STUDY ON THE PERFORMANCE OF VARIOUS TYPES OF PRECAST CONCRETE SYSTEM

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FACULTY OF ENGINEERING

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ABSTRACT

Precast concrete has been introduced since early 1960s and was over the years was implemented in construction in Malaysia. Precast concrete is a form of concrete that is prepared, cast and cured off-site which environmentally friendly, saves money, and helps the community. Reusing and recycling construction procedures like moulds and forms and concrete aggregates and additives minimises the amount of materials utilised. This study explores and reviews other researcher papers regarding the behaviour of precast frame system and precast wall panel system and comparing the different types of precast concrete connection.Adopting precast concrete will make the construction sector more efficient, clean, safe, professionally managed and handled by professionals and workers with suitable abilities, coordinated, inventive, and quality. Thus, there is some issues and challenges to implement in construction industry due to lack of familiarity with precast concrete technology which also emphasizes in this study.

ABSTRAK

KAJIAN PRESTASI PELBAGAI JENIS SISTEM KONKRIT PRATUANG

Konkrit pratuang telah diperkenalkan sejak awal 1960-an dan selama ini telah dilaksanakan dalam pembinaan di Malaysia. Konkrit pratuang ialah satu bentuk konkrit yang disediakan, dituang dan diawet di luar tapak yang mesra alam, menjimatkan wang dan membantu masyarakat. Menggunakan semula dan mengitar semula prosedur pembinaan seperti acuan dan bentuk serta agregat dan bahan tambahan konkrit meminimumkan jumlah bahan yang digunakan. Kajian ini meneroka dan menyemak kertas penyelidik lain mengenai tingkah laku sistem rangka pratuang dan sistem panel dinding pratuang dan membandingkan pelbagai jenis sambungan konkrit pratuang.Mengguna pakai konkrit pratuang akan menjadikan sektor pembinaan lebih cekap, bersih, selamat, diurus secara profesional dan dikendalikan oleh profesional dan pekerja dengan kebolehan yang sesuai, diselaraskan, inventif dan berkualiti. Justeru, terdapat beberapa isu dan cabaran yang perlu dilaksanakan dalam industri pembinaan kerana kurangnya pengetahuan tentang teknologi konkrit pratuang yang turut ditekankan dalam kajian ini.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

IBS	-	Industrialised Building System
THC	-	Tapered Head Sleeves
RC	-	Reinforced Concrete
WBS	-	Welded Bar Sleeves

CHAPTER 1

INTRODUCTION

1.1 Research background

In recent years, the problem of environmental protection and sustainability has received widespread attention, and the construction sector has been particularly concerned about the rising costs of building upkeep and the challenges surrounding building lifecycles. Precast concrete elements such as beams, columns, structural and non-structural walls, and slabs are frequently utilised in construction projects in order to reduce project length while maintaining or improving project quality. Rethinking the success of prefabricated technology in other nations has led the Malaysian building sector to reassess its own efforts (Mohamed Nor Azhari Azman *et al.*, 2012). In the building industry, precast concrete is a product that is created by pouring concrete into an easily reused mould or form, curing it in a controlled environment, transporting it to the construction site, and erecting it in its final location. In order to create a large number of structures in a short period of time and at a low cost, these components are made using industrial procedures. The strategy is regarded as a cost-effective, environmentally friendly, long-lasting, and high-performing solution with a great deal of potential (Anisha & R.C.Singh, 2017). Aside from buildings and bridges, precast may be utilised for any type of construction and may even be used in conjunction with traditional in-situ cast methods. In terms of stress and strain response, precast concrete differs from cast-in-place concrete in that it responds to both external (e.g. load induced) and

internal (e.g. autogenous volumetric changes) influences. Even if precast components are erected on-site, they cannot be thought of as a replacement for an in-situ cast structure that has the same overall structural behavior as the in-situ cast solution. (Kim S.Elliot, 2011)

The Romans were the first to use precast concrete construction, mixing lime stone, sand, and water to create an early kind of concrete and pouring it into wooden moulds. The usage of moulds ensured the precision of dimensions while also enhancing the robustness of the final product (S.Jain, 2016). An improvised version of building in the form of precast concrete structure was produced later in the early twentieth century by a British city engineer working in the United Kingdom. The Precast Institute was established on June 18th, 1954, with the goal of providing technical assistance and necessary information (Nagaraju & Anupam ,2021). Since the 1960s, IBS has been widely pushed, although the construction sector in Malaysia has remained steadfast in its use of traditional methods. As a result, initiatives were put on hold and put behind schedule with difficulties like shortages of trained craftspeople, expedited completion, high costs, and inconvenient transportation to adopt IBS in Malaysia (Salmiah & Mohd Rodzfi , 2015).

Precast concrete systems were first used in Malaysia in the 1960s for the Tuanku Abdul Rahman Flats in Kuala Lumpur and the Rifle Range Road Flats in Penang. Both projects used precast concrete systems. Construction projects in which precast concrete is used are being supported by government agencies. The Modular Design Guide was created in 1998 by the Ministry of Housing and Local Government and the CIDB. Design standards, drawings and desired proportions for architectural finish materials like gypsum board, glass, and bricks were all included in this Modular Design Guide. Modular size, strength, and stability were the foundations of precast concrete. However, there was no mention of the required level of fire protection (Ng Ban Kiong & Zainal A. , 2012). A qualitative surveys was conducted to investigate the establishment of precast manufacturing sites and the criteria for establishing such plants. As a result, precast concrete has been in great demand among contractors (Mohamed Nor Azhari Azman *et al*., 2012).

Figure 1: Tuanku Abdul Rahman Flats in Kuala Lumpur

Source: (Zuhairi *et al.*, 2017)

Figure 2: The Rifle Range Road Flats in Penang

Source: (Zuhairi *et al.*, 2017)

1.2 Problem statement

Problems associated with the traditional method of in-situ concrete construction have long been associated with unclean and dangerous work environments, as well as large numbers of inexperienced field labour teams. IBS, a precast concrete solution, can help solve many of these issues.

As Malaysians prefer off-site manufacturing, in which prefabrication takes place far away from the final assembly location. The precast residential building construction process includes design, strategic yard planning, lifting, handling, and shipment of precast sections. Buildings that can endure earthquake and wind-induced lateral loads as well as gravity loads can be constructed using this technology in short duration (Hyung & Jong-Ho, 2015). Prior to finishing the design of a precast concrete structure, there are a number of considerations to keep in mind, such as the transportation and erection considerations.

The building of precast concrete structures necessitates an understanding of several precast systems. Precast concrete systems are divided into two basic categories: precast frame systems and precast wall systems. There are some distinctions between these two systems in terms of their behaviour including the connections between beams to beams, beams to columns, columns to columns and wall to wall.

For a precast structure to be successful, the connections between precast pieces must be strong and stiff in order to withstand the imposed loads. Production tolerances of precast elements and the design and actual dimensions of the precast elements affect the efficiency of precast buildings. As a result, precast concrete connectors must have the same stiffness, strength, and ductility as cast-in-place concrete connections. A further benefit of Precast Concrete buildings is the increased resistance to progressive collapse and the utilisation of moment resisting connections to withstand wind or seismic loads.

1.3 Research Objectives

The following are the objectives of this research:

i. To evaluate the behaviour of precast frame system and precast wall panel system.
ii. To compare the different types of precast concrete connection.

1.4 Scope of work

This researches focus on the behaviour of precast frame and precast wall panel systems. Aside from that, to discuss the various forms of connections in both systems. The scope of work to achieve the objectives is as follows:

i. Gather all information and evaluate the behaviour precast frame system and precast wall system.
ii. Study of the precast concrete connection for both systems in terms of the types , materials and design.

CHAPTER 2

LITERATURE REVIEWS

2.1 Overviews

Precast concrete structure is a 3D framework made up of precast elements that can withstand gravitational, wind, and seismic loads (Jonathan, 2010). The layout, span length, construction depth, and stability system are all greatly influenced by the precast concrete construction technique's unique properties. It is a fact that precast concrete elements are limited in size, so they must be joined together with other elements to make a structure. Precast concrete elements include columns, beams, hollow-core slabs, wall panels , landing and some customized features that are specified and developed to ensure the building's stability, longevity, and structural integrity. (Ivan H. & Iyad A , 2020)

In the second part of the twenty-first century, many countries adopted various precast construction systems to provide low-income housing for the expanding urban population. In Eastern Europe and the former Soviet Union Republics, they became extremely popular following World War II (Melinda, 2015). A thorough understanding of precast concrete construction is necessary in order to appreciate the many methods used. However, the ductile qualities of IBS are important to its seismic use implementation success. Difficulty is the ability of materials and structures to deform beyond the elastic limit without sacrificing strength or energy accumulation during loading cycles. It calculates the amount of energy that the materials system and its components can dissipate before collapsing in order to evaluate its deformation capacity. The stress-strain curve expresses ductility. The moment-curvature and force-displacement relations are

employed for the structural element and structural assembly (Olteanu *et al.,* 2009). In terms of load bearing capacity, precast systems can be divided into four broad categories such as Precast Wall Systems, Precast Frame Systems, Precast Slab-Colimn System with Shear Wall and Precast Mixed Systems (Manoj Lakra *et al.*, 2018).

Prefabrication is a manufacturing process that often occurs in a specialised facility, where diverse materials are combined to make a component part of the final installation (Mohammad Fadhil *et al.*, 2015). The prefabrication process, on the other hand, might be carried out on-site (onsite fabrication). While off-site construction refers to the spectrum or parts that are manufactured or built outside of the building site before they are installed in their ultimate position (Goodier *et al.,* 2007) In the UK, there is a system called the Modern Method of Construction (MMC), which is also called prefabrication, Off-Site Production (OSP), and Off-Site Manufacturing. The Industrialized Building System (IBS) concept is said to be similar to the UK's system (OSM). OSM is utilised in Australia and the UK, while prefabrication is employed in Hong Kong and Singapore (M.N.A.Azman *et al.*, 2012).

In the last few decades, precast construction has gotten more and more attention (Alfred A. Yee, 2001). When a new production method enters the market, the company's goal must be to outdo the competition in terms of quality, price, or speed (Hubert & Alfred , 2011). Precast concrete is now widely employed in several residential and commercial construction project. Precast concrete's properties explain this. It is more durable, has better thermal qualities, and is a lot easier to handle. In addition, because precast concrete is manufactured under strict supervision, the quality of the finished product is superior (P. Karthigai & M. Neamitha, 2018).

2.2 Advantages of precast concrete

As a result, precast concrete systems have certain advantages over traditional cast-in-situ concrete such as : (E. Allen & J. Iano, 2008)

i. Close supervision of the production process results in high-quality products.
ii. Molds can be reused several times in precast production (with little or no changeover), resulting in lower mould per unit costs.
iii. Faster erection can reduce project time.
iv. Production of components is done on the ground, which increases safety.
v. Precast Concrete production can continue while foundation work is done.
vi. Process waste can be crushed and recycled as aggregates.
vii. The smooth texture and simple lines of precast concrete make it easy to clean.
viii. This may reduce shrinkage in precast concrete by using lower water-to-cement ratios
ix. Precast concrete's increased durability and lower maintenance requirements are the result of the higher quality materials and controls employed in the manufacturing process.

2.3 Disadvantages of precast concrete

Following are the disadvantages of precast concrete: (P. Karthigai & M. Neamitha, 2018)

i. When it comes to building smaller residential structures, the precast method of construction is no longer cost-effective.
ii. During the process of transporting the precast units across a greater distance, there is a possibility that they will sustain damage.
iii. As a result of a lack of familiarity with the precast method, Malaysia has not yet made full use of this construction technique.
iv. The crack pattern is virtually same in both the precast method and the conventional mode of construction.

v. Lack of integration among the stakeholders, as well as a lack of collaboration.
vi. Inadequate planning can result in problems with maintenance at a later time, depending on the nature of the problem.
vii. When compared to more traditional methods, the expense is significantly higher.

2.4 Joints and connection in structural precast system

A building's structural connection is an important component of the system. A connection is a system for resisting the action of forces or moments that consists of one or more interfaces and parts of the neighbouring components (Sayed, 2016). Thus, structural reaction is dependent on connection behaviour and features. Stabilizing units, structural layout, structural system design, and connecting details must all be in harmony with the planned structural performance. Understanding the influence of connections on the flow of forces through a structure under vertical and/or horizontal loads is the key to a successful design. Precast elements are designed to interact with each other when they are loaded, and here is where structural connections come into play (Ahmed Sabah *et al.*, 2019).

They can be fastened together. This is done by embedding steel connectors into the concrete during the casting process. A lot of care must be taken in this process. They can be put together with grout or concrete. Steel reinforcing loops are left protruding from precast concrete members in this procedure. Reinforcement is threaded through the loops between the two components. The reinforcement is subsequently encased in fresh concrete, which is placed in a designated area.

Nonetheless, the fundamentals are the same. There should be no structural compromises to the structural capacity of the connected structural elements. At the very least, it should be able to match the structural elements in terms of strength. Lapping entire anchorage lengths of steel bars ensures the continuation of reinforcement bars in reinforced concrete structures. However, in extensively reinforced constructions, when larger bar sizes are used, the long lapping length of

the bars may be impractical and frequently lead to detailing problems due to a lack of space to allow the requisite bar development lengths. Codes prohibit lap splicing or impractical lapping lengths as a result of this (Ling Jen Hua *et al.,* 2018). Additional considerations for connection design include fire hazards, inadvertent damage, consequences of temporary construction, and the inaccuracies and longevity of the construction.

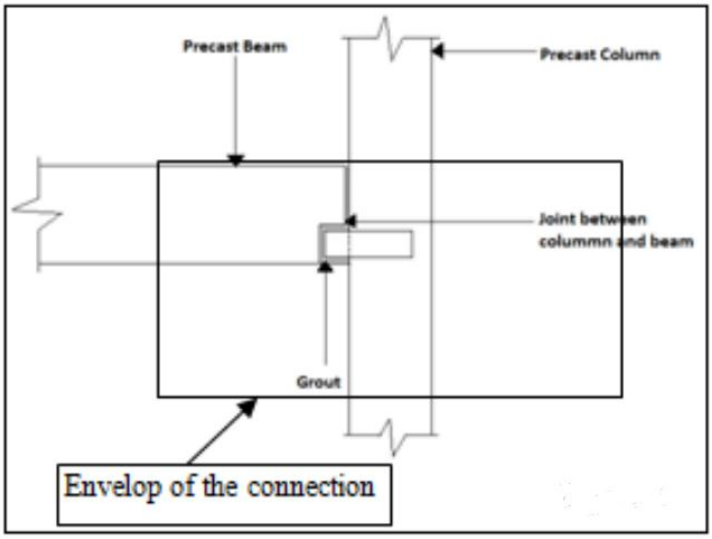

Figure 3 : Shows the full extent of the connection's envelope

Source: (Sayed, 2016)

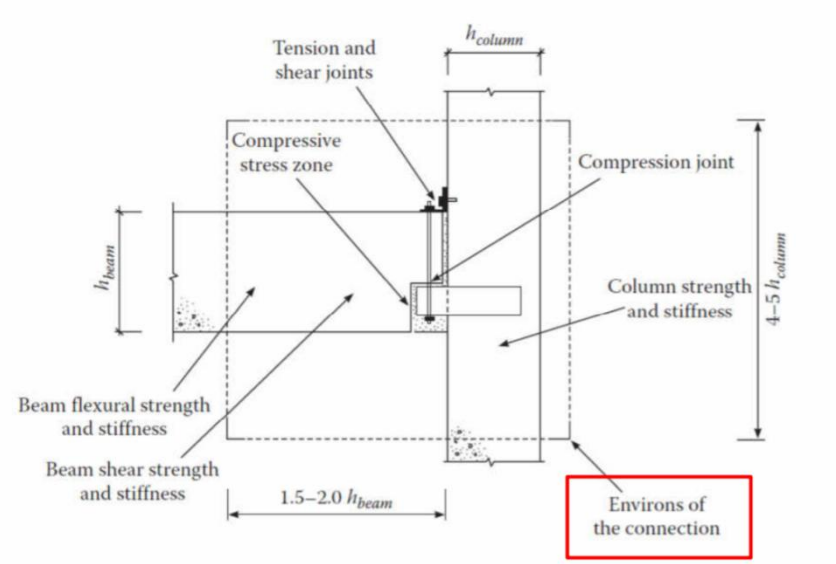

Figure 4 : Definition of 'joint' and 'connection'

Source: (Björn *et al.,* 2008)