Modular Integrated Construction (MiC) for High-rise Public Residential Housing in Hong Kong: its Building Design, Construction, and Maintenance Management

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Abstract

This dissertation explores the application of Modular Integrated Construction (MiC) for high-rise public residential housing in Hong Kong. Its design and construction concepts are reviewed. This dissertation mainly focuses on the maintenance management issues of public housing and investigates the causes, impacts, and potential solutions for water seepage and spalling defects. These are the common building defects in public housing estates in Hong Kong. Using a case study methodology, Siu Sai Wan public housing estate is selected for survey. The study employs a mixed-methods approach, combining a structured survey questionnaire with 100 residents in Siu Sai Wan Estate and semi-structured interviews with key stakeholders, including three building professionals, and three maintenance personnel.

The research identifies aging infrastructure, poor construction quality, and environmental factors as the primary causes of these defects, with water seepage and spalling showing a strong correlation. Findings reveal significant gaps in current maintenance practices, including delays in response times, poor-quality repairs, and inadequate communication. Despite the increased use of durable solutions like waterproof membrane replacement (35%) and patch repairs (25%), 60% of respondents expressed dissatisfaction with maintenance services. The study highlights the potential of innovative materials and advanced technologies, such as self-healing concrete and moisture sensors, to address these issues.

Recommendations include adopting proactive maintenance strategies, improving communication, and enhancing resident engagement. The research contributes to the understanding of building pathology in high-density urban environments and provides actionable insights for improving maintenance practices and resident satisfaction in Hong Kong's public housing estates.

The study also identifies gaps for future research, including longitudinal studies, comparative analyses across regions, and the evaluation of smart technologies.

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Chapter One: Introduction

1.1 Background

Since the 1980s, the construction of public housing in Hong Kong has involved prefabrication technology. Through continuous innovation and development, prefabrication has become characterized by standardized design, factory production, assembled construction on site, integrated decoration, information management, and intelligent applications. Compared with traditional construction, prefabrication saves resources and energy, reduces construction pollution, and improves productivity, work quality and on-site safety. As modern technology is evolving in the construction industry, precast concrete components and modular integrated construction (MiC) for high-rise buildings faces a variety of design, manufacture, site-lifting and assembly challenges. In parallel with continuous breakthroughs in construction technology at home and abroad, various technological solutions have been adopted over the past decades to facilitate its application in buildings in Hong Kong. These new construction technologies stimulate a need to conduct my research.

Modular Integrated Construction (MiC) is an off-site volumetric construction approach where entire room-sized modules (complete with finishes, building services systems, and fixtures) are manufactured in factories and assembled on-site. In Hong Kong, MiC is promoted as a highly industrialized construction method under the Construction 2.0 initiative (HKSAR Government, 2018).

Key Features:

- Volumetric prefabrication (3D units)
- Fully fitted-out modules (walls, floors, ceilings, plumbing, electrical)
- Minimal on-site work (only foundation and module connections)
- Steel or concrete structural systems

<u>Precast Concrete Construction (PCC)</u>

Precast Concrete Construction (PCC) involves factory-made 2D structural elements (walls, slabs, beams, columns) that are transported and assembled on-site with cast-in-situ concrete connections.

MiC and PCCs (Precast Concrete Components)

• MiC (also PCCs) is a kind of Off-site Prefabrication under DfMA (Design for Manufacturing and Assembly)

• PCCs and MiC both share the similar advantages such as productivity, quality, safety and environmental friendliness

• Under Housing Authority (HA)'s guidelines, MiC qualifies to achieve 6% GFA concession should be

-free-standing volumetric modules ;

-with finishes, fixtures, fittings, etc.; and

-manufactured off-site and then transported for site assembly.

Hong Kong's public housing estates are home to over 2.1 million residents, representing approximately 30% of the city's population (Hong Kong Housing Authority, 2020). These estates are characterized by high-density living, aging infrastructure, and unique environmental challenges, such as high humidity and frequent typhoons. These factors contribute to the prevalence of building defects, particularly water seepage and spalling, which pose significant risks to structural integrity, resident safety, and quality of life (Leung et al., 2014). Water seepage, often caused by aging waterproofing systems and poor construction practices, leads to moisture infiltration, which weakens concrete structures and results in spalling—the cracking and flaking of concrete surfaces. These defects not only compromise the structural integrity of buildings but also contribute to health issues, such as mold growth and respiratory problems, among residents (Yin, 2017).

Despite ongoing maintenance efforts by the Hong Kong Housing Authority, water seepage and spalling defects remain pervasive, with residents frequently reporting dissatisfaction with the quality and timeliness of repairs (Saunders et al., 2015). This highlights a critical gap in the current understanding of building pathology and the effectiveness of maintenance practices in addressing these defects. While existing research has explored the causes and impacts of water seepage and spalling, there is limited empirical evidence on the correlation between these defects, the effectiveness of current repair methods, and the potential of innovative solutions to enhance maintenance quality and efficiency (Creswell and Creswell, 2017).

Research Gap and Justification

The existing literature on building pathology in Hong Kong's public housing estates has primarily focused on identifying the causes and impacts of water seepage and spalling defects. However, there is a lack of comprehensive studies that explore the correlation between these defects, evaluate the effectiveness of current maintenance practices, and assess the potential of innovative solutions to address these issues. This research gap is particularly significant given the unique challenges posed by Hong Kong's high-density urban environment, aging infrastructure, and harsh environmental conditions.

Moreover, while the Hong Kong Housing Authority has implemented various maintenance strategies, there is limited empirical evidence on their effectiveness in addressing water seepage and spalling defects. This study seeks to fill this gap by providing a comprehensive analysis of the causes, impacts, and potential solutions for these defects, with a focus on improving maintenance practices and resident satisfaction. By employing a mixed-methods approach, the study combines quantitative data from a survey of 100 residents with qualitative insights from interviews with key stakeholders, offering a holistic understanding of the issues and actionable recommendations for improvement.

1.2 Aim and Objectives

This dissertation explores the application of Modular Integrated Construction (MiC) for high-rise public residential housing in Hong Kong. Its design and construction concepts are reviewed. However, this dissertation mainly focuses on the maintenance management issues of public housing and investigates the causes, impacts, and potential solutions for water seepage and spalling defects in Siu Sai Wan Estate (SSW), which is one of the Hong Kong public housing estates owned by the Hong Kong Housing Authority. Due to limited resources and time constraints, only SSW is chosen as a case study approach for this research. The specific objectives are as follows:

1. To explore the characteristics of residential block in Hong Kong and tall building design requirements
2. To explore the design of precast concrete components and modular integrated construction (MiC)
3. To explore the on-site construction and installation

4. To explore the benefits of mechanization and prefabrication
5. To explore the correlation between water seepage and spalling defects and identify the primary causes of these issues in public housing estates.
6. To evaluate the effectiveness of current maintenance practices in addressing water seepage and spalling defects, with a focus on response times, repair quality, and resident satisfaction.
7. To assess the potential of innovative solutions, such as waterproof membrane replacement, self-healing concrete, and advanced diagnostic technologies, to enhance maintenance quality and efficiency.
8. To provide actionable recommendations for improving maintenance practices, communication, and resident engagement in public housing estates.

1.3 Structure of Dissertation

This dissertation is structured into six chapters:

1. Introduction: Provides the background, context, and justification for the study, outlines the research aims and objectives, and presents the structure of the dissertation.
2. Literature Review: Reviews existing research on the characteristics of high-rise residential building; tall building structural design of residential building; design of precast concrete components; on site construction and installation; benefits of prefabrication and mechanization; modular integrated construction (MiC) development in public housing development; building pathology; focusing on the causes and impacts of water seepage and spalling defects, as well as current maintenance practices and innovative solutions.
3. Methodology: Describes the mixed-methods approach used in the study, including the design of the survey questionnaire and semi-structured interviews, data collection procedures, and analysis methods.
4. Data Analysis and Discussion of Findings: Presents the findings from the survey and interviews, organized into themes related to the causes, impacts, and potential solutions for water seepage and spalling defects.

Interprets the findings in relation to the research objectives and existing literature, highlighting the implications for maintenance practices and resident satisfaction.

5. Conclusion and Recommendations: Summarizes the principal achievements of the study, acknowledges its limitations, and provides actionable recommendations for improving maintenance practices and resident satisfaction. The chapter also discusses the implications for future research.

1.4 Main Achievements

The study has achieved several key outcomes:

1. Identification of Key Causes and Correlations: The research confirmed a strong correlation between water seepage and spalling defects, with aging infrastructure and poor construction quality identified as the primary causes.
2. Assessment of Current Maintenance Practices: The study revealed significant gaps in current maintenance practices, including delays in response times, poor-quality repairs, and inadequate communication, leading to low resident satisfaction.
3. Exploration of Innovative Solutions: The research highlighted the potential of innovative materials and technologies, such as waterproof membrane replacement and self-healing concrete, to address water seepage and spalling defects.
4. Actionable Recommendations: The study provided actionable recommendations for improving maintenance practices, communication, and resident engagement, with a focus on proactive strategies and advanced technologies.

1.5 Relevance and Contribution

This study is highly relevant to Hong Kong's public housing sector, where aging infrastructure and high-density living conditions exacerbate building defects. The findings contribute to the understanding of building pathology in high-density urban environments and provide actionable insights for improving maintenance practices and resident satisfaction. The study also identifies gaps for future research, including longitudinal studies, comparative analyses across regions, and the evaluation of smart technologies. The Abstract as well as Introduction Section provide a comprehensive overview of the study, highlighting its relevance, aims, and structure.

Chapter Two: Literature Review

The literature review is based on the four criteria provided below:

1. Identification of relevant issues

2. Depth of understanding of the topic

3. Coverage of relevant journals/scholarly articles

4. Critique and synthesis of existing literature

2.1 Characteristics of High-Rise Residential Building

Hong Kong's unique urban landscape, characterized by limited land availability and a dense population, has necessitated the development of high-rise residential buildings as the primary housing solution. The city's construction industry has increasingly adopted prefabrication and mechanization to enhance efficiency, quality, and sustainability in building projects. Mak (2018) provides a comprehensive professional guide on the design and construction of high-rise residential buildings in Hong Kong, emphasizing the use of prefabricated components and mechanized construction techniques.

This paper critically examines the key aspects of Mak’s (2018) guide, supported by additional references, to discuss:

- The architectural layout and structural considerations of high-rise residential buildings.
- The structural systems used in Hong Kong’s residential construction.
- The design and application of precast concrete components.
- On-site construction and installation techniques.
- The benefits of prefabrication and mechanization in terms of cost, quality, and sustainability.

The discussion integrates insights from Hong Kong’s building codes, industry best practices, and case studies to provide a holistic understanding of modern high-rise residential construction in Hong Kong.

2.1.1 Building Block Architectural Layout

In residential block architectural design, it is characterized by having a number of individual flats separated by partition walls. Hence functionally more internal walls are required in residential buildings as compared with office buildings. Walls between flat units also provide fire and acoustic insulation. These walls are normally thicker than partition walls. The spans between walls are relatively small, around 5 m apart. Only the spans in luxurious residential flats would be extended to 8 and 10 m. The architectural layouts of residential flats for public housing (see Fig. 1) and for private sector (see Fig. 2) may be somewhat different. Because of the need to provide more number of flats for low cost public housing, it is a common layout to have long corridors in order to provide passage from the flats to the lift lobby.

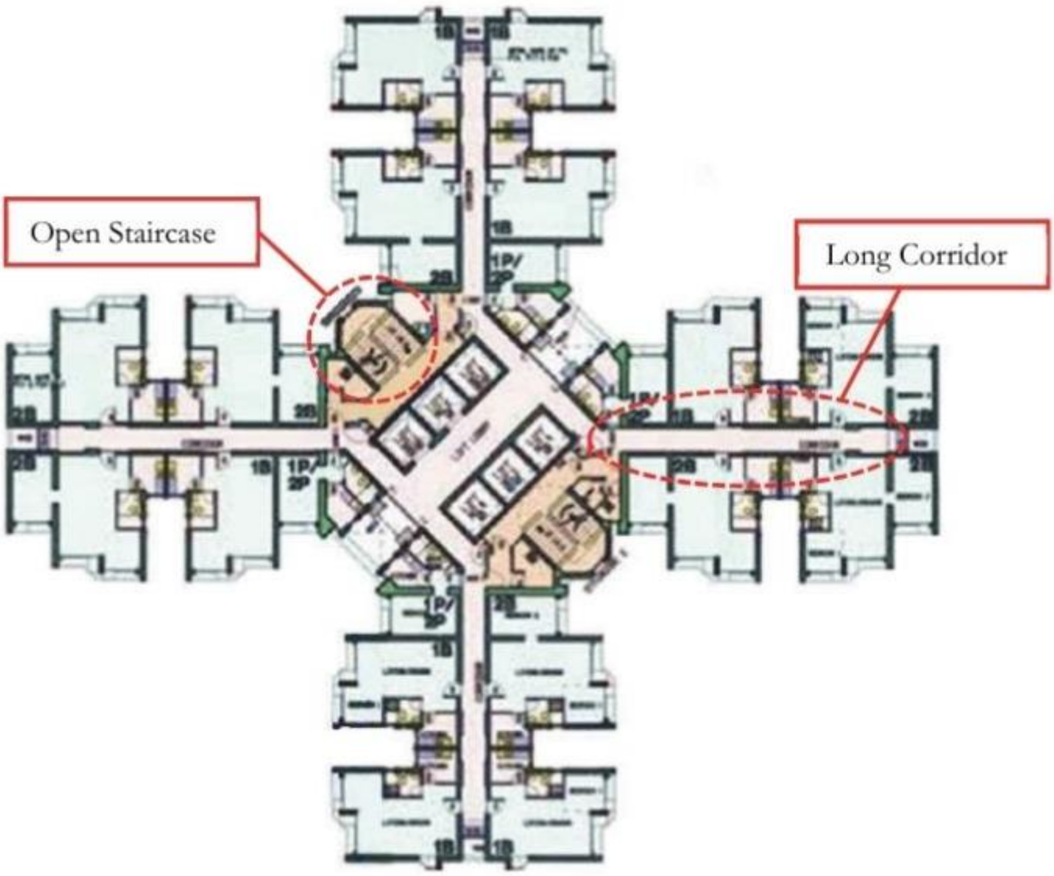


Fig. 1 Architectural layout of public housing

In private sector, corridor is normally absent, and the entrances of flats are directly connected to the lift lobby.

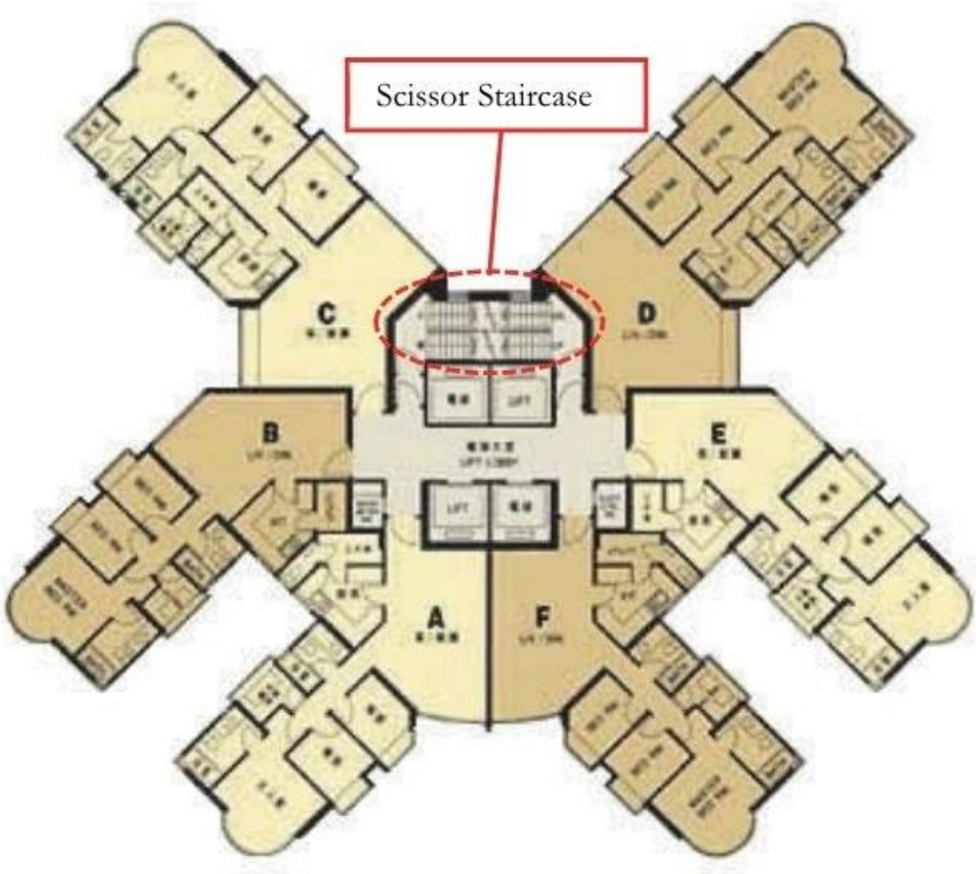


Fig. 2 Architectural design for private sector buildings

External facades could be combination of walls and windows. The sizes of window openings are optimized, to strike a balance amongst natural light, ventilation and heat insulation. Staircases in private sector are majority scissor staircases which could fit into the enclosed lift lobby. For public housing, open staircases are commonly used which provide external natural ventilation. These staircases will be located either at the lift lobby or at the far end of the long corridor away from the lift lobby. The latter is for providing nearest fire escape routes for flats further away from the lift lobby. Public housing has normally adopted a storey height of 2.7m whereby no false ceiling would be provided to house horizontal services. For private sector, the common storey height ranges from 3m to 3.3m and false ceilings are provided in specific locations like kitchen and bathroom. In public housing, standardized flat units (see Fig. 3) are adopted and the block configuration can be varied by assembling the units into different layout, such as T shape, Y shape or cruciform shape. This could give different outlook identity to the block and yet the flat units can still maintain to be standardized (see Fig. 4).

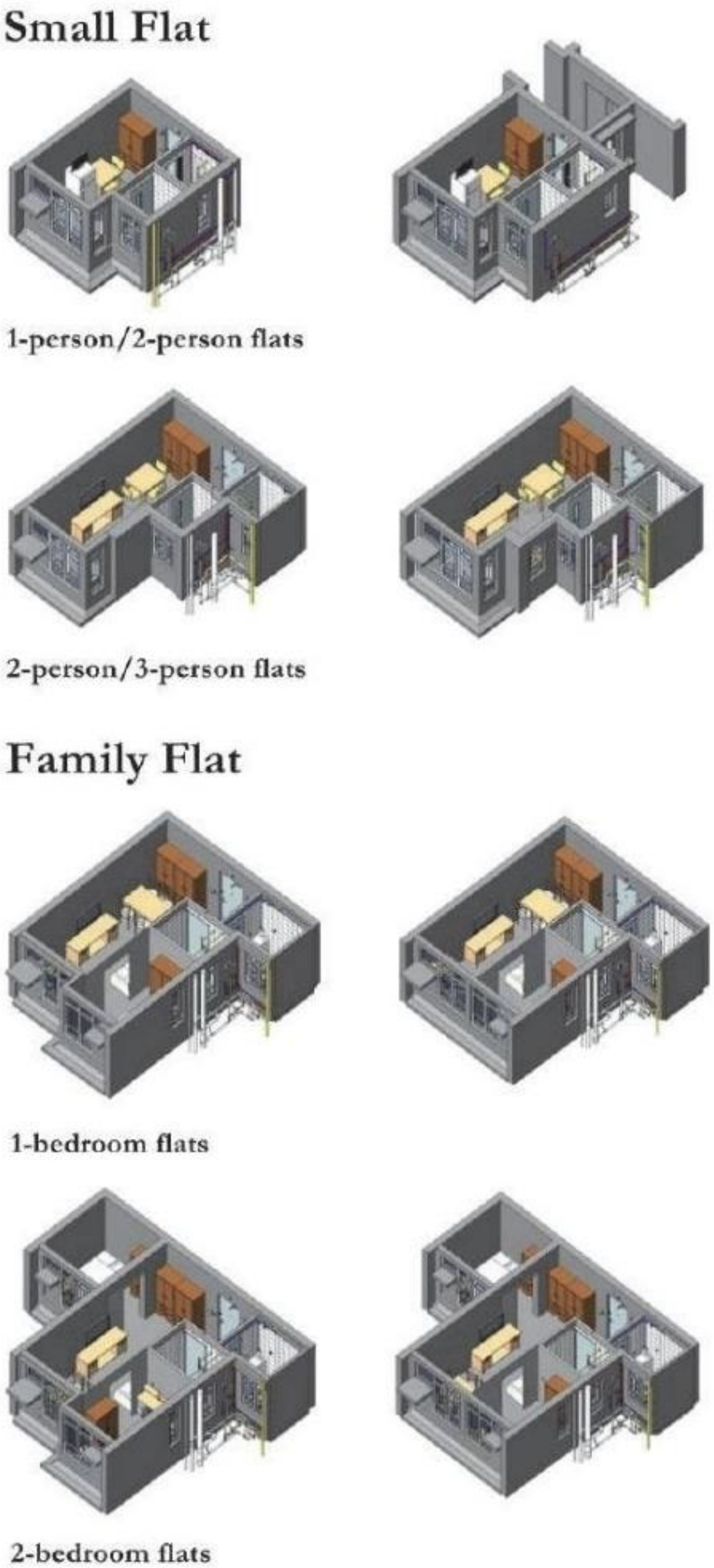


Fig. 3 Modular flats

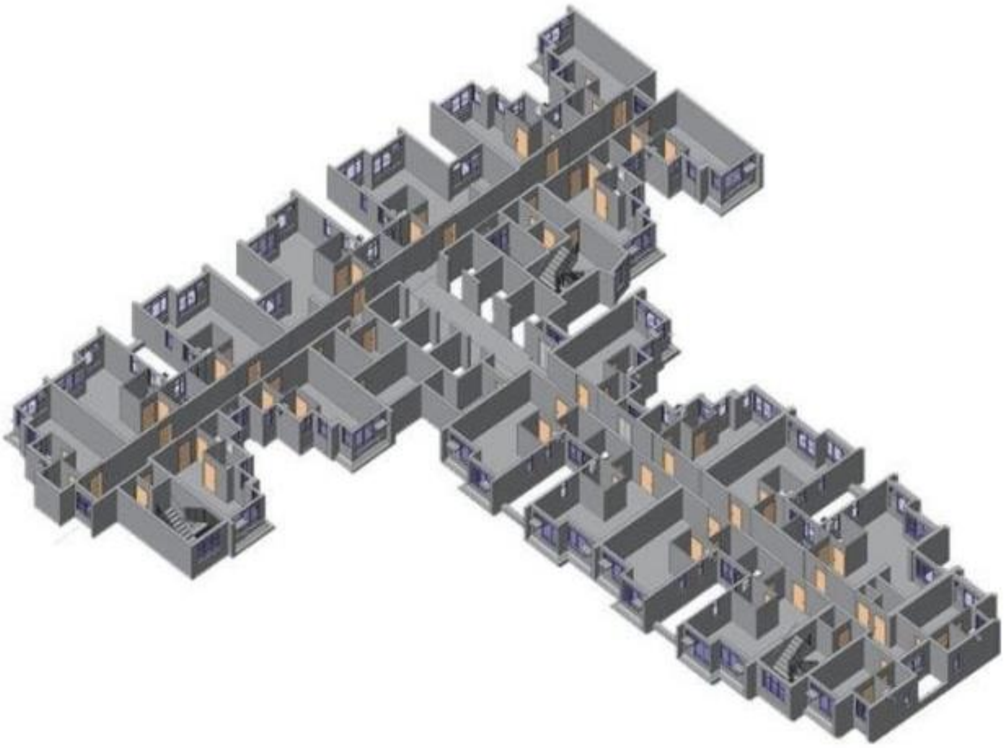


Fig. 4 Block configuration

2.1.2 Building Services Provisions

For residential buildings, electrical services runs, both horizontal and vertical, are preferably be concealed within respectively floor slabs and walls. Floor slabs are hence designed slightly thicker to accommodate. The concealed services are first collected within flats and then directed to the corridors and lift lobby area until they reach the meter room at each floor. The corridors hence become the prime concealed passage routes of the services and their thicknesses range from 250 mm to 350mm.

Water pipes and drainage pipes are seldom designed to be concealed within walls and slabs, mainly because of difficulty in maintenance in case of bursting or breakage. Locating the exact breakage point is also very difficult when concealed. The water and drainage pipes enter and exit the toilet and kitchen through external walls around the re-entrant areas and are carried down to the ground level. In the absence of these re entrant areas in some of the luxurious private sector residential blocks, the pipes are collected in services room of each floor and are carried down to the ground level.

2.1.3 Durability Considerations

High rise residential blocks in Hong Kong have been designed and constructed for over 30 years. The material used is essentially reinforced concrete and the construction methodology started off with the conventional timber formwork, site mixed concrete and labor intensive construction. The building developed serves the primary purpose of providing the basic dwellings of the population at large. Because of this traditional construction approach, it has however led to substantial investment from the community in the past in maintaining the flats for concrete spalling, reinforcement corrosion, deterioration of water pipes and drainage system, window leakage, etc.

Conventional construction adopts plywood as formwork for construction. However, plywood deteriorates after using for around ten times and beyond which the plywood starts to peel off and produces uneven and undulating surface finishes. Rectification requires cost and time for touching up and grout leakage between plywood joints also affect the concrete integrity and quality.

The government and the private developers saw the need to improve the construction in the industry and precast factory production was the emerging change brought to the construction stakeholders some years ago. Prefabrication gives more confidence to the developers in respect of more mechanized construction using steel moulds in a controlled ground environment in the factory, use of less skilled laborers but improved workmanship and accuracy, and prior quality check of finished products before delivery to site. Taking the public housing as an example, the maintenance cost has been substantially reduced after the adoption of prefabricated method of construction.

In Hong Kong, because of the proximity to the sea, high wind loading is the controlling design lateral loading. As a result of wind vibration, precast elements connected monolithically with insitu structural walls are the common design philosophy so that separation or cracking at joints would not take place.

2.2 Tall Building Structural Design of Residential Building

2.2.1 Frame Wall System

Frame wall system (see Fig. 5) is a combination of frame and shear walls. In general, the lateral rigidity of walls is much greater than that of frames and hence the walls take the majority part of the wind loads. For residential buildings up to 30-storey high, frame wall system is a commonly adopted structural system.

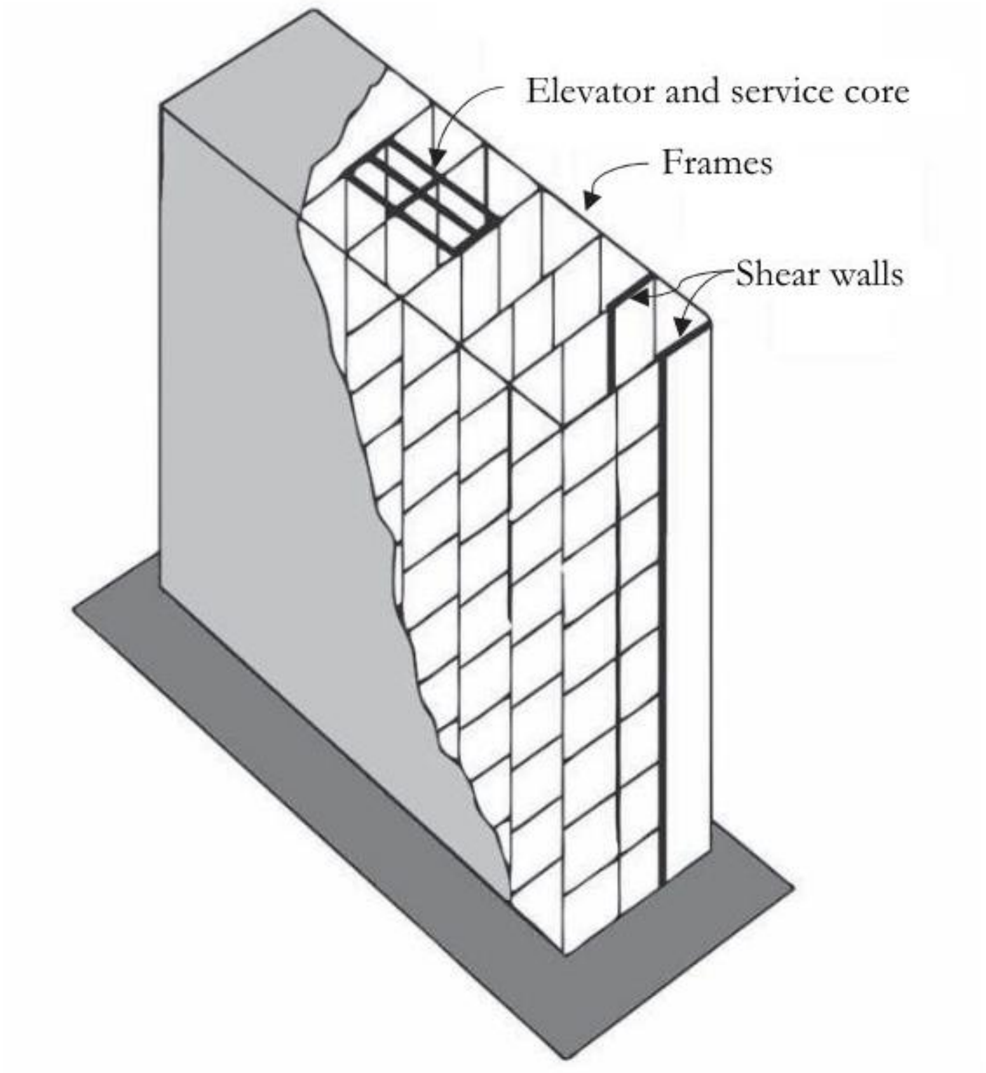


Fig. 5 Frame wall system

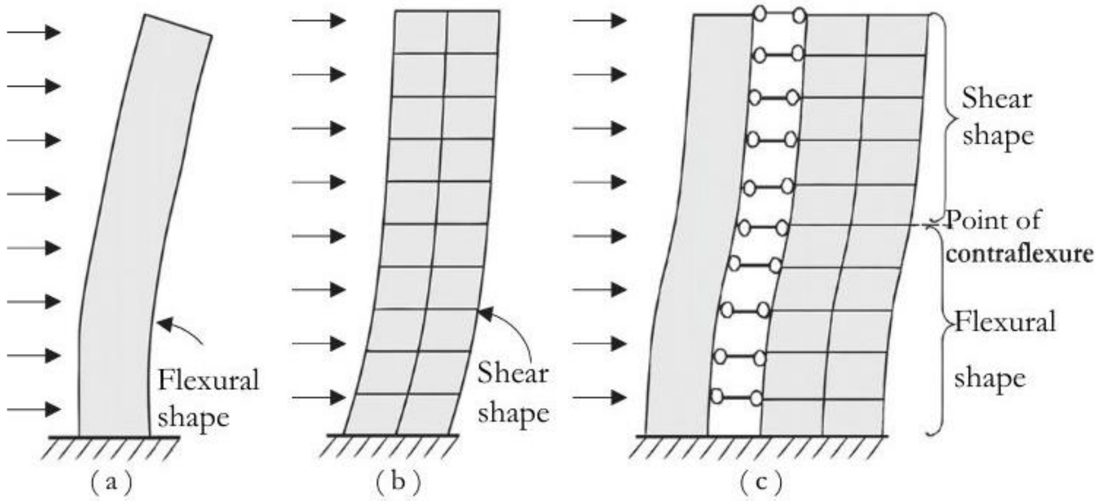


Fig. 6 Frame wall system definition

The wall deflects in flexural mode with concavity downward and maximum slope at the top (see Fig. 6). The frame deflects in shear mode with concavity upward and maximum slope at the bottom. When they are connected together by rigid slab, the deflected shape is compromised with flexural profile at bottom and shear profile at top.

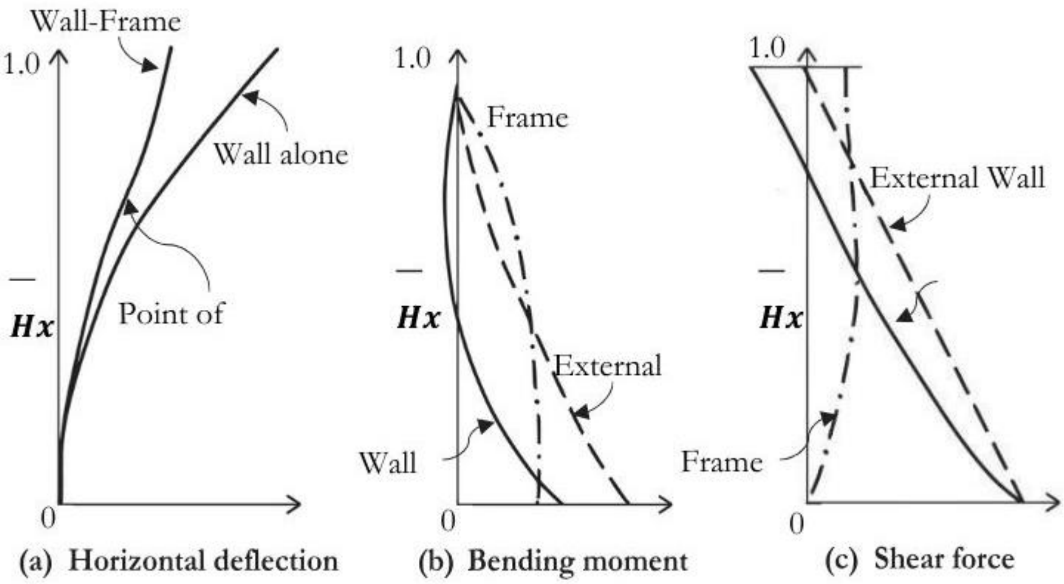


Fig. 7 Frame wall system bending moment and shear force

Fig. 7 shows that the deflected curve indicates a reversal of curvature and there is a point of inflexion. The deflection is reduced due to combining the wall and frame. The bending moment is also reversed with upper wall moment in opposite sense as that of cantilever. For design purpose, nominal reinforcement can be placed for wall above point of contra flexure.

The shear is approximately uniform over the height of the frame, except near the base. For design purpose, the floor slabs and beams of the frame can be designed as repetitive and same. The following are three computer case studies (see Fig. 8) of respectively a 10 storey, 20 storey and 30 storey buildings using the wall-frame structures. The deflections of wall structure alone and frame structure alone are calculated and then compared with a combined wall frame structure (see Fig. 9 to Fig. 18). It can be found that the deflection is substantially reduced.

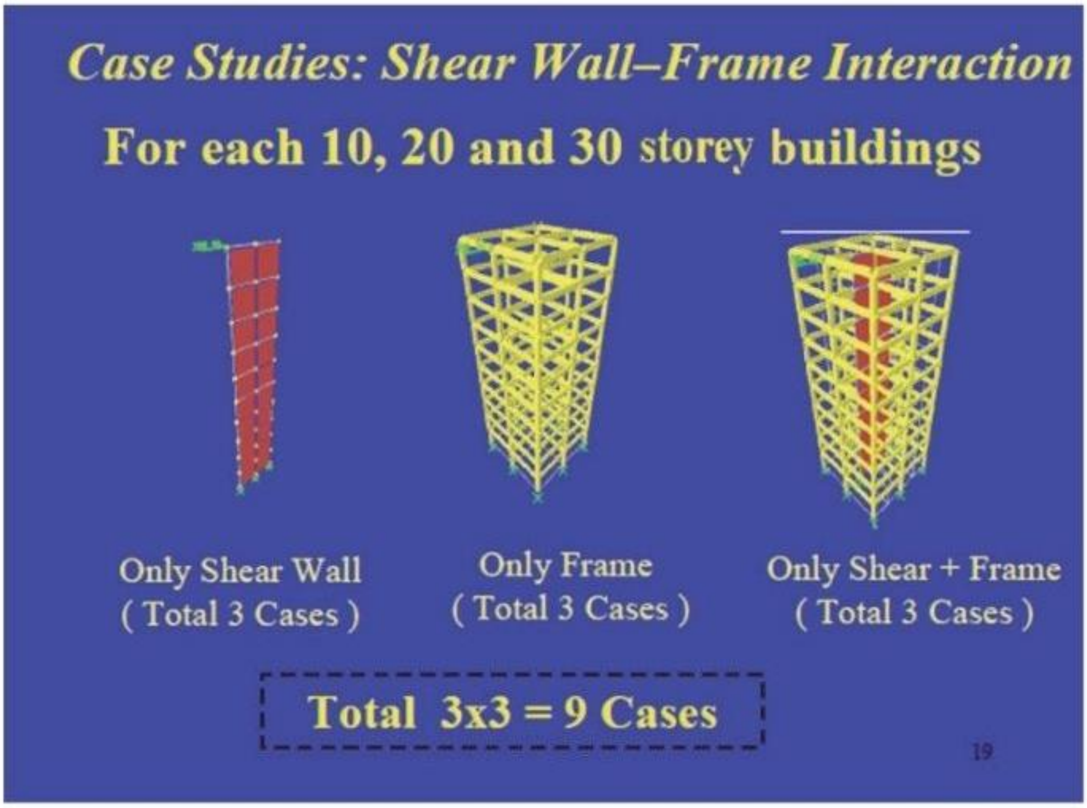


Fig. 8 Case studies of shear wall-frame interaction

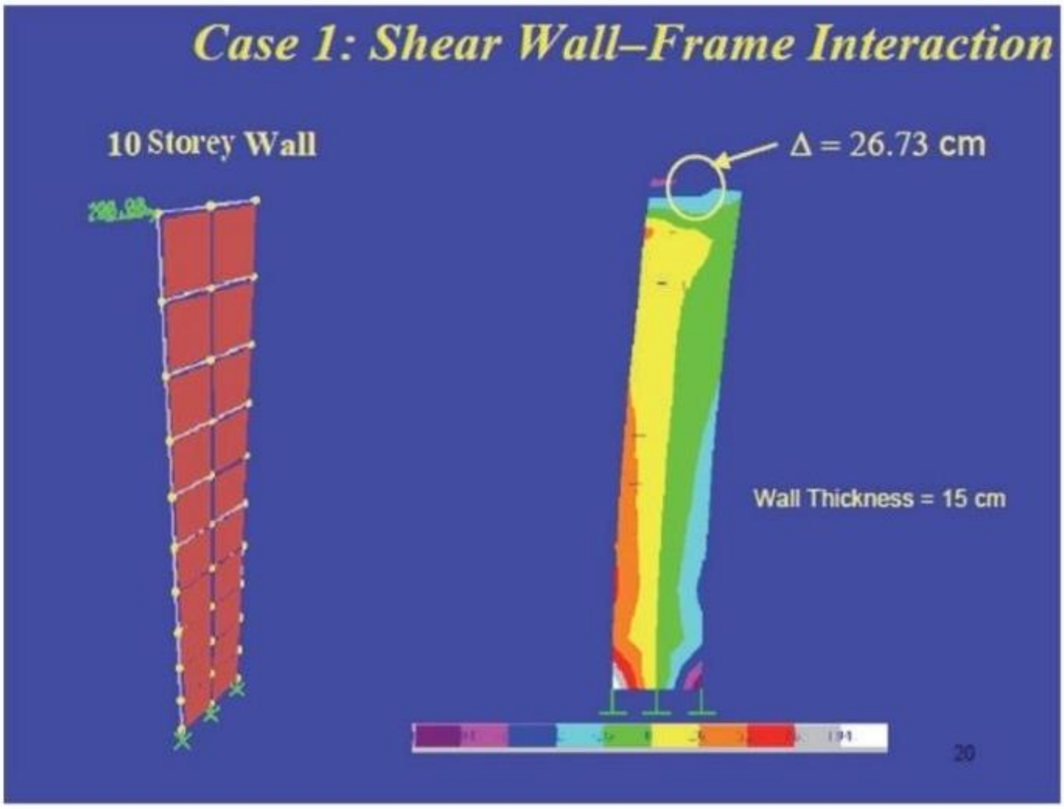


Fig. 9 Case 1: shear wall structure for 10 storey building

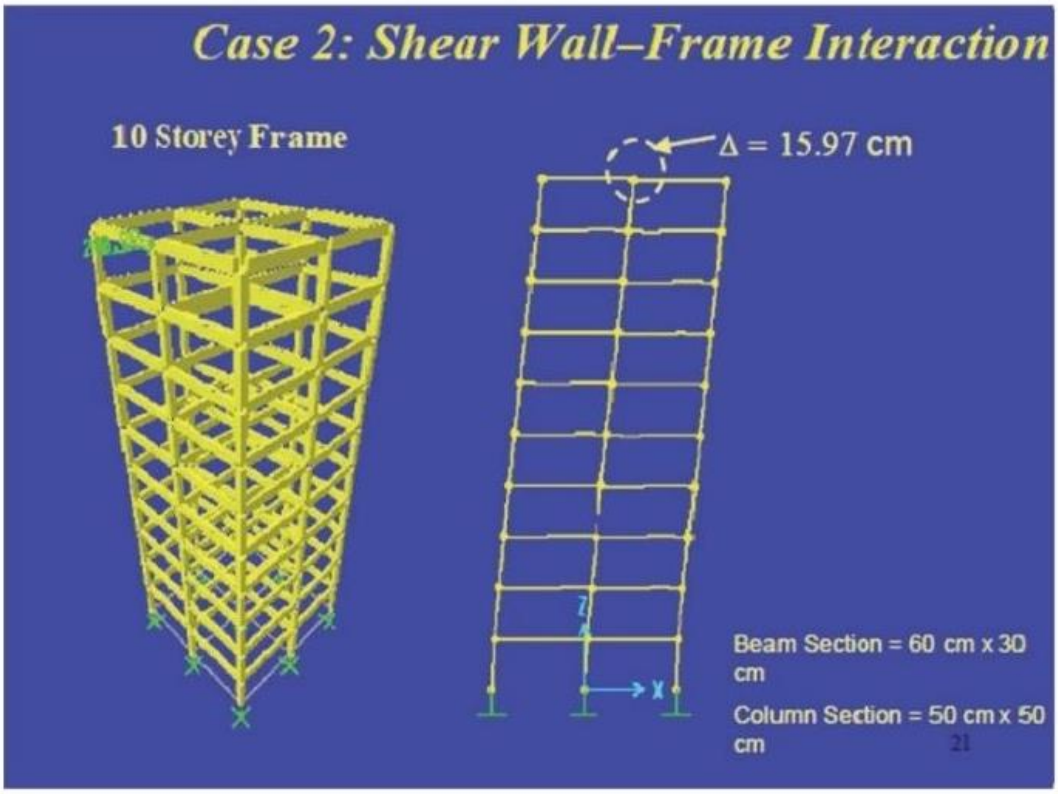


Fig. 10 Case 2: frame structure for 10 storey building

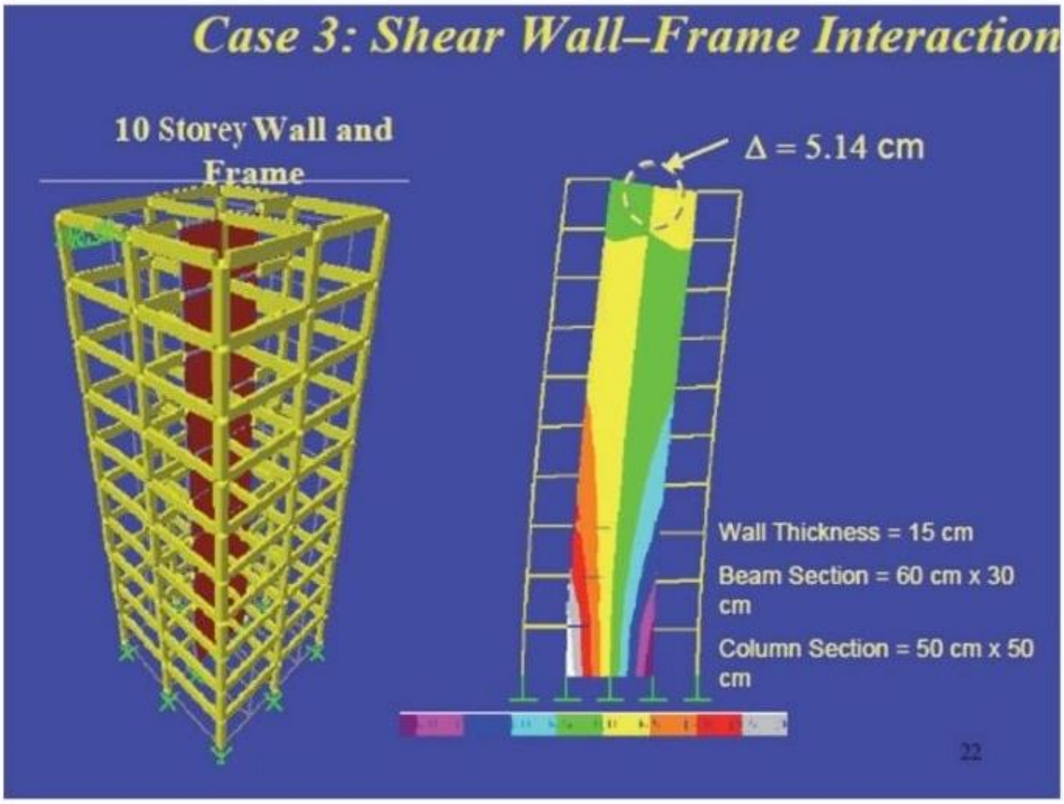


Fig. 11 Case 3: combined shear wall-frame structure for 10 storey building

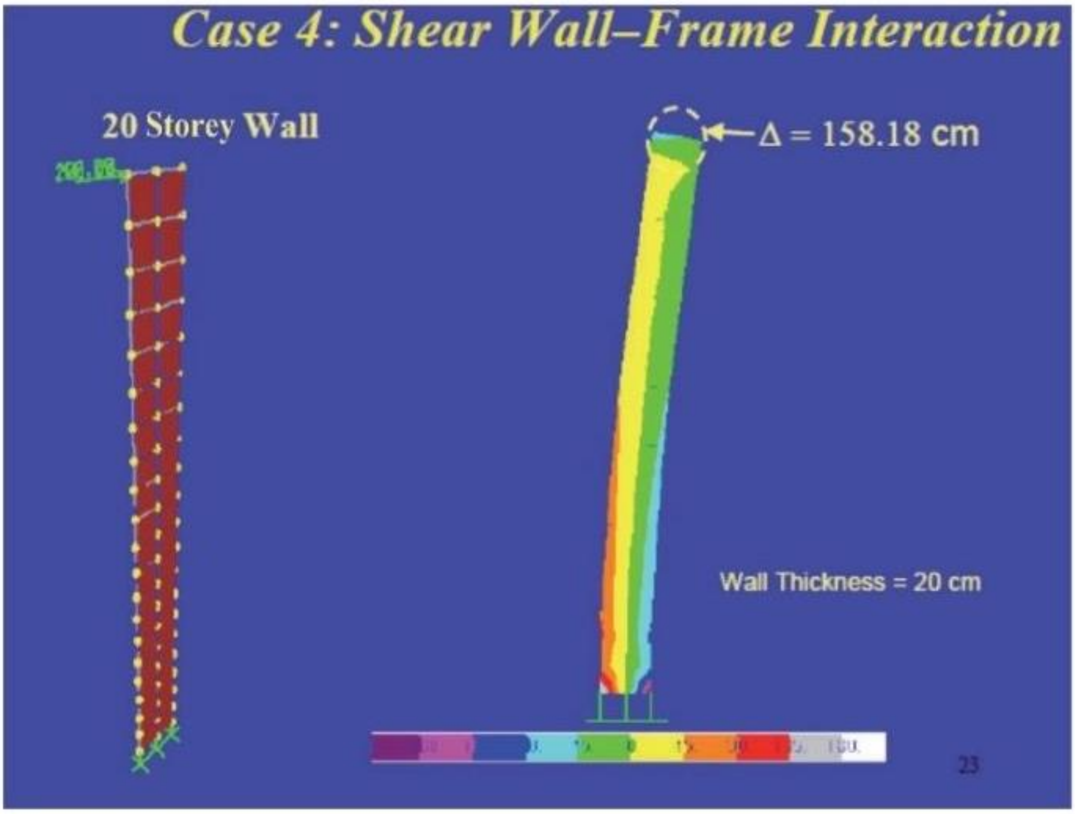


Fig. 12 Case 4: shear wall-structure for 20 storey building

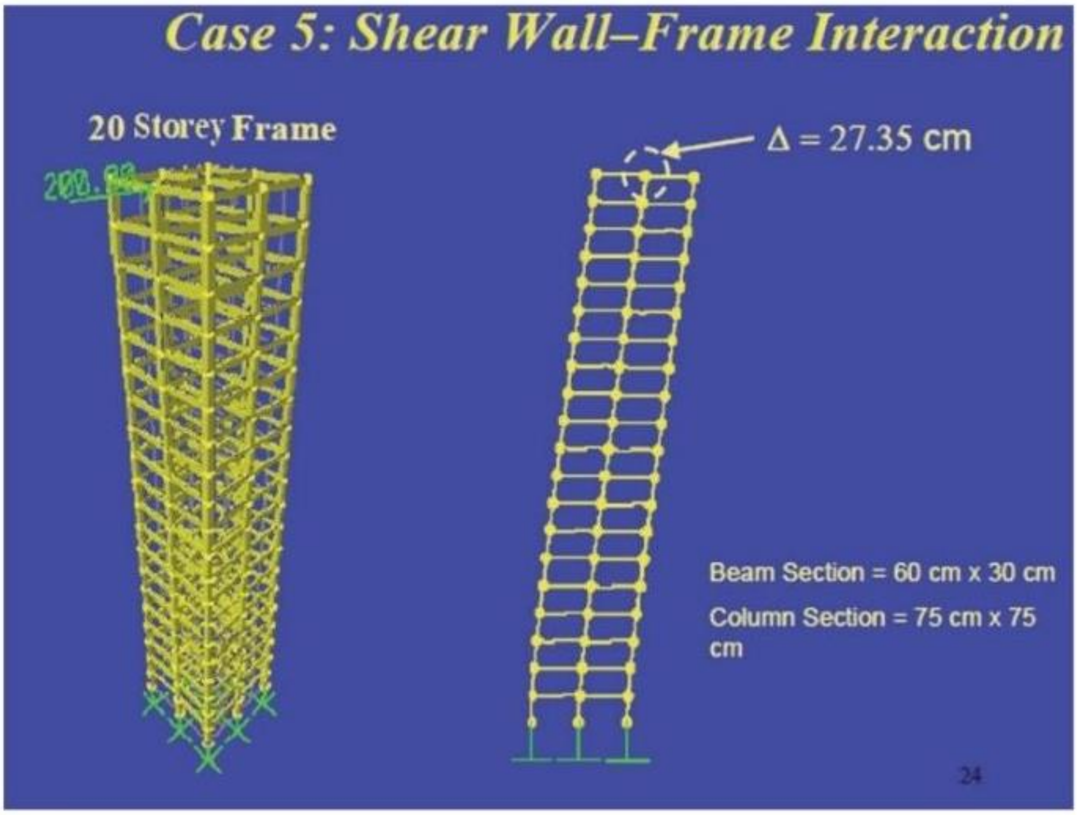


Fig. 13 Case 5: frame structure for 20 storey building

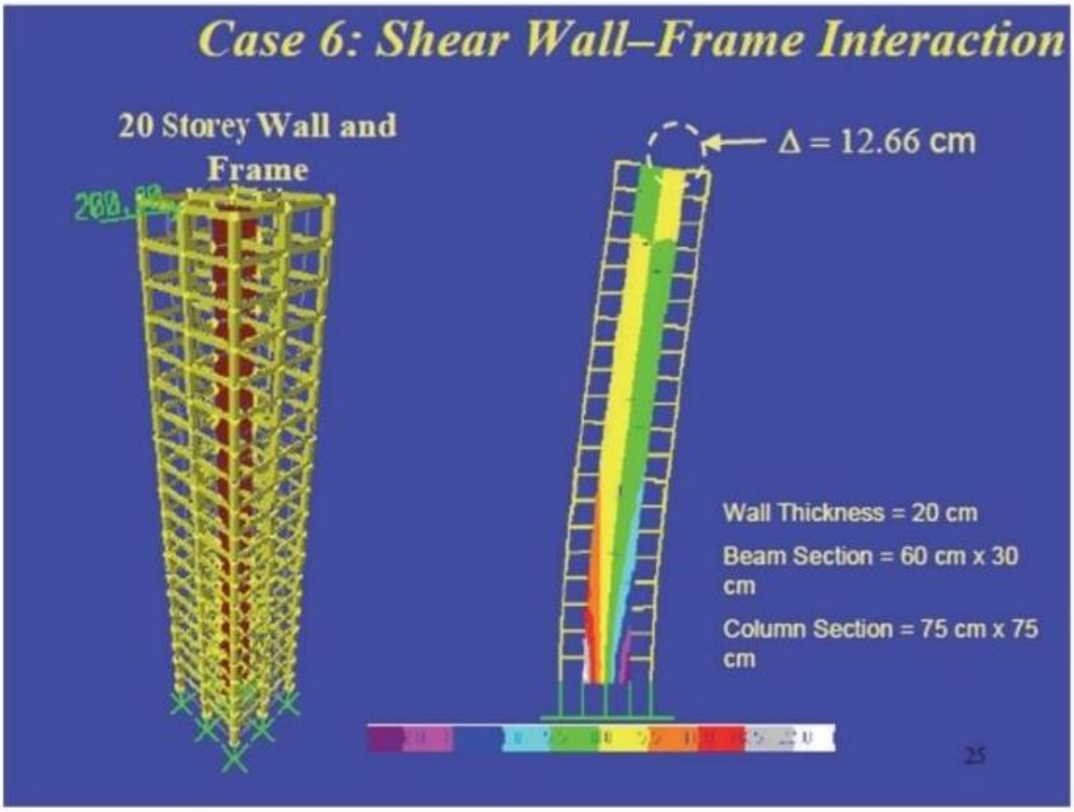


Fig. 14 Case 6: combined shear wall-frame structure for 20 storey building

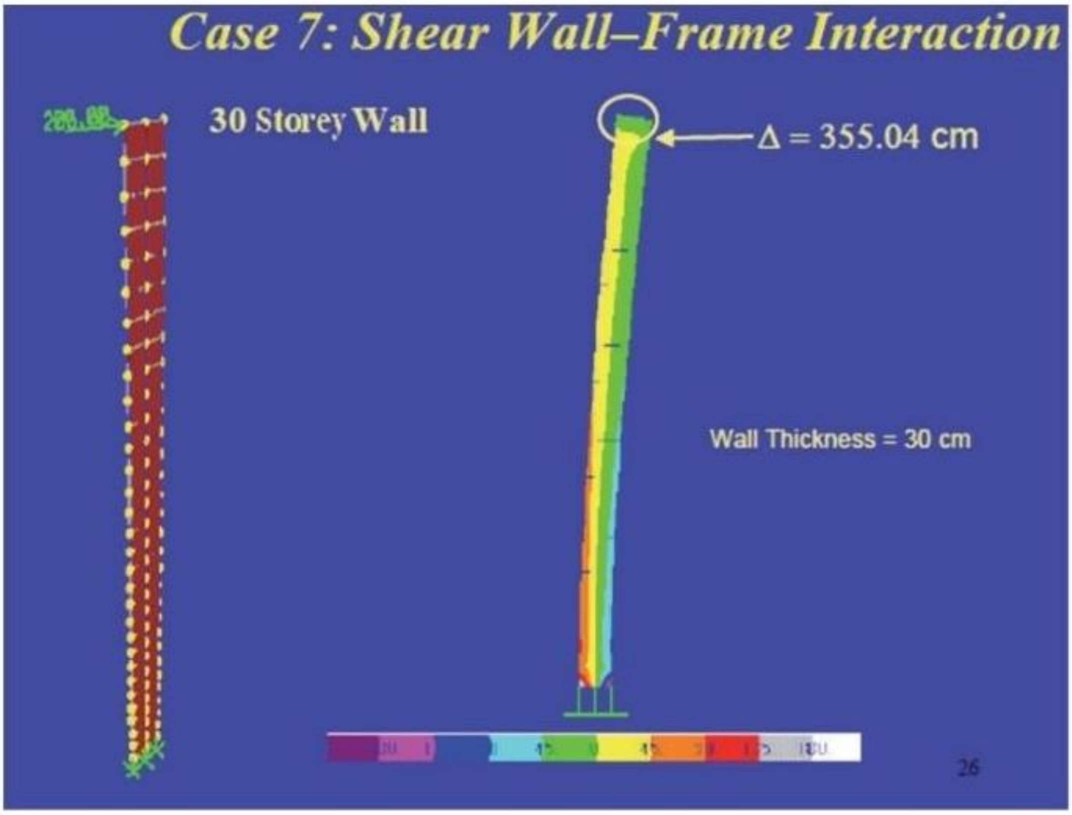


Fig. 15 Case 7: shear wall-tructure for 30 storey building

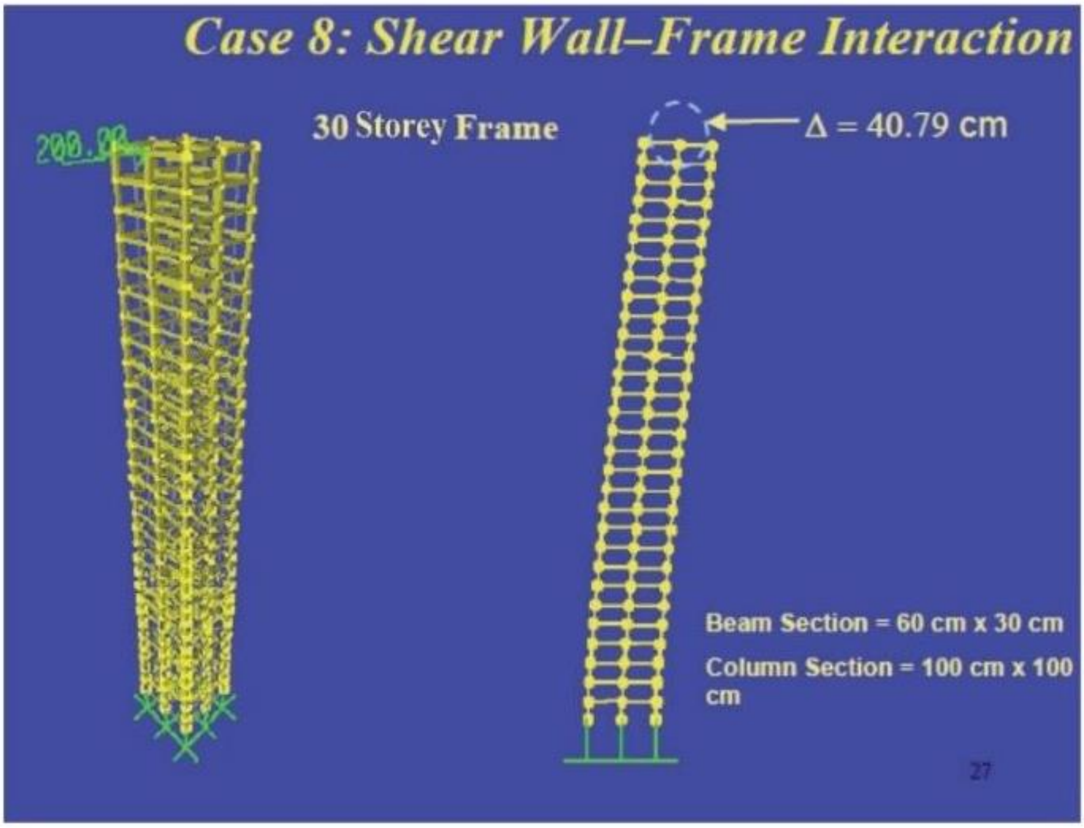


Fig. 16 Case 8: frame structure for 30 storey building

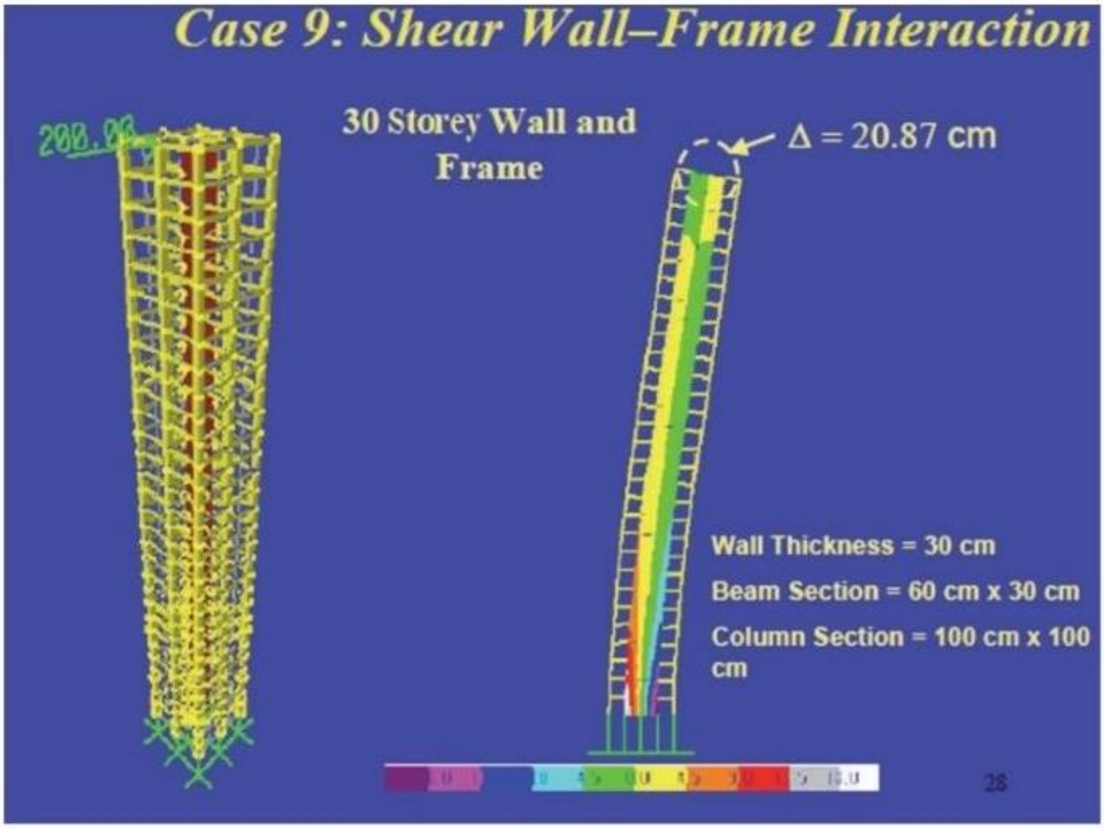


Fig. 17 Case 9: combined shear wall-frame structure for 30 storey building

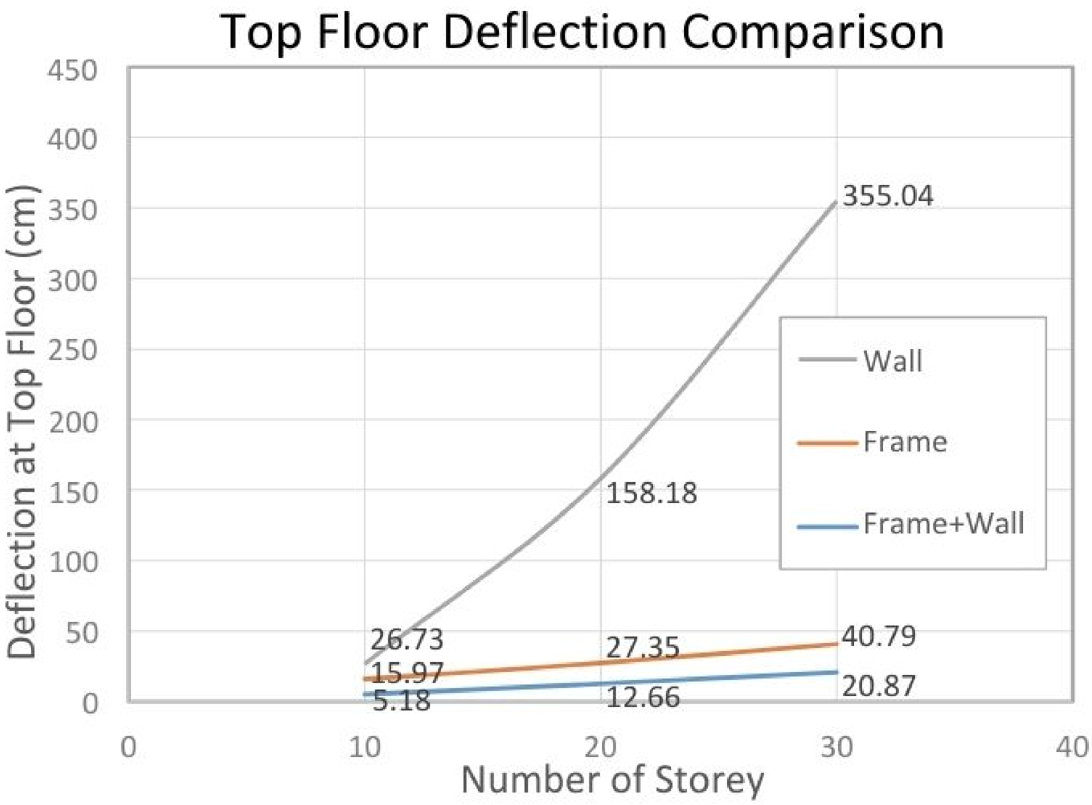


Fig. 18 Top floor deflection comparison for the case studies

In summary, Frame-Wall System is a hybrid system combining moment-resisting frames and shear walls provides lateral stability while allowing flexible internal layouts (Mak, 2016b).

Advantages:

- Balances stiffness and ductility.
- Allows for open floor plans.

Disadvantages:

- Requires careful detailing at wall-frame connections.

2.2.2 Coupled Shear Wall System

For residential buildings taller than 30 storey, shear wall system is more commonly adopted. This is because the characteristics of residential building comprise of a lot of walls partitioning flat units. Some of these walls can be thickened and utilized as shear walls to resist lateral wind load.

If these shear walls are discretely positioned, the wind resisting capacity is not significant. Shear walls are therefore purposely aligned and coupled to increase the I-value (see Fig.19). Coupling can be realized by relatively short lintel beams linking adjacent shear walls. Coupled shear wall structure can be constructed in the range of 40 to 50 storeys.

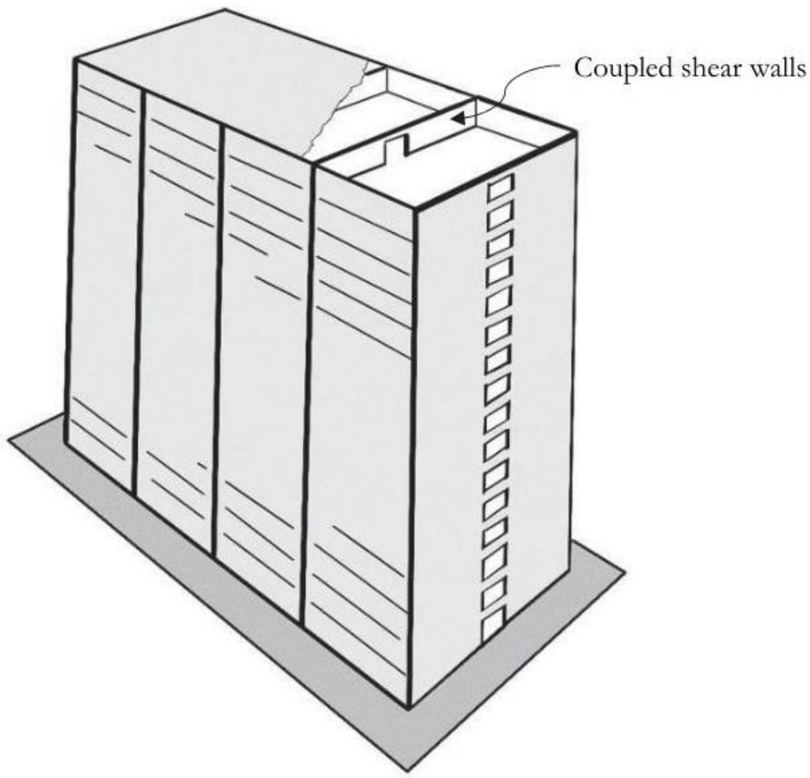


Fig. 19 Coupled shear wall system

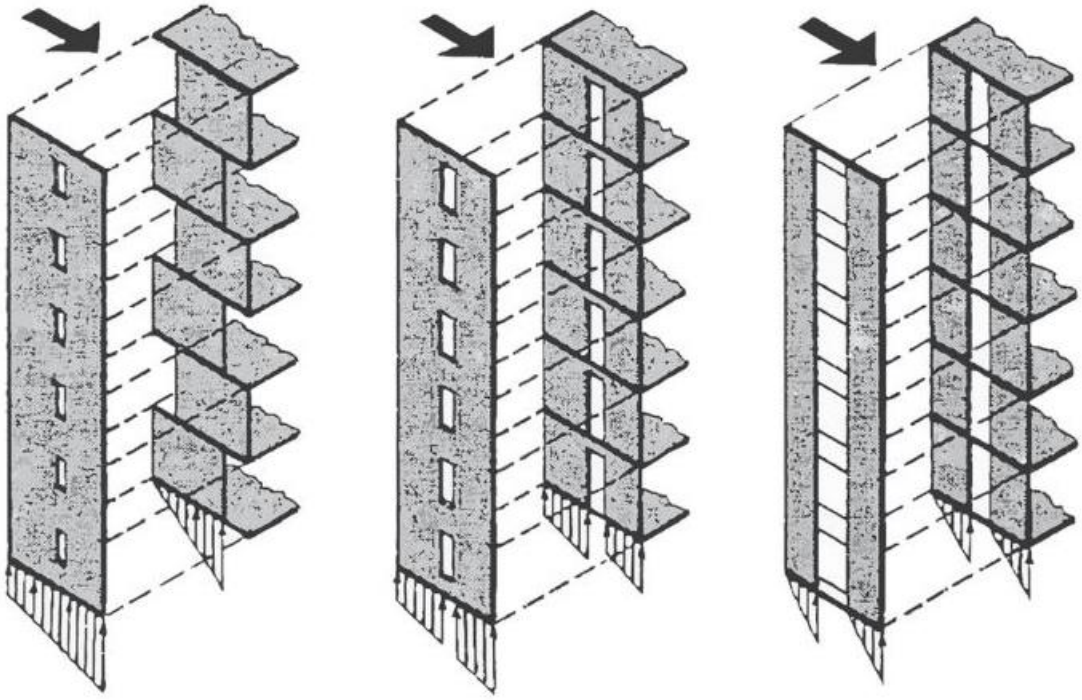


Fig. 20 Stresses at coupled shear wall system and discrete shear wall system

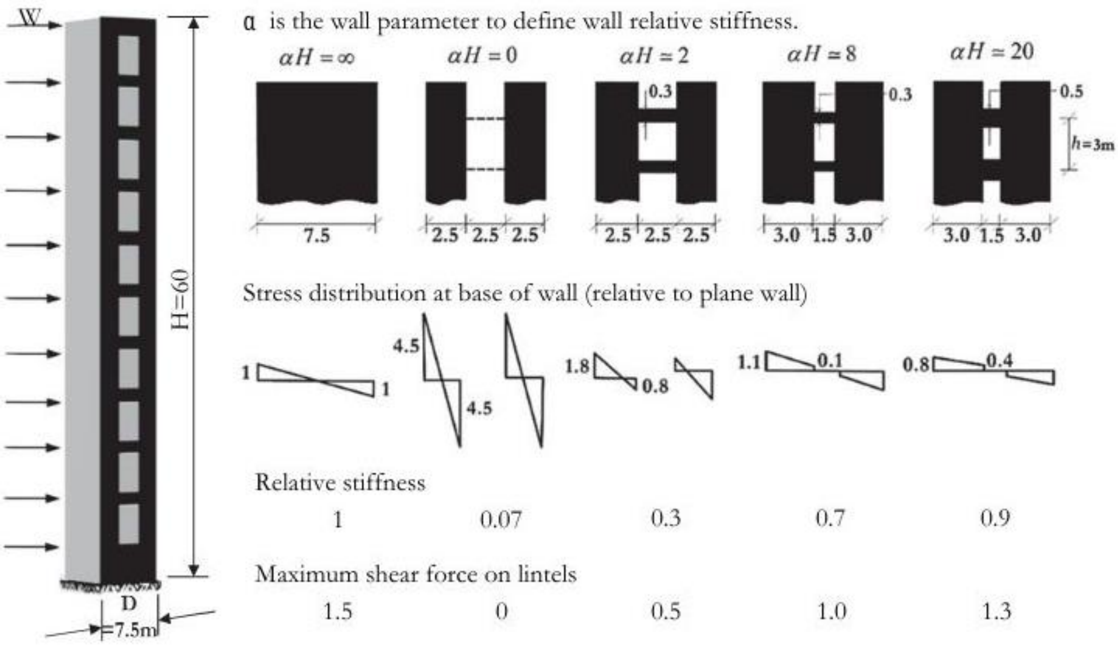


Fig. 21 Relative properties of various wall geometries

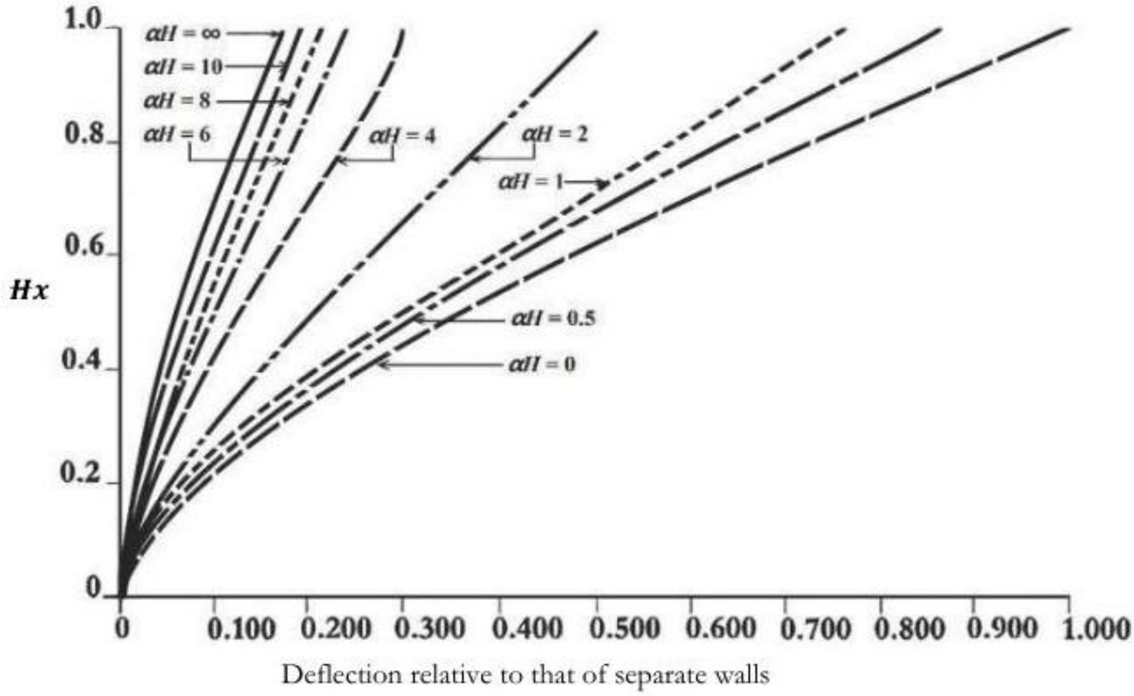


Fig. 22 Relative deflection of coupled shear walls

From the stress diagrams (see Fig. 20), it can be seen that the linking of two coupled walls can effectively transform the two coupled walls into almost a single piece of solid wall, with relative stiffness of up to 90% of the latter (see Fig. 21). The relative deflection (see Fig.22) is also very close to that of a single piece of wall. However, if the walls are discretely positioned and not linked up, the relative stiffness is only 7% of that of a single solid wall.

On top of coupling, orthogonal walls (see Fig. 23) are also aligned to form channel, I or T shape to enhance the overall stiffness. These walls when connected can allow continuous shear flow from one end of the building to the other (see Fig. 24).

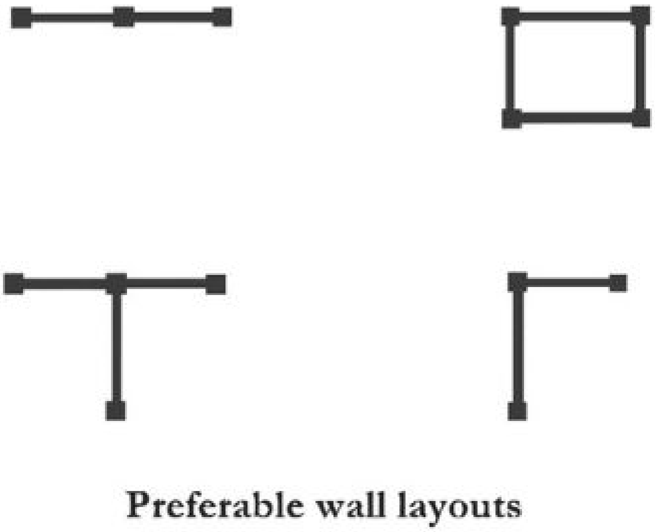


Fig. 23 Orthogonal walls

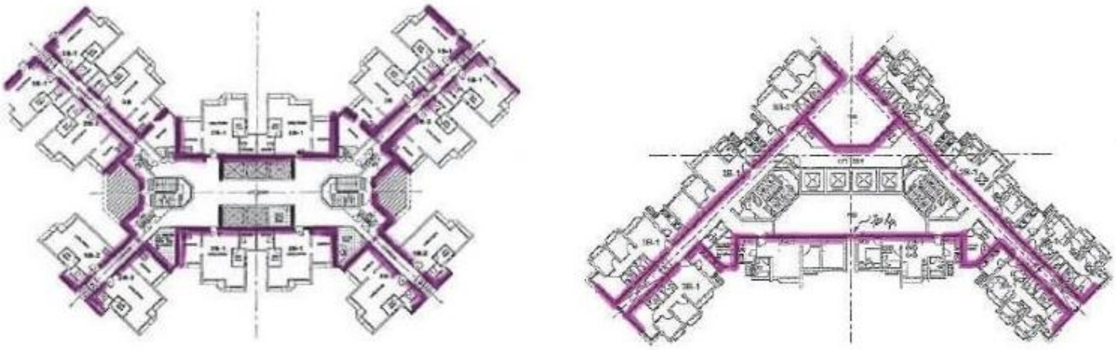


Fig. 24 Continuous shear flow

Horizontally shear flow is transferred from one shear wall to another via the floor slab which forms a rigid diaphragm across the block (see Fig. 25). If bottle-neck exists, e.g. at corridor area near re-entrant, tie-beams should be added to uniformly transfer the shear flow. Otherwise stress concentration may occur resulting in possible concrete cracking in the corridor slab.

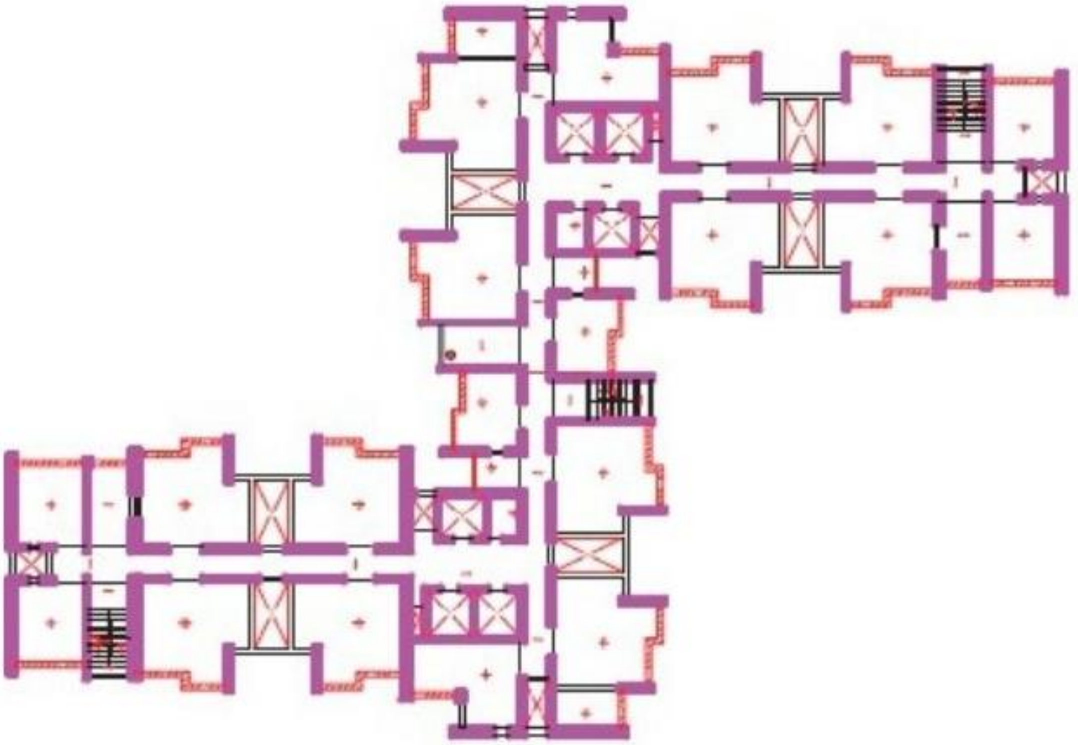


Fig. 25 Transfer of horizontal shear flow via floor rigid diaphragm

Vertically, the end gable walls and the walls further from the central core are more effective in resisting the vertical bending moment to the block due to lateral wind (see Fig. 26). As a result, the end gable walls are normally made thicker than the other walls. On the other hand, the central lift cores are less effective. When the block has long corridor, the corridor spine walls are also very effective in resisting wind bending moment.

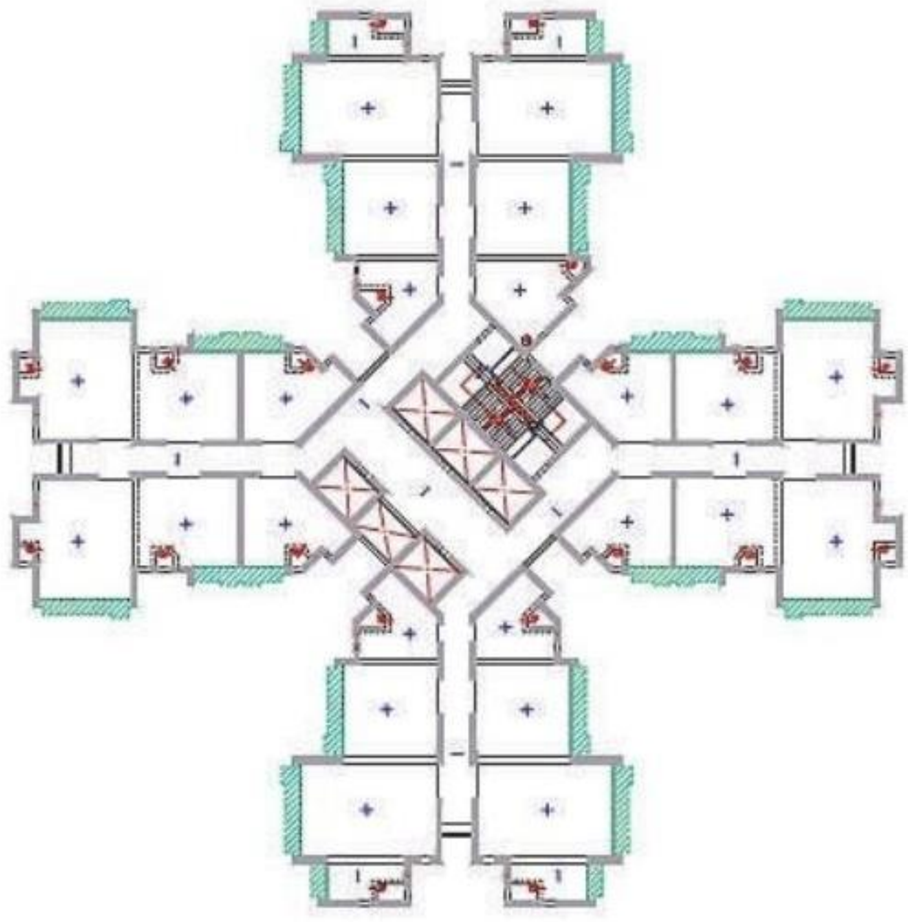


Fig. 26 End gable walls and walls further from centre better resist vertical bending moment

In the event of an exceptionally long and slender block (see Fig. 27), the torsional effect due to wind needs to be catered for. This occurs when the gust wind centre is offset from the block geometric centre. Stiffening of the cross walls and corridor walls may provide the torsional rigidity.

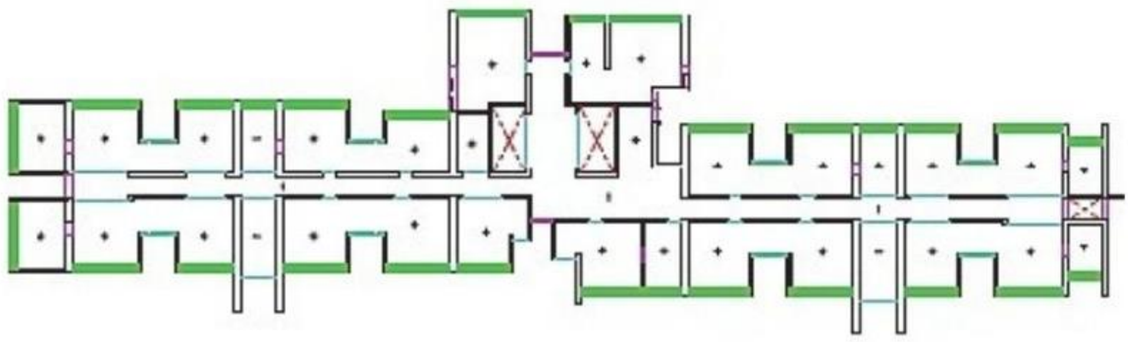


Fig. 27 Long slender block

In general, this system enhances lateral stiffness by coupling shear walls with link beams, improving resistance to wind and seismic loads (Mak, 2018).

Applications:

- Commonly used in buildings over 40 stories.
- Effective in resisting typhoon-induced sway.

2.2.3 Common Forms of Residential Buildings in Hong Kong

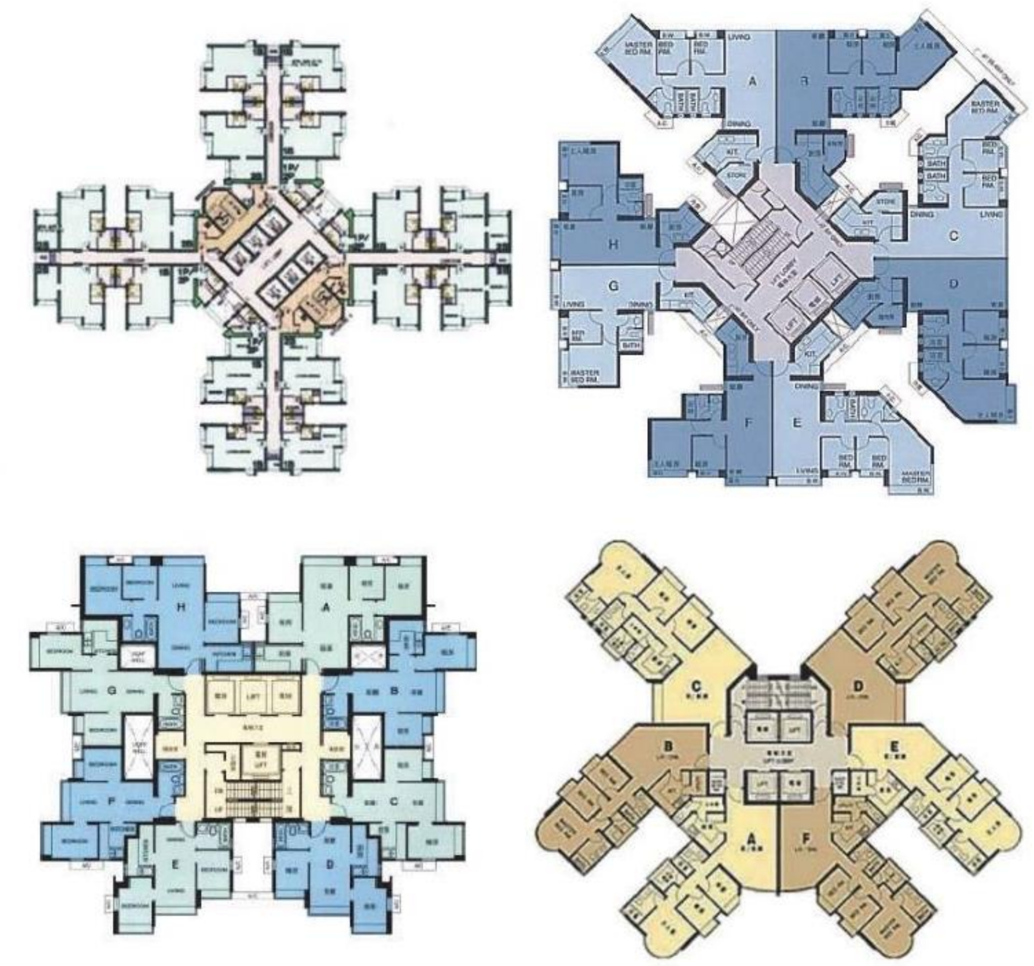


Fig. 28 Common forms of residential buildings

It can be seen in Fig. 28 that walls are aligned together to form coupled shear walls, with the agreement with the architect on the architectural layout. It should be noted that blocks with symmetrical shapes are preferred (e.g. cruciform, circular, trident, square). Otherwise, certain walls need to be thickened because of the non-symmetry and the cost may need to be increased.

In summary, standardized designs, such as Harmony and Concord blocks, facilitate mass production of precast components (Mak, 2013b).

2.3 Design of Precast Concrete Components

2.3.1 Prefabrication

With the use of standardized modular flats in public housing, the building skeleton components such as facades, slabs, staircases, partition walls, beams and bathrooms are prefabricated (see Fig. 29). Prefabrication of concrete components is essentially the construction method which transfers some of the difficult insitu reinforced concrete construction from working floor to factory. The transfer is also from elevated construction on site to construction on ground in factory (see Fig. 30).

Fig. 29 Common types of precast elements

For elevated construction, it is often difficult to handle complicated component profiles or locations which are difficult to access. Substantial falsework and working platforms may be required (see Fig. 31). In case timber formwork is used, the workmanship may be deteriorated after repetitive construction. For factory fabrication on ground, steel moulds can be used which facilitates horizontal casting of concrete and steel fixing (see Fig. 32).

Fig. 30 Prefabricated construction

Fig. 31 Traditional method of construction

Fig. 32 Factory fabrication on ground

Prefabrication improves construction speed and quality control (Mak, 2015a).

Advantages:

- Reduced On-Site Work – Minimizes weather delays.
- Higher Quality Control – Factory-controlled production.

2.3.2 Precast Facade

Precast facade (see Fig. 33) is a typical example where casting at elevated position is difficult, whether it is cast together with the working floor construction or after the structural skeleton is cast using insitu method. On the other hand, if the complicated profile is tackled on ground in the factory, it is much easier. The facade is cast horizontally in factory (see Fig. 34) like a slab instead of like a wall for insitu construction. Moreover, in the factory, the window frame can be cast into concrete which can prevent water seepage in the long run. The surface finishes can also be applied on ground instead of applying by scaffolding or working platform at height.

Fig. 33 Precast facade

Fig. 34 Façade casting horizontally like a slab

In respect of design, the facade is supported on either side by structural walls, which has the effect that it will not accumulate the loadings to the lower floors (see Fig. 35). Each facade will transfer the dead load to the structural walls on either side and will not impose onto the facade underneath. As a result, the loading of each facade, which is its self-weight, will be the same and hence the facade can be standardized. This has a significant implication to the manufacture in factory when these facades can be repetitively fabricated.

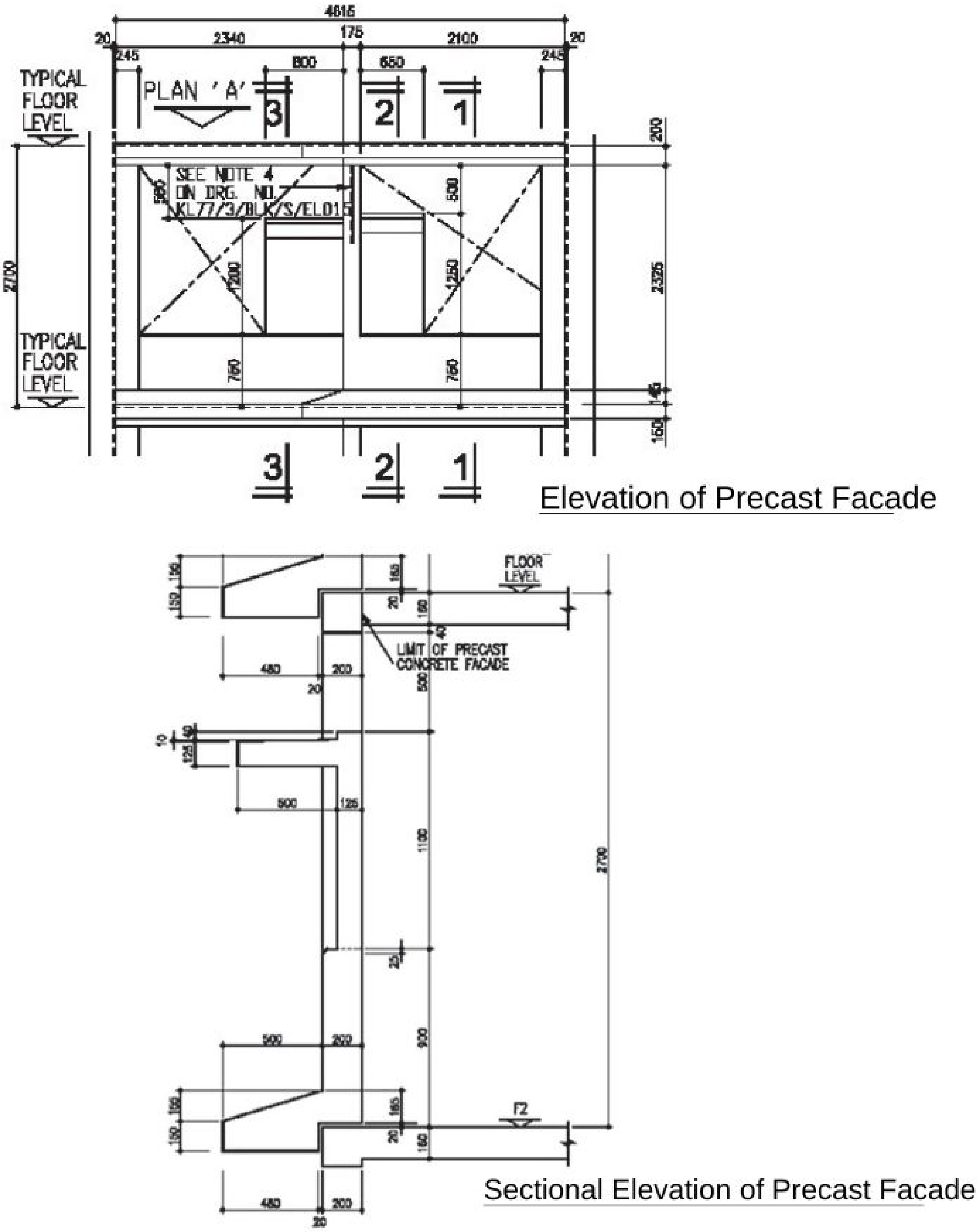


Fig. 35 Façade supported on either side by structural wall and not resting on façade at lower floor (with a gap in between)

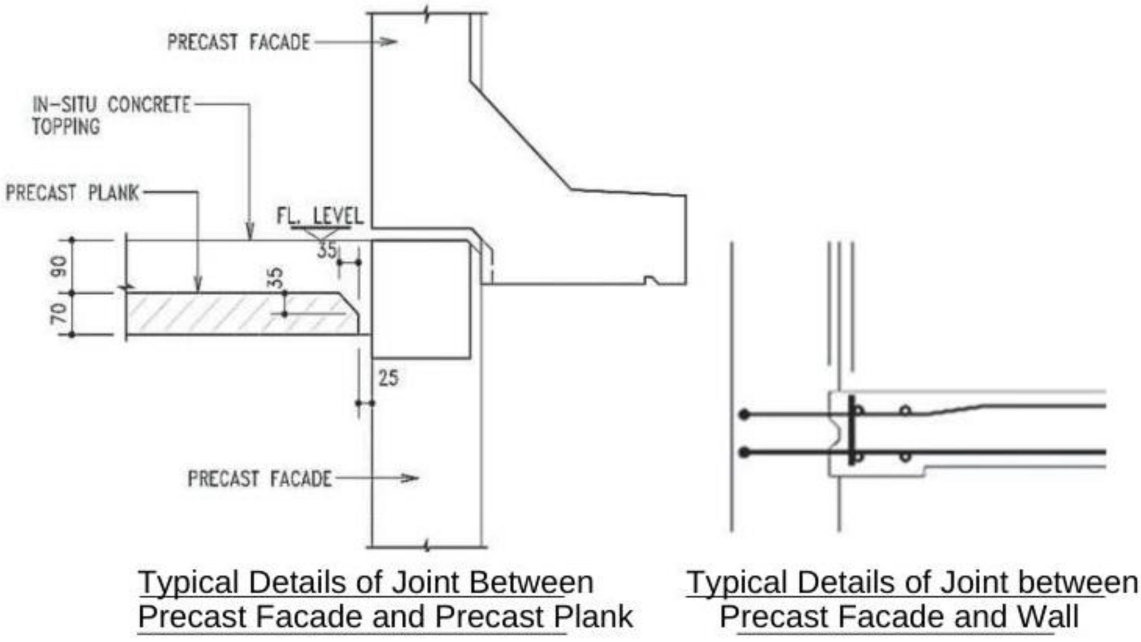


Fig. 36 Façade horizontal and vertical joints

At the horizontal joint, structurally the upper and lower facades are separated, leaving a gap in between (see Fig. 36). The gap is plugged by the floor screed (not shown) inside the flat. If there is incoming external rain trying to penetrate through the gap, the gap forms a vacuum which prevents water to further penetrate. This is a very effective water proofing mechanism. Moreover, the ledge of the upper facade cantilevering out also protects the joint from water penetration.

At the vertical joint, it is a completely cast in monolithic joint with reinforcement anchoring from the facade to the structural wall (see Fig. 36). The joint is robust and no structural movement is anticipated, even if the building is under vibration due to wind. In addition, the cast-in joint is watertight.

During the manufacturing and erection stages, the facade is required to be lifted up and transferred (see Fig. 37). The lift up loads need to be designed for so that the concrete sections will not be damaged or cracked. A common practice is to use a lifting frame so that the lifting wires can be kept vertical instead of inclined, hence no horizontal component of the lifting force will be exerted upon the concrete sections which creates undue stresses.

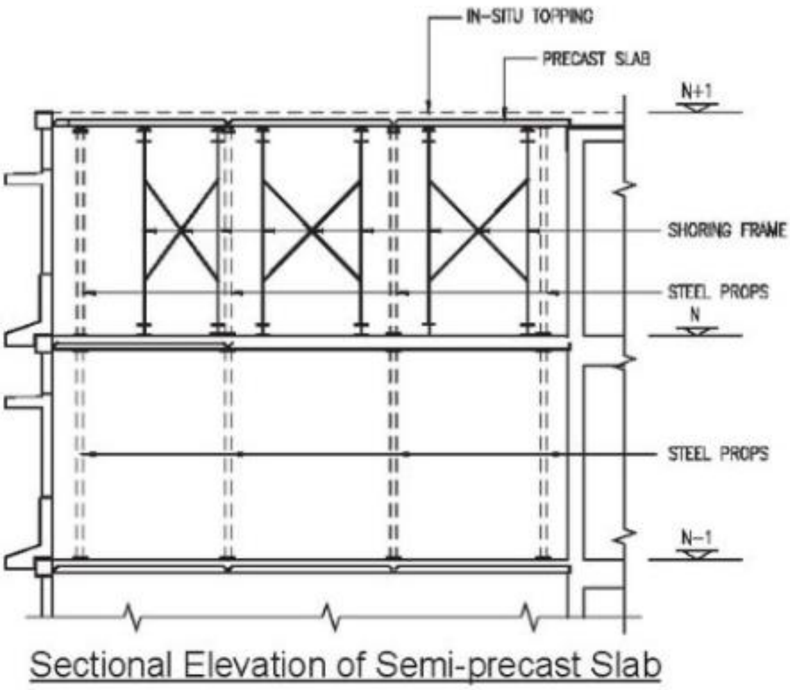
Fig. 37 Façade showing the lifting frame

2.3.3 Semi-precast Slab

Traditionally, substantial timber formwork is used for slab construction. The effect is similar to that for wall construction in that a lot of touching up works for the slab soffit is required due to deterioration of timber plywood and due to grout leakage at formwork joints. This involves additional cost for labor and plastering materials.

Semi-precast slab (see Fig. 38) is a composite construction method whereby the lower portion is precast done in the factory and the upper portion is cast in-situ. The benefit is that the slab soffit is now very smooth and needs no touching up and it also serves as formwork for casting the upper portion. No slab formwork is hence required on site. The construction is much neater and less labor on site will be deployed.

Fig. 38 Semi-precast slab



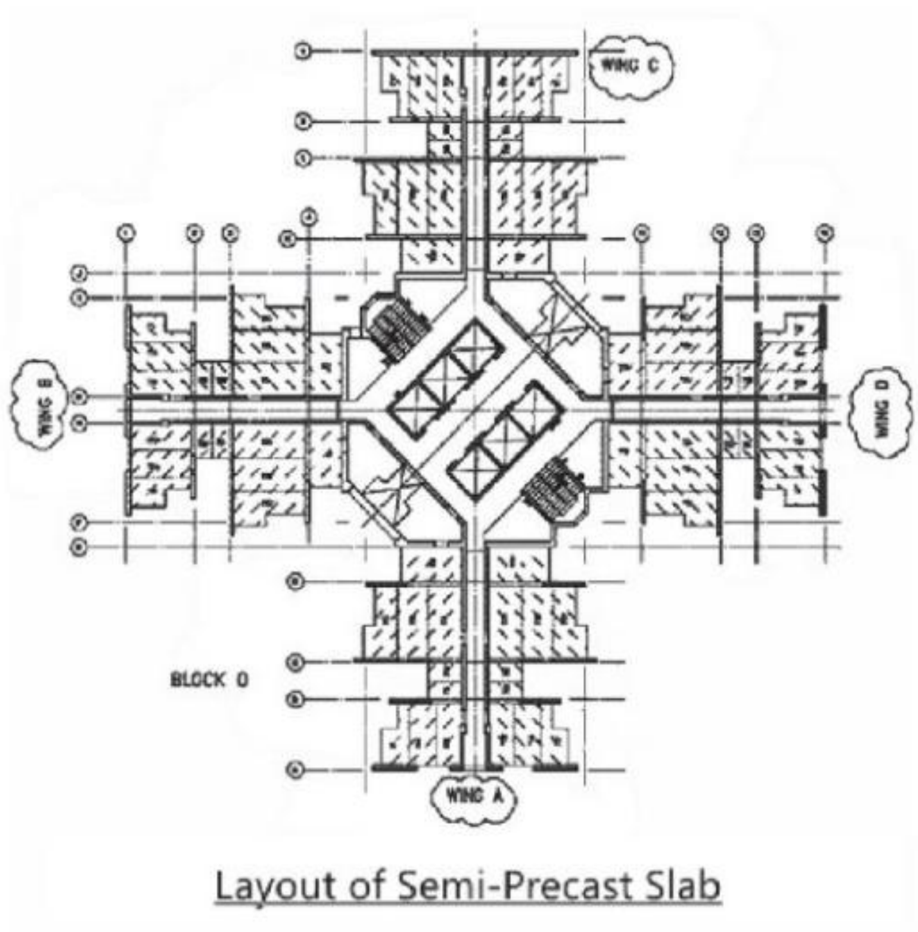


Fig. 39 Semi-precast slab (con't)

The width of semi-precast slab is maximum 2.5 m, which is the width allowed for transportation on trucks. In-situ portion of the composite slab allows the incorporation of electrical conduits which will be concealed with concrete afterwards (see Fig. 40).

The conduits can be laid and run on top of the semi-precast slab with great flexibility, to be connected to junction boxes within the slab or at the edges of the slab. Concealed conduits is a much neater construction, as compared with the traditional method of exposing the conduits underneath the slab soffit.

Reinforcement laying for the in-situ portion is also very convenient, simply laying a few sheets of fabric reinforcement on top of the precast planks (see Fig. 40). Much less labors is deployed as compared with traditional method.

Fig. 40 Laying of electrical conduits and fabric reinforcement on top of semi-precast slab

In respect of the interfacing joint of the precast planks with each other and with the adjoining walls, Fig. 41 are the typical details. For joints between precast planks, a 3mm recess is formed at the bottom gap and the recess will be plastered with non-shrink grout at later construction stage.

The interfacing of the precast planks with the in-situ concrete requires only brush roughening of the top surface of the concrete before hardening. This is adequate for connecting with the in-situ toppings. No shear keys is necessary for shear connection because of the relatively large surface areas.

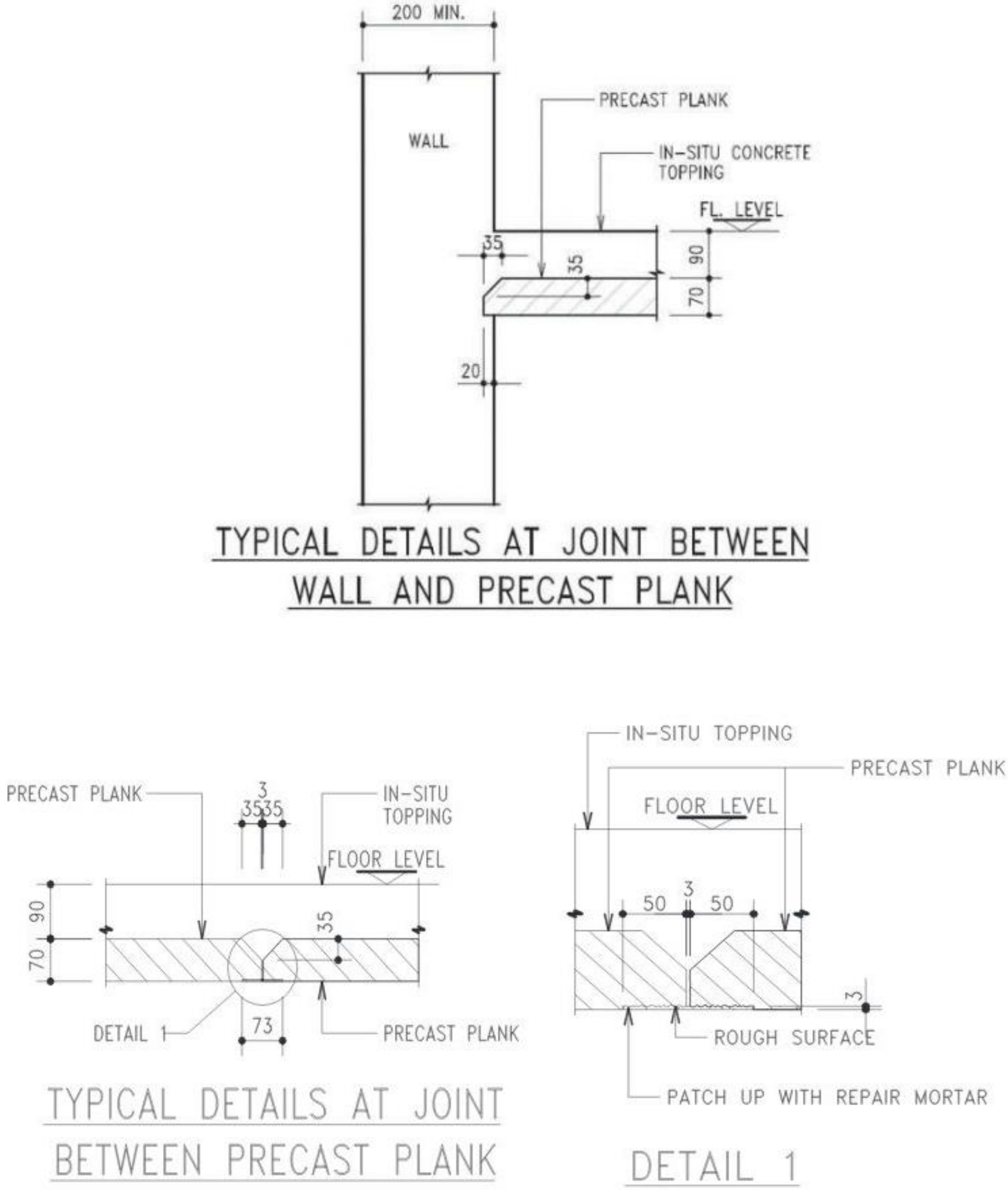


Fig. 41 Typical details of joints for semi-precast slab

2.3.4 Precast Staircase

Staircase in residential building is normally confined in a limited space within the stair core. In-situ construction is difficult because of the need for erecting formwork and falsework within the confined space, reinforcement fixing and concreting. It is sometimes even dangerous due to the possible movement of falsework by workers' passage up and down before the cast concrete has reached the necessary strength to facilitate falsework removal.

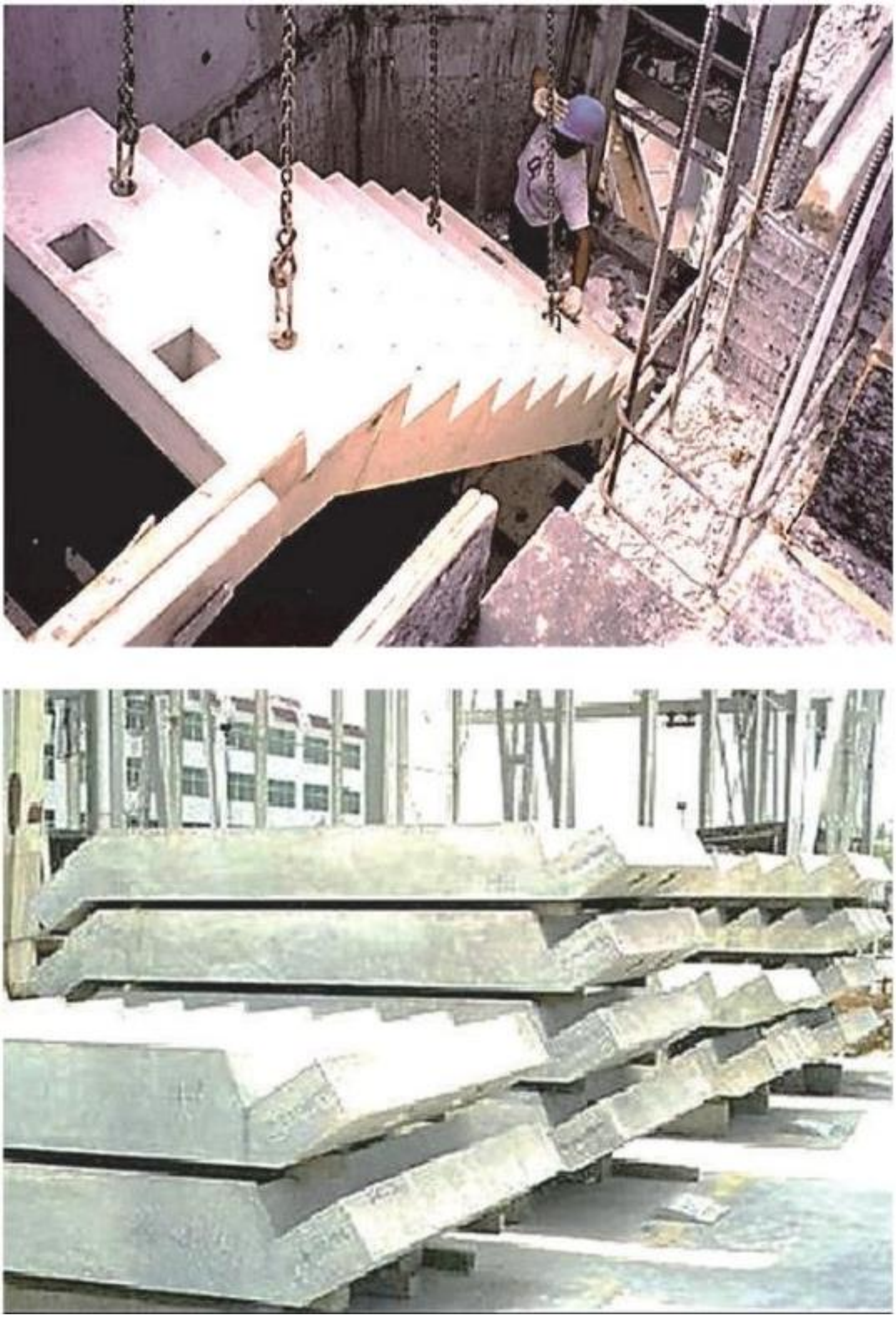
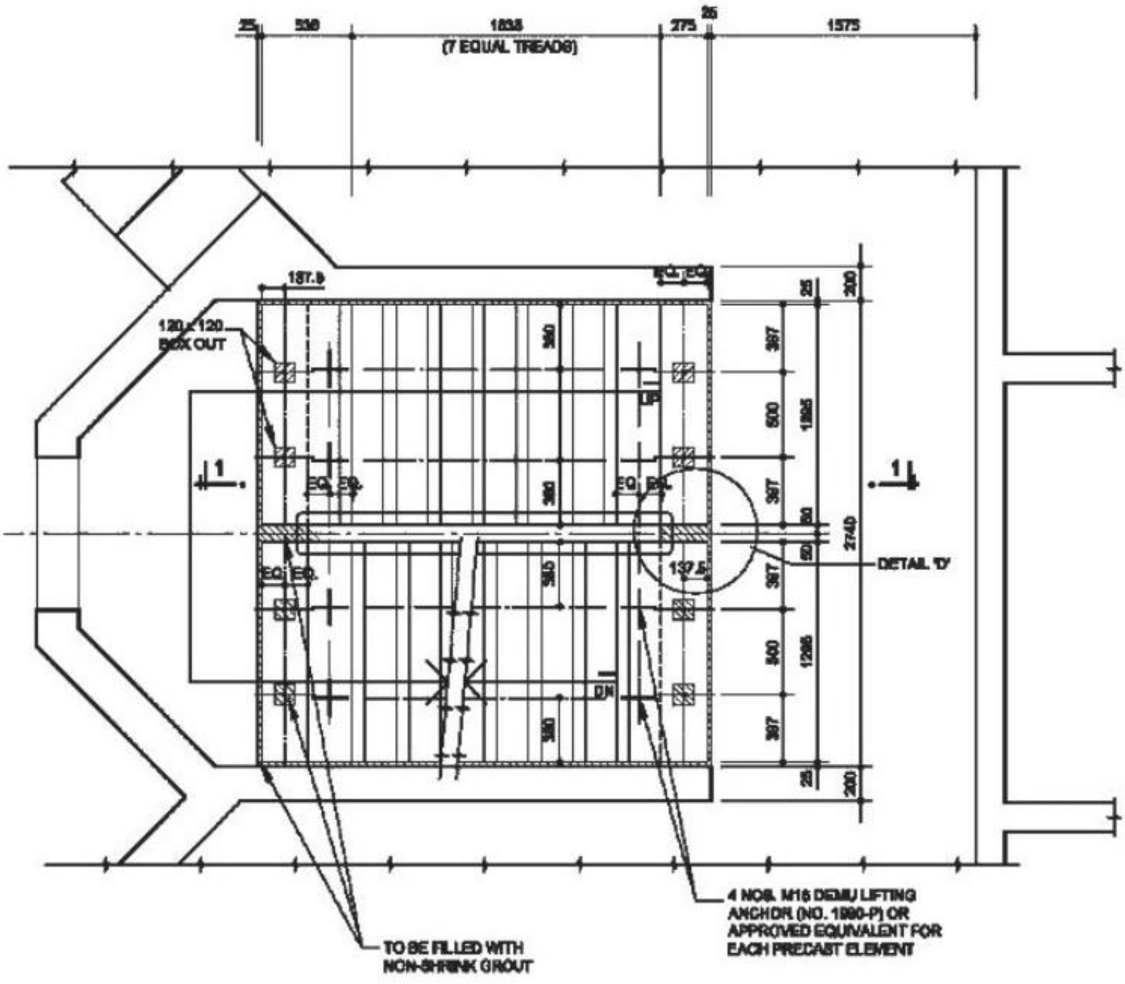


Fig. 42 Precast staircase

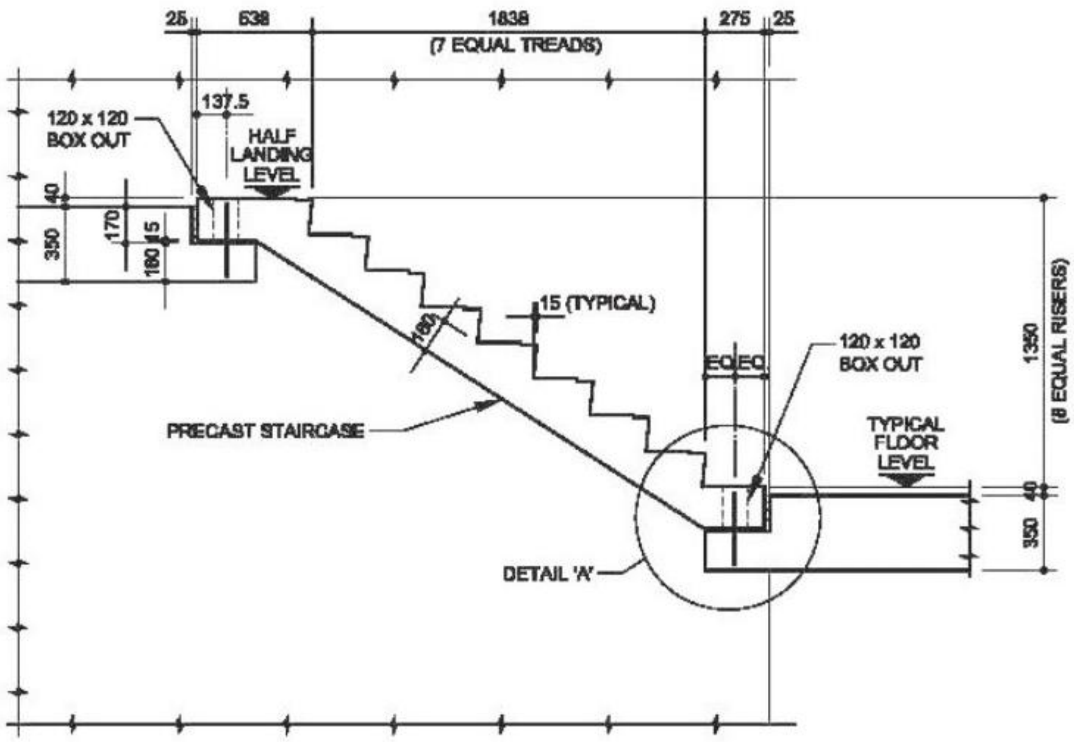
Precast staircase is simple to produce in factory and easy to install on site. Connection at supports are made by dowel bars and box-outs, to be grout filled afterwards (see Fig. 43).



Precast Staircase Plan

(1 : 25)

Fig. 43 Typical details of precast staircase



Elevation of Precast Staircase

(1 : 25)

Fig. 44 Typical details of precast staircase (con't)

2.3.5 Precast Partition Wall

There are two types of partition walls, one is by lightweight concrete and the other is by reinforced concrete. Lightweight concrete wall (see Fig. 45) is used for internal partitions, such as toilets, kitchens, etc. They are made by either hollow sections or aerated concrete. Lightweight partitions are to be erected after construction of structural frame, to serve as partitions but eliminate wet trade (previously by blockworks).

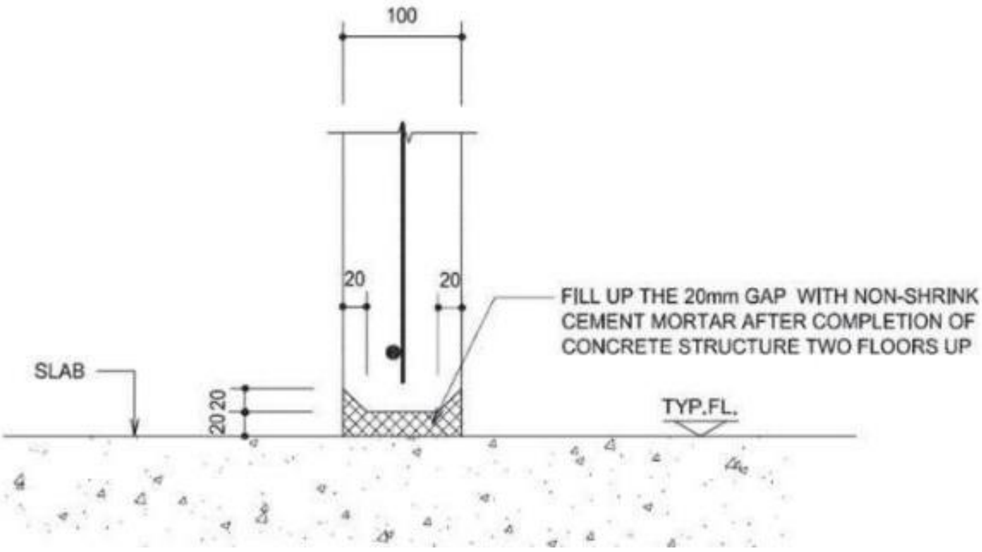


Fig. 45 Lightweight concrete wall

The partition wall is first erected up vertically, then jacked up by wedges at the bottom of the wall and afterwards filled up the bottom gap with cement mortar.

R.C. partitions (see Fig. 46) are normally used for partitioning between two flat units, for the reasons of fire protection and security. They are thin partitions which are difficult to be constructed vertically by in-situ method. These walls can be cast horizontally in factory.

The erection of RC partition wall shall be carried out by tower crane before construction of the floor slab above. The top of R.C. partition is anchored into the upper floor slab with reinforcement. This is to better stabilize the wall for security reasons.

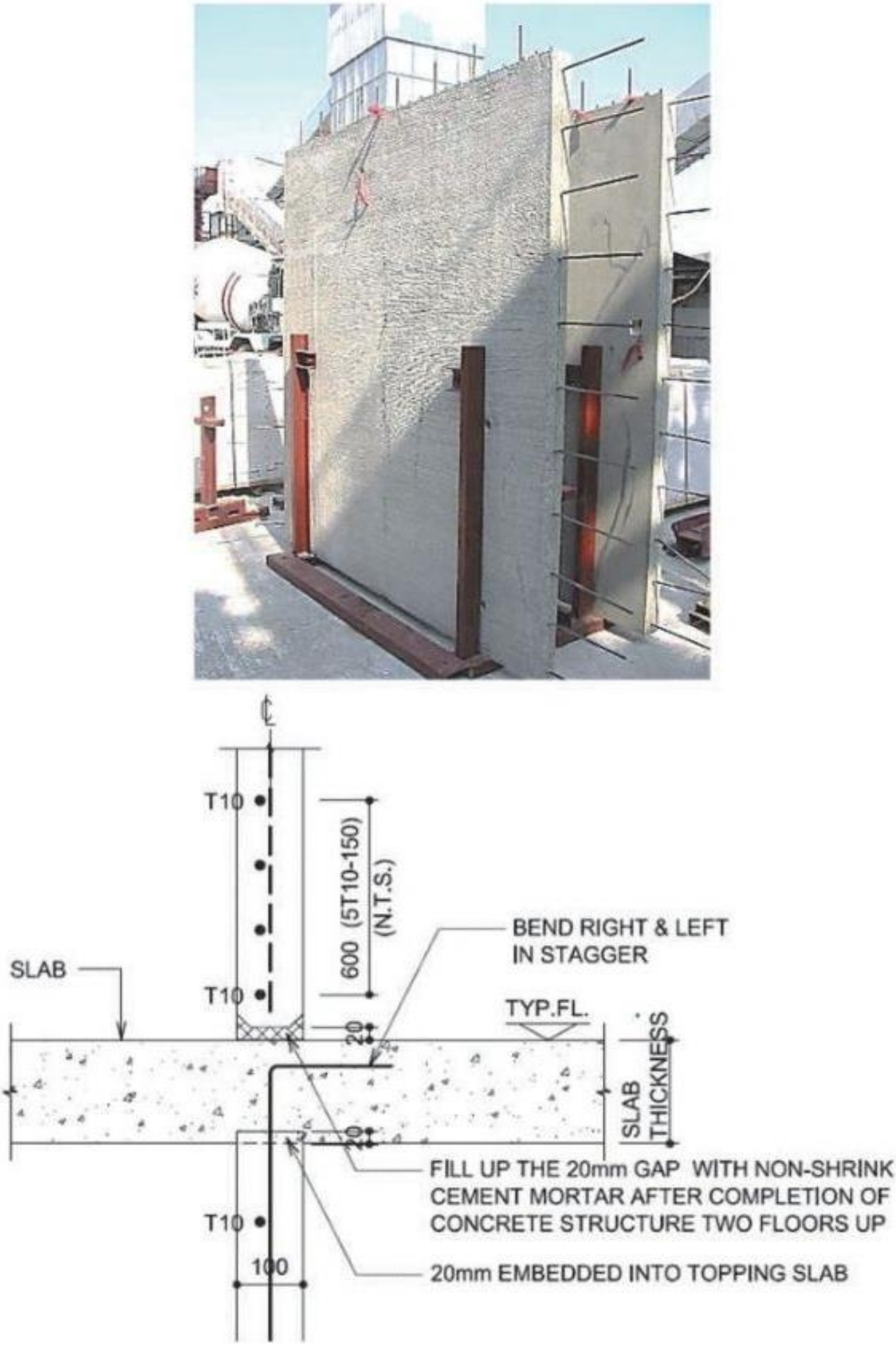


Fig. 46 R.C. partition wall

2.3.6 Precast Tie Beam

Tie beams are often provided to better transfer the horizontal shear at locations such as re-entrants. The tie beams are usually very short beams, but do not have floor slabs on either side of the beams. As a result, it is difficult to construct the beam at elevated position unless substantial temporary working platform and falsework are erected. With the use of precast tie beams (see Fig. 47), the construction will be very simple. The projected reinforcement at both ends of the tie beam can rest upon the construction joint on the top of the wall as temporary supports and the tie beam can be cast into the permanent wall supports on either sides.

Fig. 47 Precast tie beam

2.3.7 Semi-precast Wall

Semi-precast walls are usually installed at the end gable wall or re-entrant wall locations (see Fig. 48). The purpose of the wall is to allow external finishes such as tiles to be applied in the factory and on ground instead of at elevated positions on site which saves the setting up of scaffolding and/or working platform to do so. The semi-precast wall serves as a sacrificial skin like a formwork and is later connected to the permanent structural wall. This type of semi-precast wall is sometimes called the lost form. It has also the added benefit of not requiring workers to work outside the building (working at height) and hence better safety for workers.

The semi-precast wall has shear keys (reinforcement) for anchoring into the permanent wall. It is first erected with inclined supports and later on the permanent wall reinforcement and steel formwork are installed for casting of concrete.

Fig. 48 Semi-precast wall

2.3.8 Precast Bathroom

Precast bathroom (see Fig. 49) is a box-type structure which embodies numerous pipe ducts, fittings, tiles, waterproofing membranes, etc. The purpose is to transfer a lot of wet trade to the factory which is a better controlled working environment. From past experience, bathroom areas are locations which call for frequent maintenance throughout their life spans because of concrete spalling, water seepage at floor, pipe leakage, etc. With better quality assurance in factory and on ground, the aforesaid workmanship problems can be substantially eliminated.

Fig. 49 Precast bathroom

The structural design of the box structure is relatively simple, only to pay attention to the lifting forces acting on the structure during transportation and erection. In case one of the side wall is a structural shear wall, connections between the upper and lower storey walls need to be detailed.

2.4 On Site Construction and Installation

2.4.1 Mechanized Construction

For elevated construction using traditional methods, it is often difficult to construct at locations which are difficult to access. Substantial falsework and working platforms may be required. In case timber formwork is used, the workmanship may deteriorate after repetitive construction (see Fig. 50).

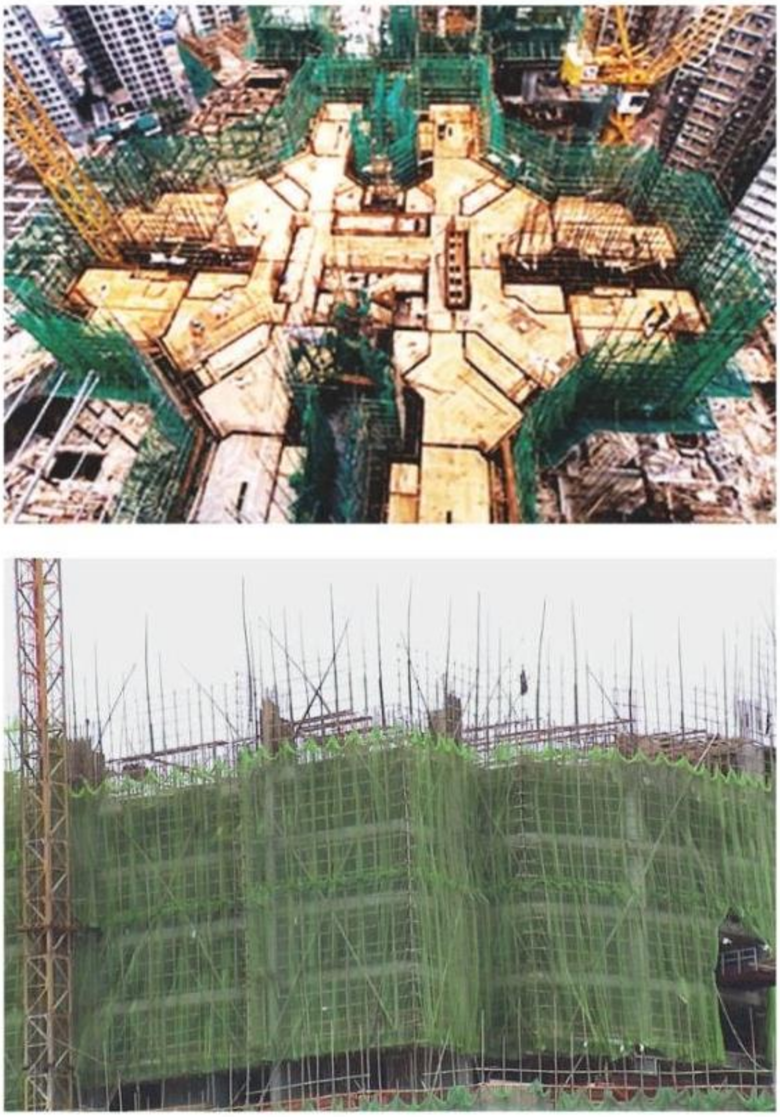


Fig. 50 Traditional construction

Mechanized construction comprise primarily the use of tower crane to move around steel formwork, concrete skips and precast components. The transportation is between ground and working floor and between different wings of working floors (see Fig. 51).

Fig. 51 Mechanization construction

2.4.1.1 Large Panel Steel Formwork

Large panel steel formwork is robust and in one single piece, without vertical joints within the panel. As a result, no vertical marks due to grout leakage on wall face after dismantled. Off-form wall surface are smooth and no undulating profile (see Fig. 52).

Fig. 52 Large panel steel formwork and off-form surface finish

Large panel steel formwork saves the need for carpentry which are expensive skilled laborers nowadays. It can be used when the flat units are relatively standardized in residential buildings (see Fig. 53.

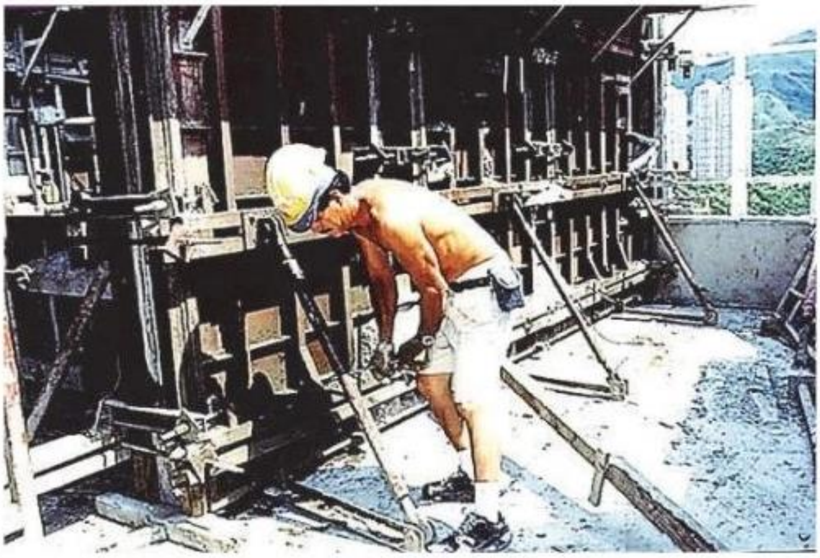


Fig. 53 Semi-skilled laborer for fixing formwork

2.4.1.2 Aluminium Formwork

Aluminium formwork panels are smaller in size, normally 600 mm in width. They are assembled into one big panel piece by connecting with bolt joints (see Fig. 54). As a result, they are more flexible in fitting different shapes and dimensions. They are transported and assembled by manual labours because of their smaller sizes.

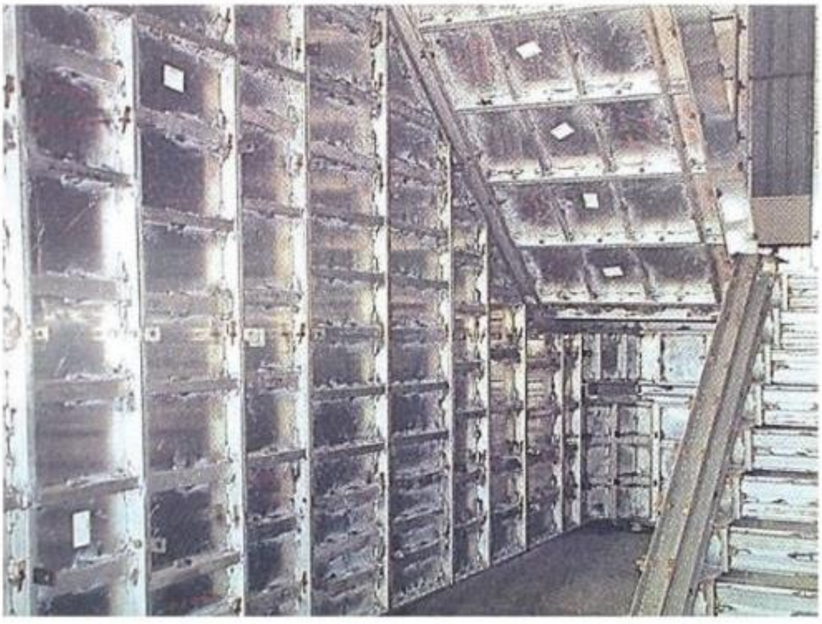


Fig. 54 Aluminum formwork

Aluminium formwork panels have still the drawback of possible vertical joint marks, though far less significant than those produced by timber formwork. Compared with large panel formwork, it is more expensive because of the cost of material, i.e. aluminium is more costly than steel.

2.4.2 Construction Cycle

2.4.2.1 Six day Construction Cycle

Six day construction cycles are common construction time using mechanization and prefabrication method. The set up for the construction include:

(i) one tower crane for each block. In this respect, if the block layout is more or less symmetric, the tower crane can be placed centrally so as to fully cover the whole block footprint. If the block layout is very linear, two tower cranes may need to be used to cover the whole footprint;

(ii) large panel steel wall formwork for one half floor. Again, if the block layout is symmetric, the formwork can be rotated over the same floor without the need to deliver the formwork to ground level for temporary storage (see Fig. 55). This could free more space at ground level as the site area for building site is often very congested;

(iii) precast components to arrive as far as possible "just in time" for the tower crane to lift up to the working floor for erection. This would again minimize storage of precast components on site. The trailer carrying the precast components can be parked on ground closest to the positions where the components are to be erected and hence saves double handling by the tower crane;

(iv) concrete to be delivered by concrete skip and tower crane from ready mix trucks at ground level.

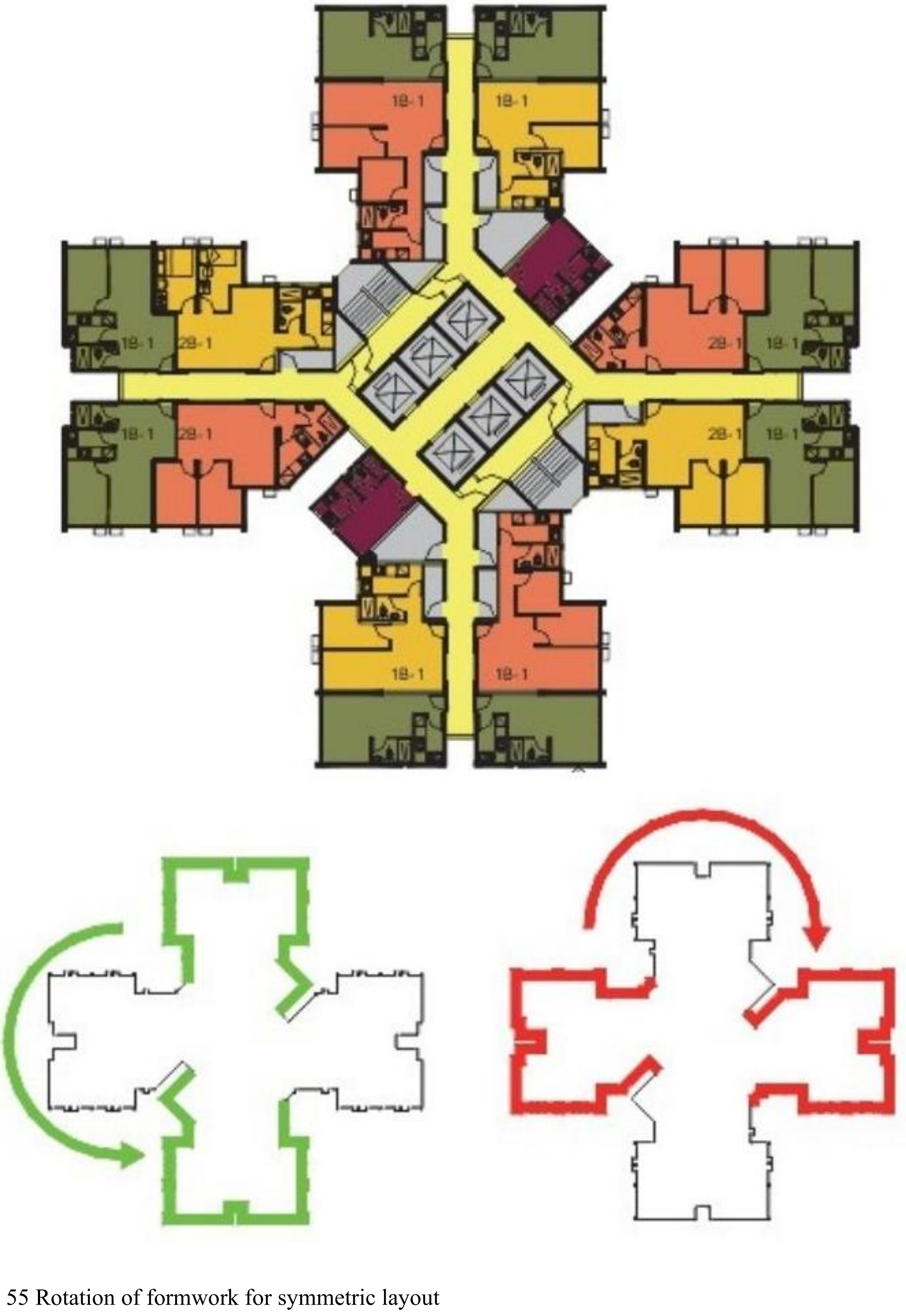


Fig. 55 Rotation of formwork for symmetric layout

The sequence of activities for six days construction cycle are described as below. For the convenience of following the sequence, it can be focussed to activities, say, in Wing A:

Day 1 (see figure 56)

Fig. 56 Day 1 activities

i) Wing A - Dismantle wall formwork (100 %). Lay semi-precast slab (100%).

ii) Wing B - Dismantle wall formwork (30%).

iii) Wing C - Install wall formwork (100%). Erect precast facades (100%).

iv) Wing D - Fix wall reinforcement (100%). Install wall formwork (30%).

Day 2 (see figure 57)

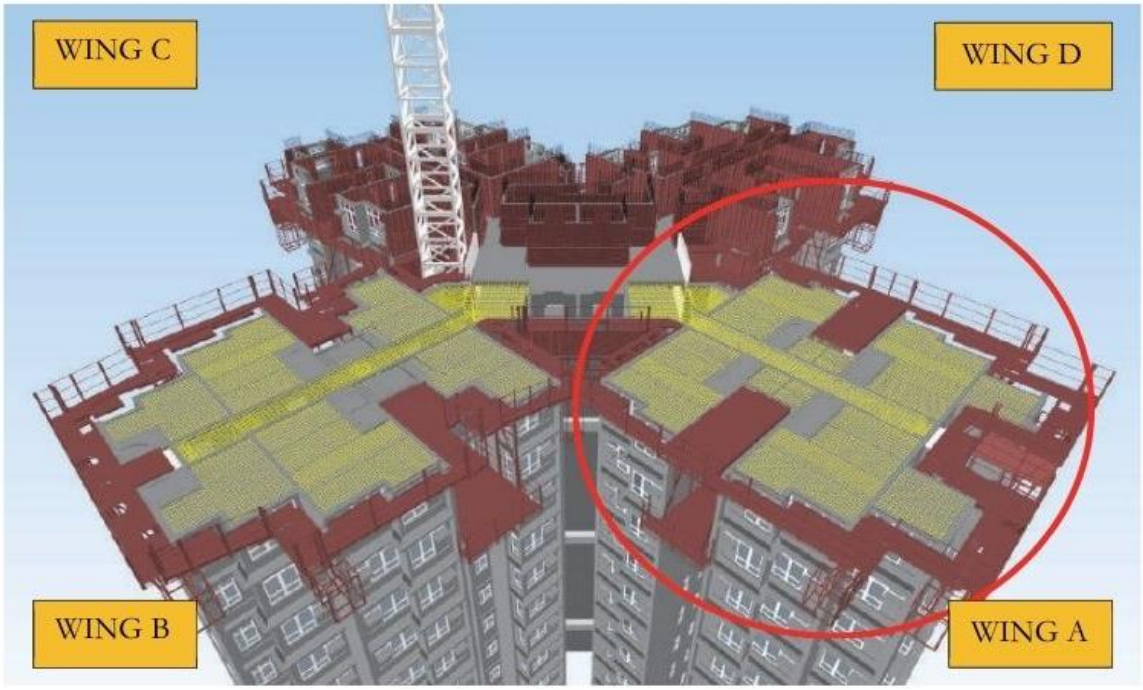


Fig. 57 Day 2 activities

i) Wing A - Lay steel fabric reinforcement over semi-precast slabs (70%).

ii) Wing B - Dismantle wall formwork (100%). Lay semi-precast Slab (100%). Fix fabric reinforcement (20%).

iii) Wing C - Concreting walls (100%).

iv) Wing D - Install wall formwork (100%).

Day 3 (see figure 58)

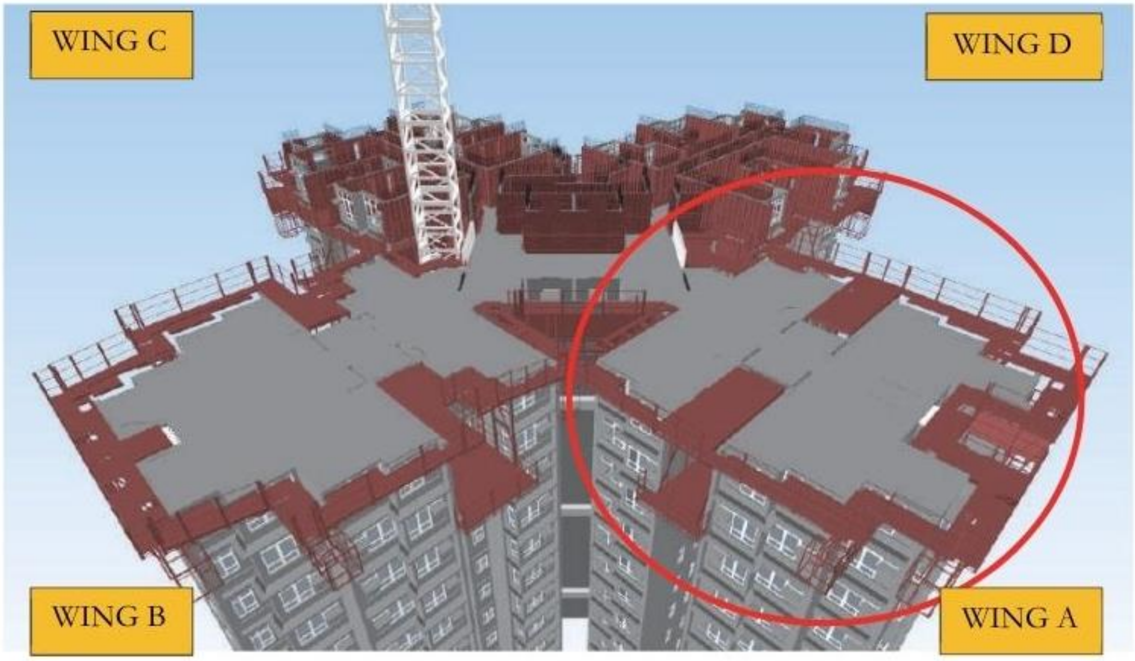


Fig. 58 Day 3 activities

i) Wing A - Lay fabric reinforcement over semi-precast slabs (100%) Concreting over semi-precast slabs (100%).

ii) Wing B - Lay fabric reinforcement over semi-precast slabs (100%). Concreting over semi-precast slabs (100%).

iii) Wing C - Dismantle wall formwork (10%).

iv) Wing D - Concreting walls (100%).

Day 4 (see figure 59)

Fig. 59 Day 4 activities

i) Wing A - Erect precast facades (100%). Fix wall reinforcement (100%). Install wall formwork (100%).

ii) Wing B - Erect precast facades (100%). Fix wall reinforcement (100%). Install wall formwork (30%).

iii) Wing C - Dismantle wall formwork (100%). Lay semi-precast slabs (100%).

iv) Wing D - Dismantle wall formwork (30%).

Day 5 (see figure 60)

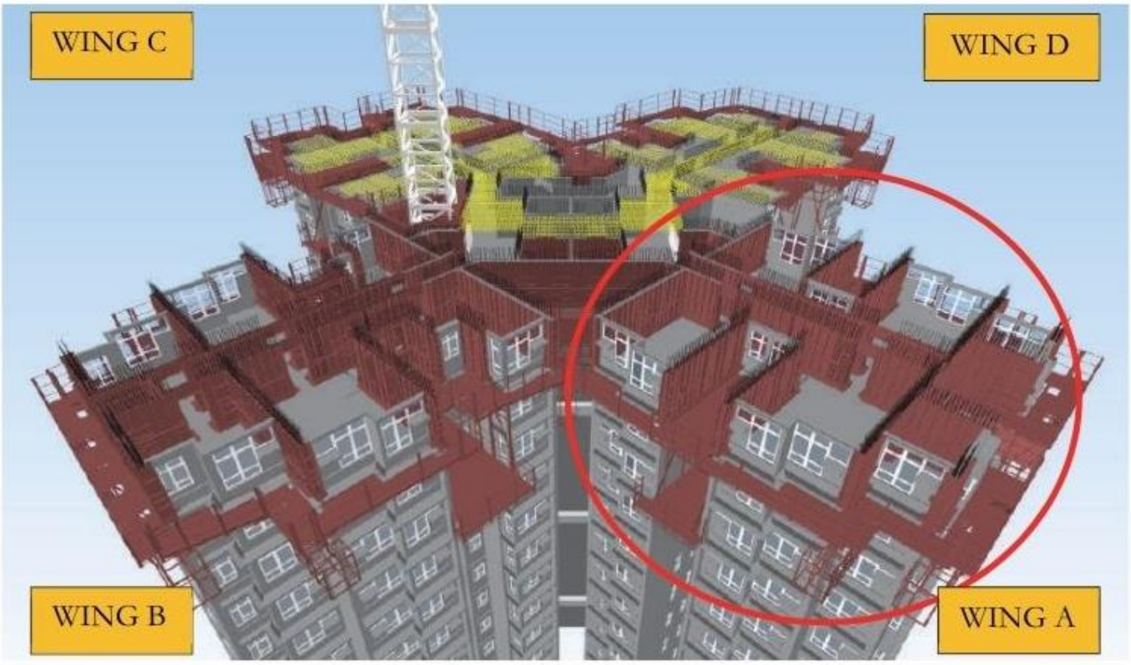


Fig. 60 Day 5 activities

i) Wing A - Concreting walls (100%).

ii) Wing B - Install wall formwork (100%).

iii) Wing C - Lay fabric reinforcement on semi-precast slabs (60%).

iv) Wing D - Dismantle wall formwork (100%). Lay semi-precast slabs (100%). Lay fabric reinforcement over semi- precast slabs.

Day 6 (see figure 61)

Fig. 61 Day 6 activities

i) Wing A - Dismantle wall formwork (10%).

ii) Wing B - Concreting walls (100%).

iii) Wing C - Lay fabric reinforcement on semi-precast slabs (100%). Concreting over semi-precast slabs (100%).

iv) Wing D - Lay fabric reinforcement on semi-precast slabs (100%). Concreting over semi-precast slabs (100%).

Throughout the 6 days construction cycle, it can be found that majority of the works are assembling various components using mechanized methods, including:

i) Erecting and dismantling of large panel steel wall formwork which are prefabricated;
ii) Connecting precast components such as facades and semi-precast slabs.
iii) Fixing of wall and slab reinforcement which contain a great percentage of prefabricated mesh reinforcement (from 60% in walls to 90% in slabs).

As a consequence, the usage of skilled labours on site is very much reduced which in turn enhanced the quality of the products in respect of accuracy arising from human errors and workmanship problems frequently found in traditional method of construction. In addition to the quality of works, site safety aspects can also be significantly improved. It covers the following:

i) Workers are confined within the working floor with precast facades and large panel steel formwork erecting along the building perimeter. This is much safer to workers in protecting them from falling from height as compared with the traditional use of scaffolding.
ii) Workers are not required to erect timber wall and slab formwork involving a lot of carpentry work which are often sources of minor accidents.
iii) With the substantial use of precast components, much of the difficult insitu works such as facades, tie beams, staircases, etc. can be transferred to the factory instead of constructing at elevated working platforms which poses higher risks to the workers.

2.4.2.2 Acceleration of Construction Cycle

The six day construction cycle hinges very much on the tower crane. The latter is basically fully occupied throughout the day in transporting precast elements, formwork and concrete skip, plus the other construction materials such as partition walls, reinforcement, equipment, etc. (see Fig. 62).

Fig. 62 Tower crane is heavily occupied

It can be found that there are idling time every day in some of the wings of the block, basically waiting for the tower crane. In order to better utilize the tower crane and hence shorten the cycle time, one effective method is to use pumped concrete which could spare the time of transporting the concrete skip by the tower crane (see Fig. 63). As a result, a 5-day cycle can be achieved.

Fig. 63 Replacement of concrete skip with pumped concrete

2.4.2.3 Dimensional Accuracy of Precast Elements for Construction

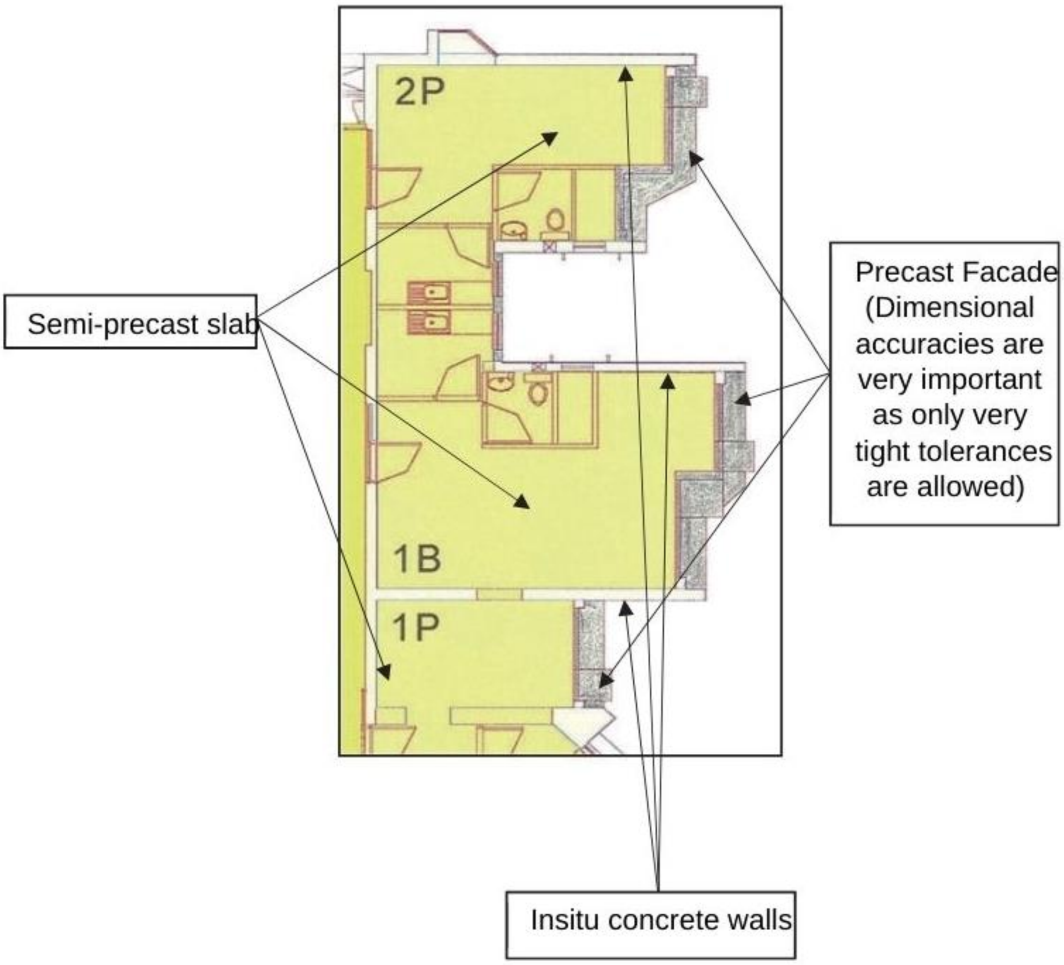


Fig. 64 Dimensional accuracy for precast components

Precast construction calls for high precision; otherwise it cannot fit into and interface with insitu construction as formwork is also prefabricated (see Fig. 64). For example, precast facades need to be fitted between two insitu walls. Where precast is connecting to precast, accuracy is also vital. This applies to semi-precast slab panels of 2.5 m width which are connected together to form the floor slabs. Generally, a maximum of 4mm tolerance between each connection is allowed. As a consequence, the dimensions of the precast elements have to be well controlled in order to facilitate a smooth construction process on site.

2.5 Benefits of Prefabrication and Mechanization

2.5.1 Benefit in Saving Construction Cost

Saving in construction cost can be realized in several aspects:

i) Fair face off-form finishes minimizes touching up and repair, which is very frequent for timber construction (e.g. slab soffit and wall finishes).

ii) Labor cost in precast factory is much lower than that for in-situ construction, first because cost is cheaper in Mainland China and second semi-skilled labor in factory instead of skilled labor at working floor is required.

iii) In-situ architectural wet trade, such as block works partitioning, tiling, plastering, etc. (see Fig. 65) are substantially reduced, mostly transferred to factory or eliminated through the use of metal formwork.

iv) Mechanized construction demands much less labor than those of conventional timber construction, particularly in terms of carpentry and temporary works.

Fig. 65 Wet trade transferred to factory

2.5.2 Benefit in Saving Maintenance Cost

Saving in maintenance cost can be achieved as follows:

i) window leakage – through precast construction, windows are cast into the facades which eliminate regular maintenance (see Fig. 66).

ii) plumbing and drainage – again through volumetric precast whereby pipes and ducting are cast in factory (see Fig. 67).

Fig. 66 Cast-in windows

Fig. 67 Cast-in ducting

2.6 Modular Integrated Construction (MiC) in Public Housing Development

(1) Precast Factory Capacity

- Six active factories currently providing PCCs to HA (Few have concrete MiC experience)
- Require upgrading of hoisting gantries
- Large storage for modules

Fig. 68 Significant investment for factory to produce MiC modules

(2) Site Storage

- Congested sites with limited temporary storage area for large scale MiC modules

Fig. 69 Limited site storage for Housing Authority (HA)'s developments

(3) Construction Vehicle Restriction

• Nearby site constraints and road access restriction (e.g. narrow road) hinder the delivery of MiC modules

Fig. 70 Site constraints and road access restriction

• Cap 374G Road Traffic (Traffic Control) Regulation 55 • Height not exceeding 4.6m • Starter bar < 32dia

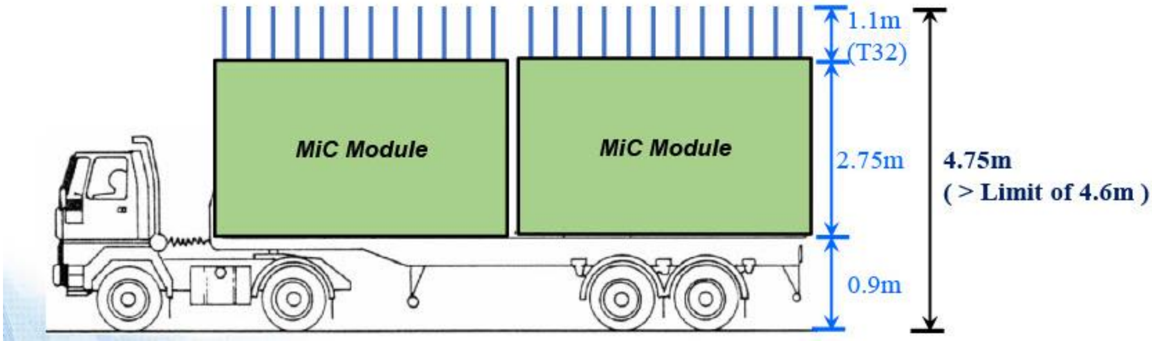


Fig. 71 Traffic control

(4) Large Footprint of Public Housing Developments

• Public housing blocks generally have more than 20 flat units (70 to 100 modules).

• Lifting and installation of MiC modules are crucial for domestic block to maintain the current 6-day construction cycle

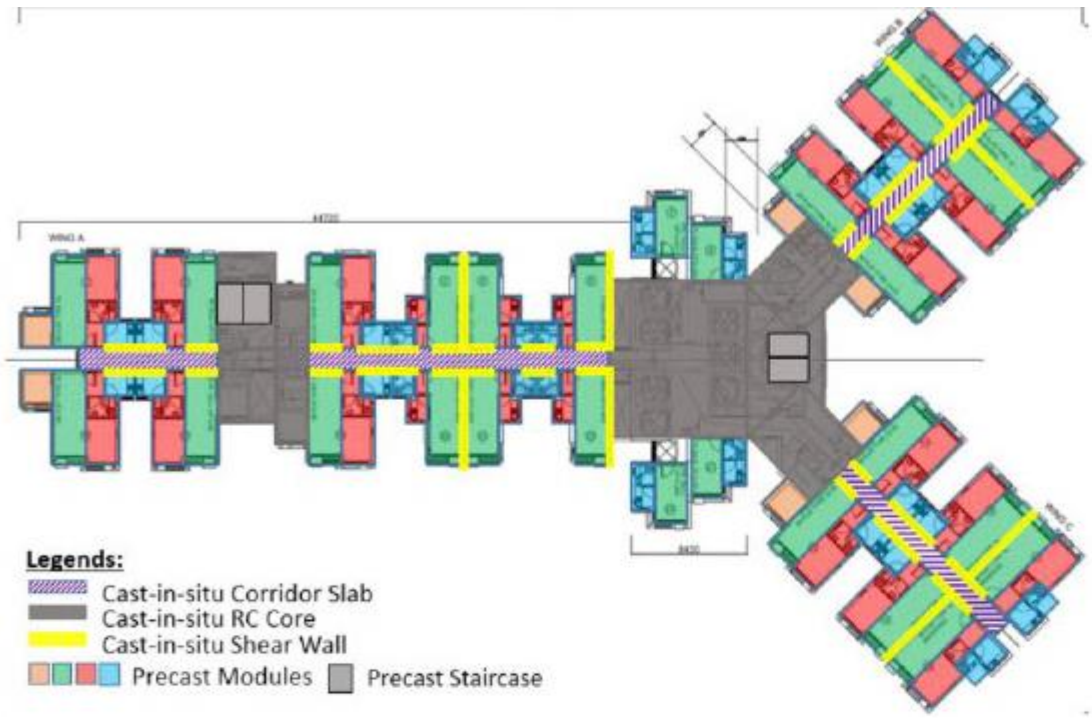


Fig. 72 Public housing blocks

(5) Size of Module

- HA's modular flat to be sub-divided into modules to suit the 2.5m width limit for transportation

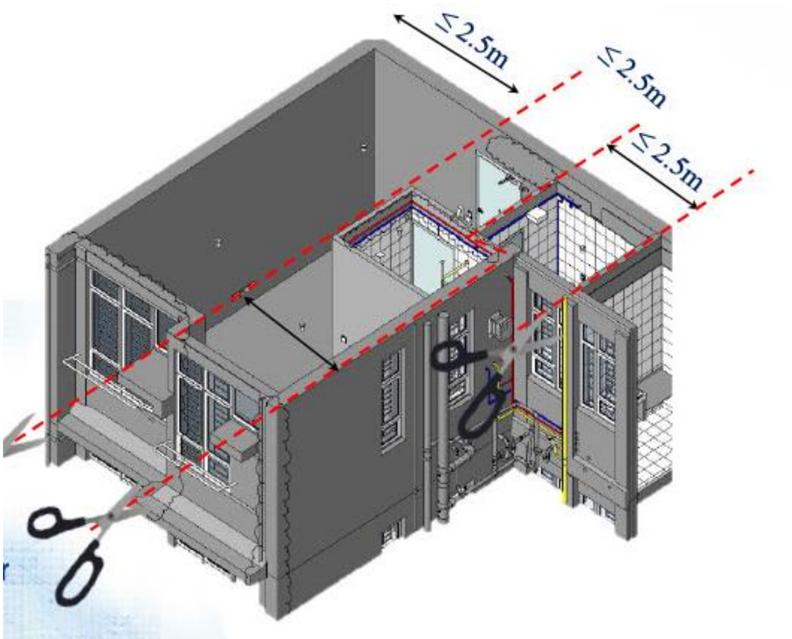


Fig. 73 Size of module

(6) Dimensional Tolerance Control

• High precision control for multi-face connection.

• Longer installation time compare with smaller modules.

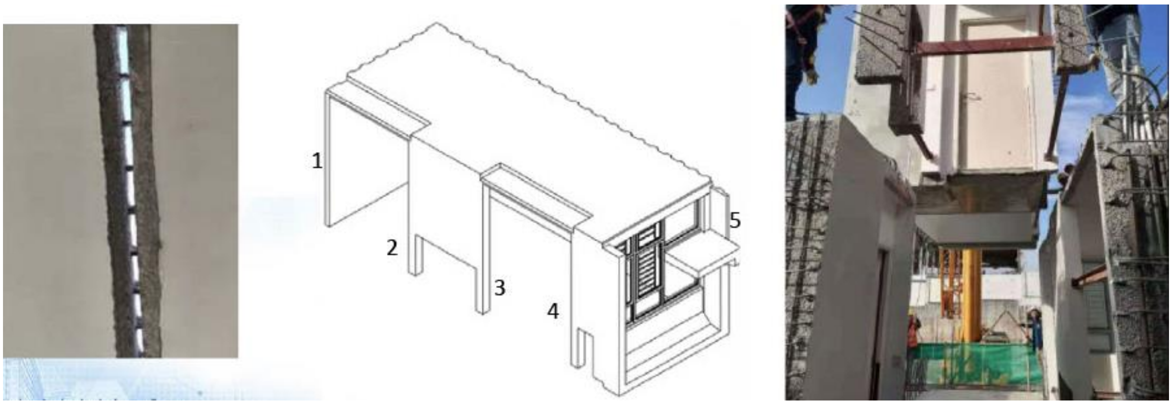


Fig. 74 Dimensional tolerance control

(7) Additional Touch-up Works

• MiC has notable benefits for projects involving substantial finishes and fitting works.

• HA’s developments are of no-frills design without sophisticated fittings and finishes.

• Damage of pre-apply painting within and outside flat.

• Re-apply painting after installation of modules and

concreting required.

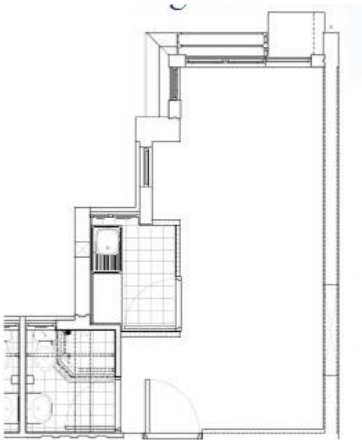


Fig. 75 Additional touch-up works

2.6.1 Modular Integrated Construction (MiC) vs. Precast Concrete Construction (PCC)

Definition of Construction Methods

Modular Integrated Construction (MiC)

Modular Integrated Construction (MiC) is an off-site volumetric construction approach where entire room-sized modules (complete with finishes, MEP systems, and fixtures) are manufactured in factories and assembled on-site. In Hong Kong, MiC is promoted as a highly industrialized construction method under the Construction 2.0 initiative (HKSAR Government, 2018).

Key Features:

- Volumetric prefabrication (3D units)
- Fully fitted-out modules (walls, floors, ceilings, plumbing, electrical)
- Minimal on-site work (only foundation and module connections)
- Steel or concrete structural systems

Precast Concrete Construction (PCC)

Precast Concrete Construction (PCC) involves factory-made 2D structural elements (walls, slabs, beams, columns) that are transported and assembled on-site with cast-in-situ concrete connections.

Key Features:

- Planar prefabrication (2D panels)
- Structural components only (finishes and MEP installed on-site)
- Hybrid construction (combines precast and in-situ concrete)
- Widely used in Hong Kong public housing since the 1980s

Comparison of MiC and PCC in Hong Kong's Public Housing

Aspect	**Modular Integrated Construction (MiC)**	**Precast Concrete Construction (PCC)**
Prefabrication Level	Fully volumetric (3D modules)	Planar (2D panels)
On-Site Work	Minimal (only module stacking & connections)	Significant (structural connections, MEP, finishes)
Construction Speed	50-70% faster than conventional (HKHA, 2020)	30-50% faster than cast-in-situ
Quality Control	Factory-controlled, high precision	Factory-controlled but requires on-site coordination
Labor Requirement	70% less on-site labor (HKHA, 2021)	40-50% less labor than traditional
Structural System	Steel or lightweight concrete modules	Reinforced concrete (precast + in-situ)
Design Flexibility	Limited by module sizes	More flexible (customizable panel designs)
Typical Applications	High-rise residential, student housing, hotels	Mass public housing, commercial buildings

Contrasting Advantages & Disadvantages

Advantages of MiC

✓ Faster construction – Modules can be installed in days (e.g., HK's InnoCell project completed in 18 months vs. 30+ months for conventional).

✓ Higher quality finishes –Factory environment reduces defects.

✓ Safer construction – Less on-site work reduces accidents.

✓ Less weather disruption – 80-90% of work is off-site (HKHA, 2021).

Disadvantages of MiC

✕ Higher initial costs – Requires specialized factories & logistics.

✕ Transport constraints – Large modules need careful planning for Hong Kong's dense urban sites.

✕ Design limitations – Standardized module sizes may restrict architectural creativity.

Advantages of PCC

✓ Proven technology – Widely adopted in Hong Kong since the 1980s (Mak, 2018).

✓ Cost-effective for mass housing – Economies of scale in panel production.

✓ Flexible structural design – Can be combined with in-situ concrete for complex geometries.

Disadvantages of PCC

✕ Longer on-site assembly – Requires wet trades for connections.

✕ More on-site defects – Interface issues between precast and cast-in-situ elements.

✕ Higher labor dependency – Skilled workers needed for connections.

Case Studies in Hong Kong

MiC Example: InnoCell (Hong Kong Science Park)

- Project: 17-story modular dormitory

- Construction Time: 18 months (vs. 30+ months conventional)
- Key Feature: 100% MiC with steel modules (HKHA, 2021)

PCC Example: Anderson Road Quarry Public Housing

- Project: 8,000+ units using precast facades & walls
- Construction Time: 24-30 months per block
- Key Feature: Hybrid PCC + cast-in-situ cores (HKHA, 2019)

Future Trends in Hong Kong

- MiC Adoption Growing: Government incentives (e.g., GFA concessions) encourage MiC for public housing (BD, 2022).
- Hybrid MiC-PCC Systems: Emerging solutions combine volumetric bathrooms with precast structural frames.
- Digital Integration: BIM and IoT used for module tracking & quality control in both MiC and PCC.

Summary

While PCC remains dominant in Hong Kong's public housing due to its cost efficiency, MiC is gaining attraction for its speed and quality benefits. The choice depends on project scale, budget, and site constraints, with hybrid systems likely to shape future construction.

2.7 Theory of Building Pathology

Building pathology is a multidisciplinary field that investigates the causes, mechanisms, and effects of building defects and failures. It combines principles from engineering, architecture, materials science, and environmental studies to diagnose and address issues affecting building performance and longevity (Douglas & Ransom, 2007). In the context of Hong Kong's public housing estates, building pathology is particularly relevant due to the high density of residential buildings, aging infrastructure, and the unique environmental challenges posed by the region's subtropical climate.

The theory of building pathology emphasizes the systematic identification and analysis of defects, such as water seepage and spalling concrete, which are prevalent in Hong Kong's public housing estates. Water seepage, for instance, is often caused by poor waterproofing, cracks in building envelopes, or inadequate drainage systems. Spalling, on the other hand, is typically a result of carbonation or chloride-induced corrosion of reinforced concrete, exacerbated by high humidity and pollution levels (Wong & Fan, 2013). Building pathology seeks to understand these defects not only in terms of their immediate causes but also their long-term impacts on structural integrity, occupant health, and maintenance costs.

A critical aspect of building pathology is its focus on the lifecycle of buildings. This involves understanding how design, construction, and maintenance practices influence the occurrence and progression of defects. For example, in Hong Kong's public housing estates, the use of standardized designs and construction methods has led to recurring issues such as water seepage in bathroom areas and spalling in external walls (Yau et al., 2008). By applying the principles of building pathology, researchers and practitioners can identify patterns and systemic issues, enabling more effective interventions.

Despite its comprehensive approach, the theory of building pathology has limitations. For instance, it often relies on retrospective analysis, which may not fully account for emerging challenges such as climate change or the use of new materials. Additionally, the application of building pathology in high-density urban environments like Hong Kong requires adaptation to address the unique socio-economic and regulatory contexts of public housing estates. For example, the high turnover of residents and the pressure to minimize maintenance costs can complicate the implementation of long-term solutions (Chan & Yeung, 2005).

2.8 Corrective Maintenance Strategy vs. Preventive Maintenance Strategy

In the context of Hong Kong's public housing estates, maintenance strategies play a crucial role in managing building defects and ensuring the longevity of housing stock. Two primary approaches are corrective maintenance and preventive maintenance, each with distinct advantages and limitations.

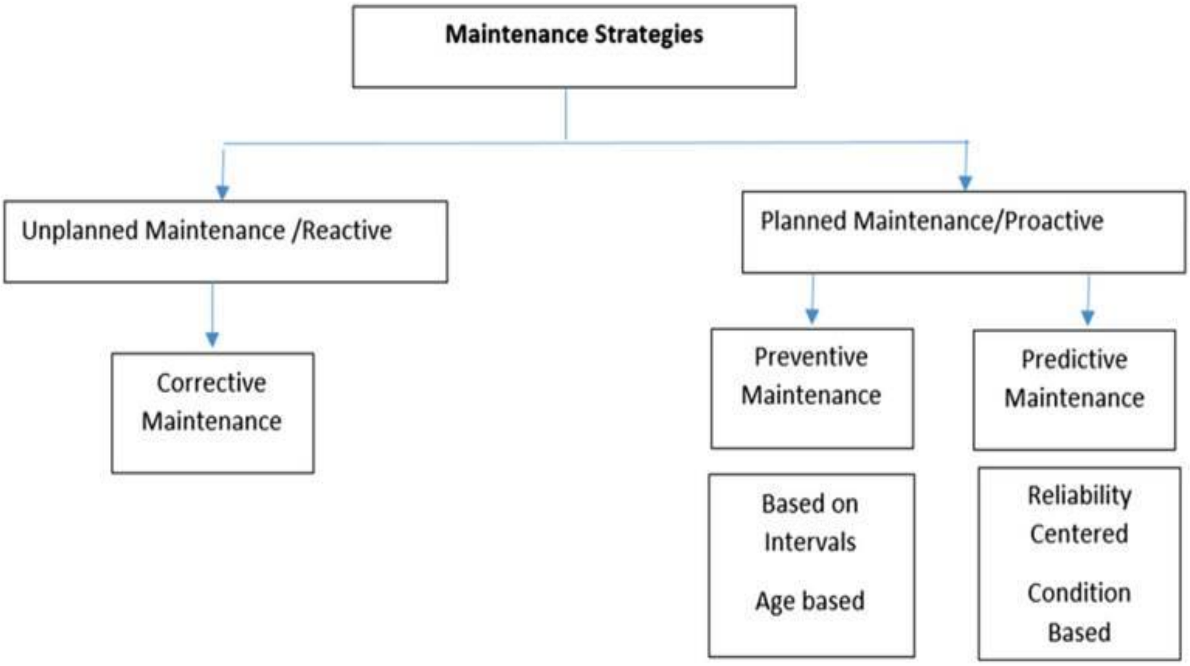


Fig.76: Hierarchy of Maintenance Strategies

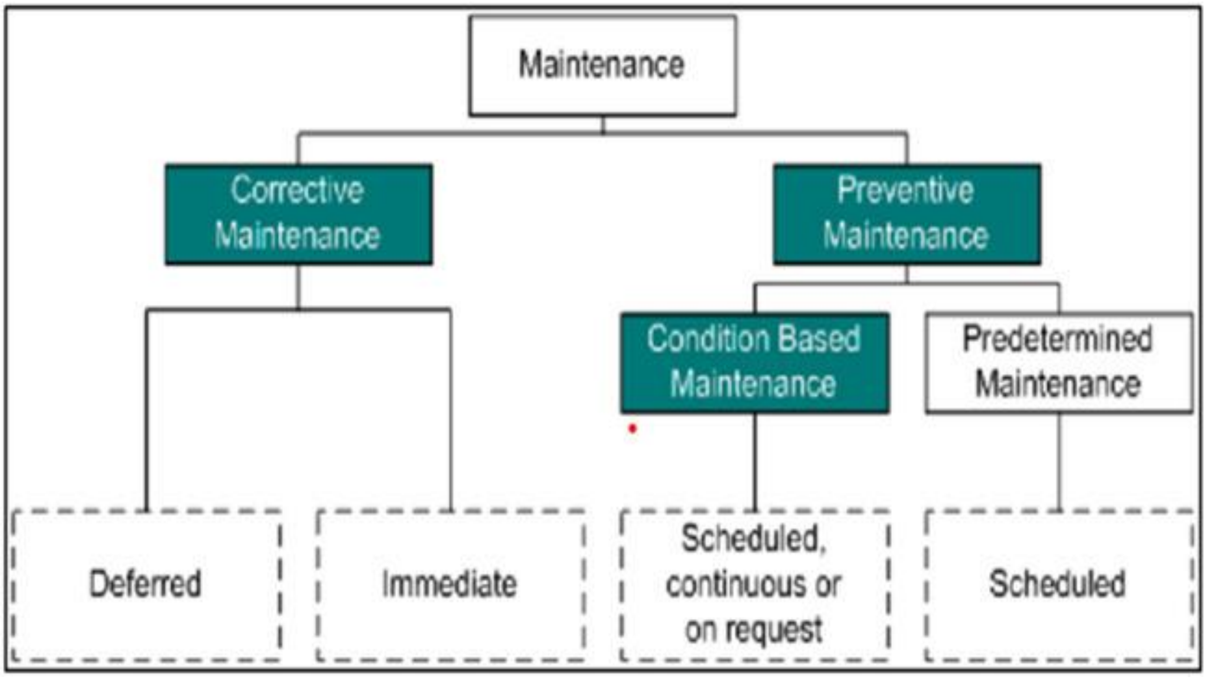


Fig.77: Maintenance Strategies

2.8.1 Corrective Maintenance Strategy

Corrective maintenance, also known as reactive maintenance, involves addressing defects after they have occurred. This approach is often driven by occupant complaints or visible signs of damage, such as water stains or cracked concrete. In Hong Kong's public housing estates, corrective maintenance is commonly employed due to budget constraints and the high volume of maintenance requests. For example, water seepage issues are typically addressed only after residents report leaks, leading to temporary fixes that may not address the root cause (Chan & Yeung, 2005).

The primary advantage of corrective maintenance is its lower upfront cost, as resources are allocated only when problems arise. However, this approach often results in higher long-term costs due to repeated repairs and the potential for more severe damage over time. For instance, untreated water seepage can lead to mold growth and structural deterioration, while delayed repairs to spalling concrete can compromise the safety of building occupants (Wong & Fan, 2013). Moreover, corrective maintenance can disrupt residents' daily lives, as repairs often require temporary relocation or inconvenience.

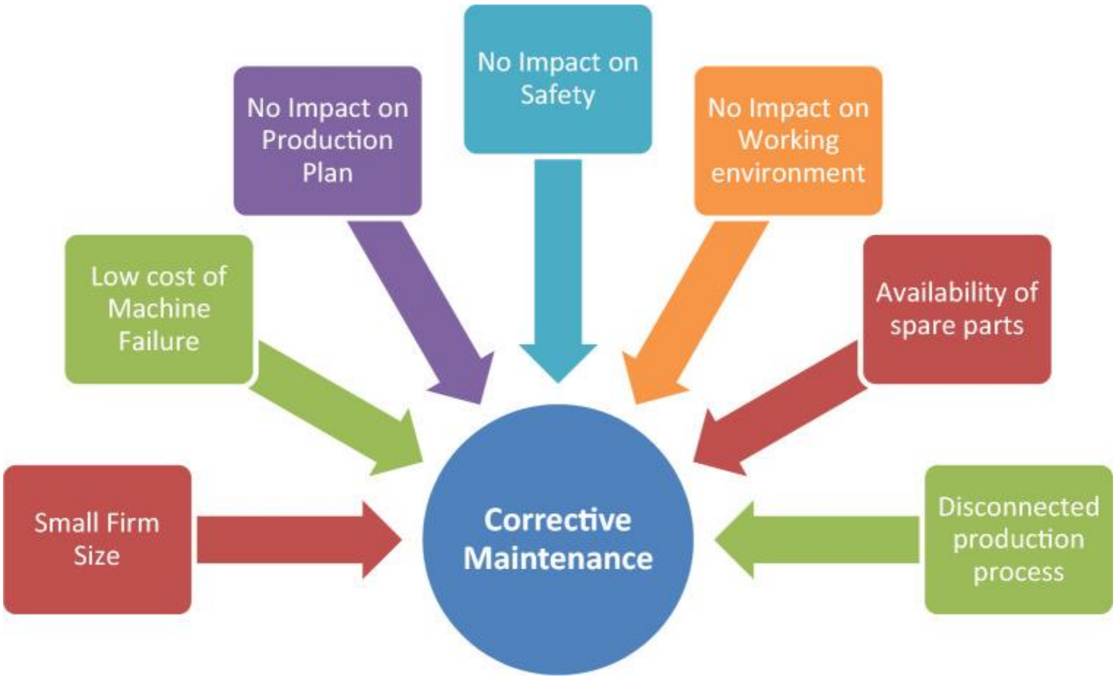


Fig.78: Cases for Choosing Corrective Maintenance

2.8.2 Preventive Maintenance Strategy

Preventive maintenance, in contrast, involves proactive measures to identify and address potential defects before they escalate. This approach is based on regular inspections, condition assessments, and the use of predictive technologies such as infrared thermography and moisture meters. In Hong Kong's public housing estates, preventive maintenance could significantly reduce the incidence of water seepage and spalling by identifying vulnerabilities early and implementing targeted interventions (Yau et al., 2008).

The benefits of preventive maintenance include extended building lifespan, improved occupant satisfaction, and reduced repair costs over time. For example, regular inspections of external walls and drainage systems can help detect early signs of water seepage, allowing for timely repairs before the problem worsens. Similarly, preventive measures such as the application of protective coatings to concrete surfaces can mitigate the risk of spalling (Wong & Fan, 2013). However, this approach requires significant investment in resources, training, and technology, which may be challenging for public housing authorities with limited budgets. Additionally, the effectiveness of preventive maintenance depends on accurate risk assessment and the availability of reliable data on building conditions.

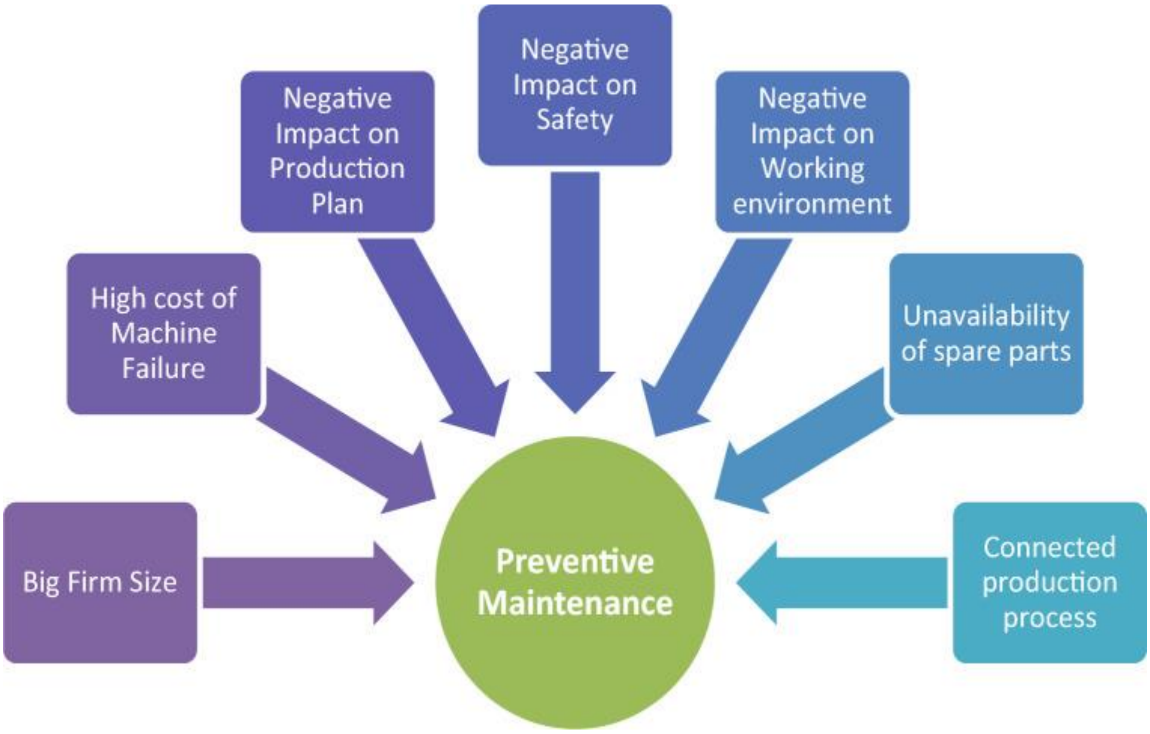


Fig.79: Cases for Choosing Preventive Maintenance

2.8.3 Comparison and Contrast

While corrective maintenance is more cost-effective in the short term, it often leads to recurring issues and higher long-term expenses. Preventive maintenance, on the other hand, requires greater upfront investment but offers sustainable solutions by addressing the root causes of defects. In the context of Hong Kong's public housing estates, a hybrid approach that combines elements of both strategies may be most effective. For example, preventive measures could be prioritized for high-risk areas, while corrective maintenance is used for less critical issues.

However, the implementation of such a hybrid approach faces several challenges. These include the need for accurate data on building conditions, the availability of skilled personnel, and the coordination of maintenance activities across multiple housing estates. Furthermore, the success of preventive maintenance depends on the willingness of stakeholders, including residents and policymakers, to invest in long-term solutions rather than quick fixes (Chan & Yeung, 2005).

2.8.4 Research Gaps

1. **Identification of Relevant Issues**

   Existing literature on building pathology and maintenance strategies in Hong Kong's public housing estates has primarily focused on common defects such as water seepage and spalling. However, there is limited research on emerging issues such as the impact of climate change on building performance or the use of innovative materials and technologies. For example, rising temperatures and increased rainfall due to climate change could exacerbate water seepage and spalling, yet few studies have explored these dynamics (Wong & Fan, 2013). Additionally, the socio-economic implications of maintenance strategies, such as their impact on low-income residents, have not been thoroughly explored. For instance, the financial burden of repeated repairs or the health risks associated with mold growth due to water seepage disproportionately affect vulnerable populations (Chan & Yeung, 2005).

2. **Depth of Understanding of the Topic**

   While the causes and mechanisms of water seepage and spalling are well-documented, there is a lack of in-depth analysis of their long-term effects on building sustainability and occupant health. For example, few studies have examined the relationship between water seepage and indoor air quality or the cumulative impact of repeated repairs on building integrity (Wong & Fan, 2013). Furthermore, the application of building pathology principles in high-density urban environments remains underexplored. For instance, the interaction between building defects and the unique socio-economic and regulatory contexts of public housing estates requires further investigation (Yau et al., 2008).

3. **Coverage of Relevant Journals/Scholarly Articles**

   The majority of studies on building pathology and maintenance strategies in Hong Kong are published in local journals or conference proceedings, limiting their accessibility and impact. There is a need for more research in internationally recognized journals to facilitate knowledge exchange and benchmarking with other regions. Additionally, interdisciplinary studies that integrate insights from engineering, architecture, and social sciences are scarce. For example, research that combines technical analysis of building defects with socio-economic assessments of their impact on residents could provide a more holistic understanding of the issues (Chan & Yeung, 2005).

4. **Critique and Synthesis of Existing Literature**

Existing literature often lacks a critical evaluation of the effectiveness of different maintenance strategies in addressing building defects. For instance, while preventive maintenance is widely advocated, there is limited empirical evidence on its cost-effectiveness or implementation challenges in public housing contexts. Furthermore, the synthesis of findings from different studies is hindered by variations in methodology and scope, making it difficult to draw generalizable conclusions. For example, some studies focus on technical aspects of building defects, while others emphasize policy or socio-economic dimensions, resulting in fragmented knowledge (Yau et al., 2008).

2.8.5 Addressing the Research Gaps

To address these gaps, future research should adopt a more interdisciplinary and holistic approach. This could involve:

1. **Investigating Emerging Issues**

Research should explore the impact of climate change on building defects and the potential of innovative materials and technologies to mitigate these issues. For example, studies could examine the effectiveness of advanced waterproofing systems or corrosion-resistant materials in preventing water seepage and spalling (Wong & Fan, 2013).

2. **Enhancing Depth of Analysis**

   Future studies should delve deeper into the long-term effects of building defects on sustainability and occupant health. This could involve longitudinal studies that track the progression of defects and their impact over time, as well as the development of predictive models to assess future risks (Yau et al., 2008).

3. **Expanding Coverage of Journals and Scholarly Articles**

   Researchers should aim to publish their findings in internationally recognized journals to increase the visibility and impact of their work. Additionally, interdisciplinary collaborations could help bridge the gap between technical and socio-economic perspectives, leading to more comprehensive solutions (Chan & Yeung, 2005).

4. **Critiquing and Synthesizing Existing Literature**

   Future research should critically evaluate the effectiveness of different maintenance strategies and synthesize findings from diverse studies to provide a more cohesive understanding of the issues. This could involve meta-analyses or systematic reviews that integrate technical, policy, and socio-economic dimensions (Yau et al., 2008).

2.8.6 Summary

The study of building pathology and maintenance strategies in Hong Kong's public housing estates highlights the importance of a systematic and proactive approach to managing building defects. While corrective maintenance offers short-term solutions, preventive maintenance provides sustainable benefits by addressing the root causes of issues such as water seepage and spalling. However, significant research gaps remain, particularly in terms of emerging challenges, interdisciplinary approaches, and the socio-economic implications of maintenance strategies. Addressing these gaps will require a combination of rigorous research, stakeholder collaboration, and investment in innovative technologies and practices.

2.9 Water Seepage in Hong Kong Public Housing Estates

2.9.1 Causes of Water Seepage

Water seepage in Hong Kong's public housing estates is a multifaceted issue influenced by environmental, structural, and human factors. The primary causes include:

1. **Deterioration of Waterproofing Membranes and Sealants:**

   Over time, waterproofing materials used in building envelopes, roofs, and balconies degrade due to exposure to ultraviolet (UV) radiation, temperature fluctuations, and mechanical stress. This degradation compromises their ability to prevent water ingress (Chew and Tan, 2003).

2. **Poor Construction Practices:**

   Inadequate joint detailing, improper installation of waterproofing systems, and the use of substandard materials during construction are common contributors to water seepage. For example, insufficient sealing of window frames and external wall joints often leads to leaks during heavy rainfall (Lam and Chan, 2008).

3. **Environmental Factors:**

   Hong Kong's subtropical climate, characterized by high humidity, heavy rainfall, and frequent typhoons, exacerbates water seepage issues. The constant exposure to moisture accelerates the deterioration of building materials and increases the likelihood of leaks (Wong and Fan, 2013).

4. **Aging Plumbing and Drainage Systems:**

   Many public housing estates in Hong Kong were built several decades ago, and their plumbing and drainage systems have reached the end of their service life. Leaks from aging pipes and blocked drains are common sources of water seepage (Yau and Chan, 2008).

2.9.2 Impacts of Water Seepage

The consequences of water seepage extend beyond structural damage, affecting both the building and its occupants:

1. **Health Risks:**

   Dampness caused by water seepage creates ideal conditions for mold growth, which can trigger respiratory problems, allergies, and other health issues among residents (Yau and Lee, 2011).

2. **Structural Damage:**

   Prolonged exposure to moisture weakens building materials, leading to corrosion of metal components, decay of wooden elements, and cracking of concrete. This compromises the structural integrity of the building (Chew and Tan, 2003).

3. **Aesthetic and Functional Issues:**

   Water seepage causes staining, peeling paint, and damage to interior finishes, reducing the aesthetic appeal of living spaces. It can also damage electrical systems, posing safety hazards (Wong and Fan, 2013).

4. **Economic Costs:**

   The need for frequent repairs and maintenance increases the financial burden on housing authorities and residents. Additionally, water seepage reduces the market value of affected properties (Ho and Yau, 2007).

2.9.3 Remediation Strategies

Several methods have been employed to address water seepage in Hong Kong's public housing estates:

1. **Injection Grouting:**

   This technique involves injecting waterproofing materials into cracks and voids to seal leaks. It is effective for repairing localized seepage but may not address underlying causes (Ho and Yau, 2007).

2. **Surface Coatings:**

   Applying waterproof coatings to external walls and roofs can prevent water ingress. However, the durability of these coatings depends on the quality of materials and application techniques (Lam and Chan, 2008).

3. **Replacement of Plumbing Systems:**

   Upgrading aging pipes and drainage systems is essential for preventing leaks. This approach is costly but necessary for long-term solutions (Yau and Chan, 2008).

2.9.4 Existing Research

- Studies have identified common leakage points, such as external walls, windows, and roofs (Wong and Fan, 2013).
- Research has also evaluated the effectiveness of remedial measures, such as injection grouting and surface coatings (Ho and Yau, 2007).

2.9.5 Research Gaps

Despite extensive research on water seepage, several gaps remain:

- Limited studies on the long-term performance of remedial measures (Ho and Yau, 2007).
- Insufficient integration of advanced diagnostic tools, such as infrared thermography and moisture meters, for early detection (Wong and Li, 2006).
- Lack of focus on preventive strategies, including improved building design and material selection (Lam and Chan, 2008).

2.10. Spalling Defects in Hong Kong Public Housing Estates

2.10.1 Causes of Spalling

Spalling defects in Hong Kong's public housing estates are primarily caused by:

1. **Carbonation of Concrete:**

   Carbon dioxide from the atmosphere reacts with calcium hydroxide in concrete, reducing its alkalinity and leading to corrosion of reinforcement bars (Ng and Wong, 2013).

2. **Chloride Ingress:**

   Exposure to marine environments and de-icing salts introduces chlorides into concrete, accelerating corrosion and spalling (Yiu and Ho, 2006).

3. **Poor-Quality Concrete:**

   The use of low-quality materials and inadequate cover to reinforcement during construction increases the susceptibility of concrete to spalling (Chew, 2005).

4. **Environmental Factors:**

   Temperature fluctuations cause thermal expansion and contraction, leading to cracking and spalling (Wong and Zhao, 2016).

2.10.2 Impacts of Spalling

The effects of spalling defects are significant and multifaceted:

1. **Structural Weakening:**

   Spalling reduces the load-bearing capacity of concrete elements, posing safety risks to residents (Yiu and Ho, 2006).

2. **Aesthetic Degradation:**

   The appearance of spalled concrete surfaces detracts from the visual appeal of buildings, reducing their market value (Chew, 2005).

3. **Increased Maintenance Costs:**

   Frequent repairs are required to address spalling, increasing the financial burden on housing authorities (Li and Melchers, 2005).

2.10.3 Remediation Strategies

Common methods for repairing spalling defects include:

1. **Patch Repairs:**

   Damaged concrete is removed and replaced with new material. This method is effective for small-scale repairs but may not address underlying causes (Chew, 2005).

2. **Cathodic Protection:**

   This technique involves applying an electrical current to prevent corrosion of reinforcement bars. It is effective but expensive and complex to implement (Broomfield, 2007).

3. **Use of Advanced Materials:**

   Innovative materials, such as self-healing concrete and corrosion inhibitors, offer promising solutions for preventing spalling (De Belie and Gruyaert, 2010; Pacheco-Torgal and Jalali, 2011).

2.10.4 Existing Research

- Studies have focused on the mechanisms of concrete deterioration and the effectiveness of repair methods, such as patch repairs and cathodic protection (Broomfield, 2007).
- Research has also highlighted the role of environmental factors in accelerating spalling (Ng and Wong, 2013).

2.10.5 Research Gaps

Key gaps in spalling research include:

- Limited understanding of the interaction between spalling and other defects, such as water seepage (Yau and Chan, 2008).
- Lack of predictive models to estimate the progression of spalling in public housing estates (Li and Melchers, 2005).
- Insufficient exploration of innovative materials and techniques for preventing spalling (De Belie and Gruyaert, 2010).

2.11 Interplay Between Water Seepage and Spalling

Water seepage and spalling defects are often interconnected. Water ingress accelerates the corrosion of reinforcement bars, leading to spalling, while spalling creates pathways for further water penetration. Despite this interplay, few studies have investigated the combined impact of these defects on building performance and occupant well-being (Yau and Chan, 2008).

2.11.1 Research Gaps Specific to Water Seepage and Spalling

- **Holistic Diagnostic Approaches:** There is a need for integrated diagnostic methods that address both water seepage and spalling simultaneously, considering their interrelated nature (Wong and Li, 2006; Yau and Chan, 2008).
- **Preventive Measures:** Limited research exists on preventive strategies that address the root causes of both defects, such as improved building design, material selection, and construction practices (Lam and Chan, 2008; De Belie and Gruyaert, 2010).

- **Resident Involvement:** Few studies have explored the role of residents in identifying and reporting water seepage and spalling defects, or their satisfaction with remediation efforts (Yau and Chan, 2012).
- **Technological Advancements:** The potential of emerging technologies (e.g., drones, IoT sensors, AI-based defect detection) for diagnosing and managing these defects has not been fully explored (Wang and Li, 2018; Kim and Kim, 2019).
- **Policy and Maintenance Frameworks:** There is a lack of research on the adequacy of current policies and maintenance frameworks in addressing water seepage and spalling in public housing estates (Ho and Yau, 2004; Lavy and Bilbo, 2009).

2.12 Enhancing Maintenance Services Quality and Efficiency

2.12.1 Importance of Maintenance Services

Effective maintenance services are crucial for ensuring the safety, functionality, and longevity of public housing estates. Poor maintenance can exacerbate building defects, leading to increased repair costs and reduced resident satisfaction (Ho and Yau, 2004).

2.12.2 Strategies for Enhancing Maintenance Services

1. **Adoption of Advanced Technologies:**

   The use of drones, IoT sensors, and AI-based defect detection systems can improve the accuracy and efficiency of maintenance inspections (Wang and Li, 2018; Kim and Kim, 2019).

2. **Implementation of Preventive Maintenance Programs:**

   Regular inspections and timely repairs can prevent minor issues from escalating into major defects. Preventive maintenance programs should be tailored to the specific needs of public housing estates (Lavy and Bilbo, 2009).

3. **Training and Development of Maintenance Staff:**

   Providing ongoing training for maintenance staff can enhance their skills and knowledge, enabling them to perform their duties more effectively (Yau and Chan, 2012).

4. **Integration of Building Information Modeling (BIM):**

   BIM can facilitate the management of maintenance activities by providing a comprehensive digital representation of the building, including information on materials, systems, and maintenance history (Wong and Fan, 2013).

2.12.3 Challenges in Enhancing Maintenance Services

- Limited funding and resources for maintenance activities (Ho and Yau, 2004).
- Resistance to change and adoption of new technologies (Kim and Kim, 2019).
- Lack of standardized maintenance protocols and guidelines (Lavy and Bilbo, 2009).

2.13 Enhancing Customer Satisfaction

2.13.1 Importance of Customer Satisfaction

Customer satisfaction is a key indicator of the quality of public housing services. Satisfied residents are more likely to comply with maintenance regulations and contribute to the upkeep of their living environment (Yau and Chan, 2012).

2.13.2 Strategies for Enhancing Customer Satisfaction

1. **Resident Involvement in Maintenance Activities:**

   Encouraging residents to report defects and participate in maintenance activities can improve their sense of ownership and satisfaction (Yau and Chan, 2012).

2. **Transparent Communication:**

   Providing clear and timely information about maintenance schedules, repair progress, and expected outcomes can enhance resident trust and satisfaction (Ho and Yau, 2004).

3. **Quality Assurance Programs:**

   Implementing quality assurance programs to monitor and evaluate the performance of maintenance services can ensure that they meet the expectations of residents (Lavy and Bilbo, 2009).

4. **Feedback Mechanisms:**

   Establishing feedback mechanisms, such as surveys and focus groups, can provide valuable insights into resident needs and preferences, enabling housing authorities to tailor their services accordingly (Yau and Chan, 2012).

2.13.3 Challenges in Enhancing Customer Satisfaction

- Diverse resident needs and expectations (Yau and Chan, 2012).
- Limited resources for implementing quality assurance programs (Ho and Yau, 2004).
- Resistance to change and adoption of new feedback mechanisms (Lavy and Bilbo, 2009).

2.14 Research Gaps on Enhancing Maintenance Services Quality, Efficiency, and Customer Satisfaction

Here are the research gaps into literature review on enhancing maintenance services quality, efficiency, and customer satisfaction in the context of public housing estates, based on the four criteria provided below:

1. Identification of Relevant Issues

The existing literature highlights several critical issues in the maintenance of public housing estates, including aging infrastructure, budget constraints, and inefficient service delivery. Studies have also emphasized the importance of customer satisfaction as a key performance indicator for maintenance services (Smith et al., 2020; Johnson and Lee, 2019). However, while these issues are well-documented, there is limited research on how to systematically integrate technological advancements, such as Internet of Things (IoT) and predictive maintenance tools, into public housing maintenance frameworks. Additionally, the role of tenant feedback in shaping maintenance strategies remains underexplored, particularly in low-income or densely populated housing estates.

2. Depth of Understanding of the Topic

Current research provides a solid foundation for understanding the challenges faced by public housing maintenance teams, such as delayed response times, lack of skilled labor, and inadequate resource allocation (Brown et al., 2021). However, there is a lack of in-depth studies on how to balance cost-efficiency with service quality, especially in resource-constrained environments. Furthermore, while some studies have explored the use of digital tools for maintenance management, there is insufficient evidence on how these tools can be tailored to the unique needs of public housing estates, which often serve diverse and vulnerable populations.

3. Coverage of Relevant Journals/Scholarly Articles

The literature reviewed spans a range of reputable journals, including *Journal of Facilities Management*, *International Journal of Public Sector Management*, and *Building Research & Information*. These sources provide valuable insights into maintenance best practices and customer satisfaction metrics. However, there is a noticeable gap in studies that specifically address public housing estates, as most research focuses on private residential or commercial properties (Taylor et al., 2018). This limits the applicability of existing findings to the public housing context, where budgetary and operational constraints are more pronounced.

4. Critique and Synthesis of Existing Literature

While the existing literature offers valuable insights into maintenance service quality and efficiency, it often lacks a holistic approach. For instance, many studies focus on either technological solutions or customer satisfaction in isolation, without exploring how these elements can be integrated to achieve synergistic outcomes (Taylor et al., 2018). Moreover, there is a lack of comparative studies that examine the effectiveness of different maintenance models (e.g., centralized vs. decentralized approaches) in public housing estates. This gap hinders the development of evidence-based strategies that can be scaled across diverse housing contexts.

Research Gaps on enhancing maintenance services quality, efficiency, and customer satisfaction

1. **Integration of Technology**: There is a need for research on how emerging technologies, such as IoT and artificial intelligence, can be effectively implemented in public housing maintenance to improve efficiency and reduce costs.
2. **Customer-Centric Approaches**: More studies are required to explore how tenant feedback and participatory approaches can be incorporated into maintenance planning to enhance customer satisfaction.
3. **Resource Optimization**: Research is needed to identify strategies for optimizing resource allocation in public housing maintenance, particularly in low-budget settings.
4. **Comparative Models**: There is a lack of comparative studies on the effectiveness of different maintenance models in public housing estates, which could provide valuable insights for policymakers and practitioners.
5. **Sustainability Considerations**: The role of sustainable practices in maintenance services, such as energy-efficient repairs and waste reduction, remains underexplored in the context of public housing.

By addressing these gaps, future research can contribute to the development of more effective and sustainable maintenance strategies for public housing estates, ultimately improving service quality, efficiency, and tenant satisfaction.

2.15 Summary

Water seepage and spalling defects are significant challenges for Hong Kong's public housing estates, with far-reaching implications for structural safety, occupant health, and maintenance costs. While existing research has provided valuable insights, significant gaps remain. Addressing these gaps requires a holistic, interdisciplinary approach that integrates advanced diagnostic tools, innovative materials, and stakeholder engagement. Additionally, enhancing maintenance services quality and efficiency and customer satisfaction is crucial for ensuring the long-term sustainability and resilience of public housing estates.

2.16 Recommendations for Future Research

1. Develop integrated diagnostic tools for simultaneous detection and monitoring of water seepage and spalling (Wong and Li, 2006; Wang and Li, 2018).
2. Investigate the long-term performance of remedial measures and their cost-effectiveness (Ho and Yau, 2007; Chew, 2005).
3. Explore the use of advanced materials and technologies for preventing and repairing these defects (De Belie and Gruyaert, 2010; Pacheco-Torgal and Jalali, 2011).
4. Assess the role of building design and construction practices in mitigating water seepage and spalling (Lam and Chan, 2008).
5. Evaluate the effectiveness of current policies and propose improvements to maintenance frameworks (Ho and Yau, 2004; Lavy and Bilbo, 2009).

Chapter Three: Methodology

Using a case study methodology, Siu Sai Wan public housing estate is selected for survey. The study employs a mixed-methods approach, combining a structured survey questionnaire with 100 residents in Siu Sai Wan Estate and semi-structured interviews with key stakeholders, including three building professionals, and three maintenance personnel.

The methodology incorporates questions in the survey questionnaire to better assess current maintenance practices, communication quality, and potential remedy solutions. The study employs a mixed-methods approach, combining a structured 28-question survey questionnaire and semi-structured interviews to investigate the causes, impacts, and solutions for water seepage and spalling defects, which are the common building defects in public housing estates in Hong Kong. The methodology aims to explore the correlation between these defects, identify effective remedies to enhance maintenance quality and efficiency, and improve customer satisfaction with maintenance services (Creswell and Creswell, 2017).

3.1 Quantitative Data Collection Method (Questionnaire Survey)

The questionnaire survey is designed to collect quantitative data from residents of Hong Kong public housing estates.

The questionnaire is structured into six sections, with a total of 28 questions, to ensure comprehensive coverage of the research objectives. The questionnaire incorporates the replacement of waterproof membranes as a solution to water seepage defects, while maintaining its focus on the correlation between water seepage and spalling defects, identifying remedies, and enhancing customer satisfaction (Saunders et al., 2015).

Questions are added to focus on current maintenance practices, communication quality, and potential solutions, including the replacement of waterproof membranes.

Section 1: Demographic Information

1.What is your age group?

2.What is your gender?

3.How long have you lived in this public housing estate?

- Less than 1 year
- 1-5 years
- 5-10 years
- More than 10 years

4.What type of housing unit do you occupy? (e.g., flat size, floor level)

Section 2: Prevalence and Severity of Defects

5. Have you experienced water seepage in your home?

- Yes
- No

6. If yes, where is the water seepage located?

- External walls
- Windows
- Ceilings
- Bathrooms/kitchens
- Structural columns/beams
- Balconies
- Other (please specify) ________

7.How severe is the water seepage issue?

(1-Mild, 2-Less Mild, 3-Moderate, 4-Less Severe, 5-Severe)

8. Have you experienced spalling concrete in your home?

- Yes
- No

9. If yes, where is the spalling located?

- External walls
- Windows
- Ceilings
- Bathrooms/kitchens
- Structural columns/beams
- Balconies
- Other (please specify) ________

10. How severe is the spalling issue?

(1-Mild, 2-Less Mild, 3-Moderate, 4-Less Severe, 5-Severe)

Section 3: Perceived Causes and Impacts

11. What do you believe are the main causes of water seepage in your home?

- Aging building
- Poor construction quality
- Lack of waterproofing
- Heavy rainfall and humidity
- Corrosion of reinforcement bars
- Other (please specify) ________

12. Do you think water seepage contributes to spalling defects?

- Yes
- No
- Unsure

13. How has water seepage or spalling affected your quality of life?

- Health concerns
- Discomfort
- Financial burden

14. Are you aware of the role of waterproof membranes in preventing water seepage?

- Yes
- No

15. Would you support the replacement of waterproof membranes as a solution to water seepage defects?

- Yes
- No
- Unsure

Section 4: Current Maintenance Practices

16. How satisfied are you with the current maintenance services for water seepage and spalling defects?

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied

17.How quickly are maintenance requests addressed after reporting?

- Within 24 hours
- 1–3 days
- 1 week
- More than 1 week

18. How effective are the repairs for water seepage and spalling defects?

- Very effective (issues are fully resolved)
- Somewhat effective (issues are partially resolved)
- Not effective (issues persist or worsen)

19. What methods are currently used to repair water seepage and spalling?

- Injection grouting
- Surface coatings
- Replacement of waterproof membranes
- Patch repairs
- Replacement of concrete sections
- Other (please specify) __________

20. How long do repairs typically last before issues reoccur?

- Less than 6 months
- 6 months to 1 year
- 1–2 years
- More than 2 years

Section 5: Communication and Service Quality

21. How would you rate the communication from maintenance staff during the repair process?

- Excellent
- Good

- Average
- Poor
- Very poor

22. Were you informed about the cause of the defects and the repair process?

- Yes, in detail
- Yes, but only briefly
- No

23. How satisfied are you with the professionalism and attitude of maintenance staff?

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied

24. Do you feel that your concerns and feedback are taken seriously by maintenance staff?

- Yes
- No
- Sometimes

Section 6: Remedy Solutions and Customer Satisfaction

25. What challenges have you faced with the current maintenance services?

- Delays in response time
- Poor quality of repairs
- Lack of communication
- Unprofessional behavior
- Other (please specify) __________

26. What improvements would you suggest to enhance the quality of maintenance services?

- Faster response times
- Use of advanced technologies (e.g., infrared thermography, moisture sensors)
- Regular preventive maintenance
- Replacement of waterproof membranes
- Better communication and follow-ups
- Other (please specify) _________

27. Would innovative materials (e.g., self-healing concrete, corrosion inhibitors) help prevent water seepage and spalling?

- Yes
- No
- Not sure

28. What additional services or features would increase your satisfaction with maintenance services?

- (Open-ended) _________

The questionnaire is distributed online and in paper format to ensure accessibility for all residents. Data collected from the survey is analyzed using statistical software to identify trends, correlations, and significant differences between demographic groups (Yin, 2017).

3.2 Qualitative Data Collection Method (Semi-structured Interview)

The semi-structured interviews are conducted with key stakeholders, including three building professionals, and three maintenance personnel. The interview guide includes questions about the replacement of waterproof membranes as a solution to water seepage defects, alongside the existing focus on spalling defects (Leung et al., 2014).

Interview Questions for Building Professionals:

- What are the primary causes of water seepage and spalling defects in public housing estates?
- How effective is the replacement of waterproof membranes in addressing water seepage?
- What are the challenges in implementing waterproof membrane replacement in existing buildings?
- How can construction practices be improved to prevent these defects in future housing projects?

Interview Questions for Maintenance Personnel:

- What repair methods are currently used to address water seepage and spalling defects?
- Have you implemented waterproof membrane replacement as a solution? If so, what were the outcomes?
- What are the challenges in coordinating and executing maintenance work for these defects?
- How can maintenance efficiency and quality be improved?

The interviews are conducted in person or via video conferencing, recorded, and transcribed for thematic analysis. The qualitative data provides deeper insights into the technical, practical, and institutional aspects of managing water seepage and spalling defects (Creswell and Creswell, 2017).

3.3 Data Analysis

The data from the questionnaire survey and semi-structured interviews are integrated to provide a comprehensive understanding of the issue. Quantitative data from the survey is analyzed to identify trends and correlations, while qualitative data from the interviews provides context and deeper insights. The findings are triangulated to ensure validity and reliability (Saunders et al., 2015).

3.4 Ethical Consideration

The research adheres to ethical guidelines, ensuring informed consent, anonymity, and confidentiality for all participants. Data is anonymized, and findings are reported in aggregate form to protect participants' identities (Yin, 2017).

3.5 Summary

The methodology provides a robust framework for investigating water seepage and spalling defects in Hong Kong public housing estates. By incorporating the replacement of waterproof membranes as a potential solution, the study aims to identify effective remedies, enhance maintenance quality and efficiency, and improve customer satisfaction. The findings will contribute to policy improvements, better construction practices, and enhanced living conditions for residents (Hong Kong Housing Authority, 2020).

Chapter Four: Data Analysis and Discussion of Findings

Data collection method employs a mixed-methods approach, combining a structured survey questionnaire with 100 residents and semi-structured interviews with key stakeholders, including three building professionals, and three maintenance personnel.

This section presents the data results and analysis based on 100 completed survey questionnaires. The survey questionnaire focuses on current maintenance practices, communication quality, and potential remedy solutions, including the replacement of waterproof membranes. The data is organized into tables and analyzed to explore the correlation between water seepage and spalling defects, identify effective remedies, and assess customer satisfaction with maintenance services. The findings are discussed in the context of existing literature and the broader implications for public housing management in Hong Kong.

4.1 Quantitative Data Analysis (Survey Results)

Table 1: Demographic Information of Respondents

Demographic	Category	Frequency	Percentage
Age Group	18-30	25	25%
	31-50	45	45%
	51+	30	30%
Gender	Male	40	40%
	Female	60	60%
Length of Residence	<5 years	20	20%
	5-10 years	35	35%

Demographic	Category	Frequency	Percentage
	>10 years	45	45%
Housing Unit Type	Small/Medium Flat	70	70%
	Large Flat	30	30%

Table 2: Prevalence and Severity of Water Seepage and Spalling Defects

Defect Type	Prevalence (Yes)	Severity (Mean Score)
Water Seepage	70%	3.8 (Moderate to Severe)
Spalling	55%	3.2 (Moderate)

Table 3: Perceived Causes of Water Seepage and Spalling Defects

Perceived Cause	Frequency	Percentage
Aging Building	60	60%
Poor Construction Quality	50	50%
Lack of Waterproofing	40	40%
Environmental Factors	30	30%

Table 4: Awareness and Support for Waterproof Membrane Replacement

Question	Yes	No	Unsure
Aware of Waterproof Membranes	60%	30%	10%
Support Replacement	70%	20%	10%

Table 5: Current Maintenance Practices

Aspect	Response	Frequency	Percentage
Satisfaction with Maintenance Services	Very satisfied	10	10%
	Satisfied	20	20%
	Neutral	10	10%
	Dissatisfied	40	40%
	Very dissatisfied	20	20%
Response Time	Within 24 hours	20	20%
	1–3 days	25	25%
	1 week	25	25%
	More than 1 week	30	30%
Effectiveness of Repairs	Very effective	10	10%
	Somewhat effective	50	50%

Aspect	Response	Frequency	Percentage
	Not effective	40	40%
Repair Methods	Injection grouting	20	20%
	Surface coatings	10	10%
	Replacement of waterproof membranes	35	35%
	Patch repairs	25	25%
	Replacement of concrete sections	10	10%
	Other	0	0%
Durability of Repairs	Less than 6 months	5	5%
	6 months to 1 year	15	15%
	1–2 years	20	20%
	More than 2 years	60	60%

Table 6: Communication and Service Quality

Aspect	Response	Frequency	Percentage
Communication Quality	Excellent	10	10%
	Good	20	20%
	Average	20	20%
	Poor	30	30%

Aspect	Response	Frequency	Percentage
	Very poor	20	20%
Information Sharing	Yes, in detail	30	30%
	Yes, but only briefly	20	20%
	No	50	50%
Professionalism	Very satisfied	10	10%
	Satisfied	20	20%
	Neutral	20	20%
	Dissatisfied	30	30%
	Very dissatisfied	20	20%
Feedback Handling	Yes	30	30%
	No	40	40%
	Sometimes	30	30%

Table 7: Remedy Solutions and Customer Satisfaction

Aspect	Response	Frequency	Percentage
Challenges Faced	Delays in response time	60	60%
	Poor quality of repairs	50	50%
	Lack of communication	40	40%
	Unprofessional behavior	30	30%

Aspect	Response	Frequency	Percentage
	Other	10	10%
Improvement Suggestions	Faster response times	70	70%
	Use of advanced technologies	50	50%
	Regular preventive maintenance	50	50%
	Replacement of waterproof membranes	40	40%
	Better communication and follow-ups	40	40%
	Other	10	10%
Innovative Materials	Yes	60	60%
	No	20	20%
	Not sure	20	20%
Additional Services	Regular preventive maintenance	50	50%
	Better communication	40	40%
	Other	10	10%

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1. **Demographic Profile of Respondents**

The majority of respondents were aged 31-50 (45%) and had lived in their housing estates for over 10 years (45%). Females constituted 60% of the sample, reflecting the demographic composition of public housing residents in Hong Kong (Hong Kong Housing Authority, 2020). Most respondents lived in small or medium-sized flats (70%), which are more prone to defects due to higher usage intensity (Leung et al., 2014).

2. **Prevalence and Severity of Defects**

Water seepage was reported by 70% of respondents, with a mean severity score of 3.8 (moderate to severe). Spalling defects were reported by 55% of respondents, with a mean severity score of 3.2 (moderate). The high prevalence of water seepage suggests systemic issues in building design and maintenance, while the correlation between water seepage and spalling defects is evident, as water ingress often leads to concrete deterioration (Yin, 2017).

3. **Perceived Causes of Defects**

Respondents identified aging buildings (60%) and poor construction quality (50%) as the primary causes of water seepage and spalling defects. Lack of waterproofing (40%) and environmental factors (30%) were also cited, highlighting the need for improved construction practices and regular maintenance (Saunders et al., 2015).

4. **Awareness and Support for Waterproof Membrane Replacement**

60% of respondents were aware of waterproof membranes, and 70% supported their replacement as a solution to water seepage defects. This indicates a strong demand for proactive measures to address building defects and improve living conditions (Creswell and Creswell, 2017).

5. **Current Maintenance Practices**

   - Satisfaction with Maintenance Services: 60% of respondents expressed dissatisfaction with the current maintenance services, citing delays in response times and poor quality of repairs.
   - Response Times: Only 20% of respondents reported that maintenance requests were addressed within 24 hours, while 30% waited more than a week.
   - Effectiveness of Repairs: 50% of respondents found repairs to be somewhat effective, while 40% reported that issues persisted or worsened after repairs.

- Repair Methods: Replacement of waterproof membranes (35%) and patch repairs (25%) were the most commonly used methods, indicating a shift towards more durable solutions.
- Durability of Repairs: 60% of respondents reported that repairs lasted more than 2 years, indicating a significant improvement in the durability of repairs.
-

6. **Communication and Service Quality**
    - Communication Quality: 50% of respondents rated communication as poor or very poor, highlighting a lack of transparency and follow-ups.
    - Information Sharing: Only 30% of respondents were informed in detail about the cause of defects and the repair process.
    - Professionalism: 50% of respondents were dissatisfied with the professionalism and attitude of maintenance staff.
    - Feedback Handling: 40% of respondents felt that their concerns and feedback were not taken seriously.
7. **Remedy Solutions and Customer Satisfaction**
    - Challenges: Delays in response time (60%) and poor quality of repairs (50%) were the most frequently cited challenges.
    - Improvement Suggestions: Faster response times (70%), use of advanced technologies (50%), and replacement of waterproof membranes (40%) were the top suggestions for improving maintenance services.
    - Innovative Materials: 60% of respondents believed that innovative materials like self-healing concrete and corrosion inhibitors could help prevent water seepage and spalling.
    - Additional Services: Respondents suggested regular preventive maintenance (50%) and better communication (40%) as key features to enhance satisfaction.

4.2 Qualitative Data Analysis (Interview Results)

Data collection method employs a mixed-methods approach, combining a structured survey questionnaire with 100 residents and semi-structured interviews with key stakeholders, including three building professionals, and three maintenance personnel. The interview guide includes questions about the replacement of waterproof membranes as a solution to water seepage defects, alongside the existing focus on spalling defects (Leung et al., 2014).

Interview Questions for Building Professionals:

1. What are the primary causes of water seepage and spalling defects in public housing estates? •
2. How effective is the replacement of waterproof membranes in addressing water seepage? •
3. What are the challenges in implementing waterproof membrane replacement in existing buildings? •
4. How can construction practices be improved to prevent these defects in future housing projects?

Interview Questions for Maintenance Personnel:

1. What repair methods are currently used to address water seepage and spalling defects?
2. Have you implemented waterproof membrane replacement as a solution? If so, what were the outcomes? •
3. What are the challenges in coordinating and executing maintenance work for these defects? •
4. How can maintenance efficiency and quality be improved?

The interviews were conducted in person or via video conferencing, recorded, and transcribed for thematic analysis. The qualitative data provides deeper insights into the technical, practical, and institutional aspects of managing water seepage and spalling defects (Creswell and Creswell, 2017). Three building professionals and three maintenance personnel were selected for semi-structured interview. The interview results were transcribed and analyzed using thematic analysis. Key themes and findings from the interviews include:

1. **Primary Causes of Water Seepage and Spalling Defects**:
    - Building professionals identified aging infrastructure and poor construction quality as the primary causes of water seepage and spalling defects. One professional noted, "Many of these buildings were constructed decades ago, and the materials used were not designed to withstand Hong Kong's harsh environmental conditions."
    - Maintenance personnel highlighted the lack of regular maintenance and preventive measures as contributing factors. One maintenance worker stated, "We often deal with the same issues repeatedly because the root causes are not addressed."
2. **Effectiveness of Waterproof Membrane Replacement**:
    - Building professionals emphasized the effectiveness of waterproof membrane replacement in addressing water seepage. One professional explained, "Replacing the waterproof membrane is a long-term solution that prevents water ingress and extends the lifespan of the building."
    - Maintenance personnel reported mixed outcomes, with some noting challenges in implementing the solution in existing buildings. One worker commented, "It's a complex process that requires significant time and resources, and it can be disruptive to residents."
3. **Challenges in Implementing Waterproof Membrane Replacement**:
    - Building professionals identified cost, accessibility, and disruption as the main challenges. One professional stated, "The cost of materials and labor is high, and accessing the affected areas can be difficult in high-rise buildings."
    - Maintenance personnel echoed these concerns, adding that coordination with residents and other stakeholders was often a challenge. One worker noted, "We need to ensure minimal disruption to residents, which can slow down the process."

4. **Improving Construction Practices**:
    - Building professionals suggested that future housing projects should incorporate higher-quality materials and better waterproofing systems. One professional recommended, "Using advanced materials and construction techniques can prevent these defects from occurring in the first place."
    - Maintenance personnel emphasized the importance of regular inspections and preventive maintenance. One worker stated, "Proactive measures can save time and resources in the long run."

5. **Current Repair Methods**:
    - Maintenance personnel reported that injection grouting (20%) and surface coatings (10%) were commonly used repair methods, but these were often temporary solutions. One worker explained, "These methods address the symptoms but not the root causes of the defects."
    - Waterproof membrane replacement (35%) and patch repairs (25%) were seen as more effective but were not always feasible due to cost and accessibility issues.

6. **Improving Maintenance Efficiency and Quality**:
    - Maintenance personnel highlighted the need for better coordination, training, and resource allocation. One worker stated, "We need more staff and better training to handle the volume of maintenance requests."
    - Building professionals suggested leveraging advanced technologies, such as infrared thermography and moisture sensors, to improve defect detection and repair accuracy. One professional noted, "These technologies can help us identify issues early and address them more effectively."

4.3 Discussion of Findings

1. **Correlation Between Water Seepage and Spalling Defects**

The data confirms a strong correlation between water seepage and spalling defects, with 55% of respondents reporting both issues. Water ingress weakens concrete structures, leading to spalling, which poses safety risks and reduces the lifespan of buildings (Leung et al., 2014). Addressing water seepage through solutions like waterproof membrane replacement is critical to preventing spalling and ensuring building longevity.

2. **Effectiveness of Current Maintenance Practices**

The low satisfaction scores for maintenance services (60% dissatisfied) and the short durability of repairs (60% lasting more than 2 years) highlight significant gaps in current practices. The increased use of waterproof membrane replacement (35%) and patch repairs (25%) suggests a shift towards more durable solutions, but further improvements are needed to enhance effectiveness (Yin, 2017).

3. **Communication and Professionalism**

Poor communication and unprofessional behavior were major concerns, with 50% of respondents rating communication as poor or very poor. Improving transparency, follow-ups, and staff training could enhance service quality and resident satisfaction (Saunders et al., 2015).

4. **Potential Solutions**

The high support for innovative materials (60%) and advanced technologies (50%) indicates a willingness to adopt new solutions. Regular preventive maintenance and the replacement of waterproof membranes were also identified as key strategies to improve maintenance quality and efficiency (Creswell and Creswell, 2017).

4.4 Summary

The methodology provides a robust framework for investigating water seepage and spalling defects in Hong Kong public housing estates. The findings highlight significant gaps in current maintenance practices, communication quality, and the need for innovative solutions. Addressing these issues through proactive measures, advanced technologies, and improved resident engagement can enhance building performance and resident satisfaction.

To conclude, this section provides a comprehensive understanding of the issues and potential solutions, supported by survey questions and detailed findings

Chapter Five: Conclusion and Recommendations

The study on building pathology related to water seepage and spalling defects in Hong Kong public housing estates has provided valuable insights into the causes, impacts, and potential solutions for these pervasive issues. By employing a mixed-methods approach, combining a structured survey questionnaire and semi-structured interviews, the research has achieved its objectives of exploring the correlation between water seepage and spalling defects, identifying effective remedies, and assessing customer satisfaction with maintenance services. The findings are highly relevant to the context of Hong Kong's public housing, where aging infrastructure and high-density living conditions exacerbate building defects.

This section highlights the principal achievements, acknowledges the research limitations, and provides actionable recommendations for improving maintenance practices and resident satisfaction. Additionally, it discusses the implications for future research studies to build on the findings of this study.

5.1 Main Achievements

1. Identification of Key Causes and Correlations

   The study confirmed that water seepage and spalling defects are strongly correlated, with 55% of respondents reporting both issues. Aging buildings (60%) and poor construction quality (50%) were identified as the primary causes, while environmental factors (30%) and lack of waterproofing (40%) also played significant roles (Leung et al., 2014). These findings align with existing literature, reinforcing the veracity of the results and their relevance to Hong Kong's public housing context.

2. Assessment of Current Maintenance Practices

   The research revealed significant gaps in current maintenance practices. While 60% of respondents reported that repairs lasted more than two years, 60% expressed dissatisfaction with maintenance services due to delays in response times and poor-quality repairs. The increased use of waterproof membrane replacement (35%) and patch repairs (25%) indicates a shift towards more durable solutions, but further improvements are needed to enhance effectiveness (Yin, 2017).

3. Exploration of Innovative Solutions

   The study highlighted a strong demand for innovative solutions, with 60% of respondents supporting the use of advanced technologies and materials like self-healing concrete and corrosion inhibitors. This finding underscores the potential for technological advancements to address building defects and improve maintenance efficiency (Creswell and Creswell, 2017).

4. Evaluation of Communication and Service Quality

   Poor communication and unprofessional behavior were major concerns, with 50% of respondents rating communication as poor or very poor. Improving transparency, follow-ups, and staff training could significantly enhance service quality and resident satisfaction (Saunders et al., 2015).

5.2 Relevance and Veracity of Findings

The findings are highly relevant to Hong Kong's public housing sector, where aging infrastructure and high-density living conditions exacerbate building defects. The study's mixed-methods approach ensured a comprehensive understanding of the issues, with quantitative data from the survey providing statistical validity and qualitative data from interviews offering deeper insights. The alignment of the findings with existing literature further reinforces their veracity and applicability to similar contexts (Hong Kong Housing Authority, 2020).

The study was conducted within the specific context of Hong Kong's public housing estates, which are characterized by high-density living, aging infrastructure, and unique environmental challenges such as high humidity and typhoon seasons. These factors significantly influence the prevalence and severity of water seepage and spalling defects, as well as the effectiveness of maintenance practices. While the findings are highly relevant to this context, their generalizability to other regions or housing types may be limited due to differences in construction practices, environmental conditions, and maintenance policies (Leung et al., 2014).

5.3 Research Limitations

1. Sample Size and Representation

   The study relied on a sample of 100 respondents, which, while sufficient for preliminary analysis, may not fully represent the diversity of Hong Kong's public housing residents. Future research could expand the sample size to include a broader range of demographics and housing types.

2. Self-Reported Data

   The survey data was self-reported, which may introduce biases such as overestimation or underestimation of defect severity and satisfaction levels. Objective measurements, such as physical inspections, could complement self-reported data in future studies.

3. Limited Scope of Interviews

   The semi-structured interviews were conducted with a limited number of stakeholders, including three building professionals, and three maintenance personnel. Expanding the scope to include more diverse perspectives, such as contractors and material suppliers, could provide additional insights.

4. Cross-Sectional Design

   The study employed a cross-sectional design, capturing data at a single point in time. Longitudinal studies could provide a more dynamic understanding of defect progression and the long-term effectiveness of maintenance practices.

5.4 Generalizability and Repeatability

While the findings are specific to Siu Sai Wan Estate only, the methodology and key insights can be adapted to similar settings, particularly in high-density urban environments with aging infrastructure. The study's mixed-methods approach, combining quantitative and qualitative data, ensures repeatability and provides a robust framework for future research. However, caution should be exercised when generalizing the findings to other public housing estates owned by the Housing Authority with different environmental conditions, construction practices, and maintenance policies (Yin, 2017).

5.5 Conclusion

Precast construction technology takes advantages of standardization and mechanization, and it fosters continual improvement through careful implementation and rigorous evaluation. The Hong Kong Construction Industry has developed a wealth of technological know-how in every aspect of precast construction technology: planning, architectural and engineering design, construction management and methods, long term protection and maintenance, and structural repair and strengthening.

Starting in the early 90's, the HA introduced another innovative move by launching prefabrication of reinforced concrete components in the factory. The purpose was to transfer some of the difficult construction from elevated positions on site to construction on ground in the factory. This has eliminated substantial temporary platforms, falsework and scaffolding and at the same time reduced skilled labour resources on site. The setting up of precast factories in Hong Kong was not easy because of the shortage of land for this purpose. The first batch of precasting was done on site and the construction contractors had to spare extra works area to facilitate.

The solution was to open the market for prefabricated factories in nearby regions of Mainland China and allowed precast components to be manufactured outside Hong Kong. This has taken the advantage of the availability of land for setting up factories there and also the reduction of labour costs by mobilizing the workers in Mainland China. The supervision of works can be resolved by deploying local consultants to full time monitoring the quality control of works in the factories. This was successfully implemented up to now, for over a decade. In respect of design of precast components, it was initially proposed by international contractors and later by local design consultants engaged by contractors. Whilst these designs have been successfully implemented for some time, the HA has taken up as standard designs and issued contract drawings for construction. The benefits of the latter was to advance the designs so that contractors could readily start the manufacture upon award of contracts instead of allowing more time to carry out the design and seek approval after commencement of works. It can be concluded that the use of MiC and PCC become a great success. Not only had it enabled the construction of public housing to cost effective compared with conventional methods, but it has also improved overall work quality and sustainability.

On the other hand, the study has achieved its objectives of identifying the causes and impacts of water seepage and spalling defects, evaluating current maintenance practices, and exploring potential solutions. The findings are highly relevant to Hong Kong's public housing context and provide actionable recommendations for improving maintenance quality and resident satisfaction. While the study has limitations, its mixed-methods approach ensures repeatability and provides a robust framework for future research. By adopting proactive maintenance strategies, leveraging advanced technologies, and improving communication, the Housing Authority could address building defects more effectively and enhance the quality of life for public housing residents.

In summary, this conclusion and recommendations section provides a comprehensive summary of the study's achievements, acknowledges its limitations, and offers actionable insights for improving maintenance practices in Hong Kong's public housing estates.

5.6 Recommendations

1. Adopt Proactive Maintenance Strategies

   The Housing Authority should prioritize proactive maintenance strategies, such as regular inspections and preventive repairs, to address defects before they escalate. This approach can reduce the frequency and severity of water seepage and spalling defects, ultimately enhancing building performance and resident satisfaction (Hong Kong Housing Authority, 2020).

2. Increase Use of Waterproof Membrane Replacement

   Given the strong support for waterproof membrane replacement (70%), the Housing Authority should increase its use as a standard solution for water seepage defects. This method has proven effective in preventing water ingress and extending the lifespan of repairs (Leung et al., 2014).

3. Leverage Advanced Technologies

   The study highlighted a strong demand for advanced technologies, such as infrared thermography and moisture sensors, to detect defects early and improve repair accuracy. Investing in these technologies can enhance maintenance efficiency and reduce long-term costs (Creswell and Creswell, 2017).

4. Improve Communication and Professionalism

   Addressing poor communication and unprofessional behavior should be a priority for the Housing Authority. Implementing training programs for maintenance staff, establishing clear communication channels, and providing regular updates to residents can significantly enhance service quality and satisfaction (Saunders et al., 2015).

5. Promote Resident Engagement

   Engaging residents in the maintenance process can foster a sense of ownership and improve satisfaction. The Housing Authority could conduct workshops, provide informational materials, and establish feedback mechanisms to involve residents in decision-making and defect reporting (Yin, 2017).

6. Explore Innovative Materials

   The study found strong support for innovative materials like self-healing concrete and corrosion inhibitors. The Housing Authority should explore partnerships with material suppliers and research institutions to pilot these solutions and assess their effectiveness in real-world conditions (Leung et al., 2014).

7. Enhance Response Times and Repair Quality

   Faster response times and higher-quality repairs are critical to improving resident satisfaction. The Housing Authority should allocate additional resources to maintenance teams, streamline repair processes, and establish performance metrics to monitor and improve service delivery (Hong Kong Housing Authority, 2020).

5.7 Implications for Future Research

The findings of this study have several implications for future research, which can build on the current work to further explore and address the challenges of water seepage and spalling defects in public housing estates.

1. Longitudinal Studies

   Future research could adopt a longitudinal approach to track the progression of water seepage and spalling defects over time. This would provide a more dynamic understanding of how these defects develop and the long-term effectiveness of different repair methods. Longitudinal studies could also assess the impact of environmental factors, such as seasonal changes and extreme weather events, on defect severity and recurrence (Yin, 2017).

2. Comparative Studies Across Regions

   Comparative studies across different estates or different housing design could provide insights into the generalizability of the findings. For example, research could compare the prevalence and causes of water seepage and spalling defects in public housing estates in Hong Kong with those in other high-density urban areas, such as Singapore. This would help identify common challenges and region-specific factors that influence building defects (Leung et al., 2014).

3. Evaluation of Innovative Materials and Technologies

   Future research should focus on evaluating the effectiveness of innovative materials and technologies, such as self-healing concrete, corrosion inhibitors, and advanced diagnostic tools. Pilot studies could be conducted to assess the performance of these solutions in real-world conditions, with a focus on their durability, cost-effectiveness, and impact on resident satisfaction (Creswell and Creswell, 2017).

4. Resident Engagement and Behavioral Studies

   Research could explore the role of resident engagement in improving maintenance outcomes. Behavioral studies could investigate how residents perceive and respond to building defects, as well as the factors that influence their satisfaction with maintenance services. This could inform the development of strategies to enhance resident participation in defect reporting and maintenance processes (Saunders et al., 2015).

5. Policy and Institutional Analysis

   Future studies could examine the role of policy and institutional frameworks in addressing building defects. This could include an analysis of the Housing Authority's maintenance policies, resource allocation, and decision-making processes. Research could also explore the impact of regulatory changes, such as stricter building codes or mandatory maintenance schedules, on the prevalence and severity of water seepage and spalling defects (Hong Kong Housing Authority, 2020).

6. Integration of Smart Technologies

   With the rise of smart cities and the Internet of Things (IoT), future research could explore the integration of smart technologies into maintenance practices. For example, sensors could be installed in buildings to monitor moisture levels and structural integrity in real-time, enabling early detection of defects and more efficient maintenance responses. Research could assess the feasibility, cost-effectiveness, and impact of such technologies on maintenance quality and resident satisfaction (Yin, 2017).

7. Economic and Social Impact Studies

Future research could investigate the economic and social impacts of water seepage and spalling defects. This could include an analysis of the financial costs associated with repairs, as well as the broader social implications, such as the impact on residents' health, well-being, and quality of life. Such studies could provide a more holistic understanding of the challenges posed by building defects and inform the development of more comprehensive solutions (Leung et al., 2014).

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Appendices

Appendix 1: Sample survey questionnaire

Section 1: Demographic Information

1.What is your age group?

2.What is your gender?

3.How long have you lived in this public housing estate?

- Less than 1 year
- 1-5 years
- 5-10 years
- More than 10 years

4.What type of housing unit do you occupy? (e.g., flat size, floor level)

Section 2: Prevalence and Severity of Defects

5. Have you experienced water seepage in your home?

- Yes
- No

6. If yes, where is the water seepage located?

- External walls
- Windows
- Ceilings
- Bathrooms/kitchens
- Structural columns/beams
- Balconies
- Other (please specify) ________

7.How severe is the water seepage issue?

(1-Mild, 2-Less Mild, 3-Moderate, 4-Less Severe, 5-Severe)

8. Have you experienced spalling concrete in your home?

- Yes
- No

9. If yes, where is the spalling located?

- External walls
- Windows
- Ceilings
- Bathrooms/kitchens
- Structural columns/beams
- Balconies
- Other (please specify) ________

10. How severe is the spalling issue?

(1-Mild, 2-Less Mild, 3-Moderate, 4-Less Severe, 5-Severe)

Section 3: Perceived Causes and Impacts

11. What do you believe are the main causes of water seepage in your home?

- Aging building
- Poor construction quality
- Lack of waterproofing
- Heavy rainfall and humidity
- Corrosion of reinforcement bars
- Other (please specify) ________

12. Do you think water seepage contributes to spalling defects?

- Yes
- No
- Unsure

13. How has water seepage or spalling affected your quality of life?

- Health concerns
- Discomfort
- Financial burden

14. Are you aware of the role of waterproof membranes in preventing water seepage?

- Yes
- No

15. Would you support the replacement of waterproof membranes as a solution to water seepage defects?

- Yes
- No
- Unsure

Section 4: Current Maintenance Practices

16. How satisfied are you with the current maintenance services for water seepage and spalling defects?

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied

17.How quickly are maintenance requests addressed after reporting?

- Within 24 hours
- 1–3 days
- 1 week
- More than 1 week

18.How effective are the repairs for water seepage and spalling defects?

- Very effective (issues are fully resolved)
- Somewhat effective (issues are partially resolved)
- Not effective (issues persist or worsen)

19. What methods are currently used to repair water seepage and spalling?

- Injection grouting
- Surface coatings
- Replacement of waterproof membranes
- Patch repairs
- Replacement of concrete sections
- Other (please specify) _________

20. How long do repairs typically last before issues reoccur?

- Less than 6 months
- 6 months to 1 year
- 1–2 years
- More than 2 years

Section 5: Communication and Service Quality

21. How would you rate the communication from maintenance staff during the repair process?

- Excellent

- Good
- Average
- Poor
- Very poor

22.Were you informed about the cause of the defects and the repair process?

- Yes, in detail
- Yes, but only briefly
- No

23.How satisfied are you with the professionalism and attitude of maintenance staff?

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied

24.Do you feel that your concerns and feedback are taken seriously by maintenance staff?

- Yes
- No
- Sometimes

Section 6: Remedy Solutions and Customer Satisfaction

25. What challenges have you faced with the current maintenance services?

- Delays in response time
- Poor quality of repairs
- Lack of communication
- Unprofessional behavior
- Other (please specify) _________

26.What improvements would you suggest to enhance the quality of maintenance services?

- Faster response times
- Use of advanced technologies (e.g., infrared thermography, moisture sensors)
- Regular preventive maintenance
- Replacement of waterproof membranes
- Better communication and follow-ups
- Other (please specify) _________

27.Would innovative materials (e.g., self-healing concrete, corrosion inhibitors) help prevent water seepage and spalling?

- Yes
- No
- Not sure

28.What additional services or features would increase your satisfaction with maintenance services?

- (Open-ended) _________

The questionnaire is distributed online and in paper format to ensure accessibility for all residents. Data collected from the survey is analyzed using statistical software to identify trends, correlations, and significant differences between demographic groups (Yin, 2017).

-end of Appendix 1-

Appendix 2: Sample semi-structured interview questions

Interview Questions for Building Professionals:

- What are the primary causes of water seepage and spalling defects in public housing estates?
- How effective is the replacement of waterproof membranes in addressing water seepage?
- What are the challenges in implementing waterproof membrane replacement in existing buildings?
- How can construction practices be improved to prevent these defects in future housing projects?

Interview Questions for Maintenance Personnel:

- What repair methods are currently used to address water seepage and spalling defects?
- Have you implemented waterproof membrane replacement as a solution? If so, what were the outcomes?
- What are the challenges in coordinating and executing maintenance work for these defects?
- How can maintenance efficiency and quality be improved?

The interviews are conducted in person or via video conferencing, recorded, and transcribed for thematic analysis. The qualitative data provides deeper insights into the technical, practical, and institutional aspects of managing water seepage and spalling defects (Creswell and Creswell, 2017).

-end of Appendix 2-

Appendix 3: List of completed questionnaire survey respondents (total 100 nos.)

INFORMATION WITHHELD

-end of Appendix 3-

Appendix 4: List of six interviewees

INFORMATION WITHHELD

-end of Appendix 4-