in such areas bear distress at high levels during an early age in service life and require repairing and maintenance in quick manners.

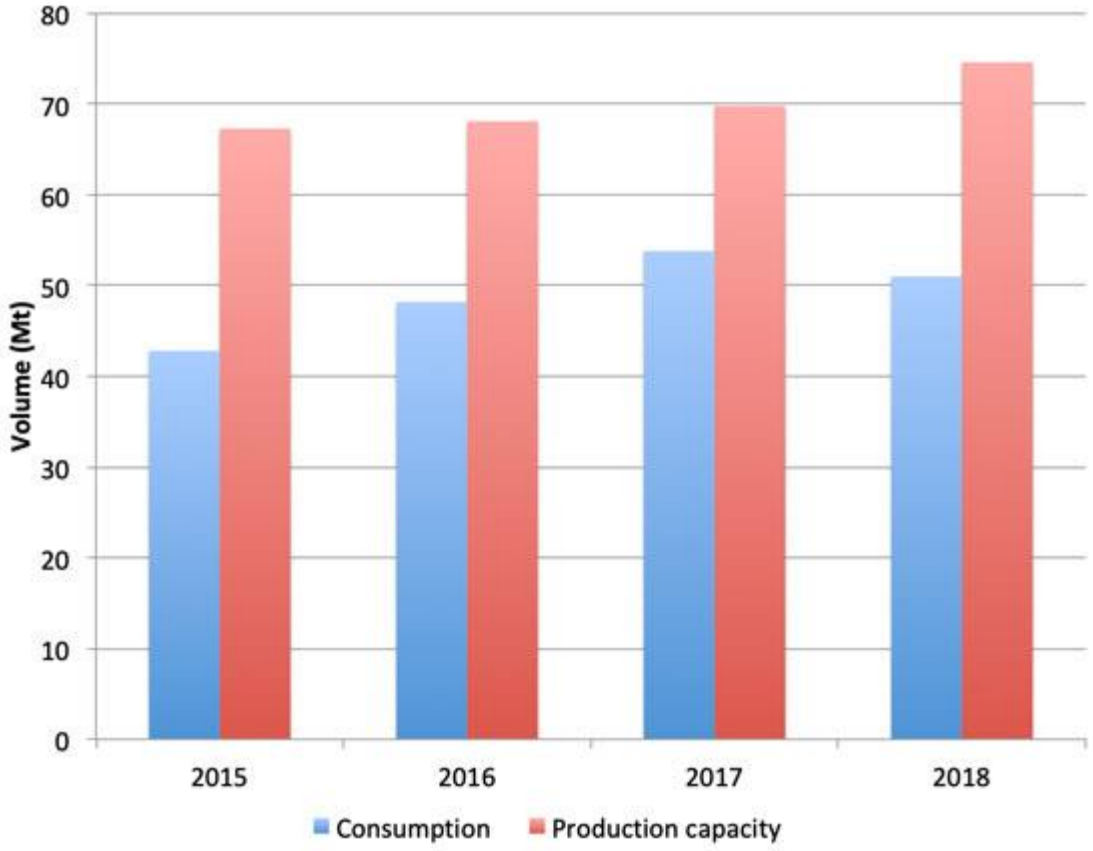

Figure 2.9: Precast Concrete Production vs. consumption from Egyptian Precast Supplier (Royal cement, Egypt)

There has been a particular shift towards utilizing Precast Concrete instead of using conventional methods as represented in Figure 2.9. Figure 2.9 as described by an Egyptian Precast vendor shows a steady increase mainly due to long-term financial beneficial reasons and quality-control measures, but frequent tests are still needed before Precast Concrete can be utilized on a vast scale. With the general increase in Precast Concrete, the usage of admixtures is increasing in the Precast Concrete field in order to improve the adaptability and resilience, thus explaining the low ratios of concrete being utilized at construction sites. Moreover, the Type II cement has been produced recently and utilized by replacing the cement of Type V. Modern productions

of cement will undertake the Euro code and the series of CEM. Steels of high tensile are most utilized in place of mild steel in the construction industries and markets of Egypt. There has been a modern trend towards the usage of bent-up bars in reinforcing the Precast Concrete and construction interrelated with it. Figure 2.10 shows Gravel Placement Techniques updated as per new Precast Euro Codes; this is a sample of updated gravel laying techniques in precast pouring.

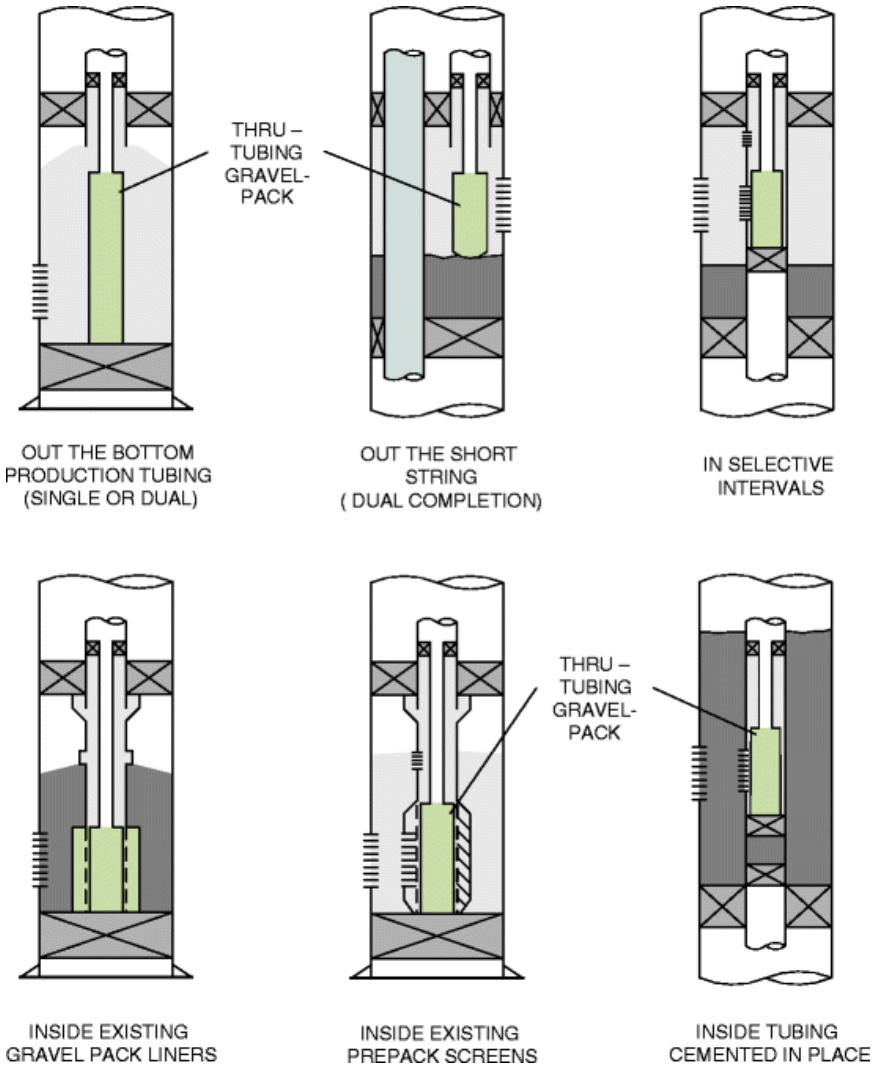

Figure 2.10: Gravel Placement Technique in precast pouring (Davorin M. et al.,2012)

2.6 YOUNG, BOOMING MARKETS OF EGYPT

The main imperatives are assessed which are required to enhance the precast adoptability in young, booming, developing markets such as Egypt; also, the constraints which are hindering the Egypt markets from blooming and from enhancements are discussed in this thesis. This thesis investigates several factors that will affect the performance of foreign trading and looks comparative for the economy. It also involves a large risk from non-tariff to maintain the regime of the native regions. In accordance with the rule and laws passed by the local government of Egypt to invest in small businesses to gain profit on a local basis and improve the economy of the country. It also involves foreign direct investments in many private sectors which are responsible for the uplift of the local economic growth of Egypt. There are different sectors which effect the businesses of developing countries heavily and have a handsome amount of percentages of the market share. Also, the comparison of the public and private sectors in Egypt is performed on the basis of the investment in the overall country's economy, It is also observed that the Suez Canal is the main driver in empowering Egypt's economy. Also, the comparison of Egypt is performed for various countries like Morocco, Jordon, Poland, Pakistan, Thailand, South Africa, Malaysia, and Tunisia, from there it is observed that the net flows as the percentage of the GDP for the foreign direct investment, the topmost country found was Morocco with a 3.1 percentage of GDP from its government, while 22.8% GDP from the private investment. Also, the evolution of net FDI is observed in Egypt for the various financial years data (2003-2019) and from these results it is observed in the year 2007, the net FDI reached 8.4% of its GDP, while in 2008 it was also 8.1% of GDP in Egypt. Currently from the results,

the most lagging FDI financial years was 2004 and in the final year of 2019 it was observed to be 2.7 % of GDP.

From the inside establishment it is observed that in 2014 the percentage participation of social insurance was 44%, in 2019 it was reduced down to about 35%, while the percentage of employees who worked contracts was also 44% in 2014 while it was reduced down to 29% in the 2019 financial year. And from the outside establishment, the percentage of participants with social insurance was about 13% while in 2019 it was down reduced to 11%.

Also, private sector employment by economic activity is bifurcated to forget the clear view of each and every sector's percentage of participation in the economic growth of Egypt. From the results and observations, an overall 21% of its economic activity is handled by the manufacturing sector. While the transport sector is providing only 4.9%, the accommodation and the food sector contribute 5.9%. The health sector contributed 2.8% while the construction sector contributed 2.1%. Variation in the sectoral chairs in private sectors is observed from different businesses such as real estate, construction, tourism, manufacturing. Figure 2.11 below shows construction being amongst the fastest growing markets within developing regions such as Egypt. This shows a forecasting view of the rapidly growing construction markets making way for more precast to take up more construction market percentages.

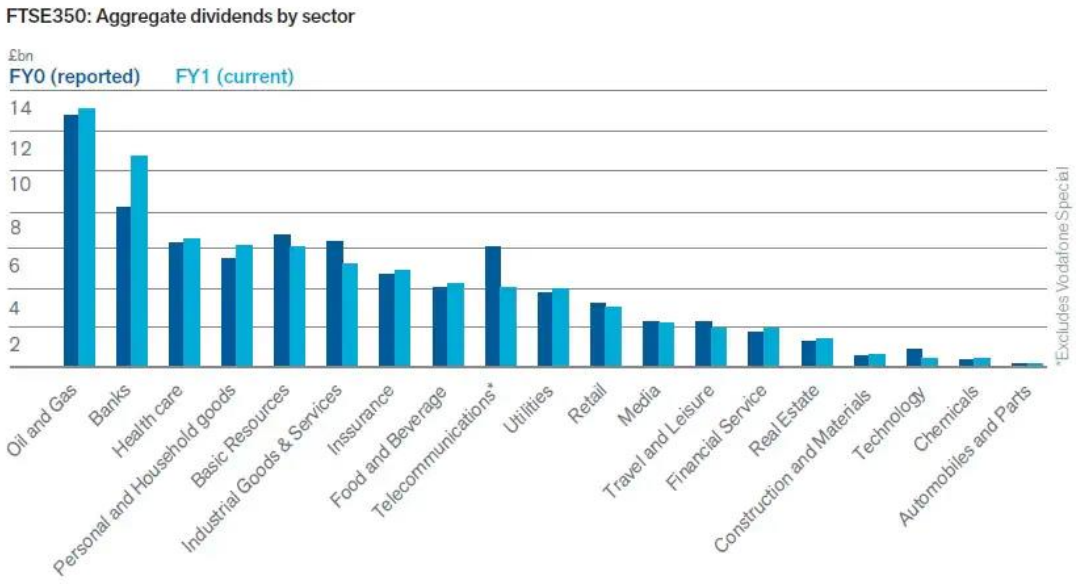

Figure 2.11: Sector Shares in different sectors within developing countries(oecd-economic-surveys, 2017)

2.7 EGYPTIAN PRECAST MARKET PENETRATION

A documented number is challenging to delineate when trying to place a figure on PCC market share percentage within Egypt. According to Tamer Saad, a structural consultant with over 12 years of experience with PCC in Egypt, the approximate market share comes at around 1 to 2% of building construction. It has an approximately 50% market share of modular non-structural building components such as fences, maintenance holes, and water containment structures. Tamer Saad has been working in Dar Al-Handasah Shair and Partners (DAR). DAR is responsible for Zone Planning within the New Capital, Egypt's most significant National Infrastructure Project currently aimed to be approximately as big as Singapore, roughly 700 kilometers squared. The New Capital Mega Project will cost about EGP 910.02 billion in total construction costs.

According to an analytical study made by MEED Projects, Egypt received more than EGP 4,7 trillion worth of identified, both planned and un-granted, projects, giving it a more extensive development pipeline than other provincial markets bar Saudi Arabia and the UAE. Construction is the most substantial forthcoming market in the state, with over EGP 1882.8 billion worth of prearranged increasing developments.

Narrowing down, the value of planned and un-awarded construction projects in Egypt is EGP 2918.34 billion. In such a context, it makes it the third-largest future market in the MENA region, behind Saudi Arabia and the UAE. Given the high population growth rate of the country, the market will continue to grow and, at one point, may well overtake its neighbors.

Considering this overtaking of the Egyptian market compared to Saudi Arabia, whose Precast Concrete projects bypass the country's market by approximately 20-fold according to the Business Development Director of Saudi Based Bina Group, a market leader in delivering Precast Residential, Commercial and Governmental Projects. Saudi Arabia sees nearly 25 percent of its construction market covered and completed using PCC structural and non-structural components, which begs why Egypt does not meet its exponential growth in building demand using more enhanced modular methods such as PCC.

Considering the rapid GDP growth of the oil-wealthy country over the past century and the rapid reform ruled by the Al Saud Royal Family, Saudi Arabia adopted modern governmental systems from the West and more quickly developed regions with the power of investment, elevating the economic ecosystem within the country. Learning from the West and having a less dense, more organized structure of growth, Saudi

Ministries of infrastructure and housing adopted modern implementation procedures involving modern building technologies. Nearly 85 Percent of Housing Developments developed via the government (Department of Housing) are fast-tracked and in high demand because of the rapid population progress witnessed in Saudi Arabia, said Ahmed Sameh, Business Development Manager of Bina Group. Tamer Saad from DAR stated that most precast projects currently ongoing within the main capital are pre-stressed slabs and load-bearing walls made using PCC, again confirming the critical factor in promoting PCC moving forward in the future to be governmental entities promoting precast use.

German municipalities, for instance, offer promotions and tax discounts or vacations on projects completed using PCC methods, allowing PCC contractors to compete with a more traditional contractor while also accounting for the time-cost tradeoff. The Time - Cost Tradeoff where building techniques offering a quicker solution reducing project time by up to 40 percent is worth a slightly more expensive PCC solution. However, the key to implementing and enforcing this lies with governmental developers and clients wanting quicker solutions and being willing to pay a slightly higher bill. In countries such as Egypt, where most Mega Projects are government-driven, governments promoting PCC use will increase PCC percentage usage and facilitate PCC vendors the opportunity to bid and be involved in larger volumes of projects.

2.8 PCC RESOURCE AVAILABILITY AND GENERAL FEASIBILITY

Eng. Gamal, the Managing Partner of Modern Technologies, a PCC Supplier with one of the largest PCC factories within Egypt, states he was one of four major Precast Suppliers within the Egyptian Region. As stated by Gamal, Modern Technologies was

the only supplier capable of heavy production of load-bearing modular units. As a vendor, he meets two major blockades when moving forward in marketing PCC.

1) Clients and Engineering designers are not knowledgeable of the long-term serviceability and generic benefits of PCC. These PCC benefits discussions are in Chapter 3.

2) There is a continuous deficiency in skills and lack of expertise in producing load-bearing modular units. This leads to inflated prices and long lead times in production, defying the sole purpose of using PCC.

Benefits of PCC, as mentioned by Arifullah performing a market study on PCC within India, says that most educational systems hardly discuss or go over the standardized use of PCC, leaving this knowledge gap within Engineering Supervision and Engineering Design Parties. This scarcity of know-how leads to an inflation of prices created by the elevated demand for the PCC product. Vendors also struggle to market the product efficiently due to a lack of knowledge and proper design and fabrication lacking due to deficient expertise. This combination founded on lack of expertise hinders growth greatly, leaving a staggered approach to PCC adoption similar to Egypt today. As stated by Arifullah, false approaches in adoption lead to false perception bringing out PCC to seem pricey and time-consuming, eventually leaving it for elimination in most tender RFPs and Conceptual Designs.

2.9 COMMON PRACTICE OF PCC IN EGYPT

On discussion with Architects, quantity surveyors, and civil engineers, the first positive impression primarily included reduced on-site waste, little life cycle charge, quality of work, and swiftness of construction [31]. Other benefits like sound control, WIFI

compatibility, thermal efficiency, environmentally friendly, and low maintenance contribute to growing considerations for Precast Concrete construction in Egypt.

Precast contractors on the other hand still face difficulty despite these positive considerations. On discussing with a prominent precast contractor (Modern Concrete), one of the key stakeholders within the company explained that for the majority of precast businesses, their main bread and butter is monotonous modular units. These Modular units refer to manholes, fences, and blast-proof barricades. These are in high demand within the new residential, governmental, and commercial expansion of the greater Cairo area, mainly focused around the New Capital, 6th of October, and the Tagamoa Area. Usually when a contractor receives an order for more customized building unit components, they either halt production temporarily to produce these customized building units or work in parallel to more modular units such as fences or manholes, etc. If the project is worthy and has large volumes of precast works including slabs, contractors would assess and consider a precast bed option furnished on site to produce slabs.

Most contractors would rely on two means of fixation. Either this is done by the Precast Contractor themselves if they are well equipped and have the resources to provide this service or they are transported and fixated on site. Other contractors who are not equipped or have high price rates of Precast fixation would usually recommend a larger more equipped contractor to fixate the precast units on site.

2.9.1 LACK OF KNOW-HOW

The inexperience and dearth of exposure to Precast Concrete design is an eminent factor that influences concrete use in Egypt. The inadequate comprehensive knowledge

regarding precast technology, the detailed awareness regarding the required incorporated processes in industrialized construction, the merits and limitations the construction method holds generates misconceptions that discourage developers from using Precast Concrete (Wijewickrama, Jayasena and Ariyachandra, n.d, 114). Egyptian developers need to contemplate that building with Precast Concrete elements solely does not assure success concerning time and cost-saving. Planning conforms to the respective boundary precondition that entails the natural selection of desirable manufacturing methods.

Simple production approaches are cost-effective, and customized machinery/molds are the keys to prosperous concrete elements production. For example, the mobile battery mold for a unique precast technological approach. Moreover, there is a need to demonstrate the merits and draw out all merits at training. The local industries need to understand the management process. For instance, when it comes to major projects like dam construction, international construction firms are in charge since they are already conversant with the materials. Precast production for dams in training is what local companies do to uptake the best approaches. The training could be through technical presentations and meetings.

2.9.2 FEAR OF INADECUATE PROFIT

Most Egyptian contractors are unaware of how much revenue they should make and do not have a particular profit target. They claim they aim to profit as much as they can or more than their current income. Contractors, therefore, do not have vivid goals and targets. The best approach to eradicating this fear is to set clear annual net and gross profits, hitting the targets and making the anticipated returns and revenues for the perils

they take. Profitable Precast Concrete firm owners have a vivid vision of their wants. They have clear goals for their business, clients, financial, operations, and profits. The precise goals are set on revenues, overhead, average mark up, and return on equity.

Firms that keep track of target profits, costs, control overhead, and observe what they keep are systematic, in control, and ahead of competitors. Contractors lacking defined profit goals never make adequate money and do not make anything at all in most cases. The Egyptian contractors need to fix revenue goals, observe them all the time, share them with their people, track progress, and ensure it is met. In developed countries like England, the Emirates has a qualified workforce that focuses on Precast Concrete construction, vast Precast Concrete structure components, and superior performing Precast Concrete systems.

2.10 CAPABILITY OF PCC BEING THE ANSWER TO AFFORDABLE HOUSING

The total requirement of skilled and unskilled labor is 33 million per day for the Egyptian Construction Sector (Business Standard, 2010). Throughout earlier years, the field experienced a shortage of labor. Abdulmutallab reported that the deficiency of trained workers and other construction sites was one of the most important causes of delays in various construction projects (Konka, 2012). The expectation is that the shortage will reach about 65% by the next decade (SPDS, 2013). If the industry does not focus on mechanization and depends too heavily on labor on-site for building, it will be challenging to satisfy the growing need for shelter in the state. Heading towards extensive mechanization and innovative building methods such as PCC seems like a plausible intervention if prearranged, designed, and implemented appropriately. If PCC

approaches lack good forecast or design and then implementation by inadequately trained personnel leads to no full realization of the benefits, many would wrongly blame the PCC technology. Therefore, the challenge is generating skilled engineers, designers, and workers in the country and ensuring appropriate PCC technology implementation.

2.11 LEARNING FROM MORE DEVELOPED REGIONS

PCC is a time-tested alternative which has successfully catered to enormous housing demands worldwide, especially in Europe, considering the sudden need to rebuild post World War II. Table 2.1 shows the PCC status in various states globally. Thomas (2009) reported that PCC provides expense reduction with excellent planning performance.

Table 2.1: Standing of molded concrete construction in various nations

Countries	Precast concrete construction scenario	Sources
United States (US)	7.9% of total concrete building is utilizing precast solutions. The primary precasting application is in parking erections contributing to 12.9% market share. Civil precasting accounts for 90.1% and 30% of US houses are prefabricated.	[20] [21]
United Kingdom (UK)	26% of the entire concrete manufactured is for precast utilization. 45% of molded concrete for housing projects. Conventional masonry remains a choice for housing (90%). Some incidences of failures lead to modification in BS codes for precast concrete construction.	[20] [21]
Russia	Stable economic conditions in Russia helped in the rise of molded concrete industry. Market share is approximately 30%.	[22]
Europe (Finland, Netherlands, Germany)	Many countries in Europe have been using molded concrete organizations for buildings. Molded concrete contributes to 10% of buildings in Germany and the Netherlands. 24% of buildings construction uses precast concrete in former East Germany. 70% of the total concrete construction is for precast concrete construction usage in Finland. 74% of this relates to structural precast concrete.	[21] [22] [23]
Singapore	Efforts by the Housing Development Board of Singapore have enabled the growth of molded concrete buildings. Molded concrete systems have been utilized in Singapore for high rise buildings for the past 30 years.	[23]
Malaysia	Building requirements in the state forced the housing ministry to adopt Industrialized Building Systems (IBS).	[23]
Turkey	1% of the total concrete produced is for precast construction.	[21]

Based in Egypt, Precast Concrete delivers a more prominent and higher-quality building product on a local comparison level. The reaping of PCC fruits within the Egyptian market is yet to come, where PCC consists of around 3 percent of the overall concrete construction market. However, with the sudden boom in housing demand and the scarcity of available manual labor for more labor-intensive traditional methods, PCC could be the answer to less labor-intensive, more mechanized solution as has been adopted in the West, having higher labor costs and a large majority of the population being white-collar employees.

Developing countries like Turkey still need more constricted backing from governmental entities to educate and promote further expertise on Precast Concrete execution methods. Lack of knowledgeable implementation could lead market leaders to perceive PCC as an unattractive building technique.

2.12 BARRIERS FACED IN DEVELOPED COUNTRIES

Looking at the tackling challenges and workarounds for PCC within developing regions is a sedated, less effective response in comparison to what is done in developed countries, so it is safe to say that the amplification of most challenging factors is within developing countries. Looking at these barriers in a developed ecosystem lays a better foundation for understanding challenges in a developing region such as Egypt.

Table 2.2 provides the various issues encountered by different states in implementing PCC to satisfy extensive housing needs.

Table 2.2: Issues encountered in the enactment of PCC in the Housing division in different republics

Place of Study	Issues Faced	Source
USA	• Lack of stable demand for precast concrete construction • Less level of standardization • Lack of expertise in design and manufacturing • Higher costs due to transportation • Limitation in sizes of elements due to transportations	(Arditi et al. 2000, 79-86)
USA	• Incompatibility of elements from various manufacturers • Communication issues • Inability to meet challenging projects due to limitations in transportation • Cost of transportation	(Polat, Gul. 2008, 169-178)
USA and Turkey	• Perception of lousy performance of buildings • Lack of expertise in design	(Polat, Gul 2010, 85-94)
Malaysia	• Requirement of huge investments and significant financing in IBS; Higher costs • Lack of involvement of small contractors, • Issues like moisture penetration and leakage, • Lack of expertise and exposure to implementation of IBS	(Rahman et al., 2006, 5-6)

Malaysia	• Heavy investment and lack of financing • Higher costs • Lack of expertise in design and execution • Lack of flexibility in payment terms • Logistics issues • Negative perceptions of the performance in the past	(Nawi, Lee and Nor 2011, 34-37)
Australia	• Retrospective addition of Offsite Manufacturing (OSM) to projects • Lack of expertise in design and higher design cost • Transportation cost and carriage cost • Lack of adequate skilled expertise • Requirements for massive financing and stringent payment terms	(Arif, 2009)
Hong Kong	• Lack of in-house expertise, • Limited access to site and transportation • Resistance to change over schematic approaches	(Jaillon, Lara, and Colleen 2009, 239-248)
India	• Absence of need for mass/mammoth housing developments • Elevated price and lack of expertise • Taxation issue not being addressed • Lack of standardization,	(Das and Jha 2011, 47)

The following are examples of the motives that hinder the popularity of Precast Concrete construction in Egypt.

- Socio-economic changes and state regulations are the dual essential factors that hindered the application of PCC in Egypt.
- Builders' preference for employing cheap labor instead of making substantial capital investments on equipment and PCC infrastructure (SPDS, 2013).
- For small building developments, cast in situ (CIS) is preferred to PCC because the previous is cheaper.
- Lack of proper roads and equipment to transport large Precast Concrete sections from manufacturing plants to erection sites.

2.13 PRECAST CAPABILITY FOR NEW COVID 19 CONSTRUCTION REGULATIONS

Working Hours reduction considering new global constraints involving Covid-19 is now the regular practice in all markets. The main question to consider here is, could shorter construction duration using optimized precast construction practice reduce exposure time of human resources? Congestion of contractors within developing districts and construction zones is evident since the National Initiative of delivering Egypt 2020, with the recent outbreak of COVID-19, labor congestion has become a top-tier risk, forcing contractors to look for means to provide for social distancing on site and reduction of labor headcount, whilst maintaining construction timeframes and delivery standards. Precast Concrete again may answer calls for more innovative approaches to construction focused on more technology-driven solutions, reducing human resource headcount whilst keeping up desired construction pace as well as labor intensive activities being performed off site during precast production (Bloom, 2020).

Considering the unknown future being premised by unexpected infectious viruses or diseases, Precast Concrete addresses social distancing and a decrease in lead times which also reduces exposure of human labor to one another, not to mention the overall decrease in headcount which also decreases exposure further.

2.14 DELIVERING A MORE CONTROLLED PRODUCT FROM PRECAST TECHNOLOGIES

The standardization and automation of the precast production process reaps a more controlled product created in a manner aimed to clone the products created, leaving less room for variance of error, whether it be human or artificial. This effect of developing controlled products of the same production environment and creation process allows for a unified product with the same means of handling, servicing, and implementation into design. This standardization would lead to an immutable reduction of error which would also lead to long-term cost-saving effect to waste, errors in production, non-compliance to design majorly due to minimizing the room for defects and flaws (Jain et al., 2016). In Egypt, this would be a bit more of a challenge considering that governmental establishments are not modular or similar in design detail. Standardization compliments precast solutions and would be key in allowing precast to penetrate the market in a better manner within the Egyptian market. The Egyptian government is adopting more of a standardized solution with the new reform which started in 2014 with mostly design but most mega projects are still tailored in design either architecturally or aesthetically.

CHAPTER 3

METHODOLOGY AND FIELD WORK

Considering the available data on the Precast Market in Egypt was somewhat evasive considering a lack of scholarly articles discussing the Egypt Market and a lack of Contractors working on highly technical precast related works, data collection was key to directing this thesis and was the core in developing a basis for methodology and field work.

The main methodology involved data collection from field professionals to properly grasp the market and have a feel of what barriers it faces. Questionnaires and interviews were done with key professionals to cover main points of what appeals and does not appeal to stakeholders and what prevents them from considering precast as a viable construction technique accordingly. Field works and direction are highlighted below for each methodology used to cover an economic and technical overview of using Precast Technology.

3.1 KEY FIELD VISITS OF PRECAST ORIENTED LOCATIONS

On meeting key stakeholders and important figures within the Precast market, field tours were also performed inspecting variant types of precast plants, on-site precast production beds and storage lots within ongoing construction locations. These site visits and locations were selected based on availability and accompanied by volunteering contractors' representatives. To grasp the precast prominence across Egypt, sites were visited in the two largest cities, Alexandria, and Cairo. Site visits were for the purposes of inspecting precast production plants and understanding their capabilities as well as to carry out meetings with key representatives of the precast

market. These key stakeholders and establishments were selected based on their track record summation of managing and executing completed as well as ongoing PCC contracts representing a majority of the precast market within Egypt. This was key in better understanding the boundaries and opportunities within the Egyptian precast market. One source of site visits and verbal alignment interview was Saudi Arabia, this was done to give a benchmark of an advanced market model to compare the Egyptian market to. Some images taken at site visits performed are shown below. Representation of site visits and alignment interviews can be seen in the Table 3.1 below.

Table 3.1: Physical Site Visits and Interactions with Key Precast Market Representatives

Site Visit/Interaction #	Location of Site/Interview	Description of Establishment	Production Capabilities of Establishment	Nature of Alignment Interaction
1	Saudi Arabia Dammam Industrial Area	Precast Plant covering 400,000 square meters. Precast Plant also features a covered area for curing purposes as well as loading station. Casting Beds also are also fitted with 4 cranes.	**178 Range of Products as categorized Below** • Double Tee Slabs • Stairs • Wall Elements • Hollow Core Slabs • Special Products • Building systems • Columns and Beams	• Physical Site Tour • Verbal Interviews with Marketing Director

2	Cairo Saadat City	Precast Plant covering 175,000 square meters. Precast Plant also features a covered area for curing purposes as well as loading station.	• Structural Elements • Portable Fences & Road Barriers • Building Blocks • Interlocking Pavers • Interlocking Retainers • Curbstones • Installation capacity of 300-400 m2 / 8 hours / • 1 crane • Available spans up to 15 m	• Physical Site Tour • Verbal Alignment Interviews with Managing Partner

3	Cairo Saadat City	Precast Plant Covering Area of 100,000 square meter. Precast Plant also features a covered area for curing purposes as well as loading station.	• Precast prestressed concrete flooring & roofing systems (hollow core slabs, single & double tee slabs) • Full wall frame system (load bearing walls & hollow core slabs). • Full structure frames (plinth foundation, columns & beams) • Solid and insulated cladding panels with wide range of different shapes and finishes • Standard and non-standard boundary walls • Miscellaneous precast concrete products (staircases, culverts) • Landscape & construction products: Curbstones, Interlock & Cement Block (Solid, Hollow & Insulated) • Ready Mix concrete	• Physical Site Tour • Verbal Alignment Interviews with Precast Plant Manager

4	Cairo 6th of October City	Precast Plant covering approximately 80,000 square meters. Precast Plant also features a covered area for curing purposes as well as loading station. Precast slab production beds are variant and changed based on demand and supply.	• Structural Elements • Portable Fences & Road Barriers • Building Blocks • Interlocking Pavers • Interlocking Retainers • Curbstones	• Physical Site Tour • Verbal interview with Precast Plant Senior Engineer • Interview with Head of Marketing and Sales

5	Cairo Nasr City	Precast Plant specialized in Providing heavy infrastructure works such as the Cairo Metro Line 3.	• Tunnel Segments • Bridge Piers • Bridge • Single- and two-piece arches • Girders. • Box, bulb-tee, tie and I-beams • Deck slabs • Caps • Piers • Parapets • Wingwalls, headwalls, end walls	• Physical Site Tour • Phone Alignment Business Call with Managing Partner • Alignment Interview with Senior Site Erection Engineer

6	Alexandria Borg El Arab	On site production of Casting Beds also seen on site was a storage yard for precast bridge beams spanning up to 30 meters.	• Prestressed Slabs • Hollow core slabs • Precast Bridge Beams (Storage Only)	• Physical Site Tour • Verbal Alignment Interview with on Site Senior Engineer • Verbal Alignment Phone interview with Managing Partner
7	Cairo New Capital	On site production plant including Casting Beds for prestressed slabs and precast hollow core components.	• Prestressed Slabs • Hollow Core Slabs • Wingwalls, headwalls, end walls (Storage Only)	• Physical Site Tour • Verbal Alignment Interview with on Site Senior Engineer. • Verbal Alignment Phone interview with Managing Partner

8	Online Call	Interview with prominent Design and Supervision Consultant known to occupy a majority of consultancy service provision across Egypt and the New Capital.	• Planning and Zoning Development Design and Supervision • Technical and Commercial Engineering Representative Services	• Recorded Interview with Senior Structural Consultant
9	Online Call	Interview with Key Architectural Consultant known to be designing prominent locations within New Cairo and the New Capital.	• Conceptual Design to Detailed Design creation and implementation, • Design and supervision consultancy.	• Alignment Interview with Owner

Figures 3.1 to 3.8 below represent site visits, some images were taken physically, other images were provided by the contractor representing certain sites or production facilities.

Figure 3.1: Image taken showing majority of precast works being modular units at precast supplier production yard

Figure 3.2: Image taken on site showing Saudi Precast Storage Yard with Fixed Cranes and Casting Bed Cranes

Figure 3.3 Interlock drainage tiles production chamber

Figure 3.4: Precast Guard Room curing after production

Figure 3.5: Image shared by contractor showing Fixed crane moving Double T Slab

Figure 3.6: Image of rafter beams fixation on site. Drainage raft beam being moved by crane

Figure 3.7: Rafter beam being cured

Figure 3.8: Image shared by Precast contractor on completed factory finished using rafter beams

3.2 GENERAL ALIGNMENT AND DISCUSSION WITH KEY PRECAST STAKEHOLDERS

Interviews both face-to-face and online were carried out across the main members of the precast industry within Egypt listed below:

- Bina Group (Saudi Arabia)
- Cretematic Structural Elements (Egypt)
- Osman Group (SCIC Precast Concrete) (Egypt)
- Modern Concrete (Egypt)
- Premco Precast (Egypt)
- Orascom CPD (Egypt)

Stakeholders such as Marketing Managers, Managing Directors, and key representatives able to speak on behalf of their company's exposure to the Egyptian and Oversea markets were asked to fill in a Questionnaire further described below in Case Study 3. Further to their response as they filled in the questionnaire, they were asked to clarify as to why they picked these answers through alignment interviews.

3.3 GENERAL ALIGNMENT AND DISCUSSION WITH KEY PRECAST CONSULTANTS AND ENGINEERS

A Structural Engineering Professional who has extensive knowledge and know-how on Structural Elements and Precast technologies was further interviewed separately as follows and was asked key questions and predicaments collected from the contractor alignment interviews and Case Study Questionnaires. The Engineer is a Top Management Design and Supervision Director exposed to most Precast Projects currently being executed in the New Capital. The interviewee works in Dar Al Handasah (DAH), a prestigious engineering consultant responsible for zoning, supervision consulting, and design consulting. This consultant functioned as a fact checker and answers were compared with contractor to avoid biasedness. Interview summary extracted from voice memo is highlighted below:

1- **Question** - As a design and supervision consultant, why do the majority of Market Request for Proposals come out in Egypt requesting Traditional building methods instead of Precast?

1- **Answer** -

A- This can be categorized into three main reasons: -

   a. Capability of Contractors.
   b. Budget and Time requirements of Client.
   c. Complexity of Design and execution of the project.

B- The above points affect availability of contractors within the market. The effect of Demand is limited to three main suppliers, Premco, Modern Concrete and Orascom. As a consultant we see these vendors as the only

capable contractors in delivering complex load bearing precast components. This leads to the entire market being dependent on only a limited number of contractors leading consultants to divert away from overloading the limited number of contractors with mass precast projects. Consultants see this as a risk. Capability of contractors not only lies in producing the components but also in fixating on site, a select few contractors are also capable of installation and erection on site further leading to an increase of demand in relation to supply. Not all contractors have the know-how and utilities to handle precast erection on site, these contractors are also limited. A handling crane defined for lifting heavy precast units is needed and again only a select few contractors possess this machinery.

2- **Question –** Many precast contractors handle erection themselves after producing Precast Concrete components, wouldn't this improve supply against demand?

2- **Answer -** Even contractors with erection capabilities do not have enough resources to handle massive projects.

3- **Question** –You have exposure to projects across the Middle East. We are comparing between Egypt and Middle Eastern countries. What makes the Middle Eastern Market much more welcoming to precast than Egypt?

3- **Answer** – Regular Design demand was at a high across the middle east over the past twenty to thirty years with high demands of modular similarly designed units making large scale precast production lines being more suitable. Saudi Arabia has seen a growth in these types of projects requiring Regular Design such as hospitals, bridges and various infrastructure all

involving similar modular components. Egyptian construction markets have a lot of variations in design when executing different projects, some projects need modern architecture finishes and shapes other projects need more traditional and classical looks, this would be trickier to handle when applying precast to customized units.

4- **Question –** You say demand in Saudi Arabia is large, but when looking at the Egyptian market currently construction volume within Egypt including the New Capital involves very large volumes of construction, despite this why is precast still not implemented?

4- **Answer –** Precast construction was used in the Ministries and Projects requiring fast delivery. The New Capital is one of the fastest executed developments in the world, to be able to use Precast within these developments ample contractors would be needed with expertise in precast. This is not available unfortunately, so the government relies on the most known construction method using traditional construction means. Only select complex projects such as ministries and large complex governmental projects applied Prestressed Slabs and Columns. The governmental establishments need to be delivered the quickest and are also the most complex so precast comes in handy for these. Construction for these

5- **Question –** Can you name some precast projects completed in the New Capital and by which contractors?

5- **Answer** –

- **a.** Prime Minister Office by Orascom
- **b.** Parliament Building by Arab Contractors.

c. Ministry of Finance by Hassan Allam

d. Central Bank by Hassan Allam

6- **Question –** As a consultant do you see a future Egyptian market where we will see clients preferring precast to more traditional methods for residential, commercial or institutional developments?

6- **Answer** –

a. The market is growing rapidly, and I see the precast market booming very soon considering the growing demand for construction within Egypt. Although the most common element that will more likely be practiced sooner and be seen more commonly is the prestressed slab component considering its ease of implementation and its common know how amongst contractors.

7- **Question –** Can you put a percentage on precast construction within Egypt?

7- **Answer** – This is a tricky one. Modular load bearing units are complex and require capable contractors, I do not reckon precast load bearing units currently go over the 5 percent market share. Modular precast components however are the most common, these include fences, man holes and modular furniture units in compounds or walkways, these can go up to 50 percent of the modular precast unit market and is the majority of precast contractors' volume of precast sales.

3.4 PRECAST VS. TRADITIONAL CONCRETE IN-SITU CASE STUDIES

Case studies below were aimed to create a comparison ground tailored for the Egyptian market to compare Traditional Concrete Developments to Precast developments being

able to pinpoint exactly which factors accentuate the benefits of precast construction the majority traditional construction methods currently used. Two financial case studies were performed combining both forecasted and actual costs of production.

For the first financial Case Study Various Projects were collected from the New Capital and priced with the support of Local and Saudi Precast Vendors. Buildings of different types were compared to allow for a wide variety of comparison for precast in several building functions.

The second financial case study looks at a massive residential development owned by one of Egypt's top developers. This was an actual study done including drawings and was priced in real-time by an actual Egyptian Precast bidder. The study was performed in partnership with a developer to focus on comparing precast developments to the common practice of traditional construction.

The final third case study was a questionnaire given to professionals only knowledgeable on the uses of PCC, using coefficients that assess the correspondence level between ranking groups. These professionals were a pool of engineers in the design consultancy field, design supervision field, precast contracting field, onsite PCC contractors , PCC marketing professionals and PCC top level business stakeholders .In essence all representatives who took the survey had a track record working in PCC . The survey considering perception of PCC is a prominent factor affecting marketing and promoted use of PCC this case study studies this perception from above mentioned key professionals in the field.

3.5 ECONOMIC ASSESSMENT - CASE STUDY 1

The first case study comprises several projects collected from the New Capital, a prominent Cairo location having the highest number of ongoing projects simultaneously. With the support of local consultants serving the New Capital, data was collected and priced in comparison to already priced BOQs. The BOQs were originally priced for traditional works and then further priced considering precast built components. Different structures of variant sizes and complexity were assessed to have a good notion in analysis of Precast Concrete prices in comparison to more traditional forms of building execution. Not all projects have been awarded, some are in the conceptual design stages and some have yet to be kicked off. The purpose of these designs is to compare precast to traditional concrete. They were priced by contractors and designers who requested an anonymous review.

Considering scarcity of precast column load bearing members being used within Egypt, the study focused on more realistic comparisons metrics aimed at comparing the most common products sold within PCC known as suspended Precast slabs in comparison to in situ poured slabs.

The costs mentioned below included: -

- Contractor final price
- Supervision Consultant Fees
- Design Consultant Fees

Table 3.2: Projects progress with precast elements

Entry	Proposed Projects	Condition
1	Building Education College 8-unit workers cottage	Conceptual Stg.
2	Building of 2-floor head office for Technical Education College	Conceptual Stg.
3	Building 8-unit workers cottage and 2 No. 12 WC lavatory amenity for educational institution	Conceptual Stg.
4	Building Education College amphitheater flat, Mampong	Conceptual Stg.
5	Building of 3-floor schoolroom tower for Nurses Training Institution	Conceptual Stg.
6	Finishing of 3-floor management office for South District Assembly	Conceptual Stg.
7	Building CSIR-BRRI new management tower	Conceptual Stg.
8	Building of 2-floor student residence flat for Secondary / Commercial School	Detailed Design Stg.
9	Building Commercial / Secondary School 3-floor 12-unit block	Detailed Design Stg.
10	Building of the annex of headquarters tower for Minerals Commission,	Detailed Design Stg.
11	Building Polytechnic amphitheater	Detailed Design Stg.
12	Building District 18-unit 3-floor institute prototype	Detailed Design Stg.
13	Building Secondary/Commercial School new auditorium	Detailed Design Stg.

Thirteen projects were assessed as follows, some only conceptual, others in detailed design stages. Conceptual drawings were shared for each and they were priced from a series of anonymous design consultants, along with traditional and precast contractors. Projects were priced using Forecast BOQs and Completed Projects actual Spend was considered to better account for related costs paid for by owner aiming to execute using Precast Concrete.

Table 3.3: Cost comparison between placed cast and floor slabs suspended precast (USD)

S.N#	Project	In situ USD (A)	Precast USD (B)	Difference USD (C=A-B)	Percentage Change (%)
1	Education College 8-unit workers cottage	348,840	275,583	73,256	21.0
2	Building of 2-floor head office for Technical Education College	364,235	309,600	54,635	15.0
3	Building 8-unit workers cottage and 2 No. 12 WC lavatory amenity for educational institution.	339,984	306,665	57,618	9.8
4	Building Education College amphitheater flat	587,871	508,508	79,363	13.5
5	Building of 3-floor schoolroom tower for Nurses Training Institution	231,989	187,401	44,588	19.2
6	Finishing of 3-floor management office for District Assembly	133,468	187,401	44,588	15.0
7	Building CSIR-BRRI new management tower	33,8850	265,997	72,853	21.5
8	Building Secondary / Commercial School 3-floor 12-unit block	138,489	94,172	44,317	32.0
9	Building of 3-storey 12-unit block for Secondary/Commercial School	336,962	26,2830	44,317	33.0
10	Building of the annex of headquarters tower for Minerals Commission	175,171	144,180	30,991	17.7
11	Building Polytechnic amphitheater	75,506	50,589	24,917	29.7

12	Building District 18-unit 3-floor institute prototype	203,001	142,101	60,901	30.0
13	Building Secondary/Commercial 50 Person School new auditorium	60,006	41,404	18,602	35.1

As mentioned in Table 3.3, cost equivalence was performed for the most common element used in PCC within the Egyptian Market and slab costs were compared for all projects ranging from various sizes.

3.6 MASS RESIDENTIAL COMPARATIVE COST ANALYSIS CASE STUDY 2

3.6.1 Project Description

Precast Works for 2,500-unit Madinaty Villa Project, New Cairo

The Case study below shows Elevations and First Floor Hollow Core (H.C) drawings as shown in Figures 3.9 to 3.11 to reflect the four townhouses scoped for the Villa Project. 2500 units of these were forecasted to kick off by the end of current year, 2021. Each unit consisted of four townhouses interconnected into one building unit. A Price List is shown below representing the cost of building and reasonable Net Profit covering overheads and operational profitability was accounted for to sustain the Precast Vendor's Business.

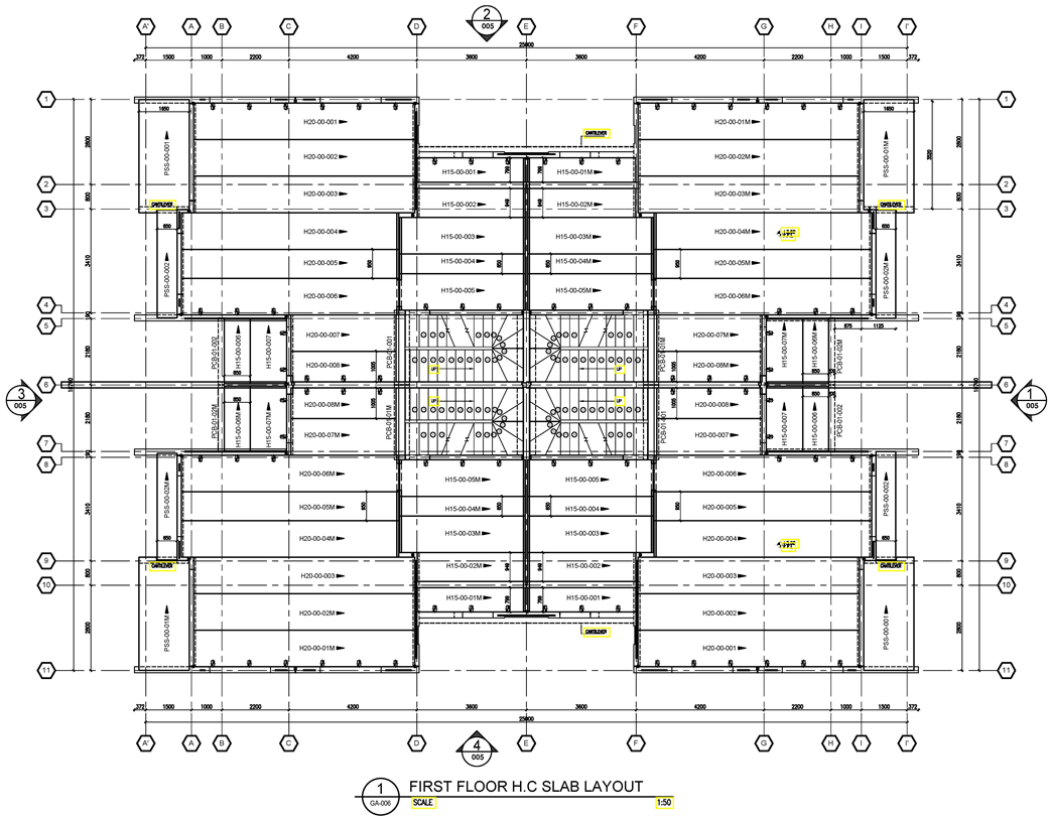

Figure 3.9: First floor layout

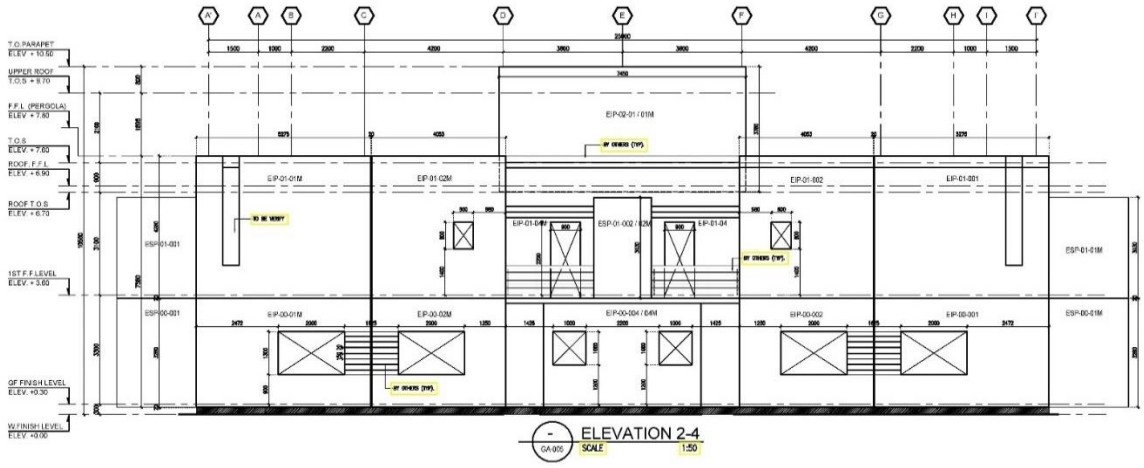

Figure 3.10: Elevation Section 2-4 Layout

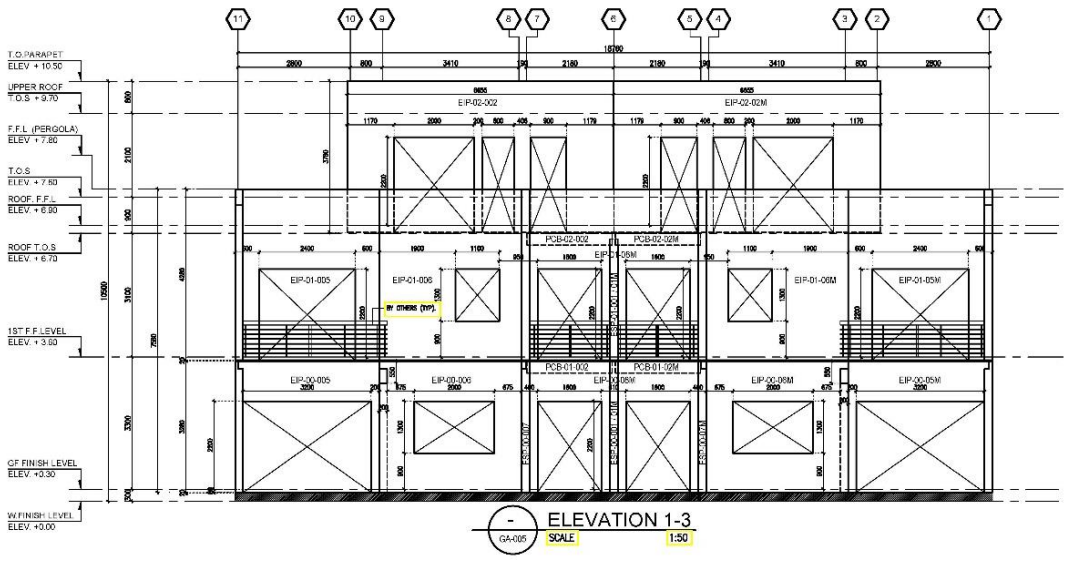

Figure 3.11: Elevation Section 1-3 Layout

The precast contractor was asked to price the project based on drawings to deliver a core and shell solution. Core and shell solution refer to concrete works being delivered, creating suitable grounds to compare the feasibility and execution of Precast Concrete in large residential projects. The study was suitable for analysis of the construction ecosystem within Egypt where the majority volume of projects is deemed to be Residential.

Assumptions that were made include on site creation of precast beds considering wide open spaced areas are available within the New Capital Area. This cost was included within Precast Slab Pricing shown below in BOQ Table 3.4.

The remaining precast components were transported to site from Saadat City located approximately 80 km from site.

To maintain an apple-to-apple comparison, load-bearing walls were accommodated into the study instead of precast columns. They were eliminated form this study

considering the lack of design drawings of the units being available. Another reason beams were eliminated was the high scarcity of this component in the market in general, leading precast contractors to price highly and creating a surge in prices which would diminish the study in creating testing grounds mimicking a more accurate environment representing the Egyptian precast market.

The study compared prices to allow contractors to accommodate overheads and transportation costs into their prices considering the New Capital is still considered a remote location.

Precast Contractor was asked to price the BOQ considering the project was to last over 8 to 10 years and to be delivered in phases. This allowed the contractor to accommodate for inflation and other increases in commodity prices. The same BOQ was given to a Residential contractor who was asked to price it based on their typical market norm traditional stipulation and considering bearing walls as a replacement of columns to respect factors within the study. The contractors were given two weeks to price BOQs. Terminology of BOQ items were modified by traditional contractors wih regard to them delivering the same core and shell finish set by the precast contractor.

BOQs were then collected from both contractors and verbal meetings were discussed to further clarify price differences and breakdowns within prices.

Table 3.4: BOQ of Precast Elements

			Cost EGP		10% Selling, EGP	
No.	**Description**	**Quantity**	**Unit Price**	**Amount**	**Unit Price**	**Amount**
1.	200mm thick Pre-cast insulated wall panel, white concrete sand blast finish @ outer face grey concrete mold finish @ inner face	2,237,500 m²	391	874,675,363	434	971,075,000
2.	200mm thick external solid wall panel, grey concrete mold finish	260,000 m²	325	84,618,242	362	94,120,000
3.	200mm thick internal solid wall panel, grey concrete mold finish	617,500 m²	277	170,749,924	307	189,572,500
4.	150mm thick solid wall panel, grey concrete mold finish	495,000 m²	238	117,900,070	265	131,175,000
5.	100mm thick parapet wall, white concrete sand blast finish @ outer face	202,500 m²	172	34,916,008	192	38,880,000
6.	precast concrete beam, grey concrete mold finish	20,000 m²	2,048	40,961,343	2,276	45,520,000
7.	precast concrete stair & landing, grey concrete mold finish	75,000 m³	2,527	189,501,086	2,807	210,525,000
8.	200mm thick solid slab, grey concrete mold finish	175,000 m³	467	81,665,551	519	90,825,000
9.	150mm thick hollow core slab	970,000 m²	90	87,076,900	100	97,000,000
10.	200mm thick hollow core slab	850,000 m²	95	80,707,500	106	90,100,000
TOTAL COST			1,762,771,986		1,958,792,500	
Price per sq.m. (2,635,000.00 m²)			669 EGP/m²		743 EGP/m²	

Table 3.5: Traditional Concrete BOQ Price for Comparison in Case Study 2

			Cost, EGP		10% Selling, EGP	
No.	**Description**	**Quantity**	**Unit Price**	**Amount**	**Unit Price**	**Amount**
1.	200mm thick insulated load bearing wall builder works, white concrete sand blast finish @ outer face grey concrete mold finish @ inner face	2,237,500 m²	615	1,377,181,250	677	1,514,037,938
2.	200mm thick external solid wall panel, grey concrete mold finish	260,000 m²	354	91,998,400	389	101,198,240
3.	200mm thick internal solid wall panel, grey concrete mold finish	617,500 m²	313	193,166,350	344	212,482,985
4.	150mm thick solid wall panel, grey concrete mold finish	495,000 m²	273	134,862,750	300	148,349,025
5.	100mm thick parapet wall, white concrete sand blast finish @ outer face	202,500 m²	205	41,546,925	226	45,701,618
6.	Regular concrete beam, grey concrete mold finish	20,000 m²	2,896	57,920,000	3,186	63,716,400
7.	precast concrete stair & landing, grey concrete mold finish	75,000 m³	3,346	250,950,000	3,681	276,055,725
8.	200mm thick solid slab, grey concrete mold finish	175,000 m³	890	155,750,000	979	171,357,725
9.	150mm thick slab	970,000 m²	400	388,232,800	440	427,056,080
10.	200mm thick slab	850,000 m²	500	425,552,500	551	468,107,750
TOTAL COST			3,117,160,975		3,428,063,485	
Price per sq.m. (2,635,000.00 m²)			1183 EGP/m²		1301 EGP/m²	

3.7 RANKED PROFESSIONAL FEEDBACK CASE STUDY 3

Questionnaires were prepared as the third Case Study covering various Markets including Egypt, Canada, and Saudi Arabia. 48 Professionals experienced with PCC were selected to give an accurate perception of Precast Concrete and Questions were focused on understanding their scoring of Precast Concrete's different traits. These

professionals have high friction with the construction markets and were therefore a significant source of accuracy when it comes to assessing and grading the performance of concrete within the Egyptian Market. PCC contractor employees and managing staff participated in questionnaires. These contractors cover approximately 60 Percent of cumulative precast works within the market. Consultants who also filled in the questionnaire have high friction supervising and designing heavy precast projects in the New Capital.

The Questionnaire was also shared with professionals abroad to be able to signify which factors were not affected by the country's infrastructure or economical standing but by the technical feasibility of the precast construction method itself.

Below is the Questionnaire shared with the professionals using Google Forms. Considering COVID-19 circumstances, questionnaires constituted a much easier way of collecting data than face-to-face interviews or virtual meetings. Below is an extract from Google Forms with the questionnaire shared with the professionals. Original Google form Extract attached in Appendices.

Choose which Party You Represent Within Construction

- Educational
- Supervision Consultant
- Design Consultant/Architect
- Contractor
- Vendor
- Project Management Office
- Client

Name (Optional) _____

Job title? _____

Country? _____

Questions asked from professionals about precast

Note: 1 represent " strongly disagree" and 5 represent (strongly agreed)

What do you think is the Percentage of Precast Construction in your region .

- 0 to 5 percent
- 5 to 15 percent
- 15 to 30 percent
- 30 to 50 percent
- 50 percent or higher

Main barriers you believe precast concrete faces in penetrating your market

- Lack of Know how or understanding of PC technology
- Expensive
- Slow Lead Delivery Times
- Poor Infrastructure / Roads
- Lack of Design Capable Engineers

Precast Concrete Life Cycle Cost in comparison to other construction methods or products

- 1
- 2

- 3
- 4
- **5**

Precast Concrete capability on reducing on-site construction waste

- 1
- 2
- 3
- 4
- 5

Precast Concrete Speed of Construction

- 1
- 2
- 3
- 4
- 5

Precast Concrete quality in delivery end product

- 1
- 2
- 3
- 4
- 5

Precast Concrete Durability

- 1
- 2
- 3
- 4
- 5

Precast Concrete Dimensional Accuracy

- 1
- 2
- 3
- 4
- 5

Precast Concrete Capability in reduction of onsite labor

- 1
- 2
- 3
- 4
- 5

Precast Concrete Capability in Reduction of on-site activity, noise, and disturbance

- 1
- 2
- 3

- 4
- 5

Precast Concrete Capability in making available Sandwich panels available for insulation

- 1
- 2
- 3
- 4
- 5

Precast Concrete needing minimal maintenance

- 1
- 2
- 3
- 4
- 5

Precast Concrete Thermal inertia reduces lifetime energy costs

- 1
- 2
- 3
- 4
- 5

Precast Concrete provides for Large spans available from prestressing

- 1
- 2
- 3
- 4
- 5

Precast Concrete provides tolerance

- 1
- 2
- 3
- 4
- 5

Precast Concrete provides acoustic insulation

- 1
- 2
- 3
- 4
- 5

Below is the scoring of each question, showing the number of individuals who selected a certain category or rating. As shown in Figure 3.12 below, there were 48 professionals who participated in the survey . Out of the 48 professionals, the highest numbers was from Egypt, 24 in total and the main focus of the study, and 12 each from Canada and Saudi Arabia. A question was asked about the percentage of precast

construction in their region as shown in Figure 3.13. 48 responses were collected for from which 75% responded believing PCC construction market share was (between 15% to 30%) while 25% believe PCC construction market share was (5% to 15%) in their region.

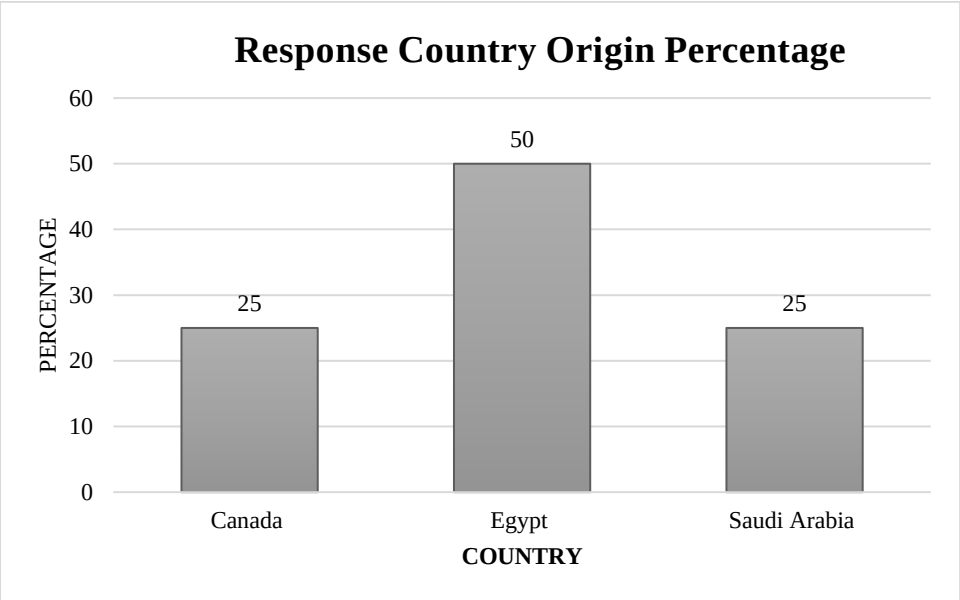

Figure 3.12: Feedback on country origin of interviewee

LEGEND	
	0 to 5 %
	5% to 15%
	15% to 30%
	30% to 50%
	50% or higher

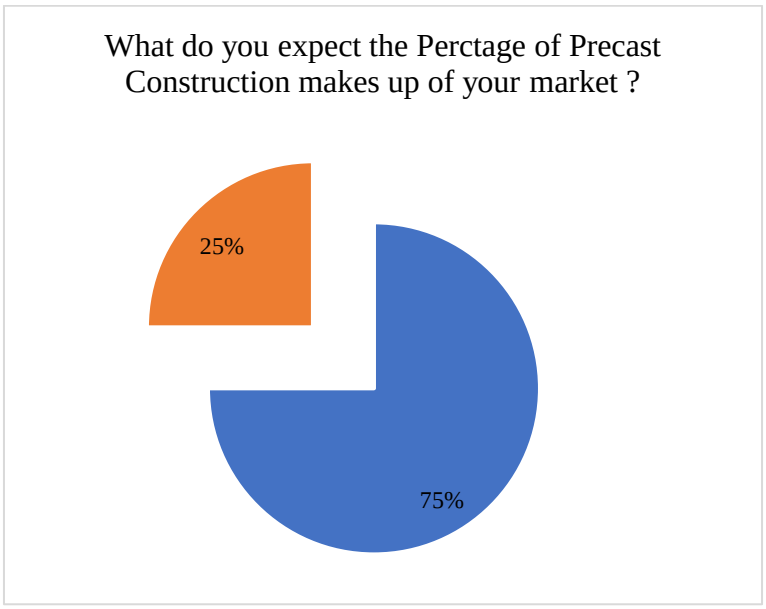

Figure 3.13: Feedback on Precast Concrete Percentage of Construction Market

LEGEND	
	Experience
	Slow lead Delivery time
	Lack of Know How or Understanding
	Poor Infrastructure
	Lack of design

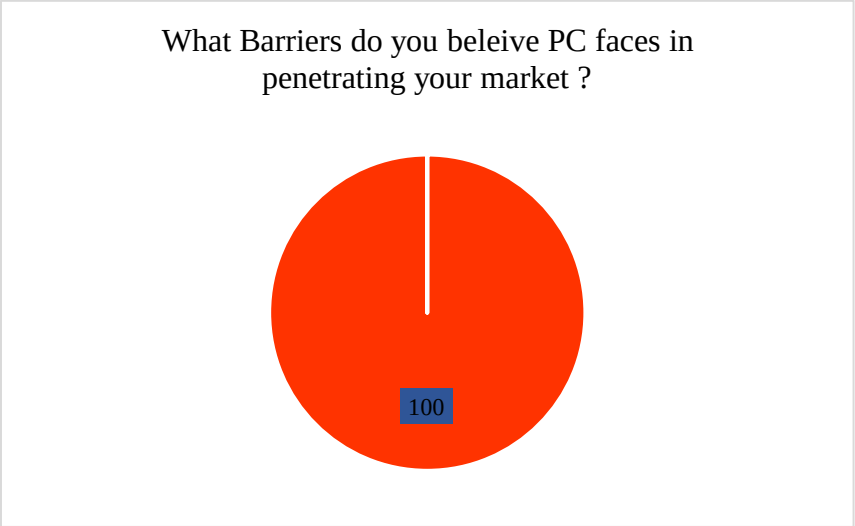

Figure 3.14: Feedback on Main Barriers Perception of Precast Concrete

From the same 48 respondents, a question was asked about the difficulties and barriers that Precast Concrete has to face when being introducing to the market. It is obvious that these continuously new PCC solutions, introduced new items or updated execution methods needs a fully sustainable, cost-effective, and time-constraining solution and know how evidently, 48 respondents replied with a lack of knowledge and understanding of precast technology.

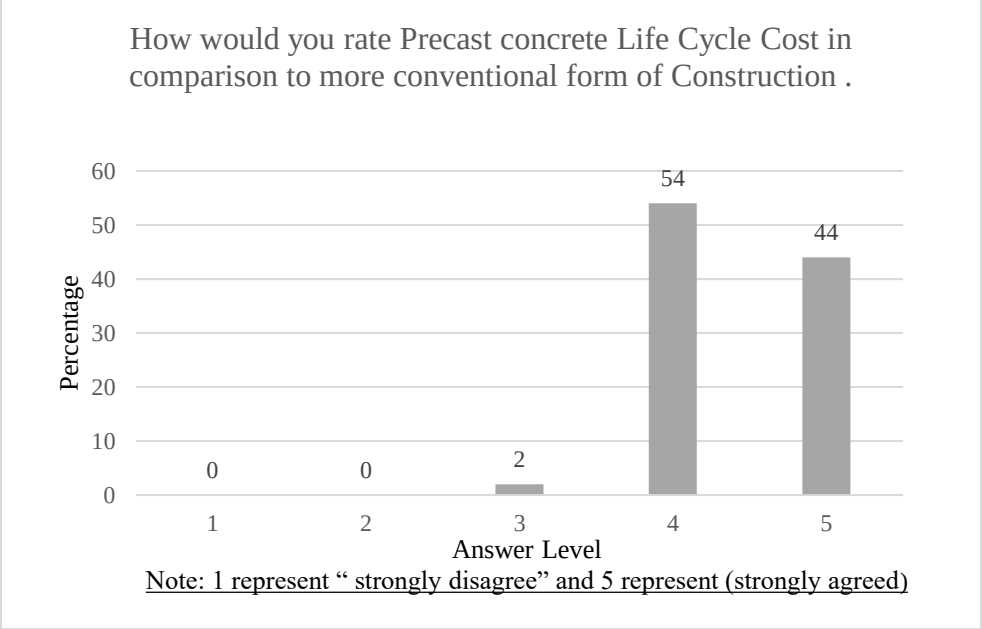

Figure 3.15: Feedback on Precast Lifecycle Cost

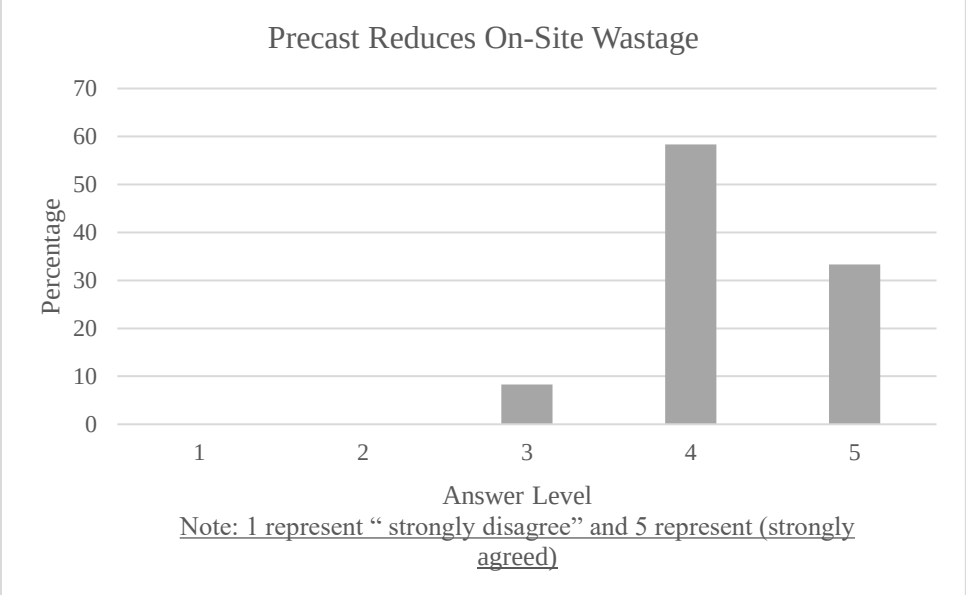

Figure 3.16: Feedback on Precast Onsite Wastage

In Figure 3.15, respondents were asked about the comparison of traditional methods of construction against precast construction for the cost of the life cycle. Majority of respondents nearly 100 percent agreed or strongly agreed, this confirms the general

perception of precast users being aligned on its long-term benefits. It is safe to say that most precast users within Egypt see that the life cycle cost of Precast Concrete construction is way more feasible than other construction materials.

The other question in Figure 3.16 was asked to ascertain whether precast construction is adoptable regarding the reduction of onsite activities and wastage. Precast is something that could be worked on in factories as well as on site adjacent to the construction area. For this, approximately (50%) of respondents replied that they strongly agreed and the rest either agreed or were neutral with the majority agreeing to mean in general they are around 90% sure.

In Figure 3.17, about the construction speed of Precast Concrete, (58%) respondents responded with agree and (30%) strongly agreed with the fact. No response was recorded for strongly disagree.

In the Figure 3.18, another question was asked about precast capability with regard to delivery and installation quality . Nearly the same notion of responses were recorded as in the above question. That is, 70% respondents strongly agreeing and the rest recorded their response as agree and neutral . A minute percentage strongly disagreed but this was considered a misperception of the question or understanding of the precast product question .

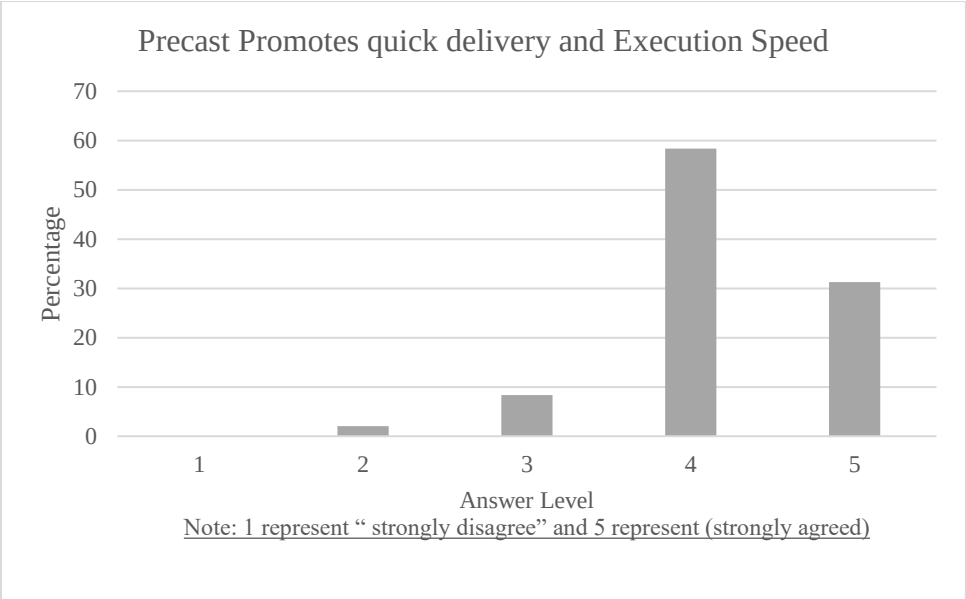

Figure 3.17: Feedback on Precast Delivery Speed

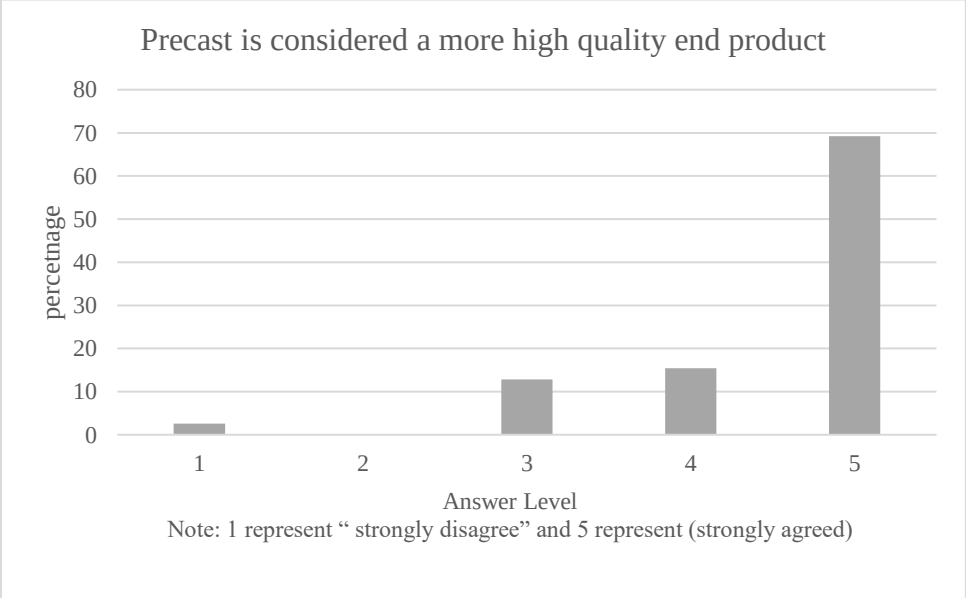

Figure 3.18: Feedback on Precast Quality Delivery

In Figure 3.19 and 3.20, a question was asked about concrete durability and dimensional accuracy of Precast Concrete. It was noted that for the first question (63%) of respondents strongly agreed that precast is considered durable. When asked about

dimensional accuracy, a general census on agreement was also seen with 35 percent agreeing and (25%) strongly agreeing. There was a 21 percent disagreement and 19 percent neutral notion .

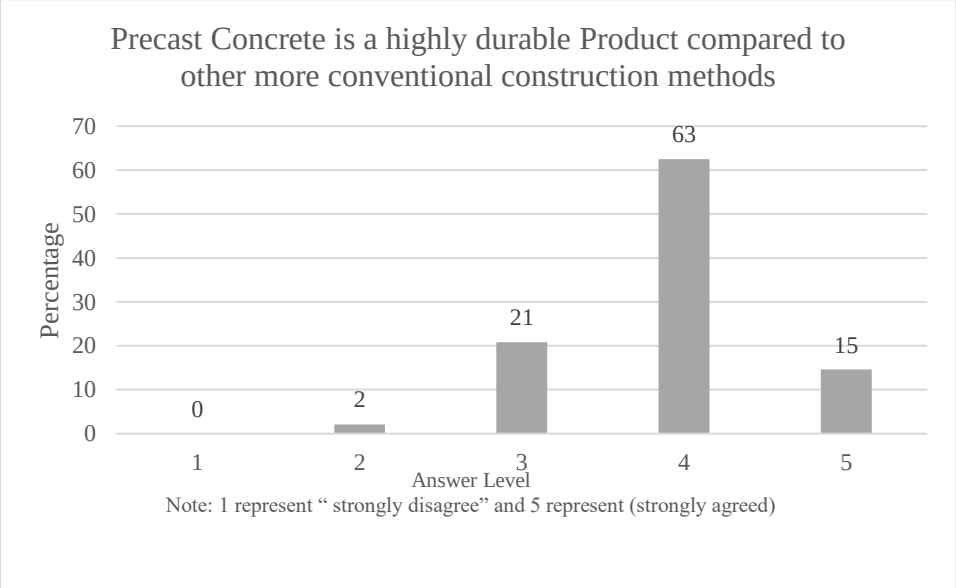

Figure 3.19: Feedback on Precast Concrete Durability

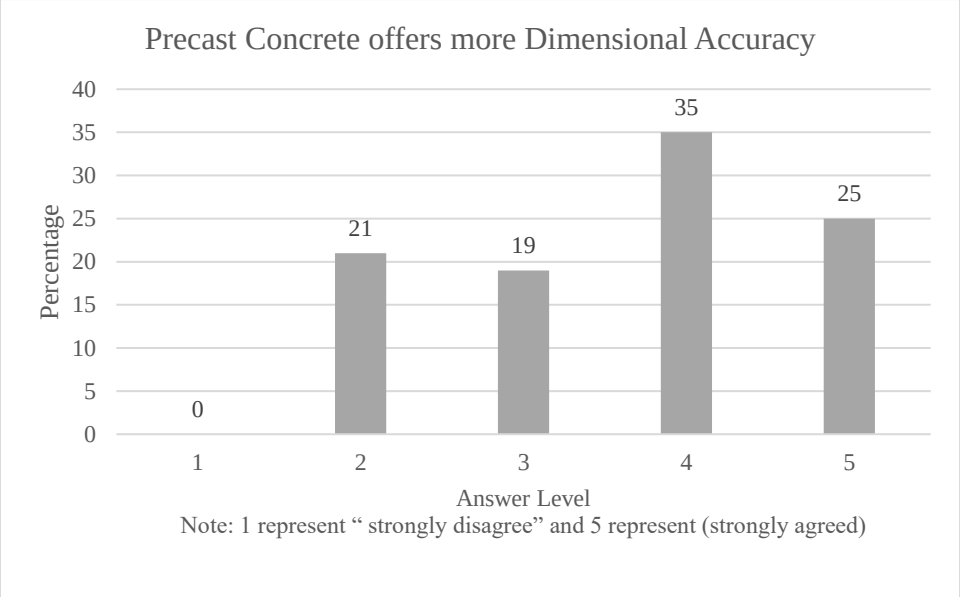

Figure 3.20: Feedback on Precast Dimensional Accuracy

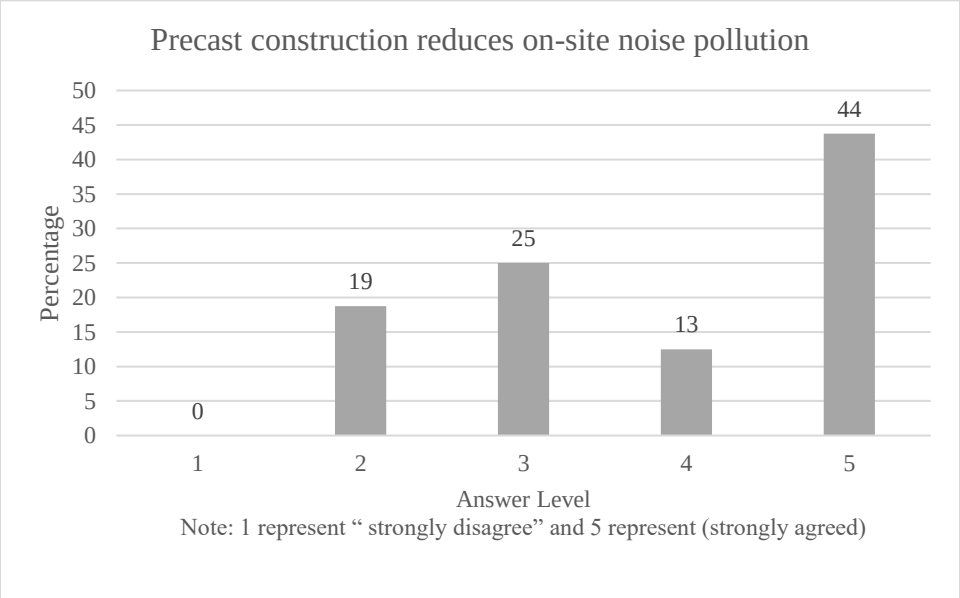

Figure 3.21: Feedback on Precast Construction Onsite Noise and Disturbance

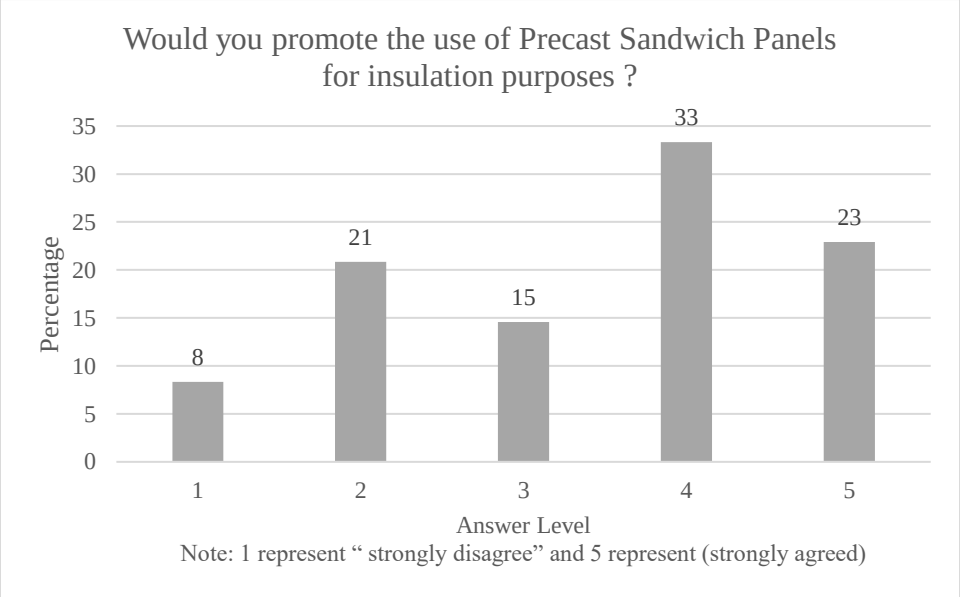

Figure 3.22: Feedback on adoption of Precast Sandwich Panels

In Figure 3.21 and 3.22, two questions were asked from the respondents, one about the reduction of noise on-site activities and another about the availability of sandwich panels for insulation purposes. To the first question, responses with highest percentage was a strong agreement of (44%). A smaller percentage of (19%) disagreed .. However, to the second question, 23% of respondents strongly agreed whereas (33%) agreed, (15%) were neutral , the rest of the (29%) either disagreed or strongly disagreed.

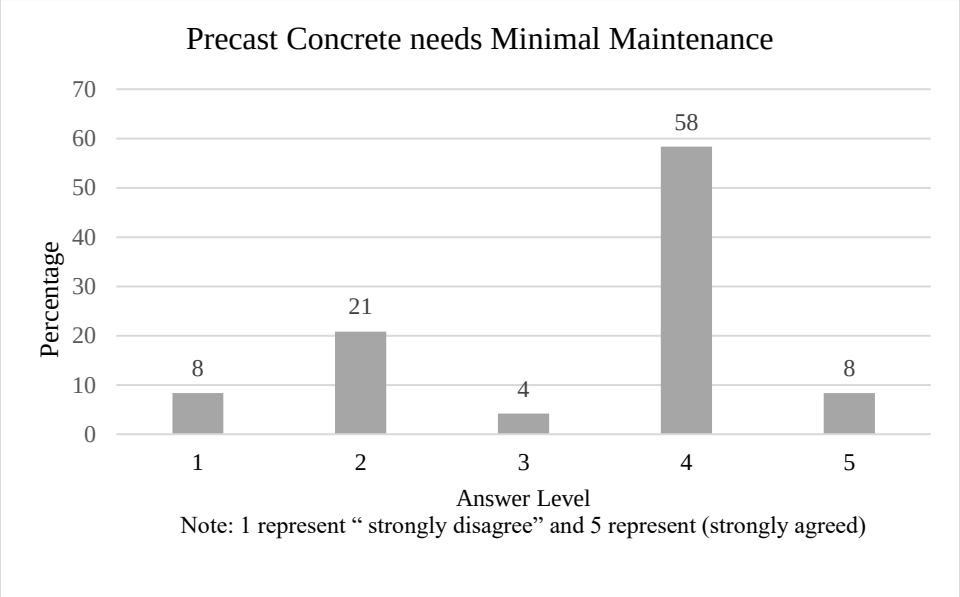

Figure 3.23: Feedback on Precast Concrete Maintenance Requirements

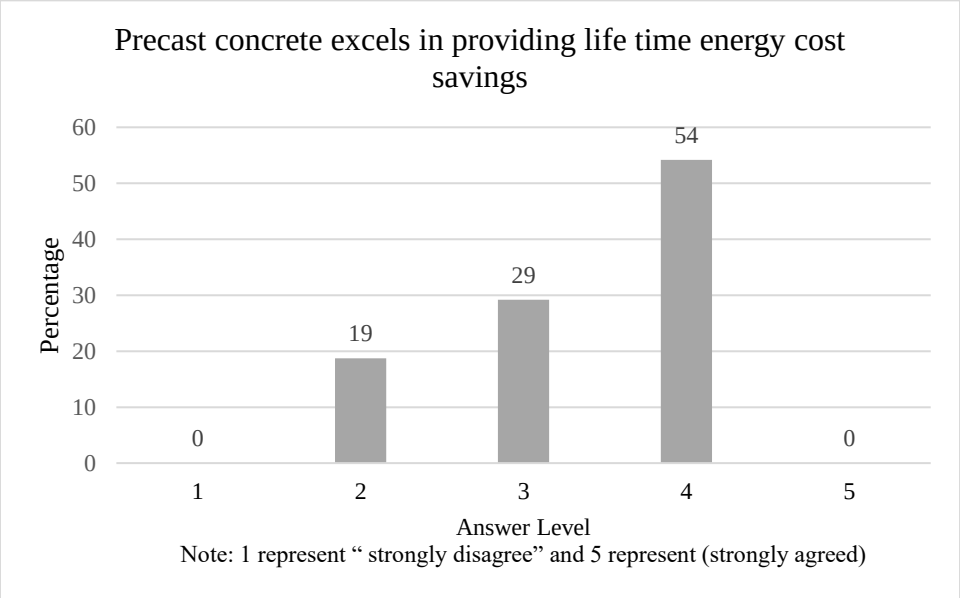

Figure 3.24: Feedback on Precast Construction capability in saving Lifetime Energy Cost

Figure, 3.23 mentions about the maintenance cost and thermal inertia which leads to reducing lifetime energy costs. (54%) "agree" was recorded for lifetime energy savings

cost question. (19%) disagreed and the rest of the (29%) had neutral perceptions. A similar trend was seen for maintenance costs being (66%) agreement and strong agreement. The remainder showed (21%) disagreement , 8% strongly disagreeing.

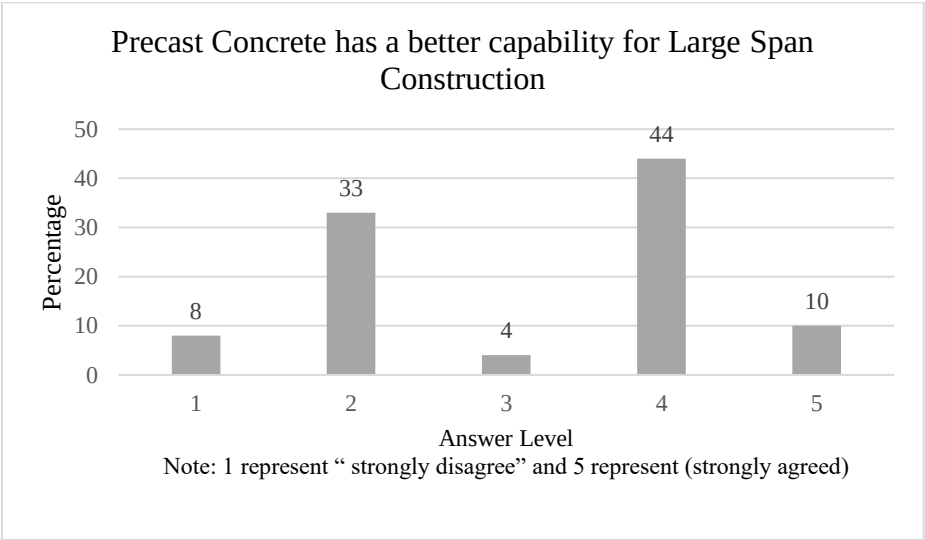

Figure 3.25: Feedback Percentage on Large Span Capability of Precast Concrete

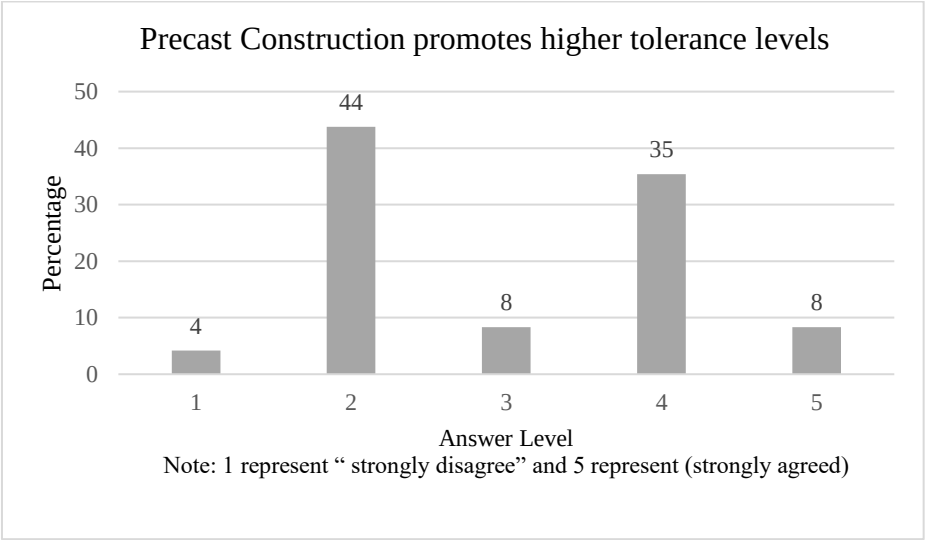

Figure 3.26: Feedback Percentage on Precast Concrete Tolerance Capability

In Figure 3.25, responses were recorded for if Precast Concrete is feasible in providing longer span .They represented tolerance capabilities. 54% agreed and strongly agreed for concrete with longer spans. (41%) disagreed and strongly disagreed.

In Figure 3.26, more disagreement were shown with 44% disagreeing that precast offers better tolerance and the remainder 43% strongly agreed. Figure 3.25 and Figure 3.26 both clearly show a lack of determination whether a strong agreement or disagreement on a reasonable perception of the Egyptian market in regard to tolerance and long spans. this could be an indication of lack of knowledge in regard to understanding precast capability here.

Another question in figure 3.27 below about acoustic insulation capability of precast suggests that 27% do agree and strongly agree with this statement whereas 62% disagree or strongly disagree.

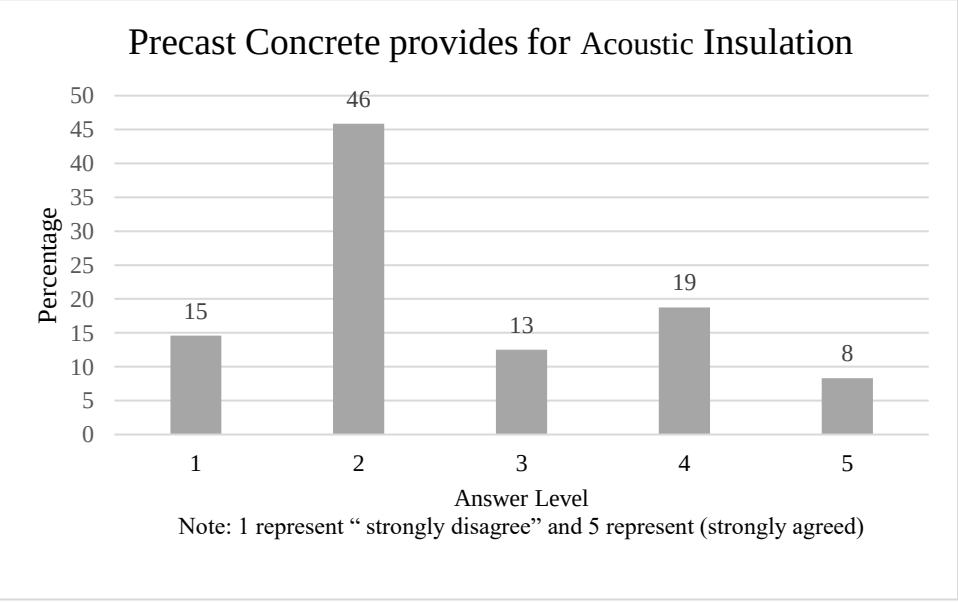

Figure 3.27: Feedback on Precast Concrete Capability for Acoustic Insulation

Table 3.6: Professional Views on Utilizing Precast Concrete Products

Merit	Ranking									
	i	ii	iii	iv	v	Sum	∑W	Mean	RII	Rank
Modest life cycle cost rate	0	0	1	26	21	48	344	4.41	0.822	1
Reduction of On-site Waste	0	0	4	28	16	48	326	4.1	0.83	2
Swiftness of construction	0	1	4	28	15	48	326	4.17	0.836	3
Eminence and Quality of Precast End Product	1	0	6	7	33	48	308	3.94	0.79	4
Robustness and Durability	0	1	10	30	7	48	304	3.89	0.799	5
Dimensional accuracy	0	10	9	17	12	48	286	3.66	0.733	6
Lessening of on-site working hours	0	9	7	30	2	48	276	3.53	0.708	7
Decrease of on-site action Noise and commotion	0	9	12	6	21	48	274	3.512	0.703	8
Insulation offered by Sandwich Panels	4	10	7	16	11	48	268	3.43	0.686	9
Negligible maintenance	4	10	2	28	4	48	264	3.38	0.677	10
Thermic inertia diminishes lifetime energy costs	0	9	14	26	0	48	262	3.38	0.677	11
Huge spans	4	16	2	21	5	48	246	3.15	0.672	12
Constricted Tolerance	2	21	4	17	4	48	232	2.9	0.631	13
Sound Insulation Capability	7	22	6	9	4	48	200	2.5	0.513	14

This case study also inquired about the views of building experts (Contractors, Consultants and Architects) that labored on the designated developments concerning the merits of utilizing molded concrete. The experts' opinions are disclosed in Table 3.6

The ranking of the merits of utilizing Precast Concrete was calculated using essential indices and the correspondence among the sampled construction experts- This was decided by applying Kendall's harmony analysis. Kendall's symphony coefficient, that assesses the correspondence level between ranking groups, is k where k is the number of sets of ranking (e.g., the number of judgments), n is the number of aspects of a problem or factors being ranked, R is average of the ranks assigned to the nth aspect of the problem, $n(n2 - 1)/12$ is the maximum possible squared deviation, that is, the numerator which will occur if there were perfect agreements among k sets of ranks, and the average rankings were 1, 2, 3, . . . , n. RI is the rank assigned by an individual judge to one aspect of the problem posed. The value of W ranges from 0 to 1 regardless of the number of rankings. W is calculated as follows:

$W = [(RI - R)\ 2]/[n\ (n2- 1)\ /12]$

A high value of W indicates a high degree of agreement between the set of rankings. The significance of W was tested using chi-square distribution. The test was based on the null hypothesis $H0$ = the k set of rankings were unrelated and the alternative hypothesis $H1$ = the k set of rankings were related. The observed chi-square value is calculated using $\lambda 2 = k(n - 1)W$, where k, n, and W are as previously defined. The critical chi-square value is read from the statistical table at $(k-1)$ degrees of freedom. Where the calculated chi-square value exceeds the critical value (that read from tables), the null hypothesis is rejected, and the alternative is accepted.

Kendall's symphony recognized a decrease in on-site wastage and building velocity as the main benefits of molded concrete. Table 3.7 shows agreement by professions on the advantages of using Precast Concrete where $R1$ is the mean of ranking and "n" is the number of advantages being ranked. W is the coefficient of concordance amongst building professionals ranging between Contractors, Consultants and Architects. This was calculated as follows:

Grand Mean = 2.41 calculated by calculating grand mean of Means of Ranking (RG).

$\sum (R1 - R\text{G})^2 = 11.34$

k = groupings

$W = [(RI - R\text{G})^2] / [n\ (n^2 - 1)/12]$

i=1

n = number of factors ranked = 14

$n\ (n^2 - 1)/12 = 14(14^2 - 1)/12 = 227.5$

$W = 11.34/227.5 = 0.050$

Table 3.7: Correspondence and agreement by experts on the merits of precast concrete

Merits	Contractors	Consultants	Architects	Ranking Sum (R1)	Means Ranking (R2)	$[(R_1)- (RG)]$	$[(R_1)- (RG)]^2$	Overall Agreement Position
Modest life cycle cost rate	2	1	2	5	1.67	-0.74	0.553	7
Lessening of on-site leftover	1	2	1	4	1.33	-1.08	1.159	3
Swiftness of construction	3	2	2	7	2.33	-0.08	0.006	10
Eminence and Quality of Precast End Product	1	1	1	3	1.00	-1.41	1.988	1
Robustness and Durability	3	3	2	7	2.33	-0.08	0.006	9
Dimensional accuracy	1	2	1	7	2.33	-0.08	0.006	9
Lessening of on-site working hours	1	1	4	4	1.33	-1.08	1.159	2
Decrease of on-site action Noise and commotion	2	3	3	8	2.67	0.26	0.066	7
Insulation offered by Sandwich Panels	3	1	2	6	2.00	-0.41	0.168	6
Negligible maintenance	3	3	3	9	3.00	0.59	0.348	4
Thermic inertia diminishes life time energy costs	4	2	5	11	3.67	1.26	1.579	1
Huge spans	3	3	3	9	3.00	0.59	0.348	3
Constricted Tolerance	4	3	3	10	3.33	0.92	0.853	1
Sound insulation	3	2	2	10	3.33	0.92	0.853	1

The data represents the responses of various professionals to the relative index. Calculating the sum of the ranking (R_1) is done by summing up all the indices. To calculate the mean of the ranking (R_2), one divides the sum of ranking (R_1) by the total number of indices, then finds the difference between the sum of ranking (R_1) and the mean of the ranking (R_2) using [(R_1) - (R_2)]. Finally, one squares the difference between the sum of ranking (R_1) and the mean of the ranking (R_2) to obtain the modulus [(R_1)-(R_2)]^2, entering the formulas in a spreadsheet will automatically produce the results.

CHAPTER 4

RESULTS & ANALYSIS

In this chapter, the results and analysis based on the results of adoptability of precast in Egypt is discussed in detail. For this purpose, a questionnaire was prepared for the constructional professionals in three countries: Canada, Egypt, and Saudi Arabia. Questions were asked about the precast construction and responses were recorded. The analysis based on the recorded responses is presented below.

4.1 CASE STUDY 1 REVIEW AND ANALYSIS

Case Study 1 as represented in below Table 4.1 comprises of several projects collected from the New Capital, a prominent Cairo location featuring the greatest number of ongoing projects simultaneously. With the support of local consultants serving the New Capital, data was collected and priced in comparison to already priced BOQs. Some of the BOQs were originally priced for traditional slab works and then further priced considering precast slab components. Not all these projects are considered real, some are considered conceptual but were priced for the purpose of comparing precast prices to traditional concrete prices. The main purpose of this Case Study is to study the most sold load bearing precast component which is the precast slab family. Contractors were asked to use precast or traditional slabs systems ,, they were free to choose the type of slab and its dimensions depending on conceptual designs and dimensions of the structure .

Generically, the survey disclosed that molded concrete slabs are less costly in PCC than cast-in-place concrete slabs within buildings, and molded columns are less costly than cast-in-place concrete buildings, mainly when produced on a large scale.

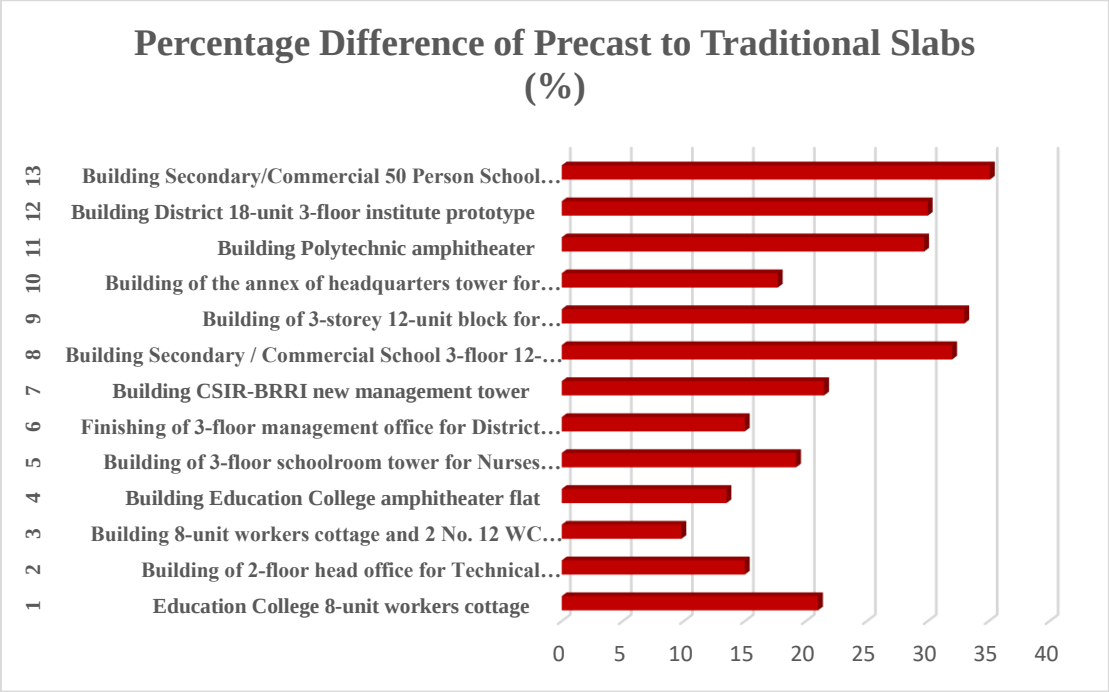

Figure 4.1 showing difference between Precast to Traditional In-Situ Slabs

From Table 3.3 and Figure 4.1 it is obvious that the cost of Precast Concrete panels is significantly lower than the cost of traditionally cast in situ concrete structures. For instance, for the building of a secondary/commercial school new auditorium, the cast in situ cost is 252,026.96 USD and for precast the cost is 173,898.56 USD, saving up to 35.14% of the overall cost of the structure. The reduction in cost may be explained due to many various factors such as less laborers required, and time constraints, which is likely is the biggest factor saving tremendous amounts of cost. For instance, in cast in situ, after pouring concrete one has to wait for 28 days curing and then continue the next activity, while for the precast, the panels could be fabricated in factory or on site without fear of time.

During the pricing of contractors of above conceptual projects using only conceptual drawings, there was a large amount of ambiguity majorly due to the lack of detailed precast or traditional structural drawings. It was seen that precast contractors had no

difficulty in pricing the BOQ whereas the traditional contractors kept coming back asking with many queries in order to accurately price structural components. This was due to the precast concrete's standardization of design making it very easy to design and implement.

Performance of Precast in residential units does perform well in savings but in more standardized structures such as large utility buildings, theaters, higher ceiling spaces, bridges and other structures showing a more standardized design performs much more cost savings in comparison to traditional. The 8-worker cottage above for instance only showed a 9.8 % cost savings compared to the more standardized small school building performing savings of up to 32 percent.

Columns and slabs played the major cost savers in the this case study .Columns were less when pricing precast , at times precast contractors used Steel I beams or steel structures combined with precast construction , this allowed for much wider spans than in traditional pricing having a larger number of columns leading to more crossing longitudinal beams .Flat slabs were also considered in traditional projects however what was saved in column numbers was spent on double reinforcing of flat slabs .

From case study one, it is recommended to use precast panels in terms of cost control as it provides a more feasible way to constructors, designers, and architects.

4.2 CASE STUDY 2 REVIEW AND ANALYSIS

Two tables are presented here, Table 3.4 refers to precast BOQs whereas Table 3.5 refers to traditional cast in situ BOQ. The difference in both the BOQs are explained below. From Table 3.4, the unit cost of each item is given. The total price per square meter is given a 743.37 EGP/m2. This price also includes the contractor's 10% profit as well. In Table 3.3, the unit price for the same specifications and same number of items is provided by the vendor. The per square meter amount for the same project is noted as 1300.97 EGP/ m2. The BOQ of the traditional construction is given in Table 3.5.

By comparing both precast and traditional BOQ, a difference of 75% has been noted. This is a huge difference in both the construction methods. This is because a lower quantity of concrete is wasted when using precast concrete. There is no fear of concrete flash setting or false setting. The arrangement could be made on site as well in any nearby factories. The transportation could be carried out at nighttime to save fuel and time consumption. The amount of labor requirement is less than cast in situ concrete. All these factors contribute to the overall cost reduction of a project.

A component contributing to the price variance was also the project being located in a wide open desert area. This allowed for ample space to lay on-site casting beds for precast panels on site diminishing transportation costs to site .

Another predicament worth considering within Case study two was the lack of understanding of contractors in pricing solid wall panels. Solid wall panels are considered more expensive and are also not a widely available product within the Egyptian market. Both contractors, both precast and traditional ones were asked to price

wall panels to better be able to assess overall project cost just by changing the main precast load bearing components. Considering the above traditional contractors may have overpriced the solid wall panels considering they are rarely found in the market and are usually subcontracted. This could lead to an increase in overall price giving the traditional contractors less of a chance to prove cost competitiveness.

4.3 CASE STUDY 3 REVIEW AND ANALYSIS

This case study is comprised of a questionnaire survey conducted by the author from 48 professionals knowledgeable on the precast construction field. The 48 professionals were head representatives in their organizations and further shared the questionnaire with their teams and subordinates accordingly. The survey covered precast construction and was shared with representatives from three different countries, including Canada, Egypt, and Saudi Arabia. The results are presented in Table 3.6 and Table 3.7.

The results from Table 3.6 disclosed that experts regard modest lifecycle charges as the chief merit of utilizing Precast Concrete commodities and consider acoustic insulation space as the least advantage. From Table 3.6, it can be observed that most of the professionals from the three countries agreed upon using the precast panels and endorse its significance in construction industry. When asked about the life cycle cost, 21% strongly agreed whereas 26% agreed. It can be stated that as a consensus, Egyptian precast users or sellers have the perception on the viability of precast lifetime benefits and the expansive life span of such structures. This factor is also one of the main contributors to why users should adopt precast concrete. When inspecting literature on more developed regions life cycle costs considering energy saving from heaters to heat the spaces in winter and air-conditioning to cool the space in warmer climates leads to a life cycle saving of costs not to mention to overall reduced utility maintenance costs .Insulative capabilities are generically not a huge marketing factor considering Egypt does not experience extreme cooled or heated temperatures and this should be considered when marketing Precast .

It could be seen from the table that Precast Concrete construction is able to reduce wastage on site. Precast factories where robotic or auto sensors machines work have negligible wastage. This makes the Precast Concrete more cost effective. This is the reason that almost 75% of professionals both strongly agree and agree on precast concrete performance in regard to minimization of waste. Longevity of precast lifespan also contributes to this factor majorly due to high durability of precast concrete and it's ease of maintenance. Looking at the amount of demolishment created from traditional construction, precast longevity will reduce climate and environmental waste on the long run .

The quality of delivery and speed of construction has been recognized by the professionals for the Precast Concrete. That is why an 83% agreement was made regarding quality of delivered precast concrete products over traditional not to mention 90 % agreement by respondents that the precast method is speedier .These number indices give an indication that precast is revered as a higher quality product being delivered with nearly zero error and with nearly 40 to 60 percent reduced delivery time , not only that but precast products are also delivered more quickly giving an overall higher level of service and client satisfaction . Census can be reached on these two points that precast is seen by the Egyptian construction market as a high end product and service .

The durability of concrete is also endorsed by the professionals where dimensional stability is partially agreed with a nominal number of respondents disagreeing as well. But, with the general notion swaying towards the agreement of respondents, one can say high precision is expected by professionals on site when using precast concrete.

Embedding one element into another element requires just a few millimeters of tolerance which needs to be maintained in precast. For high precision projects requiring dimension sensitivity, precast would be a more viable option. This precision of site however comes with high logistical tracking in production ensuring all dimensions align specially with precast where tolerance allowance is considered very low.

As a smaller number of labor and machinery is required for Precast Concrete, noise disturbance is considered low at site not to mention precast members site time in general is almost 15 percent in comparison to traditional construction methods .This is agreed on by professionals as well swaying towards believing that precast members decreases on site disruptions and noise pollution. Egypt includes many heavy residential blocks impacted by continuous upgrade and demolishment. Precast concrete members poured outside the city and delivered to be fabricated on site proves to be the perfect recipe for not disrupting congested residential spaces.

Majority of respondents did sway towards agreeing on the capability of precast providing negligible maintenance requirements but some professionals also disagreed .Precast concrete is a new trade within Egypt and has not been around long enough to properly attest to its maintenance requirements and intervals . Most precast vendors or owners do not practice preventative maintenance approaches for these precast systems due to again, a generic lack of know how.

Majority of professionals agreed on acoustic insulation capabilities of using Precast Concrete, this could be explained by the lack of acoustical testing and performance being marketed within Egypt to give precast adopters the additional option of not having to spend extra costs on sound insulation .Precast does however expend a larger

more dense mass than other traditional more porous concretes. This variance between literature and results indicates a lack of knowledge on the capabilities of Precast Concrete.

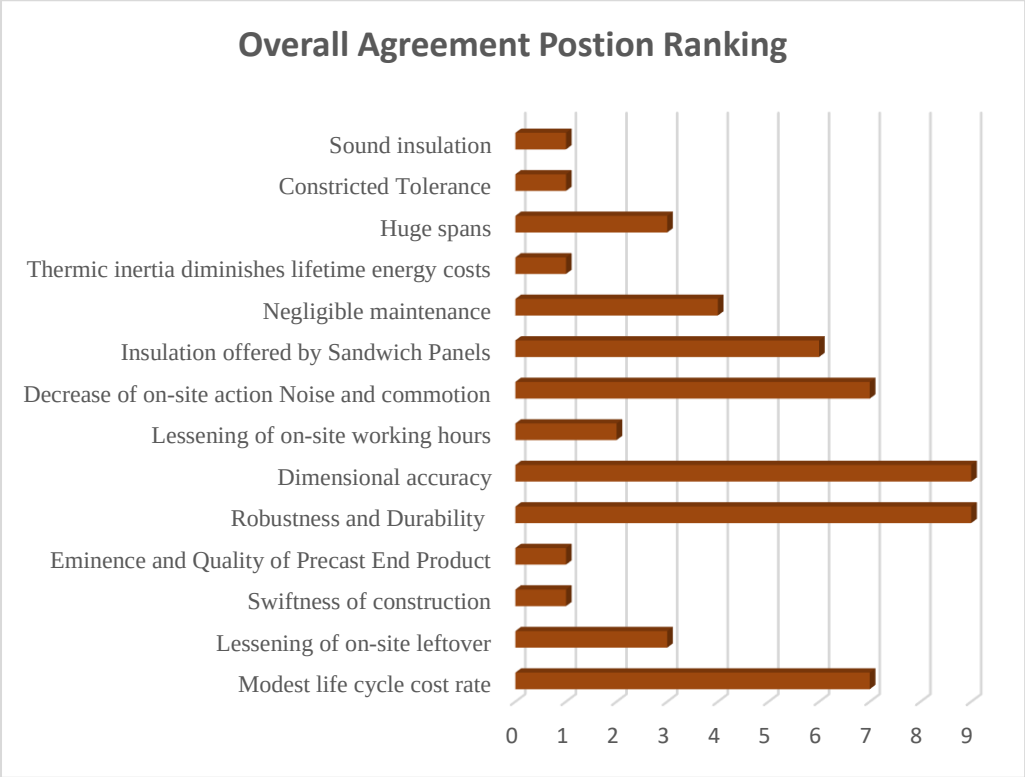

Figure 4.2 Overall Ranking of agreement of professionals on Precast Merit using Kendal's Coefficient

Reiterating Calculations:

Grand Mean = 2.41 calculated by calculating grand mean of Means of Ranking (R2).

$\sum (R1 - RG)^2 = 11.34$

k = groupings

$W = [(RI - RG)^2] / [n\,(n^2 - 1)/12]$

i=1

n = number of factors ranked = 14

$n\,(n^2 - 1)/12 = 14(14^2 - 1)/12 = 227.5$

$W = 11.34/227.5 = 0.050$

Evaluating a 95% significance level for W, the null hypothesis ($H0$ = set of ranking by Quantity Surveyors, Architects, and Civil Engineers) is unrelated. The alternative $H1$ are set of rankings that are related. $\lambda 2 = k(n-1)W$, where k is the number of groups being compared which in this case = 3 (i.e., the Quantity Surveyors, Architects, and Civil Engineers being compared). $\lambda 2 = 3(14-1)0.050 = 1.95$. From the chi-square distribution tables, the critical value = 1.95 since the observed $\lambda 2$ value = 11.070 is greater than 1.95; the null hypothesis $H0$ is rejected; and the alternative hypothesis $H1$ that the set of rankings by the above groups are related is accepted. This shows that there is high degree of agreement between Contractors, Architects, and Consultants on the advantages of using Precast Concrete suspended slabs and columns. The Kendall's concordance also identified robustness, speed of construction, insulation, and measures as the main advantages of using Precast Concrete.

From Table 3.7 and Figure 4.1, it can be observed that most of the correspondents agreed on utilizing Precast Concrete in the construction industry. The main reasons are that the Precast Concrete creates less wastage as compared to traditional methods which ultimately reduces the cost of construction. This speed, of course, can no longer be denied when comparing precast construction with traditional methods. The curing and other activities are done on site or in the factory. However, dimensional stability is a big challenge in the precast industry where the elements of precast are tight or embedded into each other. So, it must be precise within mms and allowed tolerance. Also, professionals are still unsure of concrete tolerance as this is related to dimensional

stability. For this reason, many professionals are neutral in their views. This tolerance affects the type of construction and other physical parameters related to it.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This chapter presents the results of Egyptian case studies, surveys, field data and field alignment interviews in comparison to local and global literature to evaluate the adoptability of Precast Concrete in Egyptian construction markets. Considering the available data, methodology and other parameters associated with this work particularly in Egypt, the following conclusions can be stated:

- Precast Concrete is an eminent constituent of construction in the recent decade. However, Egypt's socio-economic environment seems to show some resistance combined with a lack of awareness regarding its full-scale adoption in the heavy construction industry amidst technological advancements.
- Consultants prefer traditional to Precast Concrete in large scale projects due to the lack of supply of precast contractor services. There are only a few prominent precast contractors capable of delivering complex precast load bearing units leading to spiked increases in demand compared to supply leaving less room for competition and therefore precast prices also experience a spike in comparison to remainder of market.
- Elimination of consultancy supervision fees due to traditional construction is not enough to give Precast Concrete more competitive pricing considering consultancy fees in Egypt are considered low in comparison to global markets.
- Precast construction roughly possesses 5 percent of the load bearing construction market. Modular units such as fences, manholes and barricades are

the precast contractors' main source of revenue being easier and less complex to handle and deliver. Precast modular units make up 50 percent market share of fences, barricades, and other non-load bearing units.

- This approach has also shown a massive development in Saudi Arabia over the past decades, whereby Precast Concrete currently covers about 25% of the whole Saudi construction market making Saudi Arabia's ecosystem a blue print for the development of the Egyptian Precast Concrete market.
- By comparison, it was shown that up to 35% cost can be saved through Precast Concrete construction over traditional methods of construction.
- Comparing Case Study 1 to Case study 2 it is evident that more savings can be made in large complex structures, such as utility buildings, auditoriums, bridges and more standardized buildings in general compared to residential buildings where the cost benefits of PCC are evident but still not at it's peak compared to larger more standardized structures.
- Through comparison, the BOQ made for precast construction and the BOQ made by a Traditional contractor has a cost difference of up to 75%.
- The BOQ made for Precast Concrete construction has unit rate of 743.37 EGP/m^2, while the BOQ prepared by contractor was priced at 1300 EGP/$m^{2.}$ This stark difference could be explained by the smaller number of labors required, time efficiency and machinery utilization for Precast Concrete.
- The survey conducted from professionals has some interesting results. Almost all the professionals from three different regions have agreed up on the significant performance of Precast Concrete.

- 100 Percent agreement was seen by professionals believing the main barrier faced by PCC penetrating Egypt's market is due to a lack of knowledge and understanding of PCC Applications .
- Professionals from different parties including consultants, architects and contractors show a high degree of agreement on the advantages of using Precast Concrete suspended slabs and columns. This was proved by Kendal's coefficient.
- There is a strong level of agreement between professionals on the advantages of concrete regarding Precast Concrete's capability of providing swift construction ,delivering a high quality product and to not have a high level of tolerance on the construction site .Other items agreed on strongly by professionals was it's thermal insulation capabilities in saving lifetime operational costs .
- Moreover, the speedy construction, using precast for long spans structures such as bridges, reduction of noise and disturbance on site has a significant role in utilizing precast construction.
- Experts see that Precast Concrete will grow more quickly over the coming decades considering the sudden boom of construction seen from the New Capital. Consultants feedback to this growth mainly points towards Prestressed slabs and T Beams being the majority for precast market growth considering it is more easily adapted and understood by precast contractors.
- There is a strong level of agreement between professionals on the advantages of concrete regarding Precast Concrete's capability of providing swift construction ,delivering a high quality product and to not have a high level of tolerance on

the construction site .Other items agreed on strongly by professionals was it's thermal insulation capabilities being recognized .

5.2 RECOMMENDATIONS FOR FUTURE SCHOLARLY WORKS

- Precast Concrete has shown reduced lead times by up to 55 percent as noted by some contractors, further technical analysis should address lead time study and the cost time benefit offered by Precast Concrete Construction to completely cover all its attributes and capability within the Egyptian Market.
- It is seen from market trends in Egypt that the most growth and development within Precast Construction lies in the selling of the prestressed slabs family. Accounting for their versatility in being used with various other construction systems, further studies should be examined focusing on this segment of the precast market.
- There is a need to update current Egyptian building codes and incorporate provisions for most updated technological enhancements in Precast Concrete.
- The Precast Concrete market is believed to be emerging and promising, therefore significant measures need to be taken in educational, research work and application in order to achieve more durable and cost-effective means of applications for the Precast Concrete in Egypt. Both public, governmental, and private entities need to join and contribute to these efforts.
- Green Building protocols and LEED certified guidance have a key role to play in aligning Precast Concrete with the requirements of green and sustainable materials. Precast Concrete should be presented and promoted to be a prominent carbon footprint reducer.

- More precise data needs to be acquired from the market particularly data on completed precast projects to get better knowledge of market demand, trends and prices within the Egyptian Precast Market.
- Future studies should include development of the main pillars and points of focus in transforming the Egyptian precast market. The next steps to enhance the market needs to be examined in more detail to ensure customized addressing and tackling of barriers faced.
- More feedback is needed to be collected in understanding the perception of professionals on the drawbacks of construction joints received from Precast. Future works should be delved into with more details.
- The large difference in Precast Priced BOQs and Traditional Priced BOQs in Case Study 2 could involve more detailed drawings to accommodate more accurate pricing.
- A more precise background collected from the market needs to further clarify the main breakdowns involved in the pricing of BOQs by Precast contractors.
- Further examination needed on Temporary production precast casting beds made on site need to be covered considering transportation makes a large bulk of the Price of Precast Concrete .

5.3 RECOMMENDATIONS FOR APPLICATION

- Governmental bodies should play an active role in promoting Precast Concrete reducing tariffs and giving perks to precast contractors and tenderers. Precast gives a more environmentally friendly solution that should be exceled on by authoritarian parties.

- There are two main forms of support for the Egyptian precast market, both educational and fiscal. Considering support systems for this development is moving away from being mostly governmental on a global scale, other organizations including syndicates, technical societies and online platforms should play an active role in creating synergy to better expose local Egyptian Precast market sectors to foreign know-how. This foreign know-how could further provide marketing enhancements and more technical feasibility.
- More precast oriented coursework and studies need to be introduced and taught on an academic level by educational institutions. These institutions should educate student bodies to consider precast construction as a typical option for enhanced construction revering its numerous benefits and enhancements to the traditional construction process.
- Precast Concrete should be designed to make usage more practical and facilitate ease of installation. Follow-Up by contractors on updated execution and precast production methods could enhance the compatibility of precast to the local market.
- Establishment of Egyptian Precast Societies should be considered to enhance cohesion and more visibility on tackling the main challenges and opportunities offered by Precast.
- More detailed educational background is to be rolled out to scholarly students and practicing field engineers. For engineers and field personnel seminars and conventions could be done to promote and emphasize benefits of Precast .

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Appendix A

Google Forms Questionnaire Extract

Timestamp	Choose which Party You Represent Within Construction	Name (Optional)	Job title ?	Country ?	What do you think is the Percentage of Precast Construction in your region .	Main barriers you believe precast concrete faces in penetrating your market	Modest life cycle cost rate	Lessening of on-site leftover	Swiftness of construction	Eminence and Quality of Precast End Product	Robustness and Durability	Dimensional accuracy	Lessening of on-site working hours	Decrease of on-site action Noise and commotion	Insulation offered by Sandwich Panels	Negligible maintenance	Thermic inertia diminishes lifetime energy costs	Huge spans	Constricted Tolerance	Sound insulation
4/28/2021	Educational	Professor of Architecture & Urban Design		Egypt	5 to 15 percent	Lack of Know how or understanding of PC technology	4	5	4	5	3	2	3	2	3	2	3	1	1	3
4/28/2021	Contractor			Canada	15 to 30 percent	Lack of Know how or understanding of PC technology	4	5	5	5	4	3	2	3	3		4	2	2	4
5/2/2021	Vendor	Ahmad Sameh	Busness Development Mgr.	Saudi Arabia	15 to 30 percent	Lack of Know how or understanding of PC technology	4	4	4	4	4	5	3	4	5	1	2	2	4	1
5/2/2021	Contractor	Mariam	Consultant	Egypt	15 to 30 percent	Lack of Know how or understanding of PC technology	4	4	5	4	3	5	4	3	5	5	4	5	4	2
5/6/2021	Consultant		Architect	Egypt	16 to 30 percent	Lack of Know how or understanding of PC technology	5	5	4	5	4	2	2	2	4	4	3	1	5	3
5/16/2021	Consultant		Constractor	Egypt	17 to 30 percent	Lack of Know how or understanding of PC technology	5	4	3	4	4	4	4	3	2	4	2	4	2	3
6/12/2021	Consultant	Salah Ashour	Consultant	Egypt	18 to 30 percent	Lack of Know how or understanding of PC technology	4	4	4	5	5	3	3	5	4	2	4	2	4	2
6/15/2021	Contractor		Architect	Egypt	19 to 30 percent	Lack of Know how or understanding of PC technology	5	5	4	5	4	5	3	5	4	4	2	4		4
5/19/2021	Consultant		Constractor	Egypt	20 to 30 percent	Lack of Know how or understanding of PC technology	5	5	5	5	4	5	3		3	4	2	4	4	2
5/5/2021	Contractor		Architect	Egypt	21 to 30 percent	Lack of Know how or understanding of PC technology	4	4	4	5	5	2	4	5	4	1	2	2	3	4
5/25/2021	Consultant		Architect	Egypt	22 to 30 percent	Lack of Know how or understanding of PC technology	4	4	5	5	4	3	4	5	3	4	3	4	2	2
6/3/2021	Consultant		Constractor	Egypt	23 to 30 percent	Lack of Know how or understanding of PC technology	3	4	4	5	3	3	4	5	5	4	4	4	4	1
5/1/2021	Consultant		Consultant	Egypt	24 to 30 percent	Lack of Know how or understanding of PC technology	4	4	3	5	4	5	4	4	2	4	4	1	4	2
6/13/2021	Consultant		Consultant	Egypt	25 to 30 percent	Lack of Know how or understanding of PC technology	4	4	4	3	4	2	2	5	4	4	3	4	2	2

6/15/2021	Consultant		Consultant	Egypt	26 to 30 percent	Lack of Know how or understanding of PC technology	5	4	5	4	5	4		3	5	2	4	5	1	4
5/5/2021	Consultant	Sobhy Kamel	Consultant	Egypt	6 to 15 percent	Lack of Know how or understanding of PC technology	5	3	4		4	3	4	3	2	1	2	4	2	1
5/24/2021	Consultant		Consultant	Egypt	15 to 30 percent	Lack of Know how or understanding of PC technology	4	5	4	5	4	3	4	4	5	4	3	2	4	2
5/23/2021	Contractor		Consultant	Egypt	15 to 30 percent	Lack of Know how or understanding of PC technology	4	5	5	1	4	3	4	5	5	4	4	4	2	4
5/27/2021	Consultant		Consultant	Egypt	15 to 30 percent	Lack of Know how or understanding of PC technology	5	4	4	5	4	4	4	5	4	2	3	3	4	
6/10/2021	Consultant		Architect	Egypt	16 to 30 percent	Lack of Know how or understanding of PC technology	5	4	4	3	5	4	4	5	2	4	4	4	2	3
5/10/2021	Consultant		Constractor	Egypt	17 to 30 percent	Lack of Know how or understanding of PC technology	5	4	4	5	4	2	2	5	4	4	4	2	3	3
5/26/2021	Consultant	Rawya Adel	Consultant	Egypt	18 to 30 percent	Lack of Know how or understanding of PC technology	5	5	4	5	4	4	4	3	4	4	3	2	2	2
5/19/2021	Consultant		Architect	Egypt	19 to 30 percent	Lack of Know how or understanding of PC technology	4	3	2	5	3	5	4	3	3	1	4	4	4	2
5/10/2021	Consultant		Constractor	Egypt	20 to 30 percent	Lack of Know how or understanding of PC technology	4	4	5	5	4	5	4	2	4	4	2	4	4	1
5/7/2021	Contractor	Karim Nada	Constractor	Saudi Arabia	21 to 30 percent	Lack of Know how or understanding of PC technology	5	5	4	5	4	4	4	5	3	4	4	4	4	2
6/15/2021	Contractor		Constractor	Saudi Arabia	22 to 30 percent	Lack of Know how or understanding of PC technology	4	5	4	4	3	4	4	4	4	2	4	1	4	1
5/25/2021	Contractor	Mohamed Zaki	Constractor	Canada	23 to 30 percent	Lack of Know how or understanding of PC technology	5	5		5	4	2	4	4		4	3	4	2	4
5/17/2021	Contractor		Constractor	Canada	24 to 30 percent	Lack of Know how or understanding of PC technology	4	4	4	5	4	4	4	5	4	4	4	4	2	2
5/7/2021	Vendor		Constractor	Canada	25 to 30 percent	Lack of Know how or understanding of PC technology	5	5	3	5	4	5	5	2	5	4	3	2	4	5
6/10/2021	Vendor		Constractor	Canada	26 to 30 percent	Lack of Know how or understanding of PC technology	4	4	4	5	4	4	4	5	5	2	4	4	2	2

5/9/2021	Vendor		Consultant	Canada	7 to 15 percent	Lack of Know how or understanding of PC technology	4	4	4	5	2	4	4	5	2	4	4	4	4	2
5/5/2021	Vendor	Tamer Mahfouz	Architect	Canada	15 to 30 percent	Lack of Know how or understanding of PC technology		4	4	5	4	2	2	5	4	2	3	4	2	5
5/11/2021	Vendor		Constractor	Canada	15 to 30 percent	Lack of Know how or understanding of PC technology	5	4	5		3	4	4	2	1	4	4	2	2	2
6/10/2021	Vendor		Consultant	Canada	15 to 30 percent	Lack of Know how or understanding of PC technology	5	4	4	5	3	4	4	5	2	2	2	2	5	2
5/11/2021	Vendor		Architect	Canada	16 to 30 percent	Lack of Know how or understanding of PC technology	5		4	5	4	5	4	5	4	4	4	4	2	2
6/4/2021	Vendor		Constractor	Canada	17 to 30 percent	Lack of Know how or understanding of PC technology	4	5	3	5	5	4	4	3	2	5	4	4	2	5
5/7/2021	Consultant		Consultant	Canada	18 to 30 percent	Lack of Know how or understanding of PC technology	4	4	4	3	4	4	2	3	5	4	4	4	5	2
6/8/2021	Vendor		Consultant	Canada	19 to 30 percent	Lack of Know how or understanding of PC technology	5	5	4	3	4	4	4	3	2	2	4	5	4	2
5/7/2021	Contractor		Consultant	Saudi Arabia	20 to 30 percent	Lack of Know how or understanding of PC technology	4	4	5	5	3	2	4	2	4	4	2	2	2	1
6/7/2021	Contractor		Consultant	Saudi Arabia	21 to 30 percent	Lack of Know how or understanding of PC technology	4	5	4	5		4	2	5	4	5	4	2	2	2
5/20/2021	Vendor		Consultant	Saudi Arabia	22 to 30 percent	Lack of Know how or understanding of PC technology	5	4	5	5	4	5	3	5	1	3	3	2	3	3
5/2/2021	Consultant		Consultant	Saudi Arabia	23 to 30 percent	Lack of Know how or understanding of PC technology	5	3	4	3	5	3	4	2	2	4	4	2	2	2
5/31/2021	Vendor	Mohamed Salah	Architect	Saudi Arabia	24 to 30 percent	Lack of Know how or understanding of PC technology	4	4	5	5	4	4	3	5	4	2	3	4	2	2
5/13/2021	Contractor		Constractor	Saudi Arabia	25 to 30 percent	Lack of Know how or understanding of PC technology	4	4	4	5	5	2	4	2	5	4	4	5	5	4
5/9/2021	Contractor	Mohamed Raouf	Consultant	Saudi Arabia	26 to 30 percent	Lack of Know how or understanding of PC technology	4	4	5	4	3	5	2	3	1	4	3	2	2	1
5/4/2021	Vendor		Architect	Saudi Arabia	8 to 15 percent	Lack of Know how or understanding of PC technology	5	4	4	5	3	2	5	3	3	5	3	3	4	4

5/5/2021	Vendor		Architect	Saudi Arabia	9 to 15 percent	Lack of Know how or understanding of PC technology	4	4	5	4	4		4	5	2	4	4	5	3	5