T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

QUALITY MANAGEMENT IN THE PRODUCTION OF PRECAST CONCRETE UNITS IN IRAQ

MASTER'S THESIS

Talib Abed Faihan Hammadi AL -DULAIMI

Engineering Management Department

Engineering Management Master in English Program

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Thesis Advisor: Assoc. Prof. Dr. Redvan GHASEMLOUNIA

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İSTANBUL GEDİK ÜNİVERSİTESİ

LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

Yüksek Lisans Tez Onay Belgesi

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DEDICATION

I would like to dedicate this humble Thesis to;

My dear father and mother, whom walked with me from the beginning of the road up to this moment, they support me for every success.

My dear professors at Gedik University

My kind wife, who supported me in the scientific progress that I reached.

My children, the flower of my life and to all friends.

PREFACE

Praise be to Allah, Lord of the Worlds, and my sincere thanks and appreciation to my supervisor Assist. Prof. Dr. (Redvan Ghasemlounia) for his help, direction and his scientific observations, which gave this study a beautiful shape, and I am proud that he agreed to be a supervisor of my thesis.

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March 2023 Talib Abed Faihan Hammadi AL -DULAIMI

TABLE OF CONTENT

Page

LIST OF TABLES

Page

LIST OF FIGURE

<u>Page</u>

QUALITY MANAGEMENT IN THE PRODUCTION OF PRECAST CONCRETE UNITS IN IRAQ

ABSTRACT

A basic component for the manufacture of pre -casting is quality control. For any project that includes molten manufacturing components of pre -casting, the effective quality system is essential. The quality control system used in the pre -casting industry is examined in the thesis sheet. A pre -produced factory has been prepared to produce a lot of walls, panels, columns, beams and other structural components.

Before casting manufacturing techniques are reviewed with regard to the control plan control measures. Standard related tests and therapeutic measures are emphasized on the site. This research evaluates important topics related to the productivity and quality of pre -production. This includes the caliber of the workforce and maintenance, both of which may have an impact on the effectiveness of the quality system. The factory productivity and workflow must also be improved; Thus, several factors should be taken into account.

This research discussed weakness in quality management in pre -concrete plants in Iraq, in addition to discussing many important issues such as obtaining different cement mixtures in resisting the same type of element.

A set of solutions were suggested to obtain similar mixtures in the properties by relying on the descriptions of raw materials and components in each of the elements industry. In addition to the problems of transferring their composition

The study also aims to know the impact of quality management on production in companies and factories for pre -casting concrete in Iraq and the need to apply quality standards in order to obtain good equivalent production for international companies. The study sample consisted of three institutions working in the production of pre -casting concrete units. A random sample was chosen for workers in those institutions, and the samples were 274 employers, engineers, officials and workers, while the form of the questionnaire was distributed electronically. The descriptive analytical approach was used to explain and analyze the data using the Likert scale.

As a result of the study (Al -Burhan Factory, the modern Duhok company for the pre -casting factory and Rasan Pre-casting) made a set of improvements made on its workflow plans to produce more high -quality elements.

Keywords*: Civil engineering, Quality management, Precast concrete, Construction*

IRAK'TA PREKAST BETON BİRİMLERİNİN ÜRETİMİNDE KALİTE YÖNETİMİ

ÖZET

Ön döküm üretimi için temel bir bileşen kalite kontroldür. Ön dökümün erimiş üretim bileşenlerini içeren herhangi bir proje için etkili kalite sistemi esastır. Tez çalışmasında ön döküm endüstrisinde kullanılan kalite kontrol sistemi incelenmektedir. Çok sayıda duvar, panel, kolon, kiriş ve diğer yapısal bileşenleri üretmek için önceden üretilmiş bir fabrika hazırlanmıştır.

Dökümden önce üretim teknikleri, kontrol planı kontrol önlemleri açısından gözden geçirilir. Sitede standartla ilgili testler ve terapötik önlemler vurgulanmaktadır. Bu araştırma, üretim öncesi üretkenlik ve kalite ile ilgili önemli konuları değerlendirmektedir. Bu, her ikisi de kalite sisteminin etkinliği üzerinde etkili olabilecek işgücünün kalitesini ve bakımı içerir. Fabrika üretkenliği ve iş akışı da iyileştirilmelidir; Bu nedenle, birkaç faktör dikkate alınmalıdır.

Bu araştırma, Irak'taki ön beton tesislerinde kalite yönetimindeki zayıflığı tartışırken, aynı tür elemente karşı farklı çimento karışımları elde etmek gibi birçok önemli konuyu tartıştı.

Her bir element endüstrisindeki hammadde ve bileşenlerin açıklamalarına dayanarak, özelliklerde benzer karışımlar elde etmek için bir dizi çözüm önerilmiştir. Bileşimlerini aktarma sorunlarına ek olarak

Çalışma aynı zamanda Irak'ta ön döküm betonu için şirket ve fabrikalarda kalite yönetiminin üretim üzerindeki etkisini ve uluslararası şirketler için iyi eşdeğer üretim elde etmek için kalite standartlarını uygulama ihtiyacını bilmeyi amaçlamaktadır. Araştırmanın örneklemini, ön dökümlü beton ünitelerin üretiminde çalışan üç kurum oluşturmuştur. Bu kurumlarda çalışan işçilerden tesadüfi bir örneklem seçilmiş ve örneklemini 274 işveren, mühendis, memur ve işçi oluşturmuş, anket formu elektronik ortamda dağıtılmıştır. Likert ölçeği kullanılarak verilerin açıklanması ve analiz edilmesinde betimleyici analitik yaklaşım kullanılmıştır.

Çalışma sonucunda (Al-Burhan Fabrikası, ön döküm fabrikası ve Rasan Precasting için modern duhok şirketi) daha yüksek kaliteli elemanlar üretmek için iş akışı planlarında bir dizi iyileştirme yaptı.

Anahtar Kelimeler: *İnşaat mühendisliği, Kalite yönetimi, Prekast beton, İnşaat*

1. INTRODUCTION

1.1 Background

The brilliant civil engineer John Alexander Brodie devised the idea of prefabricated panels and it became popular in England and Liverpool at the time, depending on the tram stables at Walton, Liverpool in 1906.

At the time, this idea was not adopted in Britain, despite its spread to Eastern Europe and Scandinavia.

In the United States of America, the use of pre-casting concrete has evolved into two main substrates: the pre-casting elements used in underground elements and the pre-stress elements used in the structural models of bridges and buildings.

In Australia, between 1917 and 1932, Lino South Wales used pre-cast concrete for its stations and similar buildings. Coverage panels and structural elements were also used in North Dakota, Minnesota, where the building of air and electricity utilities and pre-installed panels were moved over 800 miles to the Bakken oil fields and assembled by three workers in record time (Mark et al. 2021).

On-site concrete casting provides a number of benefits over precasting (Reichenbach and Kromoser 2021). Such technologies are widely employed to speed up construction operations since they are commonly used to create modular and standardized building elements (Emelyanovich, Koval, and Kokorin 2019). Before being installed in their final location, the concrete members are normally cast and cured away from the construction site. As a consequence, precast concrete production may continue regardless of the weather or season, resulting in much higher job efficiency in the winter. Furthermore, the quality standards and craftsmanship of concrete-making materials and workmanship are generally superior to those of in-situ concrete. It should also be mentioned that, due to the bulk manufacturing of the members, precast construction may reduce construction costs. Despite the fact that developing countries such as Iraq were late to adopt this technology, precast concrete element production has increased considerably in a short period of time, and the volume of precast production is expected to continue to rise in the future. Because precast systems are mostly employed in load-bearing portions of construction, their quality is crucial. Quality management is one of the most important requirements for successful competitiveness in the global construction business. The quality management system should be implemented in a holistic manner, taking into account both the production and cooperative processes.

Orders and deliveries for steel, cement, and aggregates as well as for semi-finished products and parts required right on the assembly line, like release and anti-adhesive agents, are among the cooperation activities that are critical to the plant's operation. When it comes to creating and maintaining effective ordering methods, there are many manufacturers and suppliers to choose from, as well as a wide range of physical and technical qualities of the items available. There are numerous and difficult-to-predict connections connected to the utilization of different components in a particular production series, which might result in products of possibly worse quality than planned.

1.2 Research Questions

The following questions are presented in order to fulfill the research's goal:

- What is the impact of precast concrete on the Iraqi construction market?
- What is the effect of quality management on the final outcome of precast element fabrication?
- How effective is the current use of precast construction in Iraq?

1.3 Purpose of the Study

By shining a light on the quality management of precast concrete in Iraq and by noting the importance of economic factors in construction processes, this research aims to:

- An effective method was provided to increase efficiency levels by discussing production planning, which has a significant impact on the performance of the manufacturing process.

- Find out how to put building construction on the proper track to attain global advancements in managing the precast construction process.
- Identify the best solution for solving problems that appear at the elements' contact points.

1.4 Significance of the Study

Precast concrete elements are increasingly used in installations such as bridges and multi-story buildings. These elements may be exposed to partial or total failure according to some errors in manufacturing or transportation to the workplace, which leads to catastrophic consequences. This research will also provide new information on the impact of quality management on the efficiency of precast factories in Iraq. This information can be used to develop guidelines for modern and secure designs in this factory. In addition, this research will contribute to addressing many of the important problems that arise when installing and manufacturing precast elements.

1.5 Problem Statement

Quality management in Iraq doesn’t have the required popularity, and there is some weakness in using it in the construction sector in Iraq. So, this research is to clarify the effects of using quality management in precast construction and how it’s affected the quality of the final products. By proving the advantages of quality management of precast concrete and how it affects the final outcomes, it will encourage more companies to use it, and the Iraqi construction market will be on the right track that most advanced countries take all over the world.

1.6 Methodology

This research will depend on non-quantitative data to conduct a comparison between the precast concrete elements factories that use quality management in Iraq and the precast factories that work throughout the world, in addition to some qualitative data to help us investigate the actual techniques of the factory and the quality of their outcome.

- Surveys and questionnaires were depended to collect our data.
- Factory performance was measured in the Iraqi construction market

- Many big companies were chosen to see if the usage of precast elements has become popular among companies.
- SPSS program was used to analyze results.

The work employed information analysis and generalization techniques as well.

1.7 Limitations and Scope

The scope of the work includes verification of quality management systems used at the precast factories and assessment of their effectiveness.

This study is intended to study ways of quality management in precast concrete plants in Iraq.

1.8 Thesis Outline

Chapter 1: this chapter focused on providing an introduction to the variables of this study

Chapter 2: This chapter deals with quality management in the construction sector and focuses on quality management in prefabricated concrete plants, like WEB-BASED quality control.

Chapter 3: This chapter describe the methodology used for the preparation of a survey involving precast concrete plants and provide future findings and recommendations.

And this chapter also focused on Concluding Future Research Work, which should be conducted, that would lead to codified recommendations or implementation, are presented.

2. LITERATURE REVIEW

2.1 Pre-cast Concrete

Pouring concrete into a reusable template creates precast concrete, or "form, which is then processed in a controlled setting before being brought to the job site and placed into position. Contrarily, cast concrete is poured into site-specific forms and cured there. Cast concrete, on the other hand, is poured into site-specific shapes and treated there. Pre-casting stone differs from precast concrete in that it uses soft debris in the mix to give the end product a rock or natural stone appearance. Expanded polystyrene has recently been employed as the core of prefabricated wall panels. It is lighter and provides superior thermal isolation.

The external and internal walls are made of ready-mixed concrete. Because precast concrete is created in a controlled setting, factory personnel have the opportunity to treat it appropriately and keep an eye on it constantly (often referred to as a precast concrete plant) (often referred to as a precast concrete plant). The advantages of using precast concrete technology over site-casting are numerous. The ability to produce precast concrete on the ground level contributes to project safety, which helps to ensure project safety. A precast plant has more control over the quality of materials and manufacture than a building site. When comparing the cost per unit of concrete casting, models used in a precast factory can be reused hundreds to thousands of times before needing to be replaced, making them often less expensive than on-site casting.

Precast concrete configuration systems for architectural purposes come in a variety of sizes, functions, and prices. Precast architectural panels, some of which can be pre-stressed concrete structural elements, are also used to cover all or part of a building's facade or stand-alone walls used to coordinate gardens, sound insulation, and security barriers. Precast concrete units are used in rainwater drainage, water pipes, sewage, and tunnels(Bachmann and Steinle 2012).

Many surface trim options are available to complete the appearance of the four precast wallpaper kinds: sandwich, gypsum-covered sandwich, inner layer, and livery panels. Although additional colors can be applied with dyes or paints, standard cement is white or grey. The appearance and feel of concrete surfaces can also be influenced by the color and size of the rubble. The look of precast concrete molds is influenced by their shape and surface: The mold can be constructed of wood, steel, plastic, rubber, or fiberglass, and each material has its own look.

Figure 2.1: Woolworth Building Under Construction in 1912

Figure 2.2: Burg Khalifa, the World’s Tallest Building

2.1.1 Historical background

To construct their complicated network of canals and tunnels, ancient Roman architects employed concrete and quickly poured materials into templates. Today, a wide range of architectural and structural applications, ranging from individual components to entire building systems, utilize the pre-casting method.

In Liverpool, England, prefabricated buildings were first employed in the modern era, in 1905. John Alexander Brody, a city engineer, invented this operation. The tram stables in Walton, Liverpool, were constructed in 1906. In the UK, people did not like the idea very much. However, they have received a lot of support from people all around the world, particularly in Central and Eastern Europe and Scandinavia.

In the United-States, pre-casting and concrete have been divided into two sub-industries., each having a major labor organization. The precast concrete business is represented by the National Precast Concrete Association, which focuses on utility, underground, and other non-stress products (NPCA). Pre-stressed concrete components and other precast concrete components used in above-ground constructions including buildings, parking garages, and bridges are the primary focus of the pre-casting concrete business. The old Concrete Casting/Pre-Stress Institute is the industry's primary representative (PCI) (BMTPC 2019).

In Australia, the Government Railways of New South Wales used precast concrete construction extensively for their stations and other structures. They built 145 of these structures between 1917 and 1932. The entire structure, including the slab panels and structural parts, can be made of precast concrete. Pre-casting enables shops and offices to be built faster and with less labor.

For example, Jim Bridger's building in Williston, North Dakota, was ready for Minnesota, with air, electrical, plumbing and fiber optic equipment already installed in the building panels. The panels were transported more than 800 miles to the Bakken oil fields, and the commercial building was assembled as quickly as possible by three men. The structure has about 40,000 square feet of retail and office space. This system was completely developed in Minnesota.

2.1.2 The Iraqi construction markets

The nature of the market

After several years of contraction, Iraq's construction industry rebounded in 2019, with output increasing by 25% in real terms. The recovery in crude oil prices, as well as the government's investment in crude oil and natural gas projects, as well as water and sewage infrastructure, will keep the growth momentum going during the period (2019–2023). Furthermore, over the period, the government's goal of rehabilitating war-affected transportation infrastructure and housing in the country is to support the industry's output.

In July 2019, the government spent 2.6 trillion Iraqi dinars ($ 2.2 billion) to renovate the country's damaged infrastructure. In early 2018, the government announced plans to bring over 118.4 trillion Iraqi dinars (US $ 100 billion) by 2027 through foreign investment to rebuild the country's transport and energy infrastructure.

In real terms, the compound annual growth rate of the industry (CAGR) was 15.75 per cent compared to 25.89 per cent over the period (2018-2014). As a result, the construction industry is expected to grow from US $ 9.2 billion in 2018 to US $ 19.2 billion in 2023, based on steady US dollars from 2017.

However, there are dangers involved with the industry in terms of prospects. If oil prices do not recover sufficiently, the government's situation will be difficult, and it will face challenges in continuing to drive infrastructure investment. If terrorist attacks in the western and Northern provinces continue, investor confidence will be harmed, and future growth will be damaged over the forecast period

Residential construction was the main market in the sector, accounting for 42.6 percent of the industry's total value in 2018. The increased demand for housing in the parts liberated by ISIS from the country is likely to lead to market expansion.

While energy and utility construction ranked second, accounting for 18.58% of the total industrial production, followed by infrastructure construction, with a percentage almost equal to its predecessor, estimated at 18.57%, then commercial construction, with a rate of 10.5%, and industrial construction, with a rate of 6.3%, followed by building institutions with a small percentage of 3.5%

Iraq's total construction project pipeline is worth IQD251.4 trillion (US $211.6 billion), which includes all massive projects worth more than US $25 million. As of September 2019, the pipeline, which contains all projects from pre-planning to completion, is highly geared toward delayed projects, with 81.50% of the pipeline price in the pre-execution and completion stages.

However, over the projected period (2018–2022), the industry is predicted to recover and flourish, owing to the government's attempts to revive the economy and rebuild the infrastructure that was damaged during the ISIS fight.

Iraq is making an enormous attempt to expand production while waiting for international investment. Iraq is a region where many industrialized economies compete for a portion of the projects and tender opportunities. Iraq welcomes international enterprises and investors for school, hospital, road, housing, and infrastructure improvements, according to the Iraqi Ministry of Construction and Housing.

Iraq is undergoing restructuring, has significant potential, and provides a favorable market for international investors. The building elements, machinery manufacturing, and requirements of the business concern, particularly cement, are expected to remain dynamic in the coming years as a result of the restructuring process. Iraq's Ministry of Planning estimates that the country will require $100 billion in rebuilding. New investors and job possibilities have been successfully developed because of a business-friendly environment, duty-free access, and competitive labor prices.

The obstacles that face construction in Iraq

1. . There are many potential problems in the life of a construction project. The project manager is responsible for managing the construction site in a correct, safe, timely manner and within the budget. This can be a difficult request or not.

2. The primary goal of construction is to complete the project on schedule and under budget while maintaining a high level of quality. A delay is a time overrun that occurs after a contract's completion date has passed, or after the parties have agreed on a delivery date for a project.

3. In particular, the problem of construction delays is a global phenomenon. When the causes of the delays are identified, as well as their impact on the project's completion, they can be mitigated.

4. Iraq's construction industry faces numerous challenges, particularly because it is a developing country affected by global social and economic conditions that will be reflected in the Iraqi industrial reality, whether in construction or other industries. We will discuss the challenges that Iraqi construction projects face in terms of optimal implementation and potential solutions to these issues.

5. Terrorism:

Suicides, bombings, and explosives have become a regular occurrence in Iraq. As a result, the threat of terrorism confronted the Iraqi construction industry with distinct and unusual obstacles not experienced in other countries. These difficulties may have a significant influence on construction projects. The purpose of the research is to look at the impact of terrorist acts on the construction sector and to assess how much influence terrorism has on construction projects in terms of cost, schedule, and quality.

The investigations used quantitative and qualitative data collection methods, including questionnaire surveys and interviews, as well as historical data, and focused on projects in the Diyala Governorate that have been the subject of terrorist attacks (Ismail and Alhamdany 2021).

Terrorism is regarded as one of the most significant and dangerous foreign threats, particularly in nations such as Iraq, where skirmishes and battles are common. As a result, it is vital for the construction industry to efficiently allocate resources and collaborate in order to assist in the nation's security against future attacks.

Terrorism is defined as the illegal use of force and violence against people or property to intimidate or coerce governments, citizens or their elements to achieve political or social goals.

It is also characterized as a violent act when the psychological consequences outweigh the strictly physical outcome.

Terrorism has become a major issue in global politics, posing a threat to construction and other industries. As a result, the construction industry has significant hurdles in responding to the threat of terrorism. The fear of terrorist strikes against civilian and military infrastructure has grown because of a wide spectrum of terrorist assaults against government infrastructure, as well as private and commercial facilities.

As a result, for the past two decades, political economy studies have been attempting to address the topic of terrorism and counterterrorism. The inevitable repercussions of tourist events have become a serious source of worry.

Both the losses and the potential of terrorism incidents cost a lot of money. Businesses will need more protection and time. As a result, growth slows in countries where terrorism is a serious concern. It is self-evident that as a country's terrorist risk rises, foreign direct investment in that country declines significantly.

All building sector projects have a negative link with an increase in terrorist attacks, resulting in the construction industry's poor economic performance. The impact of terrorism has resulted in a massive increase in the construction industry's workload. Furthermore, projects may be canceled because the owner prefers to invest in more secure areas.

Violence and terrorism have had a significant impact on school buildings. Because of building damage, education has been disrupted for a long time. Terrorist assaults have also been launched against communications projects. It has been reported on bridges owned by the Ministry of Construction and Housing.

In terms of cost, the findings revealed that just four schools lost $1,935,000, three communications projects lost $1,525,000, and five bridges lost $19,200,000. When those expenses are added together, the loss totals 22660000.

This number is a simple indicator of the total cost because we are talking about a small number of facilities that some have succeeded in comprehensively studying, but, of course, in the presence of terrorism and wars, we will not be able to accurately calculate the cost of what may be destroyed by these terrorist attacks.

The duration of the disruption might be up to 6 years. In other words, almost 4 million people were denied access to services. Bridges provide a critical function that cannot be delayed. As a result, these people had to choose another option, which could cost them more money or perhaps their lives.

To summarize, terrorism in Iraq has risen tremendously. Terrorist incidents have a significant impact on the building business. These attacks resulted in cost overruns, service and construction delays, and poor quality. As a result of this threat, designers should take it into account while creating structural designs and features that will help mitigate the loss from attacks.

6. Safety and Health

Another key issue in the sector is safety and health concerns, as well as how a shortage of appropriately skilled personnel can have significant economic ramifications, such as a negative industry image and significant financial loss. Employees face several risks on the building site, the most serious of which is the chance of falling, as well as

- Transportation mishaps.
- Trips, falls and slips.
- Being exposed to potentially dangerous substances or conditions.
- Deaths because of flames and explosions.

In addition, there are a number of other construction-related concerns that might result in harm or injury:

- A lack of communication and a lack of clarity in training.
- Some objects that cause harm to workers due to falling or car accidents on-site
- Electrocution, which is usually caused by contact with electrical lines or inappropriate equipment use, has been linked to a lack of training.

Being wedged between objects is a risk due to unsafe access and egress, spoil-pile placement, failure to evaluate trench and protective systems, or no protective systems in place.

According to the studies, younger workers (ages 16–24) had a 37% higher risk of occupational injury than older workers did.

From ongoing on-site training to state-of-the-art PPE and monthly compliance assessments, there are many areas of health and safety compliance that need to be enforced. Many contractors perform these steps manually rather than using an automated system. This means that regular maintenance training and checks are ignored, leaving your business vulnerable to costly mistakes. For example, regulators can impose heavy penalties on companies that fail to renew required health and safety certifications.

2.2 Quality Management

Quality management refers to the actions of leadership in relation to quality.

According to the definition, it is the total of all operational processes, such as strategy, organization, execution, inspection, supervision, auditing, and others, aimed at ensuring that product quality matches changing quality standards.

A project management plan is a management strategy for organizing and overseeing a project's performance or execution. Four to five stages and a process control are common components of project management. The same fundamental project management procedures will be followed, regardless of the technique or language utilized.

The following are the main process groups:

- Beginning.
- Organization and progression.
- Execution or production.
- Controlling and monitoring.
- Putting it all together.

Both technical and management procedures are required for such a huge development. The technical procedure is a procedure that is focused on the final product. It describes the operations and techniques that will be used to create the product. It provides a design as well as strategies for carrying out each phase’s operations.

The management method is a project-based method that describes the tasks and strategies for coordinating, encouraging, and managing the job.

For those who will be keeping track of progress to ensure that the work is delivered on time, on budget, and to a satisfactory standard, in practice, it is hard to tell one type of technique from another (Halvorsen n.d.).

During the project, their tasks will cross and connect. However, during the course of a project, the technical and management processes tend to merge into a specific project procedure.

Quality, in a broader sense, refers to doing the proper thing for your client, staff, funders, company, and the workplace in which we all function. It is also about optimizing effectiveness and satisfying customers while guarding our team of people from the damage caused by poor procedures and thoughtless supervision, from the individual employee to the whole planet.

Every institution, from business and industry to medical authorities, should strive for quality.

By providing customers with the goods or services they need, producers may increase customer happiness and outperform their expectations, which boosts sales for the producer. The cost of not using is far greater, with lost business, missed opportunities, brand damage, and recalls due to manufacturing and design flaws. It is expensive to assure performance by adding benefits that customers want while preserving consistency and reliability with each iteration.

Creating elements that are devoid of flaws and faults Defective products or services necessitate revision or, if they reach the market, lead to expensive recalls and consumer unhappiness, all of which cost the firm money, time, and brand honesty. Defects discovered later in the product development process are significantly more expensive than those discovered early.

There is an important organization related to quality management, which is ISO (International Organization for Standardization). It is the major publisher and developer of international standards in the world. The International Organization for Standardization (ISO) is a non-governmental institution that serves as a link between the public and private sectors. On the one hand, several of its member institutes are either required by their governments or are part of their countries' governmental structures. Other members, on the other hand, have their origins solely in the private sector, having been founded via national industry collaborations. As a result, ISO enables an agreement to be achieved on solutions that fulfill both corporate and societal goals.

One of the organization's standards is ISO9001, an internationally recognized quality management guideline. The ISO9001 standard pertains to the procedures that a company uses to generate and govern the products and services it provides. It calls for rigorous activity control to ensure that consumers' demands and expectations are met. It was created with the goal of being applicable to nearly any product or service produced by any process, anywhere else on the globe.

Another standard is the ISO 9000 family of standards, which represents an international consensus on effective quality management methods. It includes both quality management system standards and guidelines, as well as associated standards.

A quality management system will encourage employees by outlining critical roles and duties.

Savings can be made by increasing productivity and efficiency, as flaws in products or services will be identified. Improvements can be made as a result of this.

As a result, there is less loss, ineffective or disapproved work, and fewer issues. Clients will note that purchases are consistently fulfilled, on schedule, and with accuracy. This may enhance the variety of options available on the market(Yee Weng Cheong, Hon Pui Kwan, and Agus Dwi Hariyanto 2005).

A business is doomed if its clients are dissatisfied. Customers must be satisfied, so the organization must fulfill their wants. The ISO 9001:2008 standard provides a tried-and-true framework for systematically controlling an organization's quality.

Procedures, as then they continuously provide a product that meets the needs of customers.

The organization also must set quality management system standards; record them, apply and maintain them, and continually improve their performance.

Therefore. Organizations should do the following:

- Determine the order and interaction of the procedures required for the Quality Management System and its implementation in the organization.

- Determine the essential criteria and procedures to assure the efficient operation and control of these processes.
- The availability of the necessary resources and information to support their operation and monitoring must be ensured.
- Analyze, monitor, measure these processes.
- Implement the necessary procedures to attain the desired results and to improve these processes on a continuous basis.

Organizations should manage these procedures in accordance with industry best practices. We must remember that quality is a mindset, not a program or self-control. It does not cease once you have accomplished a specific goal.

Quality must be embodied in the organization as a quality culture in which everyone feels and appreciates the importance of adhering to its ideals.

Quality is a never-ending quest for improvement with no end in sight.

2.2.1 Quality management and precast features

Builders and planners have long recognized the low acquisition costs, low maintenance requirements, and long life of precast concrete elements. This is reflected in the increasing market share of precast concrete in the construction industry, from zero in 1950 to over 55% today. Products in this category are also offered as finished products. Therefore, a manufacturer's quality control program should include verification of the quality of all components of concrete products, including control testing of each component.

The following study examines the concept of Quality Assurance and Quality Control for Indian Precast Concrete Construction Products confined to the Pune Region (QCP) and Quality Assurance Plan (QA Plan).

Researcher examines the role of precast technology in the construction industry, analyze how quality is achieved at both stages, and find solutions or methods to overcome or minimize that gap.

This study provides an understanding of his QCP and QAP processes in precast construction technology and the application of this technology.

Process strength testing requires the manufacturer time to strip the concrete, pre-stress it, and lift the concrete off the casting bed. Other in-process tests such as water-cement ratio measurements and air content tests are required to ensure proper strength, appearance and durability. Acceptance testing and inspection by the buyer should include an audit of the supplier's quality control program and sample testing of each component (Hariyanto, 2014).

Understanding of the concept of precast technology in an urban context and its importance in relation to construction quality with his QA and QC program of various elements. The following study examines the concept of Quality Assurance and Quality Control for Indian Precast Concrete Construction Products confined to the Pune Region (QCP) and Quality Assurance Plan (QA Plan).

As a result of the case study, we observe the following:

1. The results found are always positive.

2. His four stages for quality control play a key role in achieving final quality.

3. Very little scrap can be ignored. So for every 1000 Elements manufactured, will be scrap.

4. The policy chosen to save time is proper planning of assembly and manufacturing processes.

5. Special systems such as his Vollert system for element manufacturing and steam curing of hollow core slabs increase work efficiency, time and quality.

6. This technology is certainly beneficial for the construction sector. must be used by different users. Examples: contractors, engineers, architects, etc.

7. Future impact is minimized as each aspect of consideration is covered prior to execution.

Factors for achieving QA and QC

1. Good teamwork.

2. Good coordination between different departments.

3. Well-trained people for verification.

4. Use of highly qualified equipment according to IS standards.

5. Follow the process adopted and follow it Regular meetings to discuss issues.

The overall quality of a project may be determined by the actions involved in the project from beginning to end. Each step in between these two stages must be completed to the highest possible standard.

The waste of resources is reduced when a high-quality construction method is used. This also allows for easy team movement while staying within budget.

Quality Control's purpose is to make sure that almost any work is completed in line with the standards. The key goals are as follows:

- To monitor the performance of and manage the production process at all stages.
- To prevent errors from becoming a costly and detrimental occurrence.
- To achieve the highest feasible level of precast product quality as required by applicable standards and specifications.
- To ensure that the precast products' quality meets the desired level in terms of usefulness, durability, and appearance through documentation.
- To draw attention to flaws that were not found throughout the manufacturing and quality control processes.

Some of the most significant features of quality control are listed below.

- Quality assurance and quality control initiatives are a priority for management.
- Qualified professionals are required for all stages of the design and production.
- Inspection and evaluation of different materials being used.
- Shop drawings that are clear and thorough.
- All embedded elements must be properly positioned.
- Processing, storing, delivering, and installing precast members according to proper processes.

- Production documentation must be complete and correct.

The following items are included in the quality control process for precast concrete products in general:

- Materials identification, evaluation, checking, and approval
- Prior to casting,
- Element dimensions, reinforcement steel, inserts, other included materials, openings, blackouts, and so on are all checked.
- Concrete mix inspection and testing, cube tests, and final test results.
- Concrete batching, combining, conveying, putting, compacting, completing, and curing are all subject to regular inspection.
- Final pre-shipment inspections of completed precast products, including measurements, bowing, blackouts, and completing.
- All equipment, workplace conditions, the environment, and other factors that may have an impact on the product in general are monitored.

Through the following actions, the quality control department is in charge of the production area and location quality control of precast parts:

- Raw material inspection.
- Fabrication of precast molds is inspected.
- Inspection of the reinforcement and the ready-to-cast mold.
- Inspection of precast pieces throughout the manufacturing process.
- Precast elements are subjected to a final examination.
- Precast elements are allowed to cure for a period of time.
- Precast concrete members are subjected to two layers of quality assurance and control.
- Program for quality control and assurance.

Despite the quality control system in place, some areas of concern have been discovered. These arose mostly as a result of casting process project failures and poor maintenance.

An objective inspector must be hired to ensure rigorous execution of the quality system in precast production.

Various quality control methods are in place to maintain quality throughout the manufacturing process. Scheduled testing on materials and parts, dimensional inspections, ocular inspections, and other procedures are among them.

Quality control inspectors play a crucial part on-site by evaluating daily quality operations, while the engineer keeps informed on progress and makes suggestions for improvement.

A review of the quality control system reveals that it is adequate but that some parts may be improved. These factors include the remedial flow of work, equipment upkeep, and employee attitudes. Maintaining high quality will probably be among the most important issues when it comes to cost and worker skill level.

Precast production is not complete without quality control. An effective quality system is essential in any project involving the mass manufacture of precast components.

For all of the reasons stated above, the quality control system's efficacy becomes extremely important.

2.2.2 Web-based quality control

The construction business is constantly renewing itself thanks to technological advancements, and it is always looking for other ways to enhance construction productivity.

Many European countries have made substantial use of precast concrete systems. There are numerous advantages to using precast technology. It was evaluated by comparing it to concrete casting on-site. Because they are commonly utilized to speed up construction steps, they are frequently employed to speed up construction steps. utilized in the manufacture of modular and uniform construction components (Arslan et al. 2003).

Typically, concrete components are cast and then shipped away from the construction site in a safe environment. They are delivered to their final destination.

As a result, precast concrete is used. Production can go on regardless of the weather or the season, and as a result, in cold weather, task efficiency is significantly boosted.

Moreover, the quality standards and workmanship of concrete-making materials and workmanship are usually superior to those of in-situ concrete. It should also be noted that precast construction has the potential to lower construction costs. Incurred as a result of the members' mass manufacturing of concrete that has been precast. Aside from the fact that this technology is still in its early stages of development, the manufacture of precast concrete pieces has increased in many nations.

The quantity of precast production has expanded dramatically in a short period of time. In the future, it is predicted to be higher. According to the Precast Concrete Association, production reached 1,185,787 m3 towards the end of the year. In 2003, there were 106 businesses.

Because the elements are used mostly in loadbearing areas of the structures, the quality of precast systems is critical.

The precast building system is a strategic way to run a business in any industry, including the precast building industry. These devices make it easier and more precise to control the quality of precast concrete technologies. This study suggests a web-based system that evolves over time.

Quality control processes save time and money by reducing paper labor in paperwork. Taking corrective action in production and shipping saves time and money. With the steps of the erection of precast concrete components, a rigorous methodology should be built for the fabrication, transportation, and construction of these precast parts.

Quality control is defined in a variety of ways. Ishikawa (1985) claims that it is a system for trying to integrate quality development that is effective into groups in an organization's maintenance and improvement initiatives to enable more cost-effective manufacturing and service that leads to full client satisfaction.

Modeling, combining, putting, compacting, curing, and testing are all aspects of the precast concrete manufacturing process. The creation of a mix should be done with care and attention to detail.

Because the quality of the concrete is important, the appropriate norms and specifications must be followed. Generally, it is determined by the right combination of substances.

The strength properties test is commonly carried out on the specimens' values compared to the design specifications. Besides, the findings of laboratory tests performed on recently cast specimens should be included.

Before creating a new mix design, it should be examined. A proper curing procedure should be applied after the concrete has been cast, and steam curing is the preferred method. This is a common way of supplying moisture and heat at the same time. Finally, the items are extracted from the molds after proper curing. Then it is transported to the job site via the stockyard. The transport of precast members from the manufacturing factory to the construction site is a significant step, as the units may be damaged as a result of forces encountered during the process.

As a result, the precast should be carefully loaded onto cars to avoid unwanted surprises.

Stresses that are not taken into account in the design of the system. members of the structure. Lifting equipment must be appropriate for the job. so that the precast units can be easily lifted and placed.

The final step in the precast construction process is erection. According to Elliott (1996), crane accessibility, structural forms, and the positions of stability walls can all influence the erection order.

If the crack widths exceed the allowed dimensions, the design calculations should be double-checked following erection. Repairs should be made to the cracks if necessary, or the elements ought to be replaced or re-tested.

Information technology (IT) techniques such as information management, database management systems, and, most notably, the Internet have had a significant impact on the construction industry.

Rönneblad describes the processes. It is possible that effective use of IT tools can be achieved.

Boost the market share of a company. In addition, the company will acquire a competitive advantage.

Gaining competitive advantage through gaining benefits such as cost savings, increasing the pace of corporate processes, and improving the customer-supplier relationship. Collaborations (Construction Confederation).

To compete in the foreseeable future, all businesses participating in the construction industry must keep up with technological advancements. It is self-evident in today's corporate environment.

That does not have network connectivity or personnel who know how to use it. Business opportunities will be lost as a result of network tools.

Web-based management, which mostly enables corporate tasks to be carried out, reduces total expenditures and improves organization by using the Internet, one of the actions that could be performed is product quality control. This sort of technology ensures that the work is done in an efficient manner.

The use of production control systems minimizes the amount of paper used in the manufacturing process. For businesses, it lowers costs and saves time.

2.2.3 System properties

The web-based solution for precast concrete quality control is reviewed in this section.

The goal of this software is to collect data during the stages of production, transportation, and erection.

Precast quality standards and specifications are being examined. The program regulates the quality of the construction materials. production, product dimensions, and manufacturing irregularities. stage of development.

The processes of transportation and erection are also included. This program came first.

Both the manufacturer as well as the client have the ability to simply trace the stages of precast building, beginning with the foundation, beginning with concrete manufacture, and finishing with the erection of members.

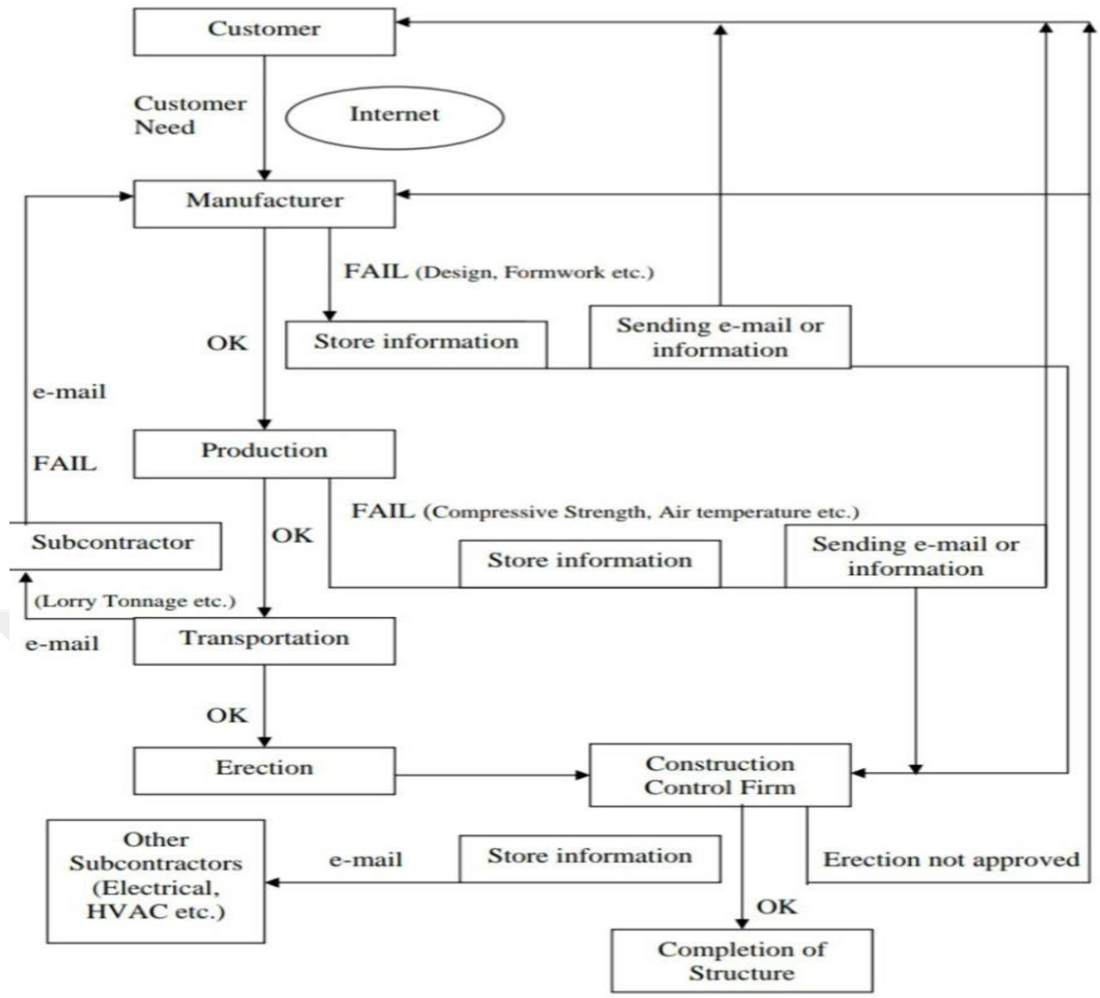

Figure 2.3: The Web-Based Solution for Precast Concrete Quality Control

The main menu includes five options: client, manufacturer, production management, transportation and erection control, and production records. The data is entered by the consumer.

Concerning the structure's project specifications, the expected delivery date, and his or her in the client menu, you may see the company's profile and other pertinent information.

Through the internet. Some characteristics of the design order menu are the structures, like load type, architectural characteristics, or a unique feature in concrete.

The dimensions of the building, the highest opening of the frame, and the potential of using a crane on-site are all included in the project detail option. Both the approximate cost, calculated and introduced by both the manufacturer and the manufacturer, would be available.

Menu for Customers can also specify a preferred finish time. The structure that is appropriate for them

The manufacturer fills in the appropriate options in the related menu after receiving project information from the customer, which comprises six choices including design, stock circumstances, bed conditions, and so on. Loading, erection, and formwork the manufacturers' design department is in charge of building design and structural analysis under the design option and inserts them into the system.

Precast casting beds are used to create permanent forms for walls and slabs. The usual length of these beds is 125 meters, but this might vary depending on the size of the production plant. Then casting beds might be made according to the project's design and specifications. The underbred circumstances option was checked. The manufacturer may make use of the opportunity to control if the necessary forms for production are available or whether the required elements are present.

Prefabricated elements can be used in production, and their stockyard availability can be determined.

- The stock condition option was checked by the manufacturer.

The manufacturer can also determine whether components in the stockyard are sufficient to execute the project and are appropriate for the environment. In the creation of a suitable design, the precast, as previously stated, members should be properly loaded on vehicles to avoid unnecessary strains.

The manufacturer can look into lifting availability and reliability. Identify whether or not loading the elements into the vehicle is feasible. Using the loading option is a good way to start. The manufacturer's most recent menu has an erection option, which allows you to choose the type of erection you want.

Some of the project's design criteria in order to continue the procedure, the appropriate options in the manufacturer's menu must meet the customer's requirements. If any of these products fails to meet the requirements, further items may be required.

Adjustments, like re-designing the project, must be made, or the project should be abandoned. The customer should be contacted by the manufacturer. The manufacturer has the ability to fill orders. If you use the "customer orders" option, this step will be completed automatically.

Each applicable item in the manufacturer's menu is selected by the computer,

Finally, the manufacturer provides the results to the customer through the Internet. A customer who is able to follow the steps of his or her project. The production control menu can be used to control all phases of manufacturing.

The system examines parameters including concrete class, concrete compressive strength, elongation, and size. Temperatures for the air, concrete, and curing are collected from sensors that are installed in new concrete at the manufacturing plant.

The system will accept the input data whether or not it has been authorized. The manufacturer does it by hand. If any of these items' results do not meet the applicable criteria or specifications and hence cannot be accepted, the system will automatically issue a warning message. This is especially critical while the system is providing the information.

- A chance for the manufacturer to make any necessary changes immediately.

From the relevant menu, you can regulate the transportation and erection steps. The customer has already input the distance between the factory and the construction site. Consequently, the system calculates the amount of time it will take to carry the appropriate portions. size and weight of the precast components, as well as informing the buyer of delivery through e-mail. The system verifies that the joints are in good working order. In addition, relationships have an impact on the design, construction, and operation. precast structures' behavior. The manufacturer will manually contribute the input data to the system, similar to the production control menu. Furthermore, the maximum crack size is limited.

When such an occurrence occurred, this system was in charge. If the crack is large and the level hits a critical level, the system sends an alert to the user. manufacturer. The manufacturer, if necessary, performs structural repairs. repairs or returns the part to the manufacturing plant for flexural testing.

That unit's strength was put to the test. Finally, if the process is approved by the software, it is completed. All phases are completed correctly. If the manufacturer or someone else wants to recognize or follow the procedures, the production records option offers data from previous or continuing manufacturing. The parties are able to speak easily with one another. Utilizing the system's mail options menu

- Procedures for Quality Control and Management Policies in the Plant

Administration and team members at the facility must be committed to consistently creating an effective product.

A commitment to quality and an understanding of the company's policies are required. This devotion is reinforced by regular training.

Personnel should also be empowered to impose basic standards for quality control (QC) in manufacturing. A precast concrete plant's organizational structure must include a quality control strategy, for which the person in charge or main executive director is able to take responsibility.

The NPCA promotes environmental stewardship and encourages construction sustainability. Producers are urged to incorporate salvaged materials into their goods and document their efforts. Reclaimed materials must be documented by manufacturers pursuing LEED (Leadership in Energy and Environmental Design) certification for their approaches (NPCA 2006).

- Quality control manual for plants

A quality control guideline for the facility that details its manufacturing as well as quality control rules and processes.

The manual should be kept in one notebook or binder so that plant staff or inspectors may easily study it. The manual must cover the following sections as well as the criteria of this manual:

1) Management's Quality Control Policy.
2) organizational chart of the company's quality control employees.
3) A description of the QC personnel's responsibilities.
4) Preparation is necessary for transporters, forklift employees, staff members, and quality control people.
5) A housekeeping strategy.

6) The manufacturer’s pre-pour, molding, post-pour, and final testing procedures.
7) All-season plant curing processes.
8) Product stripping and shipping minimum strength criteria apply.
9) Policy and procedures for product repair.
10) Unless otherwise specified on product detail drawings and/or manufacturing documentation, product dimensional tolerances.
11) Form tolerances and a maintenance policy.
12) Procedures for design qualification and testing.
13) Policy and procedures for testing raw materials.
14) Policy and procedures for equipment calibration.
15) Applicable product performance testing policies and procedures.
16) Quality control and manufacturing operations are observed by the facility using paperwork and formation.
17) Product documentation, including all design specifications and drawings, for items manufactured under franchise or licensing agreements.

Training for quality control personnel

1) Plant QC Inspectors and backup inspectors must have current completion certificates for:

- NPCA Production and Quality School (PQS) AND
- ACI Concrete Field Testing Technician-Grade I.

The plant must keep training records for five years, including course outlines, curriculum, test outcomes, and teacher certifications.

Continued development

Every year, the plant must engage in continuous improvement initiatives and Maintain relevant information as actual evidence of these activities, principles, guidelines, and illustrations in database.

One or more of the following areas must exhibit continuous improvement activities:

2) Manufacturing
3) Methodologies
4) Infrastructure
5) Execution
6) The facility should first achieve at least two of the upcoming session in order to be allowed for constant improvement goals:
7) Participate actively in the Producer Portal.
8) Use the self-audit feature in the Producer Portal to conduct semi-annual self-audits.
9) Train plant employees beyond quality personnel.

Plant characteristics

1) Make sure that inspectors and plant staff have a current copy of the NPCA Manual.
2) Create and update a written plant-specific QC manual on a regular basis.
3) Always have current versions of all ASTM Worldwide testing process and requirements currently offered.
4) Maintain a database with all requirements of the project.
5) Keep records of staff training in the company files.
6) Chose and prepare a facility quality control supervisor for every service period, with a backup in place.

The Quality Control Inspector will report to plant management rather than the production people. The daily production tasks of small facilities may contain the qualified QC Supervisor. When the plant is in production, a designated QC Inspector must be present.

1) At least once every month, Conferences with QC and facility employees should be held by supervisors or an authorized person. The minutes from

these conversations, along with a summary of the participants, should be kept in the facility database.

2) In regards to product defects, all NPCA Registered Facilities should clarify and record customer objections and the plant's following appropriate actions. During each plant audit, documentation must be retained on file for three years and made available to the auditor (Howarth and Greenwood 2018).

2.2.4 Plant protection

- Safety program

A strategy for facility security should be in place at each and every organization. (Zhu et al. 2021) The strategy must comply with all local, state, and federal regulations as well as the Occupational Safety and Health Administration's requirements (OSHA).

- Plant requirements

1. Always have a transcribed security strategy and construction safety work instructions on hand. The NPCA Guideline to Plant Safety or a comparable guideline must be readily available to plant employees in a plant-specific safety file.
2. At least once a month, management or an authorized representative must hold safety meetings with plant staff. The minutes among these conferences, along with a record of participants, should always be kept in the facility data. (Yee Weng Cheong, Hon Pui Kwan, and Agus Dwi Hariyanto 2005).

2.2.5 Mock-ups and drawings

- Drawings

Elevations, measures, communication data, as well as each piece's exposure should all be considered part erection designs.

- Drawings for custom-made precast units

For parts created especially for a client, the precast concrete manufacturer must submit stores styles for the client's acceptance. The client should be able to examine the suggested units' appropriateness for the intended use by using the full system, setup, and manufacturing data given in these designs. Dimension and position for the reinforcing steel, and every other measurement that support the design, has to be provided. Each piece's presence and all relevant information for uncovers, completes, or ends must be shown in the drawings. The permitted plans should be followed when creating the precast concrete modules.

- Drawings for traditional precast units

The precast concrete manufacturer should submit workshop models for standard precast concrete units for user confirmation. These graphics should demonstrate adherence to the company with strong design specifications. On request, installation and construction information will be included on shop drawings. Steel reinforcement size and location details, as well as any supporting design calculations, must be supplied. The precast concrete units must be made according to the approved blueprints. The assumptions utilized in the design of standard units must be indicated in the drawings. The architect for the work is in responsible to make sure that the design presumptions are suitable for the required purpose.

- Mock-ups

The plant provides representative samples for examination prior to the fabrication of architectural precast modules. A sample of 12 inches by 12 inches must be given as a minimum to exhibit the color and texture of the completed surface. If more than one finish is being specified, Whenever the back of the precast is going to be visible, provide one example for every end.

New samples must be assessed before making any changes to the components or mix proportions.

2.2.6 Materials and concrete

- Cement

Cement must meet the ASTM C150 "Standard Specification for Portland Cement" standards. Standard Performance Specification for Hydraulic Cement (ASTM C1157) or Standard Specification for Blended Hydraulic Cement (ASTM C595). To every shipment or batch of cement, a registered mill result must be utilized as actual proof of compliance (Committee 2015).

- Aggregates

The requirements of ASTM C33, "Standard Requirement for Concrete Aggregates," should be met both by the coarse aggregates. As clues of compliance, a declaration from the distributor stating that the aggregate complies with ASTM C33 is essential. The aggregates should be assessed in accordance to ASTM C1778, “Basic Manual for Lowering Threat of Harmful mutations Alkali Aggregate Reaction on Concrete,” and record for prospective destructive expansion due to alkali reactivity should be kept secure at the facility, unless they have been obtained from a source that has been authorized by the state department of state and is recognized not to be reactive. (ASTM C 1778-16 2014).

- Aggregate gradation

The gradation of every 1,500 tons (1,350 metric tons) of aggregate was using, and once per month, whichever takes place initially, should be evaluated.

Gradation must be tested after each 2,000 tons (1,800 metric tons) of fine aggregates is being used and once per month, whichever occurs initially.

The maximum quantity of coarse aggregate must be used, but it shouldn’t exceed one-fifth of the minimum thickness of the precast concrete output or three-fourths of the clear space among reinforcing and the manufacturer’s top

- Hazardous substances

All suppliers' fine and coarse aggregate must be tested for harmful compounds at first, then yearly thereafter, and anytime the aggregate is suspected of being contaminated. Current test reports must be dated no more than one year from the date of the last test or certification at the end of the month. The ASTM C33 "Standard Specification for Concrete Aggregates" specifies the standards and limitations for toxic substance testing.

- Hazardous materials

All fine and coarse aggregate from all suppliers must be tested for dangerous substances at first, then yearly after that, and if the aggregate is suspected of being contaminated. At the end of each month, current test reports must be dated no more than one year from the date of the last test or certification. The ASTM C33 "Standard Specification for Concrete Aggregates" outlines the harmful substance testing criteria and restrictions (Halvorsen,).

- Water mixing

Water used in the production of hydraulic cement concrete must meet the requirements of ASTM C1602, "Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete," and be free of oils, acids, alkalis, salts, organic material, and other substances that could affect the properties of fresh or hardened concrete. When using white cement, the mixed water must not include any iron or iron oxides that might cause stains.

2.2.7 Plant requirements

1. The following paperwork must be kept up to date in the plant's records (Oyebisi et al. 2019):

- Certified mill test reports or certifications for each shipment or lot of cement and supplemental cementitious materials,
- Aggregate supplier and test reports.
- Mix water portability test results or other test documents confirming the mix water's acceptability Current test reports must be dated no more than one year from the date of the last test or certification at the end of the month. Without testing, the municipal water supply is okay.
- Chemical admixture and other additive certified test reports or certifications must be dated within one year after the latest test or certification at the end of the month.

2. For each aggregate source utilized, documentation of adherence to ASTM C33 (excluding gradation testing) and test results demonstrating that the aggregates are non-reactive and stable must be kept. For each substance used, such documentation must be received at least once per year from the supplier, an applicable state agency, or a testing laboratory hired by the facility. Current test reports must be dated no more than one year from the date of the last test or certification at the end of the month. The maximum aggregate size must be appropriate for the cast products. At a minimum, tests for aggregate gradation and harmful chemicals must be done.
3. For a minimum of three (3) years, records of arriving raw materials and plant material testing must be kept current and on file.

4. The cement type, extra cementitious materials, and chemical admixtures must be suitable for the application. At a minimum, lightweight aggregate must be assessed for gradation and unit weight (Oyebisi et al. 2019).

2.2.8 Reinforcement

- Reinforcement bars

Steel reinforcing bars must meet the following design specifications:

ASTM A615 "Specification for Deformed and Plain Billet – Steel Bars for Concrete Reinforcement: Standard Specification" ASTM A615 "Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement" ASTM A706

If the design or project requirements allow it, other bars can be used for specific purposes.

Suppliers of reinforcing bars must provide mill certifications for each shipment. For a minimum of three (3) years, records of inbound reinforcing steel factory certifications must be kept current and on file (Oyebisi et al. 2019) (NPCA 2006).

- Wire reinforcement

Steel reinforcing bars should be used. The following specifications apply to reinforcing steel wire:

ASTM A1064 "Standard Specification for Plain and Deformed Steel Wire and Welded Wire Reinforcement for Concrete"

If the design or project constraints allow it, other wires can be utilized for specialized applications. Suppliers of reinforcing wire must provide mill certifications for each shipment. For a minimum of three (3) years, records of inbound reinforcing wire mill certificates must be kept current and on file.

- Welded-wire reinforcement

Welded wire reinforcement must meet the following design specifications: Standard Specification for Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete.

Mill certifications must accompany each shipment of bar matting and welded wire reinforcement. For a minimum of three (3) years, records of inbound reinforcing steel factory certifications must be kept current and on file.

- Zinc or epoxy-coated reinforcement

All reinforcing steel shall be galvanized or epoxy coated in accordance with ASTM A775, "Specification for Epoxy-Coated Reinforcing Steel Bars," ASTM A884, "Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Fabric for Reinforcement," or ASTM A934, "Standard Specification for Epoxy-Coated Prefabricated Structural Steel," or ASTM A934, "Standard Specification for Epoxy-Coated Prefabricated Structural Steel." or ASTM A CRSI-certified applicator must supply epoxy-coated steel with a certification or certificate of conformity."

Epoxy-coated reinforcement must be kept and handled in such a way that the epoxy coating is not damaged.

2.2.9 Plant prerequisites

1. Rods, rods matting, reinforcing wire, armored reinforcing, and linked wire reinforcement, must all have mill certifications and certificates of compliance.
2. The plant QC Inspector will double-check that any reinforcing heat numbers being utilized or stored have certifications on file.
3. Certificates for all reinforcement, including strengthening, must be kept in factory records for at least one year.

2.2.10 Multiple components

- Hoisting accessories and Hoisting equipment.

Precast concrete goods must be capacity checked and have an appropriate factor of safety for lifting and handling products, taking into account the numerous pressures operating on the device, such as form release suction, impact, and varied product positions during handling.

The capacities of commercial hoisting equipment must be indicated on them or displayed in the productive zones.

As required by OSHA 29 CFR 1926.704, lifting inserts embedded or otherwise attached to precast concrete elements must be capable of carrying at least four times the maximum intended load imposed or transferred to them (c).

Slings raise bars, chains, hooks, and other lifting gear must be capacity-tested and have a sufficient safety factor when managing and hoisting goods.

According to OSHA 29 CFR 1926.704, lifting gear must be able to withstand not less than five times higher loads that are planned to be enforced or transferred to it. (d).

- Plates and steel shapes with embedding

The placement of forms and plates made of steel in precast concrete must meet the ASTM A36 "Standard Specification for Carbon Structural Steel" criteria. If the design specifies the needs, additional types of steel plates could be employed.

For each cargo received, applicable mill test records must be kept at the facility.

- Headed studs and deformed anchor studs

Unless greater strengths are required by design, soldering studs to steel material concrete anchorage plates must meet the standards of ASTM A108, "Standard Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality."

- Manufacturing add-ons

Braces for reinforcements, registers, shackles and other related tools used in the production of prefabricated concrete products. must be suitable for their purpose uses and cause minimal surface marring.

Dissimilar metal accessories should not be used unless the surfaces of the manufacturing accessories are permanently coated against corrosion.

Epoxy-coated reinforcement must be utilized with coated tie wires.

- Reinforcement with fiber

Data must be produced to demonstrate unequivocally that the kind, brand, quality, and quantity of fibers to be used in the concrete mix will not harm the concrete or the precast concrete product.

ASTM C1116, "Standard Specification for Fiber-Reinforced Concrete and Shotcrete," is the standard for the first type or third type of fiber-reinforced concrete.

2.2.11 Joint sealants and connectors

A minimum of once per year, certifications of compliance are must be acquired from each provider and stored in a folder for each tube to-structure connector and each type of joint sealant that the company uses.

2.2.12 Plant prerequisites

1. The maximum capacity of commercial lifting inserts and hardware must be approved and advertised. At a minimum, inspect all lifting equipment at a minimum and keep censorship data in the files of the factory. Present observations and inspection determinations must not exceed one year from the date of the last test or certification at the end of the month (NPCA 2006).
2. A qualified testing lab must test non-commercial lifting inserts and hardware for the specified working load limit (WLL). A factor of safety must be satisfied in accordance with the standards of OSHA rule 29 CFR 1926.704 (c & d).
3. When required, corrosion and other metals that are different from the implanted steel must be prevented.
4. Fiber reinforcement and accessories must be acceptable for their intended usage.

2.2.13 Concrete mixes

- Mix proportions

ACI 211.1, "Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete," must be followed while mixing concrete. "Practice for Selecting Proportions for Structural Lightweight Concrete," according to ACI 211.2. ACI 237, "Self-Consolidating Concrete," or ACI 211.3, "Practice for Selecting Proportions for No-Slump Concrete." (SCC) For any combination of aggregates, cement, water, and admixtures, mix ratios must be determined by a professional laboratory, the specifications of the project, or the plant staff of the precast.

For variations in material supply, aggregate gradation, aggregate moisture content, cement content, or admixtures, mix proportions must be adjusted correctly.

- Lightweight, heavyweight, and enormous concrete

|Plants utilizing regular, Enormous Concrete and heavyweight some of the methods that used for quality control should be collected in the manual of the laboratory for these activities in specific ways. Detailed written procedures must, at a minimum, include the actions required for principle mixture validation and follow daily quality control activities.

In the plant files, initial mix qualifications must be noted.

Trial batching and in-depth concrete testing will be included in the documentation. The creation of acceptable tolerance limits for test results of regular quality monitoring testing is part of the mix qualification processes.

The regular quality monitoring testing approval standards at the principle mixture efficiency must be followed throughout subsequent daily quality control activities.

- Self-consolidating concrete

Plants that use SCC must incorporate SCC-specific quality control methods into their plant-specific quality control handbook. Detailed written procedures must, at a minimum, include the actions required for principle mixture validation and follow regular quality monitoring activities.

In the plant files, initial mix qualifications must be noted.

Trial batching and in-depth concrete testing will be included in the documentation. The creation of suitable bearing limits for checking outcome of regular quality monitoring testing is part of the mix qualification processes.

The regular quality monitoring testing approval standards at the principle mixture efficiency must be followed throughout subsequent daily quality control activities.

- Zero slump/dry-cast concrete

Specific quality control methods for dry-cast/zero slump concrete plants must be included in their plant-specific QC handbook.

Detailed written procedures must, at a minimum, include the actions required for principle mixture validation and follow regular quality monitoring activities.

In the plant files, initial mix qualifications must be noted.

Trial batching and in-depth concrete testing must be included in the documentation. The creation of acceptable tolerance limits for test results of daily quality control testing is part of the mix qualification processes. The regular quality monitoring testing approval standards at the principle mixture efficiency must be followed in subsequent daily quality control activities.

- Uhpc (ultra-high performance concrete)

In their plant-specific quality control manual, plants that use ultra-high performance concrete must incorporate specialized quality control methods.

The processes required for principle mixture validation and following regular quality monitoring activities will be addressed in the procedures.

In the plant files, initial mix qualifications must be noted.

Trial batching and in-depth concrete testing must be included in the documentation. The creation of suitable bearing limits for checking outcome of regular quality monitoring testing is part of the mix qualification processes.

The regular quality monitoring testing approval standards set at the principle mixture efficiency must be followed in subsequent daily quality control activities.

- When utilize face mix, compatibility

Whenever backup mixes and faces are used separately, each mix's features should be taken into account to guarantee that elasticity modulus, thermal coefficient of expansion, and shrinkage are all kept to a minimum (Reichenbach and Kromoser 2021).

- Water-cementitious materials ratio

Each mix design's water-cementitious materials ratio must be determined and recorded.

Entrained air must be present in concrete that will be subjected to freezing and thawing, and the water-cementitious materials ratio must be less than 0.45.

If the concrete will not be exposed to freezing but must be waterproof, it must have a water-cementitious materials ratio of 0.48 or below.

Reinforced concrete exposed to deicer salts, brackish water, or saltwater must have a water-cementitious materials ratio of 0.40 or below for corrosion protection.

- Air content (plastic)

Air content may be lowered by 1% for specified compressive strengths above 5,000 psi (34 MPa).

Table 2.1: The Air Content of Concrete That Will Be Exposed To Freezing and Thawing Shall Be Within the Limits

Nominal maximum aggregate size		
Size (inches)	**Air content %**	
	Severe exposure	**Moderate exposure**
3/8	6 to 9	4.5 to 7.5
1/2	5.5 to 8.5	4 to 7
3/4	4.5 to 7.5	3.5 to 6.5
1	4.5 to 7.5	3 to 6
1 1/2	4.5 to 7	3 to 6

- Compressive force

The average of the strengths of two specimens built from the same concrete batch, cured in the same way, and evaluated at the same age is known as a compressive strength test.

The concrete's compressive strength, as verified by testing,

The specimens must be on par with or superior than the design specifications.

If no strength is given, the strength must be adequate to prevent damage from product handling, and the concrete strength must Never allow the product to be carried with a pressure below 2,500 psi (17 MPa).

- Admixtures

Admixtures must be used according to the directions provided by the manufacturer. When multiple additives are added to mixture of concrete, to make sure that each admixture operates as intended without impacting on the others, data must be gathered.

Concrete must be mixed with additives in a controlled manner way in order to ensure equal distribution. Admixture dosing equipment must be certified by the admixture provider.

Current certificates must be dated no more than one year from the latest exam or certification at the end of the month.

2.2.14 Plant requirements

1. Each mix's proportions must be carefully noted and kept at the mixer and in the plant files. The mixtures' water to cementitious material ratio must not be greater than the previously indicated and must be documented in the mix percentage. If the concrete will be exposed to freezing and thawing, it must be air-entrained.
2. The concrete's compressive strength (7- or 28-day age) must be evaluated at least once per week or every 150 cubic meters (150 cubic yards) of concrete, whichever comes first. Strength data must be kept for at least three (3) years in the files. If the product is shipped before the strength data is obtained, additional compressive cylinders must be tested before shipment to confirm that the minimum strength criteria are satisfied. When the rebound hammer has been tuned properly, the test of the rebound hammer may be used to determine strength. The quality control manager should evaluate and track strength data on a regular basis (Barsisa 2020).

2.2.15 Mixing and batching

- Batching and mixing plant requirements

Plants must be fitted such that batching and mixing produce properly mixed concrete with the requisite workability of fresh concrete and the needed qualities of hardened concrete in sufficient quantities to keep the casting schedule on track.

ASTM C94, "Standard Specification for Ready-Mixed Concrete," applies to batching and mixing plants and their activities. Plants can also follow the batching and mixing criteria outlined in ASTM C685, "Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing."

- Storage of cement and supplementary cementations materials

Each type of bulk cement and supplemental cementitious ingredients must be stored in separate bins or silos. To avoid moisture incursion, bins and silos must be waterproof. To avoid moisture contact, cement and supplemental cementitious materials in bags must be stored under cover.

- Handling and storage of aggregates

Aggregates must be handled and stored in a way that minimizes particle size segregation, keeps gradations within prescribed limits, prevents contamination from underlying soil, and prevents cross-contamination between neighboring aggregate stocks.

Furthermore, organic matter (such as leaves and twigs) must not be collected, and plants must not be permitted to grow in aggregate stockpiles.

- Mixing equipment

ASTM C94 or ASTM C685 must be followed for maintaining and operating weigh batching equipment (ASTM International 2020).

Tools must be able to batch and measure the raw components for concrete. Plants that employ volumetric batching (for liquids) or a combination of volumetric and mass batching (for solids) must remain within the following limits:

1. Percent cement; 0 to 4 percent for quantities smaller than 1 cubic yard
2. Water makes up 1%
3. Fine aggregates make up 2%
4. Coarse aggregates make up 2%
5. Cumulative weigh batch aggregate makes up 1%.
6. The mixtures or the dose per bag of cement 3%. Whichever is higher

Metrics should be monitored annually or anytime their accuracy is questioned. The batch control location must prominently display calibration labels.

Present calibration and posters must have a maximum one-year expiration date from the latest test or certification at the end of the month.

The equipment operator must have easy access to the calibration records for batch plant scales.

Balance criteria must take into account the entire anticipated application range of use, as well as the percent of inaccuracy for each test weight.

At each quadrant of the range of anticipated loads, the certified test weight must be within 0.2 percent of the scales' calibration. The weight or volume of liquid admixtures must be measured.

Weight measurements are required for powdered admixtures. The admixture dispensers must be calibrated at least once annually. Reports of current calibration must be no older than a year old. After the latest test or certification at the end of the month. Volumetric or continuous batching plants must be able to mix concrete components according to the specified tolerance limits:

- 0 to + 4% (weight) cement
- 1% (weight or volume) water
- Fine Aggregates 2% (weight)
- Coarse Aggregates 2% (weight)
- Admixtures: 3% (weight or volume)

- Component release into mixers

While materials are discharged into the mixer, the mixer drum or blades must rotate. Materials must be released into the mixer in a certain order to guarantee a uniform mix.

Admixtures must be introduced into the mixer in the order indicated by the admixture supplier to achieve consistent dispersion throughout the mix.

At the concrete batching station, the discharge and mixing sequence must be documented and preserved (Bachmann and Steinle 2012).

- Mixers

The manufacturer specifies the size for the batch and it must not be larger than the capacity indicated. Mixers must be able to produce concrete with a consistent consistency and fine aggregate dispersion.

ASTM C94 for batch mixing and ASTM C685 for continuous mixing are the standards to follow.

Cleanliness, clearances on blades and shoes, correct gate seals, and lockout controls must all be checked regularly on mixers.

- Mixing

A fixed central mixer, a mixing screw (volumetric type), or truck mixing and delivery are all options for mixing concrete.

For batch mixers, uniformity tests according to ASTM C94 must be performed by the equipment manufacturer or competent plant staff to determine mixing time or drum rotations.

The precast factory must keep daily reports on the actual concrete mix proportions used in each batch and the amounts of manufactured concrete for at least three (3) years.

- Ready-mixed concrete

Ready-mixed concrete supplied by a ready-mixed concrete manufacturer must comply with ASTM C94 and the standards outlined previously.

A ready-mixed concrete producer's batching facilities must meet the same specifications as the batch plant facilities mentioned above. The National Ready-Mixed Concrete Association has certified the supplier's facilities. (NRMCA) or the State Department of Transportation as proof of compliance mentioned previously

Furthermore, the plant must keep a file containing current combination designs, batch plant printouts, truck delivery receipts, and relevant raw material certificates and gradations. The needed frequency of raw materials testing will be determined by the total amount of raw materials utilized by the precast plant. Concrete testing is required at the final installation position.

Each shipment must be accompanied by a truck delivery receipt. Keep track of all water supplied to ready-mixed concrete deliveries at the plant. Precast concrete products cannot be made with "bring-back" concrete or any other concrete that was originally intended for someone other than the precast concrete maker.

- Plant requirements

1. Aggregate stockpiles must be correctly designed to prevent contamination and segregation.

2. Every year, the scales must be calibrated, and the calibration label must be visibly posted at the concrete batch control station.
3. Current calibration reports and stickers must be dated within one year after the latest test or certification at the end of the month. All concrete components' batching tolerances must meet the tolerances mentioned previously
4. Mixers must be inspected regularly for cleanliness, blade and shoe clearances, correct gate seals, and lockout controls, among other things.
5. Ready-mixed concrete delivered must come from an NRMCA or State DOT-certified facility or meet all of the aforementioned standards. The ready-mix supplier's conformity must be documented and kept on file. The precast plant's files must contain documentation of the ready-mix supplier's compliance. Any water supplied at the precast factory, as well as truck delivery receipts, must be recorded. For the creation of precast concrete goods, only fresh concrete destined for the precast concrete maker is authorized.
6. The precast factory must keep daily documentation of the actual concrete mix proportions used in each batch and the concrete volumes produced for at least three (3) years.

2.2.16 Production practices

- Plant layout

The plant's physical layout must allow for the efficient manufacturing, processing, storage, and shipment of concrete products while minimizing product damage.

The following broad rules must be included in the plant layout:

1. Reduce the distances that fresh concrete must be transported.
2. There is enough room to avoid tripping hazards and ensure safety.
3. Do not strip things or hoist them over people or equipment.
4. During the casting process, avoid marking or splashing on other items.
5. Material storage space that is adequate.

6. There is enough area to strip items and check and fix them once they've been poured.

- Housekeeping

Every plant must have a well-functioning housekeeping program. The program's goal is to create a clean, safe environment in which high-quality precast concrete products may be produced quickly.

Housekeeping will be spot-checked daily by the plant QC Inspector.

- Forms and forming equipment

Precasting equipment and forms for the production of precast concrete

Products must be of sufficient quality to prevent product damage as a result of stresses and vibrations applied to the products.

All forms and forming equipment (including pallets, headers, and truing rings) must be measured for dimensional compliance with applicable tolerances prior to beginning use and at least once a year thereafter. Current reports must be dated no more than one year from the date of the previous report at the end of the month.

After each use, the forms must be thoroughly cleaned to remove any concrete build-up. Form release agent coatings must not be allowed to build up.

Forms for manufacturing precast concrete items must meet industry standards and procedures in terms of kind and design. They should be able to regularly deliver items with consistent dimensions. Forms must be built in such a way that the stresses and vibrations they will be subjected to will not cause product damage (Oyebisi et al. 2019).

- Handling of Materials

Hoists, overhead cranes, gantries, mobile cranes, and forklift trucks must be used to lift and handle objects that are less than the equipment's rated capacity.

All handling equipment must have inspection and maintenance records kept in line with applicable regulations.

- Products that are machine-made or dry-cast

This manual's applicable requirements apply to precast concrete products made with automated equipment and/or the dry-cast process.

For goods produced in the plant with mechanized equipment, QC staff must verify the reinforcing steel for compliance with the design on a minimum of one (1) reinforcing steel cage or 3% of each production run daily, whichever is larger. At least one cage must be checked when a shift changes during a production run or when a setting is modified. These reinforcing steel inspections must be documented and kept for a minimum of three (3) years in the plant's records (Bachmann and Steinle 2012).

Regardless of any slumping of the concrete after stripping, the dimensions of machine-made items must be within permissible tolerances.

For each type of product cast, daily dimensional tests of machine-made items are required. QC staff must execute dimensional checks on a minimum of one (1) product or 3% of each production run daily, whichever is greater, chosen at random. These dimensional checks must be documented and kept for a minimum of three (3) years in the plant records (Quality-Policy-2020.pdf n.d.).

If a non-conforming product is detected, the plant must fix all non-conforming concerns immediately.

- Precast architectural concrete

Architectural precast concrete is described as concrete that will be permanently exposed to view and requires additional care in the selection of concrete materials, shaping, placement, and finishing to achieve the ideal architectural aesthetic when required by the owner or specification.

The level of quality in terms of appearance is of paramount importance by its very nature. Individual job specifications must specify that the final product must match previously approved samples and/or industry standards.

Plant-specific methods must be documented to ensure consistent quality. Unless a specific use or standard permits for deviations, strength and durability must not be compromised for architectural appeal.

To achieve the desired finish, natural stone or clay items might be used as a veneer. Procedures must be created to handle variances in heat and moisture transfer between the veneer and the concrete.

- Surface finishes

All visible surfaces must be free of form faults, joint marks, and color variations as determined by approved samples and/or mockups. All features, such as false joints and chamfers, must match the authorized shop drawings.

Architectural finishes must adhere to the project documents' criteria and be completed in accordance with industry standards or supplier specifications.

When the project documents need it, precast concrete companies must submit finishes for approval. Because color variations and surface flaws are not always visible on small-scale samples, life-size mockups are recommended for architectural finish certification. Prior to the start of production, the sample finishes must be authorized.

- As cast

Surfaces must be cast using certified forms while following industry best practices for cleaning concrete forms, creating concrete mixes, placing concrete, and curing concrete. Air bubble-induced small surface holes up to 14 inches in diameter and tiny color differences are acceptable, but serious flaws like extreme honeycombing, sand scars, or other serious flaws will not be accepted.

To reduce color variation, special attention should be paid to raw material selection and control of the water-cementitious materials ratio.

To reduce air spaces on surfaces, proper casting processes and mix design must be applied.

Mockups should be cast to ensure that color variation and the number of voids are acceptable.

- Finish with exposed aggregate

Brushing, water washing, abrasive blasting, or a combination of these techniques must be used to eliminate organic surface retarders in accordance with the project parameters. There must be no honeycombing or aggregate segregation in the finish. Surface retarders must be applied to the form in a uniform and consistent manner. To protect the surface retarder, keep concrete drop heights low during placement. Surface retarders may also be scraped during the installation of vertical and curved pieces. Place the concrete in the form from the bottom to the top. Remove the concrete's surface to a predetermined approximation of depth using an abrasive grain that is frequently projected onto the surface pneumatically.

- Finish with an abrasive blast

The blasting media must be free of harmful chemicals. To avoid inhaling small particles, proper safety equipment should be worn. To achieve consistency, pieces must be blasted at the same age. Using an abrasive grit that is often projected on the surface pneumatically, remove the surface of the concrete to a set approximate depth.

- Finish with acid etch

Only after appropriate curing and a minimum compressive strength of 4,000 psi should acid etching be done. Paint or protect all exposed metal surfaces and exposed insulation before applying acid.

To avoid streaking and overexposure, properly moisten the concrete surface before adding acid. Returns, flat areas, or sites where acid may puddle or concentrate should all be avoided, as this can lead to overexposure. Within 15 minutes of applying the acid, rinse the surface with clean water to eliminate any remaining residue. In the concrete, use exclusively acid-resistant siliceous aggregate. If applicable, provisions must be made to safeguard hardware and insulation.

- Honed or polished

Remove the surface of the concrete to a predetermined approximate depth using water and an abrasive grit grinder. Prior to grinding, the concrete's compressive strength should be at least 5,000 psi, with all repairs and bug holes filled and cured.

- Bush-hammered or tooling

Only trained individuals should abrade the surface of the precast using tooling techniques, hammers, or other equipment. To accommodate for the lost concrete surface, the reinforcement's protective layer should be raised.

- Unformed surfaces

Surfaces must be polished manually with a float or with a vibrating screed. Normal color variations, minor chips, indentations, and spalls are acceptable, but no significant faults, such as excessive honeycombing or other serious abnormalities, are permitted. If no other method of finishing is specified, such surfaces must be completed with a strike-off to level the concrete with the form's top.

- Unique finishes

Trowel, broom, and other finishes must be done in accordance with project documents and industry standards or supplier specifications.

When the project documents need it, precast concrete companies must submit finishes for approval. Prior to the start of production, the sample finishes must be authorized.

- Architectural finishes

Architectural finishes must adhere to the project papers' criteria and be completed in accordance with industry standards or supplier specifications.

When the project documents need it, precast concrete companies must submit finishes for approval. Because color variations and surface flaws are not always visible on small scale samples, life-size mockups are recommended for architectural finish certification. Prior to the start of production, the sample finishes must be authorized.

Aggregate exposure must be no more than 1/3 the average diameter of coarse aggregate and no more than 12 times the average diameter of the smallest size of coarse aggregate with all finishes.

The surface of a unit with two or more different mixes or finishes must have a groove or recess built into it. To minimize cracking at the groove or recess, the different face mixes must have substantially identical shrinkage behavior.

- Veneer embedded

It's critical to consider the changes in quality between the veneer and the concrete backer when designing using veneer. Other elements concrete shrinkage rates, exposure, bridge lengths, linkage styling, the type of veneer material, and the thickness of the precast backer, may any one of these factors could raise the likelihood of bowing (typically outward). The difference in thermal expansion coefficients between the veneer and the concrete backer should be kept to a minimum.

Otherwise, length change may occur at various rates, causing unequal tensions and outward bowing. To alleviate this worry, precasters can incorporate an inward bend or camber into the form while casting the panels, apply prestressing, or use a second reinforcing cage when panel thickness permits. Additional tie-back connections have been shown to aid in the prevention of bowing.

- Stone products

A bond breaker is often utilized to prevent concrete from adhering directly to the stone. Stone veneer and the precast concrete backing can move differently thanks to bond breakers, which helps to keep the veneer from staining and breaking. Bond breakers are commonly made from the following materials:

- 6 to 10-millimeter-thick polyethylene sheet
- Closed-cell, 1/8-to 1/4-inch thick foam pad
- Thin liquid bond breaker (such as polyurethane)

Attaching stone to precast concrete should be done with a flexible, mechanical anchor. Corrosion-resistant anchors are also recommended.

The shape of the anchor varies based on the nature and strength of the stone. The veneer-embedded portion of most anchors, however, is positioned at a 30 to 45-degree angle from the back of the stone, penetrating approximately 3/4-inch or half the thickness of the veneer – whichever is greater.

- Clay-based materials

Typically, clay components are cast into or bonded to concrete to form a monolithic unit. Thermal expansion coefficients, absorption, modulus of elasticity, and volume change of the clay product should all be considered in the design, as well as in-service variables such as temperature differentials between the outside and inner surfaces.

Many clay materials are "fired," meaning they expand when exposed to moisture, especially humidity. However, the precast concrete panel can compensate for this. Grout or concrete mortar, for example, shrinks and compensates for expansion between clay materials. Under stress, the mortar joints may also suffer elastic deformation, which can compensate for clay brick expansion.

When using certain clay components in precast concrete, there are special recommendations. First, while there are many different types of bricks, not all of them are suitable for use in precast. Due to form tolerances and unit alignment, precast concrete requires strict tolerances in individual bricks. ASTM C1088, Type TBX, should be met by bricks. (Note: For precast bricks, the suggested tolerance is plus or minus 1/8 inch.) Otherwise, concrete placement may cause bricks to shift or tilt, necessitating repair. In the case of non-brick clay goods, glazed or unglazed ceramic tile should meet ANSI A137.1 with a tolerance of 1%.

Bond strength is affected by the absorption and initial rate of absorption of clay products directly bonded to precast concrete.

When tested in line with ASTM C216, brick absorption should be between 6% and 9%. According to ASTM C67, bricks should have an initial rate of absorption of fewer than 20 grams per minute per 30 square inches. It is not necessary to moisten these bricks. To avoid extracting moisture from the concrete and weakening the bond, bricks above this value should be wetted. To avoid excessive suction of moisture from the curing concrete, terra cotta is usually soaked before use. The bond strength of a veneer material and precast concrete typically exceeds that of traditional field-laid applications. Clay goods should also have some physical characteristics that allow for mechanical bonding with concrete, such as grooves or scoring on the rear side. Almost any brick design can be used, such as running bond or stack patterns. Custom designs and material combinations are also possible. The smaller veneer goods should be cut as little as possible in the units.

- Plant specifications:

1) All production staff must make continuous efforts to keep the work area clean. A QC Inspector spot-checks at least once per work shift.
2) Keep track of dimensional checks on forms and forming equipment on all new equipment and every year after that. Current reports must be dated no more than one year from the date of the previous report at the end of the month.
3) Keep records of all handling equipment inspections in compliance with applicable regulations.

4) Perform routine reinforcement examinations on no less than one (1) reinforcing cage and no less than three percent of each production run, for reinforcement fabricated with mechanized equipment and used in machine-cast or dry-cast products. A shift change happens during a production run or when a setting is modified.

5) Dimension inspections must be done and documented on a minimum of one (1) product or 3% of each production run daily, whichever is greater, for machine-cast and/or dry-cast goods.

6) Architectural precast concrete must match authorized samples and fulfill industry standards in appearance. Veneer compatibility must be determined and verified. In the plant-specific QC manual, production and quality control measures must be designed and documented.

7) Unless otherwise specified, keep records for at least three (3) years.

2.2.17 Fabrication of block outs and reinforcements

- Reinforcement fabrication

Allowances for precast concrete product and/or statement of work or plans must be followed while fabricating all reinforcing steel, according to a detailed steel reinforcing plan document. The plant must specify the dimensional tolerance scheme that will apply to the product on the plan documents or in the plant-specific quality control manual, such as but not limited to the Concrete Reinforcing Steel Institute (CRSI) publication, if no given window or citation have been established "Placing Reinforcing Bars" and/or the Reinforcing Steel Institute of Canada/Institut D'acier D'armature du Canada (RSIC/IAAC) publication.

The pre-pour inspection must include a check for conformity to approved design standards on reinforcing steel cages. All reinforcing bars must be bent in accordance with CRSI and RSIC/IAAC fabrication standards, with bend diameters not smaller than those specified by CRSI and RSIC/IAAC. Reinforcement cages must be formed either by tying or clipping the bars, wires, or welded wire reinforcements into rigid assemblies, or by welding. Harm to every coating on epoxy-coated reinforcement steel must be repaired using patching material in accordance with the manufacturer's guidelines. When an epoxy-coated retaining wall is chopped or welded, patching material must be used to fix the cut ends and weld regions. Flame cutting is not permitted on epoxy-coated reinforcing steel.

- Steel reinforcing welding

If the corresponding ASTM product standards allow it, reinforcing cages can be welded. Welding of reinforcing steel may also be permitted in other circumstances decided by the manufacturer, such as when the steel is not employed for structural purposes.

In such circumstances, caution and prudence must be utilized to ensure that the precast product's integrity is preserved.

Reinforcing steel used mostly for structural reasons can be welded as long as it meets the requirements of the American Concrete Institute's "Building Code Requirements for Reinforced Concrete" (ACI 318) and the American Welding Society's "Structural Welding Code-Reinforcing Steel" (AWS chevalier) (AWS D1.4).

Welding ASTM A615 reinforcing steel is generally not considered acceptable. The carbon equivalent for welded bars should be less than 0.45 percent for bars bigger than #7 and 0.55 percent for bars #6 and lower, according to the American Welding Society's D1.4 Structural Welding Code for Reinforcing Steel. If welding ASTM A615 steel, the carbon equivalent must be calculated and the bars must be warmed if necessary. For welding applications, ASTM A706 weld able grade rebar is allowed. For ASTM A615 reinforcing steel, the Carbon Equivalent (CE) is computed as follows:

CE = percentage of C + percentage of Mn/6

C: carbon.

Mn: manganese.

For ASTM A706 reinforcing steel, the Carbon Equivalent (CE) is computed as follows:

CE = C% + Mn% + Cu% + Ni% + Cr%

C: carbon.

Mn: manganese.

Cu: copper.

Ni: nickel.

Cr: chromium.

- Steel assemblies welding

The American Welding Society D1.1, "Structural Welding Code Structural Steel," must be followed when welding steel assemblies that are cast into or attached to precast concrete products.

- Block out fabrication and positioning

Blackouts can be created from any hard, nonabsorbent material that will not affect the concrete and can be kept in place throughout casting and curing.

Dimensional block out tolerances must be defined for each product and block out type.

Unless project standards prevent it, block outs can be maintained in place during casting with non-corrosive supports or reinforcing steel.

- Plant characteristics

1) Reinforcement must be fabricated to applicable tolerances and be rigidly supported.

2) Welding of ASTM A615 reinforcing steel is permitted when an approved welding procedure meets AWS D1.4/D1.4M requirements. Copies of the approved welding process must be kept on hand and available for review in the Plant Specific Quality Control Manual.

3) Unless project specifications prohibit it, block outs must be non-absorptive and held rigidly in place with non-corrosive supports or reinforcing steel.

2.2.18 Pre-pour activities

- Form cleaning

After each use, forms must be cleaned. Concrete, glue, polystyrene, and any other items stuck to the forms must be removed.

- Form of release agent application

Once the forms have been cleaned and the seams have been sealed, the Forms Release Officer should be applied. Form release agent-free reinforcement and other things to be embedded in concrete are required. It is important to avoid using too much release agent, which might result in puddling. If there is any puddling, it must be eliminated before casting.

- Positioning of reinforcement

The design must specify the placement of reinforcing steel, and the concrete cover must meet product specifications.

The strength of concrete coatings shall be one-third of the prescribed value but not more than 12 inches unless otherwise stated. The concrete roof should be at least 12 inches in thickness, but it is recommended that it be higher. To ensure that reinforcement does not move a great deal throughout casting procedures, positive measures need to be taken. Any form surfaces must be kept clear of cages. When working with small diameter bars or wire, use wheelchairs, spacers and positioning wheels. To be used in straight-walled goods, rolled welded-wire reinforcement must be mechanically straightened.

A documented process for inspections of steel and reinforcing cages must be in place that contains details of the cage design required relative to the actual cage used, as well as the following information, as appropriate to the work manufactured:

- WWR spacing and/or style of bars;
- Size and/or diameter of WWR bar;
- steel zone (As);
- The total number of bars

(According to the detailed reinforcing steel plan documents, inspections may involve one or more of the above).

- The concrete cover is never less than 12 "clear;
- The effective depth (d), which is the distance between the centroid of the tensile reinforcing component and the compressive face
- Length of cover splice.
- Cage measurements, if applicable: distance, breadth, depth, and/or diameter;
- Requirements for steel reinforcement

\- Oil, dirt, and other pollutants are not permitted.

- If welded, it fulfills the criteria needed.
- If welded, it doesn't have any damaging features like gouges and undercuts.
- If welded, any damage, such as gouges and undercuts, is excluded.

- If the design calls for a bend in the reinforcing steel around a corner Straight pieces linked together cannot be used in place of project specifications, precise reinforcing steel designs, or both.

QC personnel shall verify the reinforcing steel for compliance with the design QC staff must randomly select at least one (1) reinforcing steel cage or three percent of each production run each day, whichever is greater. When a manufacturing run has a shift change, at least one cage must be checked. These reinforcing steel checks must be kept for a minimum of 3 (3) years in the plant records.

- Positioning of miscellaneous embedded items

The locations specified in the design must be used for embedded items. Inserts, plates, weldments, lifting mechanisms, and other items that will be incorporated into precast concrete products must be held firmly in place throughout casting operations.

- Plant characteristics

Prior to casting each form, pre-pour inspections must be completed. Dimensions, form tightening, form cleaning, application of form release agent, placing and fastening of reinforcement, embedded components, and block outs all need to be examined.

A procedure must be in place at the plant to determine when a form passed the pre-pour inspection and is ready to be cast. Pre-pour inspection documentation may be done on a piece-by-piece or production basis, but at least every day. For manufactured goods, pre-pour inspections must include verifying the form condition before each work shift and inspecting and identifying reinforcing cages.

2.2.19 Casting in concrete

- Concrete transport

Concrete can first be transported from the mixture to the casting site in a manner that does not stain it or cause excessive segregation. It is permissible to pour concrete directly from the mixer into the forms.

- Filling forms with concrete

Conventional concrete should be poured into forms as close to the final destination as possible to minimize concrete free fall. To avoid segregation, SCC should be dropped into forms at a minimum distance and permission to circulate freely to complete the form.

- Position of the facial blend

When applying a facial mixture, be careful not to apply cement to the reinforcement, as this may compromise the bonding of the replacement mixture.

- Back-up mix placement

When installing the backup mixer, care should be taken not to disrupt the front mixer.

- Consolidation of concrete

The concrete must be mixed in order to minimize the segregation of the concrete. The frequencies and amplitudes of the vibrators used to reinforce the concrete must be sufficient to produce solid concrete.

Internal vibrators must be lowered horizontally into the concrete without being pushed downward until the vibrator’s tip reaches the bottom of the forms or enters into a previously consolidated lift.

Vibrate the concrete till air bubbles in the vibrator's sphere of action effectively cease to rise to the surface. Retract the vibrator at a slower rate than it was lowered. Replace the vibrator and redo the vibration procedure till all the concrete in the products has been solidified. Vibrators should not be used shift the concrete laterally.

The external vibrators (shape vibrators) have to be positioned on the shape structure in positions that distribute their impact the most uniformly, not specifically on the form skins. Air bubbles should be visible on the surface for the duration of the external vibrators' operation.

Floor shakers (vibrating caps) shall travel at a speed which prevents air bubbles from rising to the surface.

If the items are free of honeycombed sections, consolidation of machine-made products is considered sufficient.

SCC is frequently referred to as "vibration-free concrete." The manufacturer may find that light vibrations or shocks on the formwork will completely compact the concrete for a more sophisticated formwork or formwork including substantial reinforcing or blackouts. Bug holes, honeycombing, voids, and inadequate formwork filling can all be avoided using this method.

- Unformed surface finish

Wet-cast precast concrete products with unworked surfaces, such as step and platform slabs, which will be used as walking road surfaces of light-duty vehicles, must be completed as required. If no other finishing method is specified, these surfaces must be completed with a strike-off for leveling the concrete with the top of the formwork.

- Secondary pours

Procedures must be devised for goods that require secondary pours to ensure that the concrete cast during the secondary pour appropriately bonds to the precast concrete product and becomes an integral component of it.

- Precautions for hot weather

In hot weather, concrete must not exceed 90 degrees F at the time of placement (32 degrees C).

According to ACI 305R, "Hot Weather Concreting," excessive heat is described as any combination of the following conditions that tend to degrade the quality of freshly-mixed or cured concrete by speeding up moisture loss and cement hydration. For the purposes of this guide, these conditions include:

- Extremely hot surroundings.
- Concrete that is extremely hot.
- The relative humidity level is low.
- Wind
- The rays of the sun

In hot weather, extra vigilance should be exercised when casting concrete outdoors to avoid drying shrinkage, splitting and low strength. These safeguards could include:

1) Use cool water or add ice to the mixture water.

2) Increase of aggregate inventories.

3) Fog spraying occurs right before casting.

4) When concreting, place fog sprays windward that are above the products, especially when finishing unformed surfaces.

5) After the concrete has dried, use a product to help prevent water from evaporating from the surface, such as wet burlap, plastic sheeting, or curing compound.

6) Keep an eye on the temperature of the concrete as it cures.

- Precautions for cold weather

In cold weather, concrete must be at least 45 degrees Fahrenheit at the time of placement (7 degrees C). Cold weather is defined in this guide and in accordance with ACI 306R, "Cold Weather Concreting," as the period during which the ambient temperature of the casting medium satisfies the following requirements for more than three. (3) consecutive days:

- The average daily air temperature is less than 40 degrees F (5 degrees C).
- The air temperature is not higher than 5 degrees F (10 degrees C) for more than one-half of any 24-hour period.

- Plant specifications

1) On a daily basis, the plant QC Inspector shall inspect plant equipment used to transport concrete to ensure that concrete does not segregate or become contaminated. Each product line’s concrete transport, placing, consolidation, and finishing shall be spot-checked and documented by the QC Inspector.

2) Employees must be properly trained to use internal and external vibrators.

3) During hot and cold weather, the facility must retain established processes for concreting.

2.2.20 Concrete curing

To help prevent Delayed Ettringite Formation, internal concrete temperature monitoring standards are devised (DEF). The commentary also provides further information by presenting five concrete mix design solutions that will prevent both ASR and DEF.

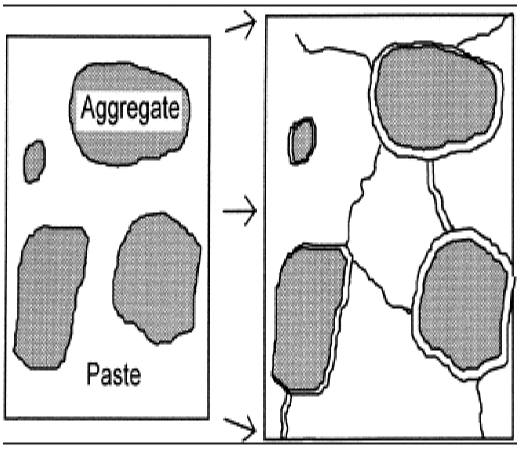

Figure 2.4: Ettringite Formation

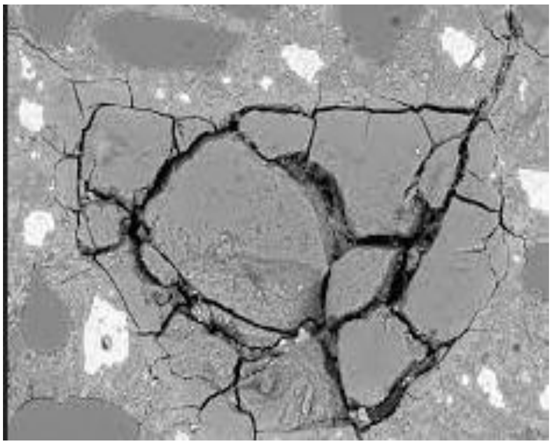

Figure 2.5: Ettringite Formation

- General

Hardening should start as early as possible, prior to the appearance of shrinkage cracks, and no later than 4 hours after the pouring of the precast concrete unit. Concrete temperature must not exceed 150º Fahrenheit (65º Celsius). Concrete temperatures must not exceed 160 degrees F whether approved procedures are used to prevent late ettringite training (DEF) (71 degrees C). At least once every three months, check the highest interior concrete temperature zone's maximum concrete temperature (s). Testing will be used to determine the highest internal concrete temperature. When determining the minimal quantity of testing required for verification, all product dimensions, mix configurations, and curing circumstances must be considered.

When curing concrete using steam or radiant heat, it is necessary to develop curing procedures and keep track of the temperature of the concrete and surrounding area.

- Moisture retention curing

Preventing moisture from evaporating from the exposed surfaces of precast concrete parts when the concrete temperature is above 55 degrees Fahrenheit is thought to be an efficient method of curing (13 ^{o}C). The curing period must be extended if the concrete temperature is below 55 degrees F (13 ^{o}C) but above 35 degrees F (2 (^{o}C) and moisture evaporation is prevented. The effectiveness of forms in limiting evaporation from contact surfaces is required.

A membrane-curing chemical that is applied thickly enough to prevent moisture evaporation is also an efficient curing procedure.

The necessity for curing with heat and moisture will be influenced by local regions, ambient temperature, and humidity levels.

- Curing with heat and moisture

After the concrete has reached its initial setting, it may be exposed to steam, hot air, or other means of rapid curing. Chemical admixtures are not included. When heat-curing concrete, record the initial set (ASTM C403) at least once every quarter. If steam is utilized, it must be applied in a proper enclosure that allows for unimpeded steam circulation. If hot air is utilized to cure the concrete, more care must be taken to minimize moisture loss. These standards do not apply to products treated in an autoclave using steam under pressure.

The ambient curing temperature (for both wet-cast and dry-cast products) must be checked and recorded at least once every week when using accelerated curing with heat and moisture. The factory must create an ambient curing cycle that guarantees the ambient curing temperature does not rise above 150 degrees Fahrenheit, barring the use of techniques to prevent delayed ettringite formation (DEF) (65 ^{o}C). The rise in ambient curing temperature cannot be allowed to surpass 40 degrees F (22 ^{o}C) per hour.

Gas-fired heaters shouldn't be used to directly heat exposed concrete surfaces since there's a chance that the concrete could become severely carbonated.

- Plant characteristics

Check if the blend designs generate the highest heat, the largest mass of concrete and the hottest curing conditions will not cause the maximum concrete temperature to be exceeded.

If items are cured with heat and moisture to expedite strength gain, the ambient curing temperature must be checked at least once a week during the curing period. Temperature data must be kept in the plant files.

Determine the required initial-set period if heat curing is utilized.

Moisture loss must be prevented by using a curing agent, wet curing, or impervious sheeting on products cast outside or in dry environments.

The QC Inspector will look for signs of plastic cracking in product curing and exposed surfaces of stripped items. The loss must be documented.

2.2.21 Getting products out of their forms

- Minimum strength requirement

The concrete must reach the appropriate compressive stripping strength before the products can be removed from the forms Failure to meet this requirement, the utility must identify the product's micro-strengths before stripping. In order to ensure that the strengths required for abstraction are achieved, one-day compressive force tests are required for each component every three months.

Dry-cast and/or machine-made goods are exempt from these criteria.

- Stripping causes product damage

Before shipment Qualified factory staff must analyze damaged products during stripping to determine whether repairs are needed, and if so what repairs are required

In the final inspection report, it is important to maintain records containing damage and repairs.

- Surfaces with sculpture

If formed surfaces are free of air spaces and honeycombed regions, they are deemed satisfactory unless otherwise stated in the design.

- Inspection after pouring

After peeling the goods from the items, we should do the checking to make sure they are similar to the design. Fixable problems are scheduled into primary and secondary problems. Inspection records must be maintained for at least three years after casting.

- Plant characteristics

Each product should be inspected after poured. to document harm, damage or the appearance of a beehive, weak endurance or other problems during inspections. Each product must be stamped on either acceptable or unacceptable. (BMTPC 2019).

2.2.22 Restoration of concrete

- Minor flaw correction

Minor flaws are those that do not hinder the functional usage or estimated life of a precast concrete product. Minor flaws can be fixed using any approach that does not compromise the product.

When repairing honeycombed sections, all bulk material should be cleaned, and areas should be reduced to mainly horizontal or vertical networks to a depth where coarse assembled particles are crashed under chopping rather than separated. The manufacturer's instructions must be followed when using proprietary repair materials. If no property reform substance is used, the area must be saturated with water and wet immediately prior to repair, but there must be no extra water. On the chipped surfaces, apply a cement-sand grout or an approved bonding agent, then quickly consolidate an appropriate repair material into the cavity.

- Correcting serious flaws

Major flaws in pre-cast concrete products are those that affect the functional usage or expected life of the product. The product will be rejected until serious flaws are corrected. Qualified professionals must assess major flaws to determine whether repairs are feasible and, if so, to create a repair procedure. Inspection of proper mending and curing techniques is required.

- Inspection of repairs

Products that require honeycombed area repairs or substantial repairs must be inspected while being repaired.

Any significant repairs must be noted and filed with the product's final inspection report.

- Plant requirements

1. The facility must have policies in place for fixing products that have defects like honeycombing, excessive air voids, and small and major flaws. A list of approved repair products must be included in the procedures.
2. After the repairs have been performed and inspected, a mark on the product must be made indicating whether it is acceptable or refused.

3. The QC Inspector will inspect the fixes.
4. Significant repairs must be noted.

2.2.23 Product identification, storage, and shipment

- Product recognition

Products must be labeled according to project standards. Unless product specifications or aesthetic considerations prevent it, products must be clearly identified as conforming to this manual. For plants taking part in the NPCA Plant Certification Program, this symbol will serve as the "NPCA Certified Plant" emblem.

- Storage locations

To prevent harm to goods stored there, product storage rooms must be solid and level.

- Products' storage

Products must be housed in such a way that damage from uneven bearing, it minimizes improper placement of dunnage blocks, excessive product stacking, and handling challenges. 4.8.3 Products' Storage.

Rejected products that cannot be fixed effectively must be clearly marked as such so that plant staff may quickly identify them as such. Rejected products must be kept apart from the regular supply.

- Product distribution

Trucks and other modes of transportation used to transport precast concrete goods from the factory to the customer's specified site must be equipped and maintained to deliver those items without causing them to be repaired or rejected.

All products and accessories sent on each load must be documented for at least a year. If any items were damaged during delivery, the documentation must reflect this.

- The final exam

To ensure proper identification and design conformity, products must be inspected before shipping. A procedure for sampling and inspecting bulk-shipped materials must be created by the precast facility. Products that have been shipped to the project site individually must be examined independently. Inspections need to be documented. To ensure proper identification and design conformity, products must be inspected before shipping. A procedure for sampling and inspecting bulk-shipped materials must be created by the precast facility. Products that have been shipped to the project site individually must be examined independently. Inspections need to be documented.

Nonconforming products must be clearly marked, and the inspection report must detail any faults. Products will only be sent if they match the requirements. Certain minor restrictions may be waived by the buyer at their discretion. Before shipping, defects must be communicated to management so that corrective action can be implemented.

- Plant requirements

1. Storage spaces must be kept solid and level to prevent product damage during handling and sinking into the ground.
2. Products must be stored in a way that minimizes harm.
3. The QC Inspector is responsible for inspecting the storage space and stored products on a daily basis.
4. Products must undergo a final examination before being sent. The results of this inspection must be recorded in the plant's records. The inspection must ensure that the product meets project requirements, plans, and other contract papers; that it has the appropriate post-pour inspection markings; and that any necessary repairs have been completed and inspected.

2.2.24 Operations of quality control

- Required records summary

Except as otherwise provided in this Handbook, all Required Documentation and Records shall be retained for a minimum of three (3) Years. Before their first audit, new plants in the NPCA Plant Certification Program must have records going back at least 30 days. After that, all necessary records and paperwork need to be preserved for as long as the statutory minimum retention period.

All required records should be kept in one central area at the factory, in accordance with the advice. Additionally, it is very helpful if the records are organised in the same sequence as the chapters in this manual.

- Records of tests and raw materials

The precast factory is required to maintain third-party staff credentials, calibration records for third-party and/or facility-owned test equipment, and records of incoming raw materials and certificates for a minimum of three (3) years. These documents must at least contain the following:

1. Test reports and certificates for cement mills.
2. Certifications and reports in aggregate.
3. Tests for water portability or appropriateness.
4. Test reports and certificates for chemical admixtures and supplemental cementitious materials.
5. Certifications for reinforcement mills.
6. Certification for fiber-reinforcement.
7. Supplier certificates and test reports for joint sealants, gaskets, and connectors.
8. Certifications and reports from accessory suppliers.
9. Batch records or delivery tickets for ready-mixed concrete.
10. Provisions from America as needed for a specific project.
11. Provisions from the United States as needed for a given project.
12. Test equipment calibration records and Laboratory Accreditation or ACI certificates from any third-party company or testing organization.

Records that call for yearly certifications and/or test reports must be dated no more than a year after the most recent certification or test at the end of the month.

To make sure that the components used to create precast concrete products adhere to the required requirements, test records are helpful. They are useful for identifying issues that appear soon after a product is manufactured or after it has been in use for a while. Accessories are adornments offered with products but do not include wiring, seats, or clips.

- Independent third-party testing laboratory

AASHTO laboratory accreditation or ISO/IEC 17025 accreditation are two options for third-party laboratories. The credentials of the testing personnel as well as the calibration records for the utilized equipment must be obtained by plants that contract with a third-party laboratory for testing and/or calibration services.

Technicians from a third-party laboratory conducting plastic concrete testing at the precast production must be ACI Field Technician Level I accredited.

Compressive strength and/or aggregate testing technicians from outside laboratories are required to present a current ACI certification for the tests in addition to a certificate of equipment calibration.

Plants that must comply with owner-specific certification and testing standards must keep suitable documents on file for auditor examination.

- Product drawings and work orders

The precast plant must keep all work orders for each project until it is completed. The precast plant must save product drawings for at least three (3) years. Because most work orders are internal documents, they do not need to be preserved for quality assurance.

On the other side, product drawings are important records that may be used in product evaluation years after the product has been used. Precast manufacturing facilities that produce customised goods should have drawings, computer scans, microfilms of the drawings, or other methods of product drawing preservation in place.

- Calibration logs for equipment

Equipment calibration records must be kept in a place where the equipment operator may easily access them.

Any piece of equipment that requires calibration must be clearly marked with the most recent calibration stickers. The gadgets on the following list all need to be calibrated at least once a year. At the end of the month, the date of the most recent calibration or certification must be included in all current calibration reports.

Water meters, concrete batching scales

- Mixture batching machines
- Compression testing devices for concrete
- Weighing scales
- air pressure gauge.
- High-density (unit weight) bucket—rebound hammer (if used)
- Clocks and temperature recorders
- Bearing test equipment with three edges
- Measuring instruments for pipes and manholes
- Vacuum and hydrostatic testing apparatus

The calibration of the three machines used to test three-edge bearings, compression testing apparatus, and batching scales will be carried out by an impartial third-party calibration organization. The supplier, in-house, or a third-party calibration organization must do all other calibrations.

- Records of aggregate and concrete testing

Records of aggregate gradation, organic pollutants in aggregates, and aggregate moisture content shall be retained for a minimum of three (3) years. For a minimum of three (3) years, the precast plant is required to retain records on concrete temperature, slump, air content, density (unit weight), and compressive strength tests.

They are not very helpful unless aggregate and concrete testing documents can be easily located to show which products were made using the materials tested. Test reports may be helpful if there is an easy method for connecting them to certain items.

- Reports on Concrete Mixing

The precast plant is required to record and maintain daily reports of the actual concrete mix proportions for each mix used and the volume of concrete produced for at least three (3) years.

To make the records meaningful, a means of identifying which items are made from each batch should be employed. Electronic batching files should be backed up at least once a week.

- Records of general plant and product inspections

The precast manufacturer is required to maintain product inspection records and inspection reports from QC Inspectors for at least three (3) years. Records of final product inspections are only helpful inasmuch as they demonstrate that the products were determined to be of acceptable quality when they were allowed to leave the facility. They are therefore perfect for managing plants.

- Plant specifications

Keep the pertinent documents in a file that is both organised and accessible. Documentation for specific commodities must be easily searchable and indexed by date or piece number. Records must be retained for as little period as practicable.

2.2.25 Aggregateg testing

- Aggregate gradation

For every 1,500 tonnes (1,350 metric tonnes) of fine aggregate and every 2,000 tonnes (1,800 metric tonnes) of coarse aggregate, the aggregate supplier or the precast factory must execute gradation tests. The "Standard Test Method of Sieve Analysis of Fine and Coarse Aggregates," ASTM C136, must be followed for grading aggregates.

To ascertain whether aggregates match the standards, gradation tests are carried out. In concrete mixtures, aggregates with predetermined gradations (particle size distributions) are frequently employed. Finding gradation variances so that concrete mixtures can be altered or rebuilt is one of the reasons for conducting aggregate gradation tests. A general rule of thumb states that an adjustment or redesign is required if the fine aggregate's fineness modulus changes by 0.20 or more.

Concrete mix modifications may be necessary when there are significant variations in coarse aggregate gradations. The amount of material that passes through the No. 50 (0.300 mm) sieve often reflects variations in the workability and bleeding characteristics of the concrete.

2.2.26 Moisture level

- Concrete (conventional and/or dry-cast)

In accordance with ASTM C70, "Standard Test Method for Surface Moisture in Fine Aggregates," or ASTM C566, alternative methods such as moisture metres or probes, aggregate surface moisture content (water in excess of that absorbed by the aggregates) shall be determined at least once daily. "Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying," for conventional and/or dry-cast concrete. In addition to using an oven, drying aggregate with a microwave or hot plate is permissible.

When aggregate bins are outfitted with moisture probes or metres, aggregate surface moisture content must be assessed at least once per week in traditional and/or dry-cast operations to assure moisture probe accuracy and performance.

Knowing the moisture level of the aggregate is critical for determining the water content of the concrete batch. This information can also be used to determine and make changes to mix designs.

- Concrete that self-consolidates

The aggregate surface moisture content must be assessed at least once per week when moisture sensors or metres are used with automatic mixing water adjustment systems in SCC processes in order to verify calibration. Tests must adhere to either ASTM C566, "Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying," or ASTM C70, "Standard Test Method for Surface Moisture in Fine Aggregate." Aggregate can also be dried using a microwave or hot plate in addition to an oven. Samples for moisture tests should be taken as near as possible to the probe's site.

Because SCC concrete is so moisture sensitive, accurate water content control is needed. Verifying the surface moisture of the aggregates will enable the proper adjustments to be made to the mix water because the aggregates' moisture content varies throughout the day. Slump Flow and VSI testing will only vouch for an SCC mixture's compliance with specifications if moisture tests are not conducted routinely (every three batches).

For SCC processes created without moisture probes or metres and automatic mixing water adjustment systems, the aggregate surface moisture content must be measured at least once a day prior to making the first batch of SCC and then once every four hours after the first batch, while SCC is being mixed. Testing must adhere to ASTM C70, "Standard Test Method for Surface The "Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying," also known as "Moisture in Fine Aggregate," is ASTM C566. In addition to an oven, a microwave or hot plate can also be used to dry aggregate.

Additionally, each of the three batches of SCC produced must pass compliance testing for Slump Flow and VSI (This is to ensure that moisture fluctuations in aggregates are properly accounted for.) The additional slump flow and VSI testing may be replaced by moisture tests every three batches as described in this section.

In situations when the plant is producing SCC, the unit weight of the mix should be examined as an additional type of mix proportioning verification in addition to slump flow and VSI.

- Requirements for plants

The plant records must keep track of aggregate gradations, harmful substances, and aggregate moisture tests.

- Independent testing

If the test result from the documented initial mix qualification does not fall within the stated acceptable tolerance range, plant employees must take corrective action.

2.2.27 Visual stability index, slump, and slump flow

- Slump

Each 150 cubic yards (115 cubic meters) of fresh concrete of each mix design must undergo a slump test, or once per day, whichever comes first. ASTM C143, "Standard Test Method for Slump of Hydraulic-Cement Concrete," must be followed while doing slump testing. SCC, no-slump, or dry-cast concrete does not require slump testing.

- Index of slump flow and visual stability

SCC mixtures must have slump flow and visual stability index (VSI) tests of fresh concrete performed every day by testing the first batch of SCC as stipulated by the first mix qualification process. If the upper specification limit is exceeded, reject the concrete. If the slump flow test result falls below the lower production range limit, the concrete should be rejected unless the mixture has been approved for vibration and then vibrated. Following that, slump flow and VSI testing will be carried out as follows:

- Changing the design of the mix.
- When it comes to basic resources.

The ASTM C1611 "Standard Test Method for Slump Flow of Self-Consolidating Concrete" must be followed while doing slump flow and VSI testing.

- Temperature

The temperature of fresh concrete from each mix design must be measured when slump or air content tests and compressive test specimens are conducted. Along with other recent concrete test results, the temperature of the concrete should be documented. When determining the temperature of freshly mixed Portland cement concrete, the ASTM C1064, "Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete," must be used.

A number of properties of fresh concrete are influenced by its temperature.

Cold concrete takes longer to cure than warm concrete. Warm concrete hardens more quickly than cold concrete, but it will eventually lose strength.

The batch plant operator may alter mixes based on the temperature of fresh concrete, and the concrete foreman can better assign workers. Curing warm concrete is much more critical than curing cool concrete because warm concrete dries faster.

- Density (Weight in Units)

Tests for density (unit weight) of new concrete of each mix design must be carried out at least once per week or every 150 cubic yards, whichever occurs first, to confirm the production of batch mixes. Every 100 cubic yards (75 cubic metres) of lightweight concrete must undergo testing, or once every month, whichever comes first. Testing must adhere to ASTM C138, "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete." Unless otherwise specified, density (unit weight) testing is not necessary for dry-cast concrete.

For lightweight concrete products, the density (unit weight) of concrete is frequently specified. If the density exceeds or falls below the prescribed limitations, the mix should be adjusted to raise or decrease the density.

The density should be measured again after the adjustments have been made. Dividing the total weight for a cubic yard or a cubic meter (theoretical) by the density of the concrete is the best way to check the concrete's production (the actual volume of concrete produced from quantities of materials that are theoretically needed for one cubic yard or one cubic metre of concrete).

- Air Quality

A minimum of once per day, the air content of every 150 cubic yards (115 cubic metres) of wet-cast concrete of each mix design featuring air-entrainment must be evaluated. When compressive strength specimens are cast, tests for air content must be conducted on all wet cast concrete of fresh concrete of each mix design made without air entrainment at least once a week. The air content of freshly mixed concrete must be determined using either the pressure method, ASTM C231, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method," or the volumetric method, ASTM C173, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method." After establishing a connection between air content and density (unit weight), For ASTM C231 or ASTM C173, an ASTM C138 density (unit weight) test can be used instead. Air content testing is not necessary for dry-cast concrete (Committee 2015).

2.2.28 Strength in compression

- Wet-cast

According to ASTM C31, "Standard Practice for Making and Curing Concrete Test Specimens in the Field," compression strength cylinders must be manufactured. Specimens must be treated similarly to how concrete products are cured.

Unless the project specifies otherwise, the specimens

The main goal of creating and evaluating compressive strength specimens is to see if the concrete strength meets the specifications. Early strength testing can also be used to evaluate curing techniques and determine concrete consistency. It is advised to utilize 4 × 8-inch cylinders unless the specifications restrict it because doing so is simpler and less expensive than using 6 × 12-inch specimens. 4 × 8-inch cylinder-made specimens are smaller, simpler to make, use less concrete, are simpler to handle, and require less storage space.

- Dry-cast or machine-cast

Machine-cast and/or dry-cast concrete products can be vibrated or cut into test cylinders or product cores. Test cylinders must be vibrated in accordance with ASTM C497 in the same manner as the items they represent are produced.

- SCC

For fabricating compressive strength cylinders, ASTM C1758, "Standard Practice for Fabricating Test Specimens with Self-Consolidating Concrete," must be followed. Unless the project specifies otherwise, specimens must be cured in a manner equivalent to the curing of the concrete products represented by the specimens.

- Specimens of compressive strength

Each mix contains 150 cubic yards (115 cubic meters) of concrete, at least four compressive strength specimens must be created, or once per week, whichever comes first. Two specimens must be tested within seven days of receiving them, and the remaining two must be tested within twenty-eight days of receiving them, or at the age specified by the design, if the specified design strength has not been met by then. ASTM C39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," must be used to test specimens constructed in cylinder molds. For testing cubes or cores cut from goods, ASTM C42, "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete," must be followed.

- Cores or Centers

Three cores from the same manufacturing date and mix design may be used to assess concrete strength if cylinder tests are below the required level. The acquisition and testing of cores must follow ASTM C42.

- Impact hammer with calibration.

If the concrete strength is less than required and the compressive strength test specimens are exhausted, the concrete strength after additional curing can be assessed using a calibrated impact rebound hammer.

The rebound hammer should be used to assess concrete strength at different sites or for quality control purposes, not for acceptance or determining structural appropriateness. The ASTM C805, "Standard Test Method for Rebound Number of Hardened Concrete," must be followed while using an impact rebound hammer.

- Plant specifications:

1. QC testers must be appropriately trained in order to conduct the tests.
2. During the NCPA audit, it is necessary to demonstrate competent ACI Field Technician Grade 1 test methodologies and procedures for cylinder manufacturing, slump, temperature, density (unit weight), and air content.
3. If employed, record the quantity of tests carried out on each neoprene compression test pad.
4. The plant must get the tester's ACI certificate as well as the calibration records for the equipment used if concrete testing is carried out by a third party at the point of placement. Getting this documentation from the provider guarantees that the test participants have received the necessary training and that the tools being used are current.
5. Concrete compressive strength cylinders do not need to be tested by a third party on the manufacturing property. The most recent equipment calibration certificate as well as copies of the tester's ACI certificate are required for plants that utilise third-party providers for compressive strength testing. (ACI 2011).

3. METHODOLOGY

3.1 Introduction

"The principles and procedures for logical processes" is the research technique (Fellows & Liu, 2015). Since the study is exploratory in nature, the scientific research technique was used. The review of literature and interviews were determined to be the most suitable strategies for the exploratory research due to the nature of the research.

After reading through a wealth of literature on the advantages of precast for the construction industry and its function in the green construction industry, the techniques by which this study was conducted will be described in this chapter.

The study methodology, research technique, data collection method, interview question design, and process serve as the foundation for the analysis and discussion in the following chapters.

3.2 Research Approach

This research uses an inductive "down-up" technique because the type of research is a learning process that promotes the research to develop from specialized to generic. The purpose of this survey is to look at using precast elements in the construction sector and how to use them in Iraq and how to employ QM in precast concrete factory.

3.3 Target Population

This survey was distributed via the Internet to about 42 companies and engineering offices in Baghdad, Erbil, and Basra, and we got about 42 responses from participants, whose identities will remain anonymous according to agreed privacy.

This questionnaire was sent to all groups involved in construction.

Table 3.1: Responses

Company	Number of participants	Percentage
Civil engineer	**73**	26.6%
Architect	**2 4**	8.76%
Construction workers	**163**	59.5%
Owner	**14**	5.1%
Total	274	100%

3.4 Data Collection

- Qualitative method

80 per cent of all research budgets are spent on quantitative research, which is used to evaluate how common the activity under study is. There are other methods to collect quantitative data, but surveys are the most useful and widely used.

The survey's methodology is as continues to follow:

A group of a demographic is chosen to get a detailed questionnaire. Surveys are made with the aim of collecting particular data. Frequently, the questions are asked in a predetermined order, and the respondents must select from a predetermined list of responses.

A total of 42 contractor and engineering offices received the study questionnaire through email, and a number of these businesses were contacted by phone in addition to visit 3 precast concrete factory to evaluate the quality management proses inside the factory.

- Quantitative method

Like quantitative research, qualitative research has benefits and drawbacks. There are several types of qualitative collecting data strategies: direct and indirect. When the aim of the qualitative study is explicitly mentioned to the respondents in some other method, the direct method is employed. When the goal is concealed or kept a secret, the indirect strategy is adopted.

A direct approach is allowed when the goal of the research is to understand a respondent's understanding, attitude, assumptions, and attitudes. As a result of allowing us to learn more about the respondent's ideas and views rather than their behaviors, a direct technique is typically less expensive and time-consuming. It's important to keep in mind that our conclusions are based on the declared behavior of our respondents, which may or may not represent their actual behavior. It's crucial to remember that our findings are based on our respondents' stated conduct, which may or may not reflect their real behavior or reasons.

In our study, we conducted a series of interviews. In some companies, the engineering staff gathers information and gets deeper insights.

3.5 Questionnaire and Survey Design

Questionnaire surveys are a frequent method for collecting data for academic or commercial research in a range of sectors. Face-to-face interviews, phone interviews, and mail surveys are some examples of traditional ways to complete questionnaire surveys. The use of an online poll to gather data appears to have the potential to gather large volumes of information quickly (i.e. with less error because written data is not transferred onto a computer), economically (as it requires little human resource effort to collect or manage data), and within relatively short time frames.

To better understand whether precast techniques are used in precast construction and construction stages within design consultant companies in Iraq, a study was undertaken. The results of the survey are discussed below.

The questions were segmented into many sections using Likert scale to ensure research reliability and provide a holistic picture of the precast concrete execution situation in firms (strengths and drawbacks), execution drivers, and the expected function of the government from the participant perspective.

Table 3.2: 5-Point Likert Scale

Likert Scale	**Interval**	**Difference**	**Scale**
1	1-1.79	0.79	Strongly Disagree
2	1.8-2.59	0.79	Disagree
3	2.6-3.39	0.79	Neutral
4	3.4-4.19	0.79	Agree
5	4.2-5	0.8	Strongly Agree

The reliability of the questionnaire in its two parts has been verified by calculating the Alpha Crumbach factories as shown in table (3.3) and table (3.4).

Table 3.3: Reliability Statistics for Section A

Reliability Statistics	
Cronbach's Alpha	N of Items
.990	23

Table 3.4: Reliability Statistics for Section B

Reliability Statistics	
Cronbach's Alpha	N of Items
.992	31

3.6 Data Analysis

The Likert scale was used in the questionnaire and the data was analyzed using statistical SPSS program.

3.7 Limitations

Many employees were unable to provide recorded data from case studies because it was either prohibited by the consultant company or the project's owner, making analysis of data from the projects described in the interview impractical.

3.8 Survey

- **Section A**

3.8.1 Quality management principle in construction sector in Iraq

It was noted from the questionnaire that quality management is an essential part of a large part of engineering companies and offices and many of these offices strive to develop their cadres and improve engineering performance through training courses.

That is, quality management in Iraq's construction market is booming slowly day by day.

In order to know whether the contracting contract in the construction projects contains a paragraph or a legal text requiring the executing authority (contractor) to comply with the technical requirements and specifications of the project during the implementation, the answers of members of the sample (40.4%) are in the affirmative.

The responsibility for ensuring optimal execution lies with the general supervisor of the contractor. The role of the supervising engineer (employer representative) is to ensure that all the shortcomings that arose during the semi-final inspection have been fixed and if so, the responsibility for origin is transferred from the contractor to the employer.

The result of this part of the questionnaire is consistent with the neutral opinion on the spread of quality management in the construction sector in Iraq.

Table 3.5: Quality Management Principle

	Questions	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**mean**	**Std deviation**	**rank**
1	You learned about the principles of quality management (QM) while working		10	10	110	21	3.94	0.685	1
			6.6%	6.6%	72.8%	13.9%			
2	Your professional activities expose you to the idea of (ISO)	10	50	30	61		2.94	1.002	3
		6.6%	33.1%	19.9%	40.4%	0%			
3	There is a division or department in your office or company that specializes in quality management	20	45	35	40	11	2.85	1.170	4
		13.2%	29.8%	23.2%	26.5%	7.3%			
4	A legal provision in the contract that require the implementing agency to adhere to the technical requirements and specifications of the project while it is being implemented		40	10	61	40	3.67	1.136	2
			26.5%	6.6%	40.4%	26.5%			
Weighted mean							3.3493		
Std deviation								0.9265	

3.8.2 Precast concrete system in Iraq

It is clear from the respondent sample that the prevalence of the use of precast concrete systems is widespread in their cities and there is great desire to adopt precast concrete systems as it is considered but the lack of appropriate equipment may be an obstacle to adopting this system.

Table 3.6: Precast Concrete System

	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	mean	Std deviation	rank
1	You learned about precast concrete while you were studying in university.	10 6.6%	15 9.9%	15 9.9%	66 43.7%	45 29.8%	3.8	1.166	3
2	You learned about precast concrete in your professional activities.	40 26.5%	20 13.2%	11 7.3%	65 43%	15 9.9%	2.97	1.426	4
3	Precast concrete system is common to use in your city.	20 13.2%	0 0	30 19.9%	21 13.9%	80 53%	3.93	1.389	1
4	You want to adopt precast concrete system in your projects.	20 13.2%	0 0	30 19.9%	26 17.2%	75 49.7%	3.90	1.375	2
5	Your equipment is fit to apply precast concrete in your projects.	34 22.5%	25 16.6%	41 27.2%	50 33.1%	1 7%	2.73	1.207	5
Weighted mean							3.4662		
Std deviation							1.25129		

3.8.3 The reason to adopt precast system in your projects

The format shows that users want tools that contribute to reducing the time for construct and adding more time to the design process, as well as improving productivity through improved communication among all project parties at early stages, which is one of the most important reasons for the desire to adopt precast element in construct This allows design teams to address the difficulties and shortcomings of the design process and allows for more effective data exchange, communication, and collaboration at all stages of the design process. We also note that accuracy is required, with a number of engineers noting that they see the value of using precast elements in obtaining high-quality charts and documents that enable them to communicate more effectively with colleagues from different disciplines. Saving time and cost is the main objective of engineering project task forces, particularly for contractors who believe that using precast building can reduce construction costs, improve budget estimation and manage costs. as it became clear from the table the great desire of the respondents to develop construction operations in Iraq.

Table 3.7: The Reason to Adopt Precast System in Your Projects

	Questions	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**mean**	**Std deviation**	**rank**
1	Reducing implementation cost.		10	5	51	85	4.4	0.841	2
			6.6%	3.3%	33.8%	56.3%			
2	Improving the cost management process.		10	15	75	51	4.11	0.834	6
			6.6%	9.9%	49.7%	33.8%			
3	More Precise Implementation Diagrams.	5		15	65	66	4.24	0.885	4
		3.3%		9.9%	43%	43.7%			
4	Reduce the time.		5	11	55	80	4.39	0.766	3
			3.3%	7.3%	36.4%	53%			
5	Improving communication between all parties.	12	34	30	45	30	3.51	1.259	7
		7.9%	15.9%	19.9%	29.8%	26.5%			
6	Owner Requirements.	7	25	23	41	55	3.78	1.264	8
		4.6%	16.6%	15.2%	32.2%	40.4%			
7	Giving the company competitive advantages.		5	10	83	53	4.22	0.711	5
			3.3%	6.6%	55%	35.1%			
8	Development of the construction process.				54	97	4.64	0.481	1
					35.8%	64.2%			
Weighted mean							4.1606		
Std deviation							0.82568		

3.8.4 The obstacle that faces the implementation of precast concrete system

Reasons for respondents' unwillingness to adopt precast systems are shown in table (3.8).

The biggest impediment to not wanting to introduce the precast building system concept into the construction industry was do not use it on a real project yet because the lack of sufficient expertise in this area, so we know very well that there is a shortage of experts.

It also showed that customers did not interfere in the type of construction used in general.

Table 3.8: The Obstacle That Faces the Implementation of Precast Concrete System

	Questions	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**mean**	**Std deviation**	**rank**
1	Complex system.	40	25	35	40	11	2.72	1.308	4
		26.5%	16.6%	23.2%	26.5%	92.7%			
2	We couldn't identify its benefits.	24	30	16	56	25	3.19	1.358	2
		15.9%	19.9%	10.6%	37.1%	16.6%			
3	We haven't used it on a real project yet.		26	24	54	47	3.81	1.063	1
			17.2%	15.9%	35.8%	31.1%			
4	Not spread in our city yet.	56	44	10	31	10	2.3	1.332	5
		37.1%	29.1%	6.6%	20.5%	6.6%			
5	Customers did not order it.	65	33	12	32	9	2.25	1.358	6
		43%	21.9%	7.9%	21.2%	6%			
6	Expensive system.	37	23	35	45	11	2.8	1.301	3
		24.5%	15.2%	23.2%	29.8%	7.3%			
Weighted mean							2.8444		
Std deviation							1.23793		

- **Section B:**

3.8.5 Quality management inside planet

A total of 3 factories (AL Burhan factory, the modern DUHOK company for precast concrete and RASAN precast factory) were studied to define situation of quality management in this factories.

The following points were noted from the questionnaire analysis and quality policy discussion with factory managers:

1. The lack of an independent quality management department in most factories, and their quality management depends on monitoring and follow-up by the director of the company, engineers and observers.
2. There is no officer or specialized team for quality management in most of the factories.
3. There is no government support for the Precast factories so that the factories have the possibility to pay attention to the quality of production in a large way.
4. For this product not reaching high quality so that customers are satisfied.
5. Not having enough conviction among customers to not applying quality standards
6. Company managers consider that the quality management system is not important and may increase the cost.
7. Some customers do not care about the high quality of the product and take the lowest quality and cost.
8. Lack of control from the competent authorities in government ministries leads to lack of interest in quality by customers.
9. It also notes the weighted mean of this section is 3.049 which corresponds to impartiality in opinion.

Table 3.9: Quality Management in Iraqi Planet

	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	mean	Std deviation	rank
1	The plant has a clear vision and long-term goals	10	11	12	77	13	3.59	1.063	12
		8.1%	8.9%	9.8%	62.6%	10.6%			
2	The plant has a quality policy		10	23	65	25	3.85	0.836	7
		%	8.1%	18.7%	52.8%	20.3%			
3	Staff are aware of the existence of a quality policy	5	11	24	67	16	3.63	0.96	10
		4.1%	8.9%	19.5%	54.5%	13%			
4	Staff are aware of the contents of the quality policy	2	53	45	13	10	2.8	0.947	16
		1.6%	43.1%	36.6%	10.6%	8.1%			
5	Quality Officer was hired	9	64	40	10		2.41	0.746	20
		7.3%	52%	32.5%	8.1%				
6	Implementation of a coordinated quality management system through the quality project team	22	57	36	8		2.24	0.823	22
		17.9%	46.3%	29.3%	6.5%				
7	Quality management team meetings held on a regular basis	20	73	30			2.08	0.635	24
		16.3%	59.3%	24.4%					
8	The plant has an updated routine agenda.		10	22	78	13	3.76	0.747	8
			8.1%	17.9%	63.4%	10.6%			
9	The plant uses work plans using SMART methodology	10	13	14	54	32	3.7	1.187	9
		8.1%	10.6%	11.4%	43.9%	26%			
10	Work plans examined on a monthly basis and followed up	35	68	14	6		1.95	0.818	26
		28.5%	55.3%	11.4%	4.9%				
11	Equipment officer was hired	26	72	20	5		2.03	0.735	25
		21.1%	58.5%	16.3%	4.1%				

Table 3.9: (Cont.) Quality Management in Iraqi Planet

	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	mean	Std deviation	rank
12	The staff member has the expertise to calibrate and maintain the equipment	13 10.6%	34 27.6%	53 43.1%	23 18.7%		2.7	0.896	18
13	The plant has a clear record of all existing equipment		8 6.5%	12 9.8%	85 69.1%	17 13.8%	3.92	0.708	6
14	Standard operating procedures exist for all machines			20 16.3%	79 64.2%	25 19.5%	4.03	0.6	4
15	The person responsible for each machine and authorized to use it is documented	8 6.5%	22 17.9%	33 26.8%	45 36.6%	15 12.2%	3.3	1.101	14
16	The plant has a person responsible for monitoring the raw material stock and ordering the plant's supplies.			15 12.2%	72 58.5%	36 29.3%	4.17	0.623	2
17	Inventory record is the same for actual inventory			10 8.1%	80 65%	33 26.8%	4.19	0.563	1
18	Storage areas secure the right environment for raw materials in terms of moisture and heat		8 6.5%	12 9.8%	77 62.6%	26 21.1%	3.98	0.757	5
19	All workers are committed to implementing the quality management system as it is established	7 5.7%	13 10.6%	23 18.7%	59 48%	21 17.1%	3.6	1.069	11

Table 3.9: (Cont.) Quality Management in Iraqi Planet

	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	mean	Std deviation	rank
20	New workers are subjected to an introductory course in quality management	21	49	34	19		2.41	0.949	20
		17.1%	39.8%	27.6%	15.4%				
21	Each employee has their own file and is evaluated periodically	21	71	22	9		2.15	0.79	23
		17.1%	57.7%	17.9%	7.3%				
22	Office areas are isolated from casting and processing areas		7	13	78	25	3.98	0.735	5
			5.7%	10.6%	63.4%	20.3%			
23	Emergency numbers are available near phones and visible	35	68	12	8		1.81	0.605	27
		28.5%	55.3%	9.8%	6.5%				
24	Complete and updated critical condition sheets are existing.	36	74	13			2.55	0.738	19
		29.3%	60.2%	10.6%					
25	All critical conditions papers are located in a logical location	11	40	65	7		4.1	0.762	3
		8.9%	32.5%	52.8%	5.7%				
26	Clear and specific criteria have been established for the acceptance or rejection of samples		5	15	66	37	2.76	0.959	17
			4.1%	12.2%	53.7%	30.1%			
27	The plant verifies the validity of all inspection methods conducted in the materials laboratory	11	34	58	13	7	2.76	0.959	17
		8.9%	27.6%	47.2%	10.6%	5.7%			

Table 3.9: (Cont.) Quality Management in Iraqi Planet

28	Internal quality control results are constantly monitored	20	60	23	15	5	2.39	1.029	21
		16.3%	48.8%	18.7%	12.2%	4.1%			
29	The plant has a database/record of customers	13	26	48	36		2.87	0.958	15
		10.6%	20.3%	39.8%	29.3%				
30	The plant has a service guide that includes the types and specifications of manufactured items	7	13	30	53	20	3.54	1.066	13
		5.7%	10.6%	24.4%	43.1%	16.3%			
31	The plant service guide is sent to all customers	20	78	25			2.04	0.606	24
		16.3%	63.4%	20.3%					
Weighted mean							**3.049**		
Std deviation							**0.76966**		

3.8.6 The researcher proposes a set of recommendations that include

- Establishment of an ad hoc committee to develop and improve the plant's component transfers sector", a significant loss of material and time was observed as a result of the lack of mechanisms used in the transport process, this delays the delivery of items to the client. This shortage has also resulted in significant damage to the mechanisms that are not prepared for very large loads and are able to move to long distances and return again to transport the remaining payments, resulting in an excessive cost of maintaining these mechanisms and a significant waste of time. That is, the Commission's task is to coordinate the quality of the elements with the size of the mechanisms.
- To pay attention to the quality of transport mechanisms and their adherence to specific standards, and to subject workers in this area to tests that confirm their competence and ability to deal with the different conditions they may encounter during workers to ensure the proper and timely arrival of personnel.
- A template has been proposed to characterize and inspect materials used in the items industry in order to obtain similar elements in terms of mechanical specifications and other templates to characterize products.

- The need to establish an examination laboratory based on the international standards of ISO and to assign it to qualified cadres for this process with periodic calibration of all laboratory departments. The relevant authorities, such as the Ministry of Planning and in coordination with the relevant ministries and other relevant bodies, shall identify and circulate to all State departments sober laboratories approved for testing.
- Review and audit of construction designs by certain entities not associated with the designer and indicate their conformity
- Technical specifications, enforceability and beneficiary's needs in terms of design calculations and checks and others.
- All engineering colleges and institutes are obliged to teach an independent scientific subject on quality management to create a conscious engineering generation
- the importance of quality and the means of managing it in various aspects of engineering work.
- Appropriate distribution of experienced and newly graduating engineers by project managers Concrete to ensure the quality of execution.
- Expand the use of statistical methods to ensure quality and using statistical quality control maps.

4. CONCLUSION AND RECOMMENDATIONS

The results of this study indicate that the QA/QC system has not been applied. The study also indicates the need to appoint an independent inspection agency to ensure strict implementation of quality systems in casting factories. Various measures should ensure compliance with quality during the production process. This includes the test of scheduled materials and clips, tests and dimensions, visual inspection, and more . Quality inspectors play a major role in checking daily quality operations in this field, and quality guarantee engineers offer progress and make suggestions for improvement. Despite the quality monitoring system, some areas of problems have been identified. This was primarily due to the deviations of the casting process and the lack of maintenance. A large number of contradictions were associated with the defects of the sectoral surface. A review of the QA/QC control system showed that although the system has no deficiency, it can improve certain aspects. This includes therapeutic work, equipment maintenance, and employee interruption. Among the factors to maintain good quality.

In order to apply the progress made in ready -made construction technology in our country, studies and the necessary research and exploration in this field must be conducted in order to use modern methods in line with our needs and our resources of raw materials and the available workforce. Research and studies should not be limited to the technology of producing concrete units with a limited scope, however, the areas of design of housing units must include manufactured in a way that is compatible with climatic, economic and social conditions in Iraq.

4.1 Future Work

The recommendation of future work:

- Digitizing test of material and elements by using special program.
- Develop a system to control the planning quality, time programming control of precast concrete projects.

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APPENDICES

Appendix 1: Survey Questionnaire

QUALITY MANAGEMENT IN THE PRODUCTION OF PRECAST CONCRETE UNITS IN IRAQ A COMPARATIVE STUDY

Dear Respondents,

You are invited to participate in our data gathering as part of our Research paper entitled: **"QUALITY MANAGEMENT IN THE PRODUCTION OF PRECAST CONCRETE UNITS IN IRAQ."** Rest assured that the data gathered will be kept strictly confidential and will only be used for the purpose of this researched work.

Thank you for your time and cooperation.

The Researcher:

Talib Abed FAIHAN

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1. Demographic Profile

Name :……………………

Age:………………………….

City:………………………….

Current work:………………

Profession/ Designation:

[ ] Engineer

[ ] Architect

[ ] Construction workers

[ ] owner

No. of years in construction Industries:

[ ] Less than a year

[ ] 1-3 years

[ ] 4-6 years

[ ] 7-10 years

[ ] More than 10 Years

Section A:(general section for an engineer, architect, Construction workers, and project owner)

Direction: Kindly read the items properly and write a check (√) on the appropriate box that corresponds

1. Quality management principle:

	Questions	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1	you learned about the principles of quality management (QM) while working					
2	your professional activities expose you to the idea of (ISO)					
3	there is a division or department in your office or company that specializes in quality management					
4	A legal provision in the contract that require the implementing agency to adhere to the technical requirements and specifications of the project while it is being implemented					

2. Precast concrete system:

	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	You learned about precast concrete while you were studying in university.					
2	You learned about precast concrete in your professional activities.					
3	Precast concrete system is common to use in your city.					
4	You want to adopt precast concrete system in your projects.					
5	your equipment is fit to apply precast concrete in your projects.					

3. The reason to adopt precast system in your projects:

	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Reducing implementation cost.					
2	Improving the cost management process.					
3	More Precise Implementation Diagrams.					
4	reduce the time.					
5	Improving communication between all parties.					
6	Owner Requirements.					
7	Giving the company competitive advantages.					
8	Development of the construction process.					

4. The obstacle that faces the implementation of precast concrete system:

	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	complex system.					
2	We couldn't identify its benefits.					
3	We haven't used it on a real project yet.					
4	Not spread in our city yet.					
5	Customers did not order it.					
6	Expensive system.					

Section B:(Factory section)

1. Quality management inside planet:

	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	The plant has a clear vision and long-term goals					
2	The plant has a quality policy					
3	Staff are aware of the existence of a quality policy					
4	Staff are aware of the contents of the quality policy					
5	Quality Officer was hired					
6	Implementation of a coordinated quality management system through the quality project team					
7	Quality management team meetings held on a regular basis					
8	The plant has an updated routine agenda.					
9	The plant uses workplans using SMART methodology					
10	Workplans examined on a monthly basis and followed up					
11	Equipment officer was hired					
12	The staff member has the expertise to calibrate and maintain the equipment					
13	The plant has a clear record of all existing equipment					

14	Standard operating procedures exist for all machines					
15	The person responsible for each machine and authorized to use it is documented					
16	The plant has a person responsible for monitoring the raw material stock and ordering the plant's supplies.					
17	Inventory record is the same for actual inventory					
18	Storage areas secure the right environment for raw materials in terms of moisture and heat					
19	All workers are committed to implementing the quality management system as it is established					
20	New workers are subjected to an introductory course in quality management					
21	Each employee has their own file and is evaluated periodically					
22	Office areas are isolated from casting and processing areas					
23	Emergency numbers are available near phones and visible					
24	Complete and updated critical condition sheets are existing.					
25	All critical conditions papers are located in a logical location					
26	Clear and specific criteria have been established for the acceptance or rejection of samples					
27	The plant verifies the validity of all inspection methods conducted in the materials laboratory					
28	Internal quality control results are constantly monitored					
29	The plant has a database/record of customers					
30	The plant has a service guide that includes the types and specifications of manufactured items					
31	The plant service guide is sent to all customers					

Thank you for your cooperation.

The Researcher

RESUME

Talib Abed Faihan Hammadi AL -DULAIMI

EDUCATION:

- Bachelor's degree: In Civil Engineering from Anbar University-Graduation Year (2004-2005)
- Master's degree - Department of Engineering Management - Istanbul Gedik University in the year 2023)

QUALIFICATIONS

- He holds a Bachelor's degree in Civil Engineering from Anbar University-the year of graduation (2004-2005)*
- He holds a diploma from the Technical Institute in Al -Saqlawiya - the year of graduation 1991*

SCIENTIFIC EXPERTISE:

- Civil engineering works, where these works were practiced at Najran General Contracting Company *
- Engineering Projects Management *