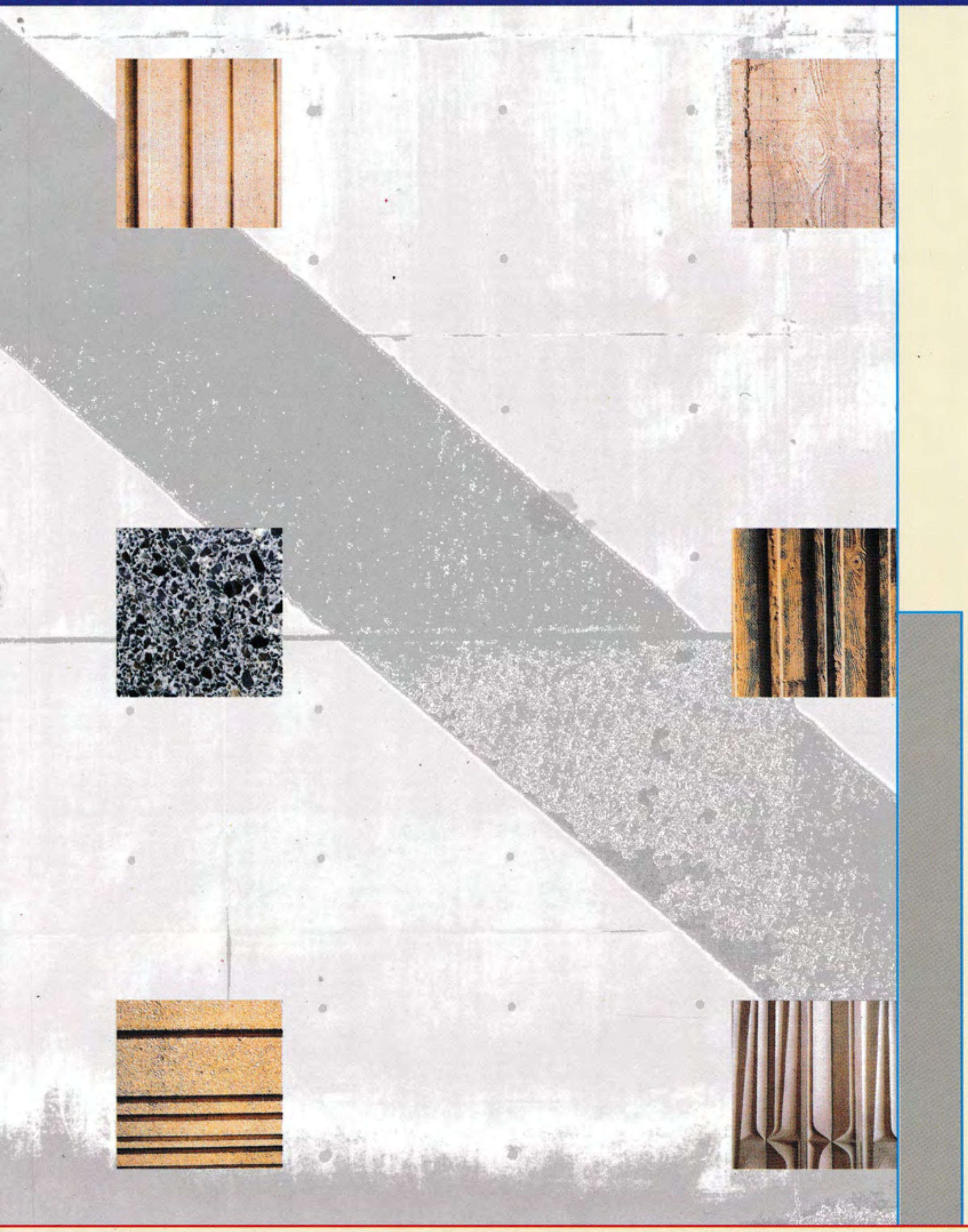
ARCHITECTURE IN PRECAST CONCRETE



BCA Buildability Series

ARCHITECTURE IN PRECAST CONCRETE

Building and Construction Authority

SINGAPORE INSTITUTE OF ARCHITECTS

This Handbook on **ARCHITECTURE IN PRECAST CONCRETE** is published by the Buildability Development Section, Technology Development Division of the Building and Construction Authority.

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FOREWORD

The Building and Construction Authority, BCA (formerly CIDB) has been promoting extensively the use of buildable designs to increase site productivity. With the impending legislation of minimum buildability score as a requirement for building plan approval, BCA has organised a comprehensive promotion and training programme on buildability to prepare the industry. As part of this effort, the Guide to Precast Concrete and Prefabricated Reinforcement for Buildings, Prefabricated Reinforcement Handbook and the Structural Precast Concrete Handbook have been published as design aids for the industry.

This fourth publication is a joint effort of the BCA and the Singapore Institute of Architects (SIA). Its aim is to encourage wider use of architectural precast components, especially in private residential developments. The recent trend of using buildable designs such as flat plate construction and drywalls for residential projects shows that more developers and designers are recognising the benefits of adopting buildable designs. However, the perception that precast concrete lacks architectural variety and offers limited flexibility has discouraged its use in private residential projects. In fact, with advancements in precast technology, architects can now enjoy a wider range of options in terms of form, finishes and colours for precast concrete components.

The main value of this publication lies in two areas. Firstly, there are demonstration studies on three actual residential projects in Singapore which were originally designed for conventionally in-situ construction. The studies show that a wide variety of architectural precast and other prefabricated components can be used in residential projects with reasonable cost effectiveness. Secondly, this publication proposes standard dimensions for staircases, internal walls, prefabricated bathrooms and precast civil defence shelters. If these are adopted widely by the industry, there will be considerable positive impact on productivity and cost.

We trust that this publication will provide the industry with more options and possibilities to meet minimum buildability score requirement for building plan approval in the near future.

Chua Koon Hoe
Chief Executive Officer
Building and Construction Authority

MESSAGE

The construction industry is one of the largest recruiters of foreign labour, many of whom are unskilled. There is a need for the construction industry to raise its quality, productivity and skills level to meet the ever-changing demands of our affluent society. The industry must explore ways to improve the construction practices and processes to facilitate the integration of the different issues of the entire construction value chain.

The Singapore Institute of Architects was commissioned by the Building and Construction Authority to produce the Handbook – "Architecture in Precast Concrete". It aims to promote the integration of modular co-ordination and standardisation into design and encourage architects to use precast concrete components at the early planning stage. This would lead to more efficient construction methods, thus resulting in the improvement in productivity, quality and buildability.

This Handbook identifies the various available architectural precast concrete components and demonstrates that precast concrete construction system and components can be adopted in private residential developments. The use of precast concrete does not limit nor compromises the shapes, forms and colour of the design. It provides a useful reference for architects exploring various concepts in prefabrication design.

I would like to thank the Building and Construction Authority for engaging the Institute to jointly undertake this assignment. This project is another successful public-private sector collaboration, which addresses current issues and finding solutions and direction for a more productive building industry.

Special thanks also go to Mr Goh Peng Thong and the team members for their time and effort in preparing this Handbook. I am confident that the Handbook will promote a better understanding and wider application of architectural precast concrete components.

Tham Tuck Cheong
President
Singapore Institute of Architects

ACKNOWLEDGEMENT

This Handbook on ARCHITECTURE IN PRECAST CONCRETE was made possible by a team of BCA officers and SIA members with inputs from various government agencies, contractors and precasters. BCA and SIA would like to thank the resource persons for their valuable and generous contributions.

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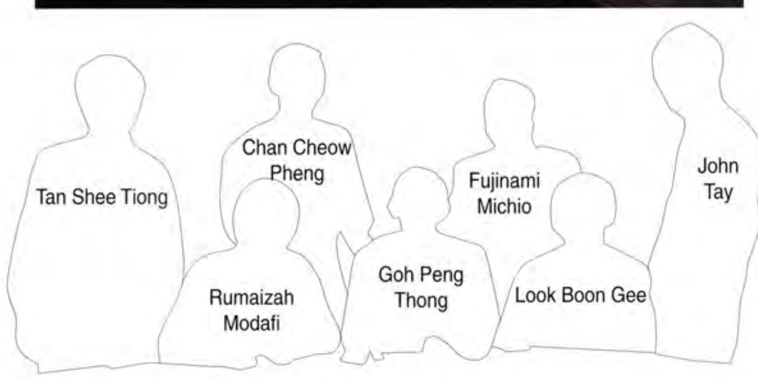

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	Mr Wong Wai Yin	Individual capacity

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Mr Lee Kut Cheung	RSP Architects Planners & Engineers Pte Ltd
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Mdm Chia Oi Leng	ST Architects & Engineers Pte Ltd

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CPL Management Services Pte Ltd
Tat Chuan Development Pte Ltd
TSP Architects & Planners Pte Ltd

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CHAPTER THREE PLANNING AND DESIGN GUIDELINES

CHAPTER FOUR ARCHITECTURAL PRECAST COMPONENTS

INTRODUCTION

The construction industry has been plagued by low productivity partly due to the large number of unskilled and relatively low-cost foreign workers. There is a need to reduce the industry's dependence on unskilled foreign workers and to maintain high quality constructed buildings. The Ministry of Manpower has introduced measures such as foreign workers ratio, man-year entitlement and differentiated foreign worker levies to raise productivity. These measures must be complemented by upstream measures to have maximum impact on site productivity.

Upstream measures at design stage are effective means in bringing about greater site productivity improvement. This is because buildable designs can facilitate the use of more labour-efficient construction methods. In the past, buildable designs were mostly proposed by design-and-build project teams or were alternative designs by contractors. Design-and-build projects constitute a small percentage of all projects awarded while alternative designs are usually not in favour due to tight project schedules. The best way to widen the use of buildable designs is to train designers to adopt buildable designs right from the start of the design process. Precast concrete construction has been identified as one form of buildable designs to improve site productivity.

Precast Concrete Construction For Residential Projects

Precast concrete building technology had been used in Singapore since 1970s. The Housing & Development Board (HDB) has implemented its prefabricated construction programme since 1970s. The HDB precast programme is logical as most of the building requirements and structural dimensions are standardised. It therefore makes sense to go into precasting.

Private residential housing developments have not gone into precast technology in a big way as most private housing developments are tailor-made to suit client's requirements. Most of the private residential developments are unique in nature and lack repetition. This has led to the misconception that precast concrete for private residential project is not a viable option.

This study carried out by BCA and SIA has reached the findings that the use of precast components for a private residential development, be it a big project or a small-size project, is a good alternative design scheme. Besides, precast construction has many advantages over the conventional construction method.

It can be concluded by this study that most private residential buildings are suitable for construction using precast concrete. Buildings with an orthogonal plan are, of course, ideal for precasting because they exhibit a high degree of regularity or repetition in structural grids and member sizes, among others.

Misconceptions

Irregular layouts are on many occasions equally suitable for precasting, if not totally, then certainly partially. It is a common misconception that precast concrete lacks flexibility. In fact, architectural precast concrete is where creativity and variety can be expressed. Modern precast concrete buildings can be designed economically with a variety of plans and elevations. Balconies, parapet, gable-end walls, façade walls and other elevation treatments can all be done using precast concrete. Unique shapes, designs and various finished effects (using tile, granite, sand blasting, polished concrete finishing etc.) can be adopted, resulting in higher consistency and quality. With the use of high strength concrete, the sizes of load-bearing elements can be reduced to make precast concrete components lighter and more cost competitive.

Benefits

Speed of construction is a major consideration in most building projects. In this aspect, precast construction excels. Beside faster erection, the precast units can be manufactured in the factory while the foundation works are carried out at the site simultaneously. In addition, precast concrete construction can increase the overall speed of construction by allowing other trades to commence at lower floors whilst work continues on erecting the upper storeys.

As the precast components are manufactured in the factory under close supervision, the quality of workmanship will be better than in-situ components. Similarly, the accuracy in the construction and overall workmanship of the project can also be improved by using precast concrete technology.

Contents Of Handbook

This Handbook covers the study and recommendations made by BCA and SIA on the use of suitable architectural precast components for residential projects. In Chapter one, the use of precast components and application of modular co-ordination concept were demonstrated in three real private residential developments. Chapter two covers the costing aspects of precast concrete construction. This Handbook also provides recommendations on finishes and standardised dimensions for the following components:

- Precast / Prefabricated bathroom
- Precast staircase
- Precast civil defence shelter

Architects will find this Handbook a valuable reference in designing a precast project. The demonstrative studies will convince architects that precast construction technology is a viable alternative to conventional in-situ construction for private residential development.

CHAPTER ONE
DEMONSTRATION PROJECTS

1.1 General

Three private residential projects completed previously, using conventional in-situ construction method, were selected for the demonstration studies. The selection of the projects is not based on the merits of their design or construction. They are selected to represent the three types of private residential development; namely the high-rise, medium-rise and low-rise.

Precast concrete construction technology has not been extensively used for private residential developments locally. Many private residential designs are developed with various types of floor plan to suit housing trends and demands. This probably explains why the average buildability score for private residential developments is lower than the commercial developments where more standardised layouts and precast components are used.

The demonstration studies explored the feasibility of converting three conventional in-situ projects into precast concrete design. For the three projects selected, each project requires different design approach owing to different site constraints, units' layout and size of the project.

Consents from the respective developers and architects had been obtained. The three projects selected were:
1. Valley Park (high-rise)
2. The Bayron (medium-rise)
3. Casa Pasir Ris (low-rise)

The demonstration studies covered the following areas:
- Review the original design and evaluate the suitability and feasibility of adopting precast construction.
- Assess the dimensions of the grid spacings used in the original design and modify where necessary so that modular co-ordination can be applied.
- Review the need to adjust floor layouts and external elevations to facilitate precasting.
- Substitute in-situ building components with precast or prefabricated components.
- Assess whether the URA planning parameters or building regulations are affected.
- Evaluate the cost implication.

1.2 High-Rise Residential: Valley Park

1.2.1 The existing building

The following are the data of the existing building:

A. PROJECT DATA

Architect	:	TSP Architects & Planners Pte Ltd
Building Type	:	Private Residential
No. of Units	:	728
Building Height	:	20 storey
Location	:	River Valley Road / Kellock Road
Site Area	:	43,284.76m^2
Gross Floor Area	:	109,721.18m^2
Plot Ratio	:	2.5
Building Coverage	:	30.49%
Construction Cost	:	$210 million
Year of Completion	:	1997
Construction Period	:	32 months (as per tender specifications)

B. EXISTING DESIGN

The project was a conventional in-situ reinforced concrete structure with brickwall and plastering. Precast balconies were used in the original design.

C. EXISTING DESIGN FEATURES

The following features were incorporated into the facade:

- Precast balcony
- Concrete ledge for air-conditioning unit

1.2.2 Proposed precast design of the building

The existing layout plan, its dimensions and structural system are reviewed. Modifications to the dimensions are made to facilitate the application of modular co-ordination. These modifications do not affect the planning approval parameters. The maximum difference in floor area of the residential units resulted from the modifications ranges from 0.1% to less than 2%. For this development, owing to its large land area, it is possible to manufacture the precast concrete panels on-site, resulting in saving of the transportation cost.

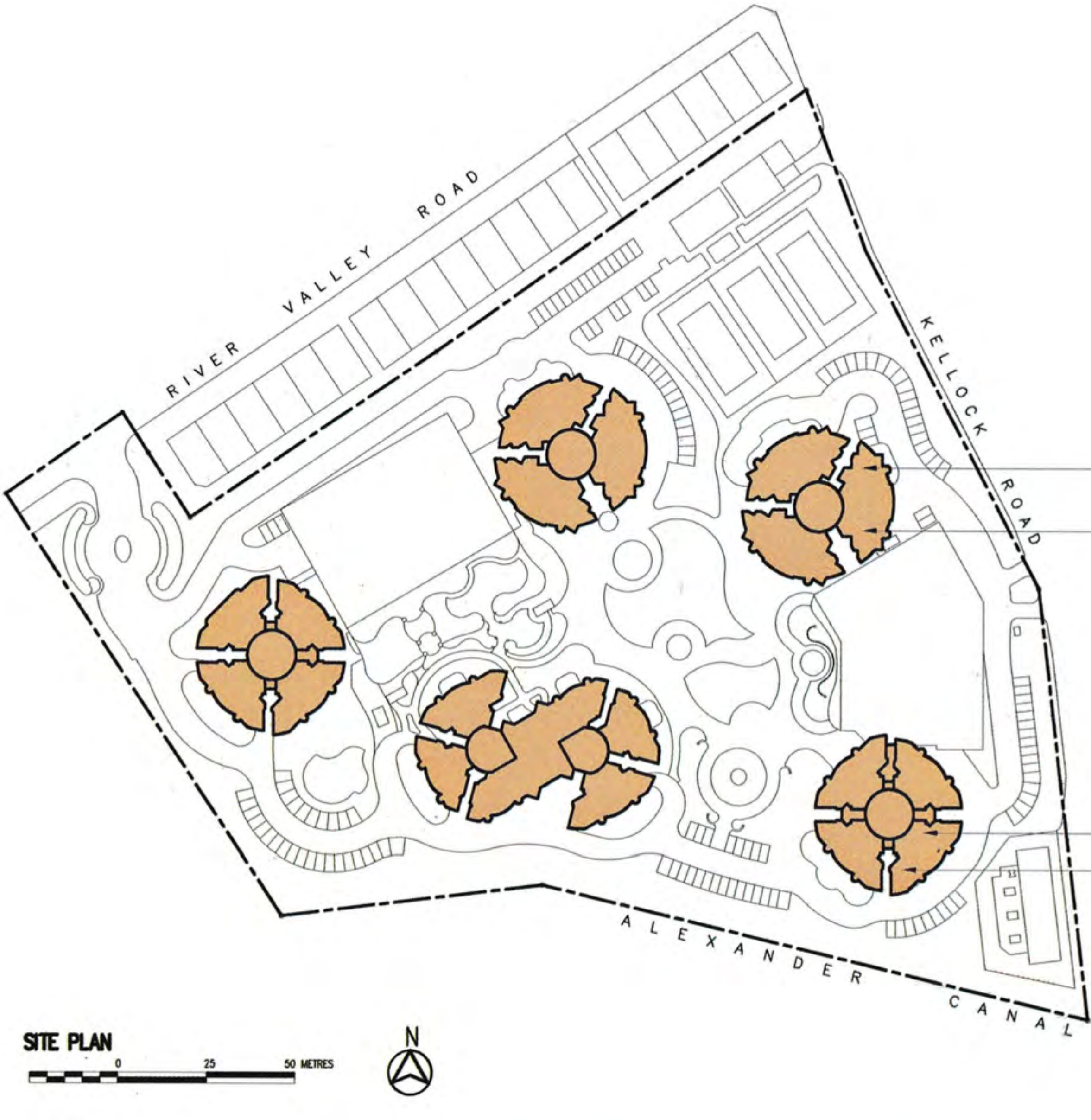
The changes made to the existing design are summarised as follows:

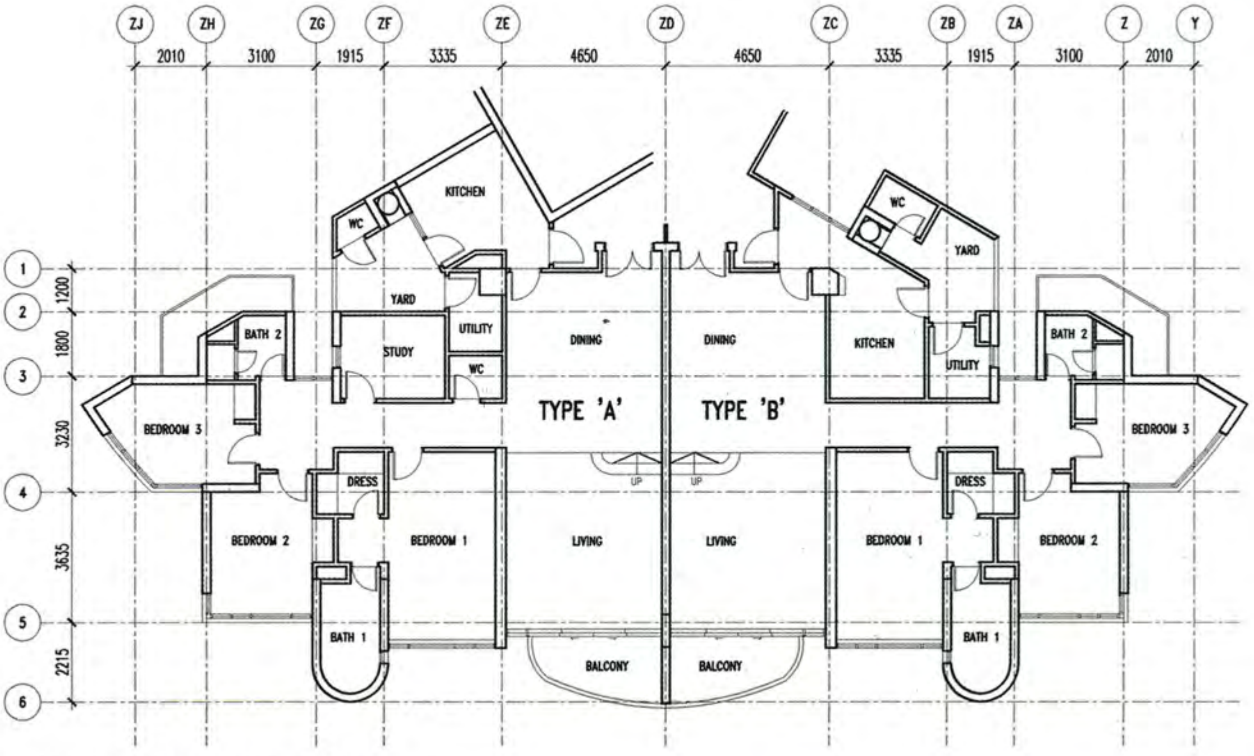
	EXISTING DESIGN	PROPOSED PRECAST DESIGN
A.	**Structural**	
i.	*Column And Slab:*	
(a)	In-situ concrete column and beam frame.	Precast shear wall and beam where indicated.
(b)	In-situ concrete slab.	2.4m wide and 80mm thick precast half-slab supported by precast shear wall and finish with 100mm thick in-situ concrete topping.
ii.	*Staircase:*	
(a)	In-situ staircase	Precast staircase with landing.
B.	**Architectural**	
i.	*External Facade And Feature:*	
(a)	External plastered brickwall with spray textured acrylic coating.	Acid-treated textured external precast concrete panel.
ii.	*Bathroom:*	
(a)	Master bathroom designed with in-situ external concrete wall and internal brickwall finished with in-situ laid marble internal wall and floor.	Precast concrete cell with pre-finished internal cast in polished concrete (with marble chips) to wall and floor, prefabricated ceiling and sanitary fittings.
(b)	Second bathroom and maid's toilet - Brickwall finished with ceramic tile to wall and floor and plasterboard suspended ceiling.	Prefabricated bathroom cubicle manufactured in steel frame wall panel pre-laid with ceramic tile, and prefabricated plasterboard ceiling and sanitary fittings.
(c)	Normal S-trap to floor trap in all bathrooms and kitchen. 50mm screed allowed.	'Shallow floor trap' (used in HDB Hougang pilot project) to be set within the concrete topping for the precast half-slab (kitchen only) or precast floor (bathroom only). 100mm screed allowed.
iii.	*Internal Wall:*	
(a)	100mm thick internal plastered brickwall partition.	Precast 600mm wide x 100mm thick hollow core concrete lightweight panel or 90mm thick solid lightweight concrete panels. Skimmed coated.
iv.	*Others:*	
(a)	Site-installed aluminum window frame.	Unitised aluminum window frame cast in precast external wall panel.
(b)	Non-modular grids.	Modular grids.
(c)	Type C & D Units - second bathroom and yard irregular in shape.	Shapes are regularised to allow the use of precast shear wall.
(d)	In-situ refuse chute.	Precast refuse chute.

Notes:

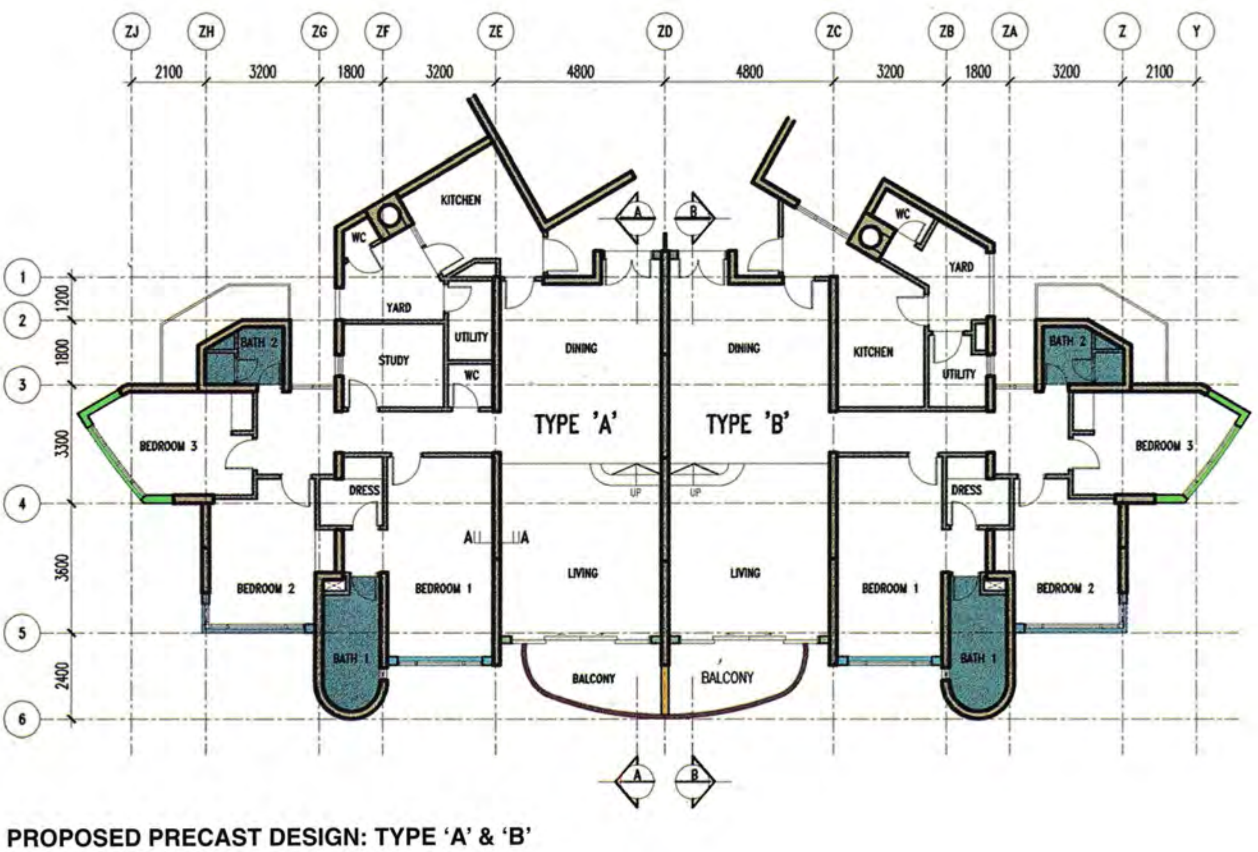
(i) Except for precision internal walls, most precast components can be site cast as there is ample space.

(ii) The modifications under the proposed precast design will not affect the approved planning parameters or the building plan approval.


RIVER VALLEY ROAD
KELLOCK ROAD
ALEXANDER CANAL
TYPE 'B'
TYPE 'A'
TYPE 'C'
TYPE 'B'
SITE PLAN
0
25
50 METRES
N



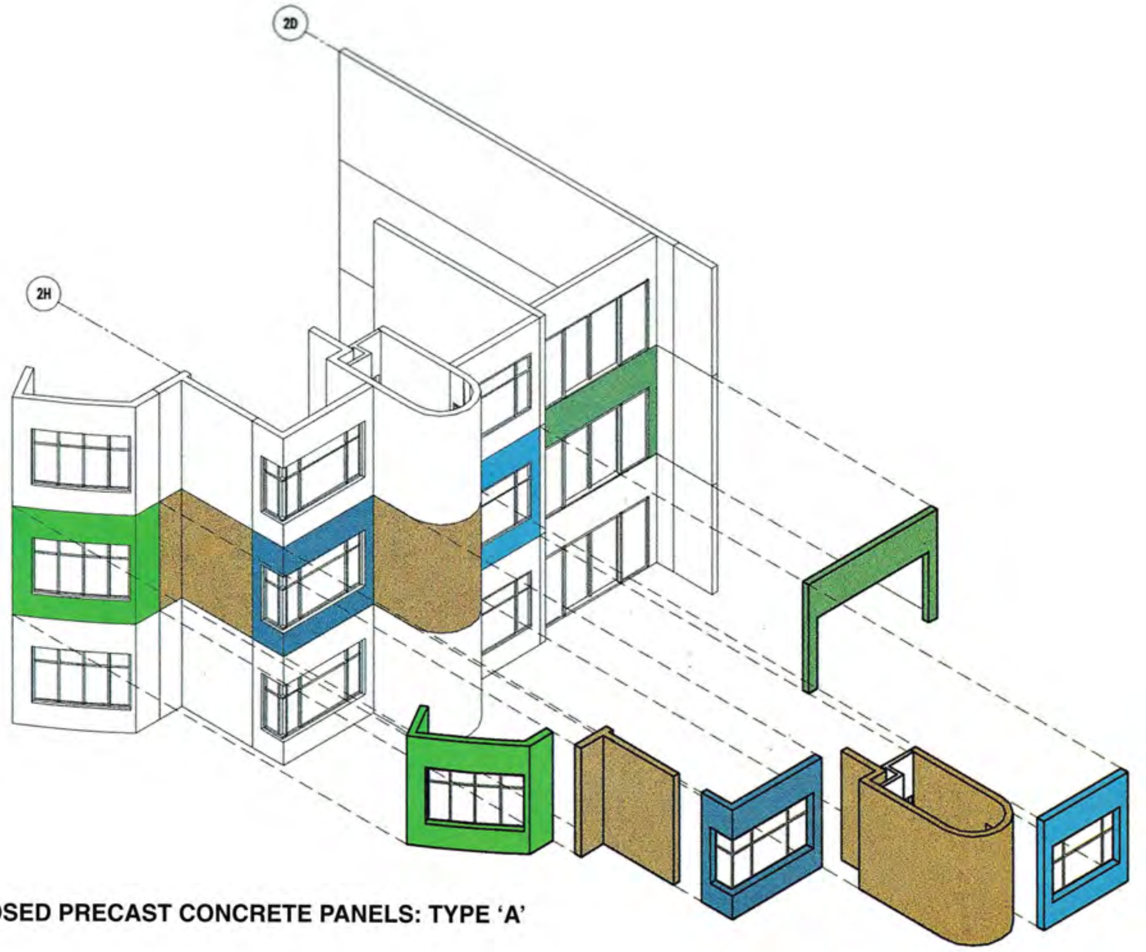
EXISTING DESIGN: TYPE 'A' & 'B'



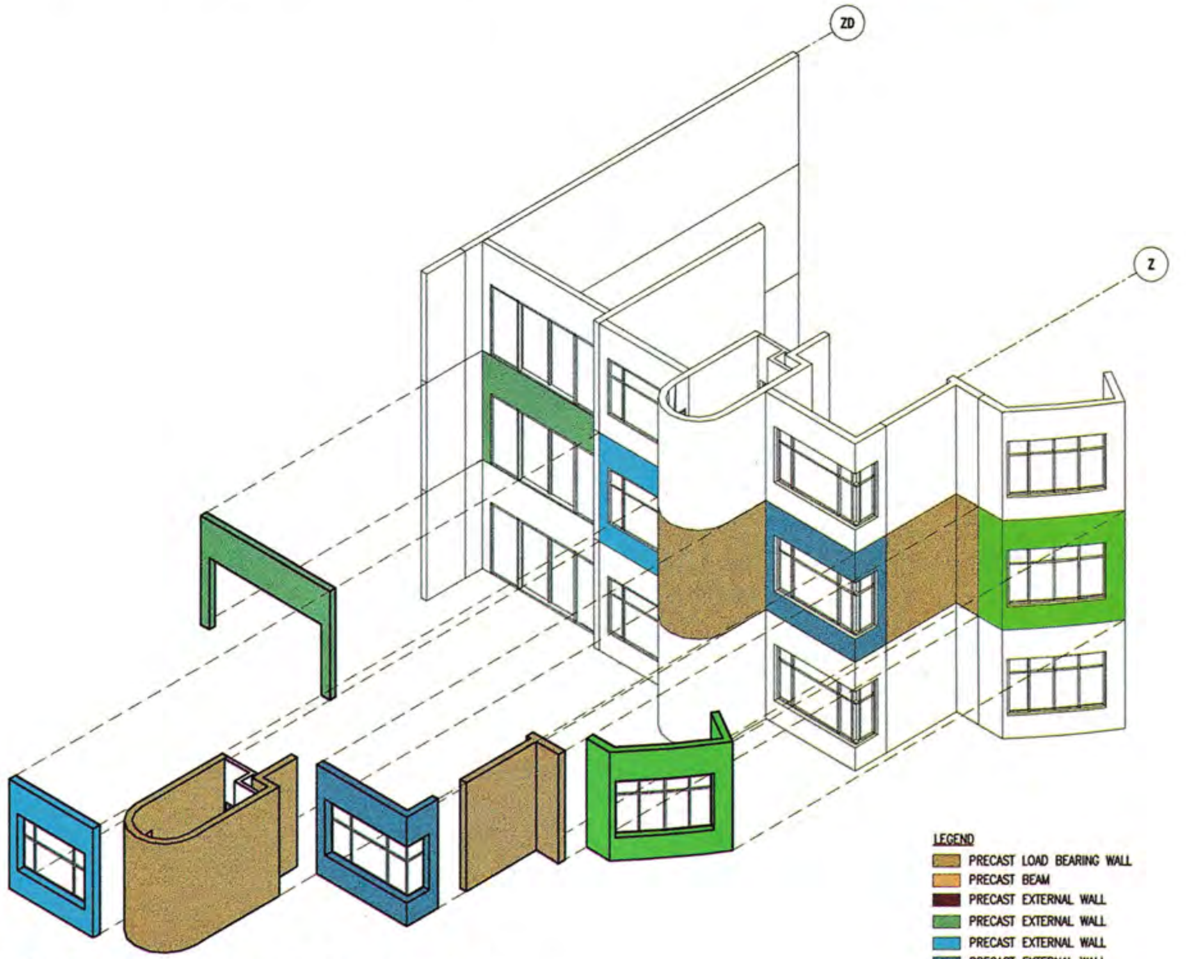
PROPOSED PRECAST DESIGN: TYPE 'A' & 'B'

LEGEND

- PRECAST LOAD BEARING WALL
- 100 THK LIGHTWEIGHT CONCRETE WALL
- PREFABRICATED TOILET
- PRECAST BALCONY
- PRECAST BEAM
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL



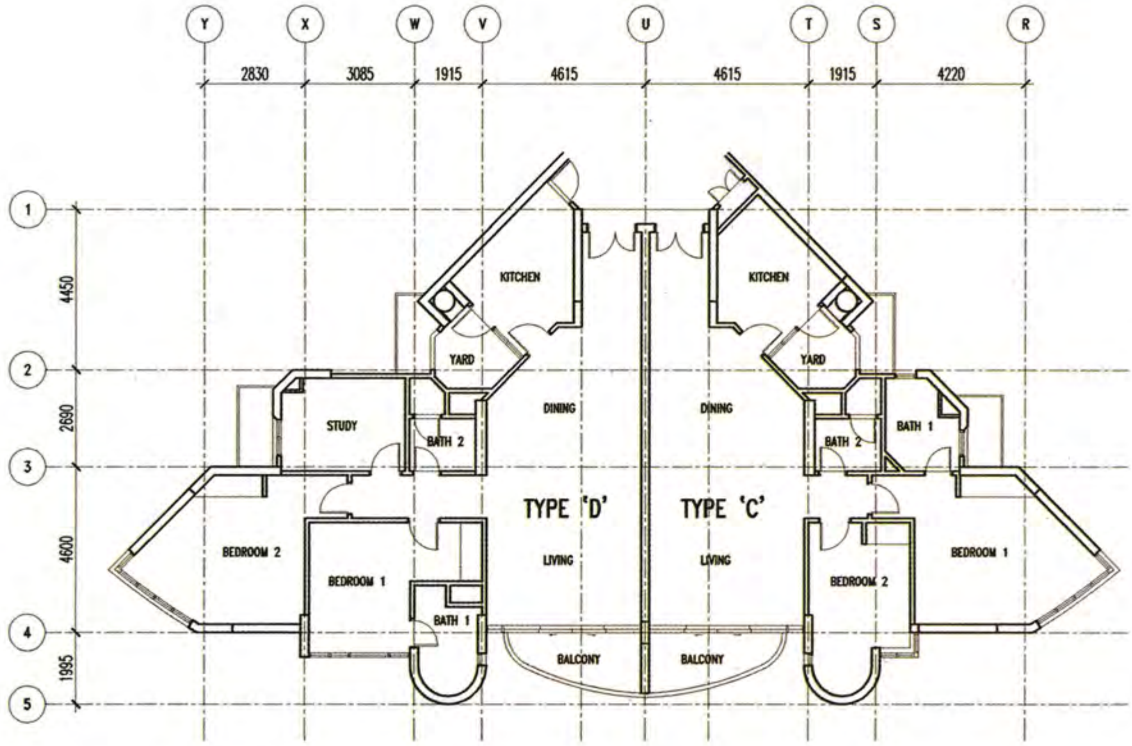
PROPOSED PRECAST CONCRETE PANELS: TYPE 'A'



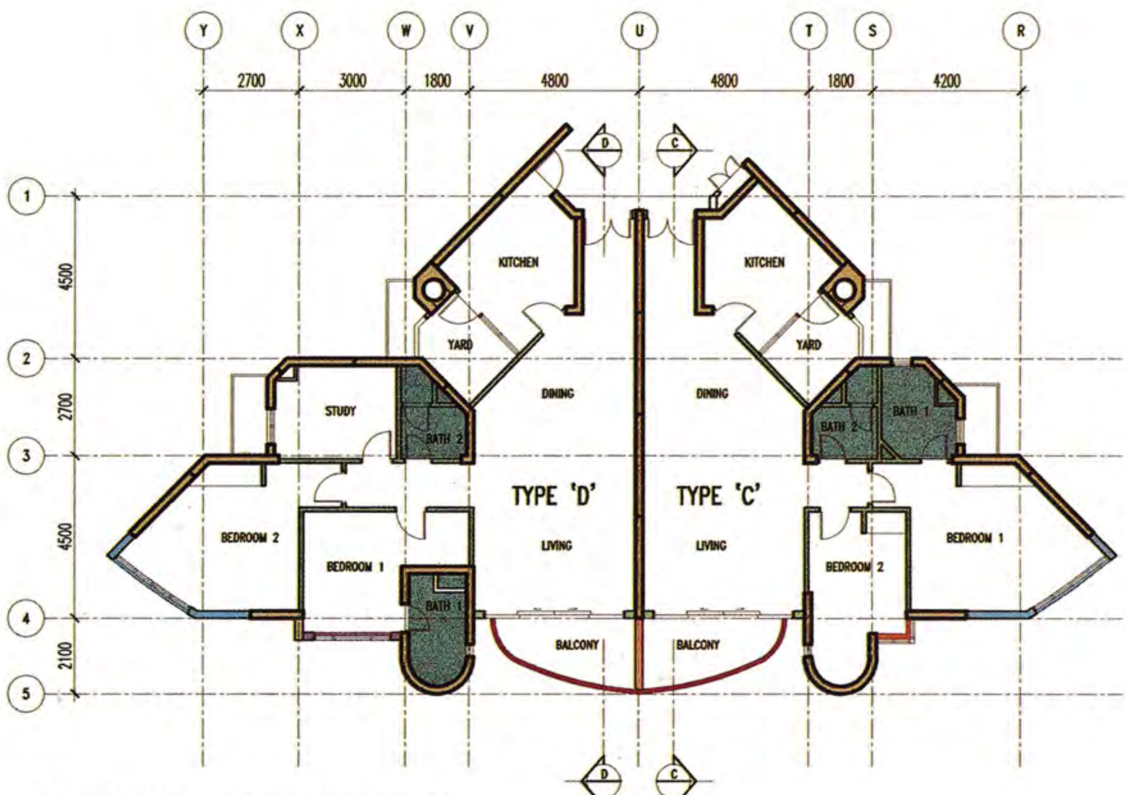
PROPOSED PRECAST CONCRETE PANELS: TYPE 'B'

LEGEND

- PRECAST LOAD BEARING WALL
- PRECAST BEAM
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL



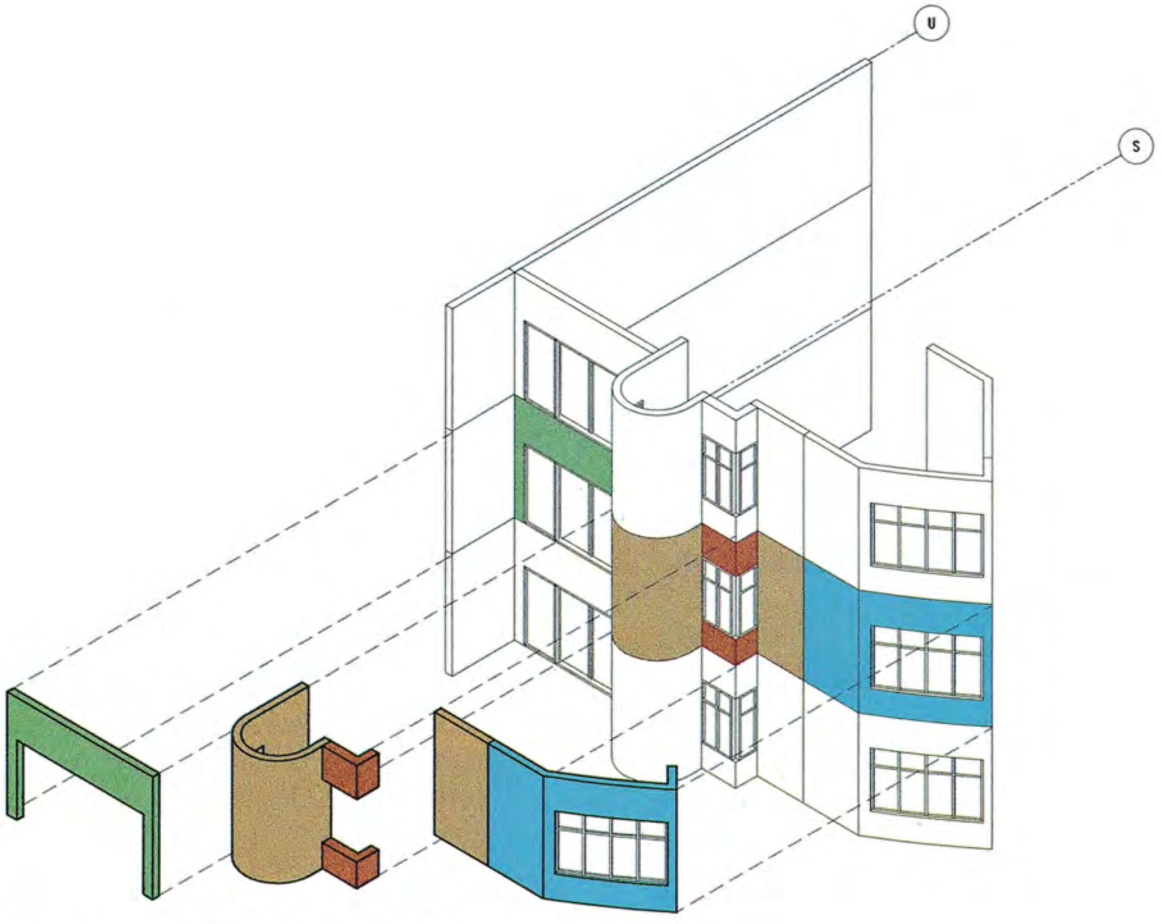
EXISTING DESIGN: TYPE 'C' & 'D'



PROPOSED PRECAST DESIGN: TYPE 'C' & 'D'

LEGEND

- PRECAST LOAD BEARING WALL
- 100 THK LIGHTWEIGHT CONCRETE WALL
- PREFABRICATED TOILET
- PRECAST BALCONY
- PRECAST BEAM
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL



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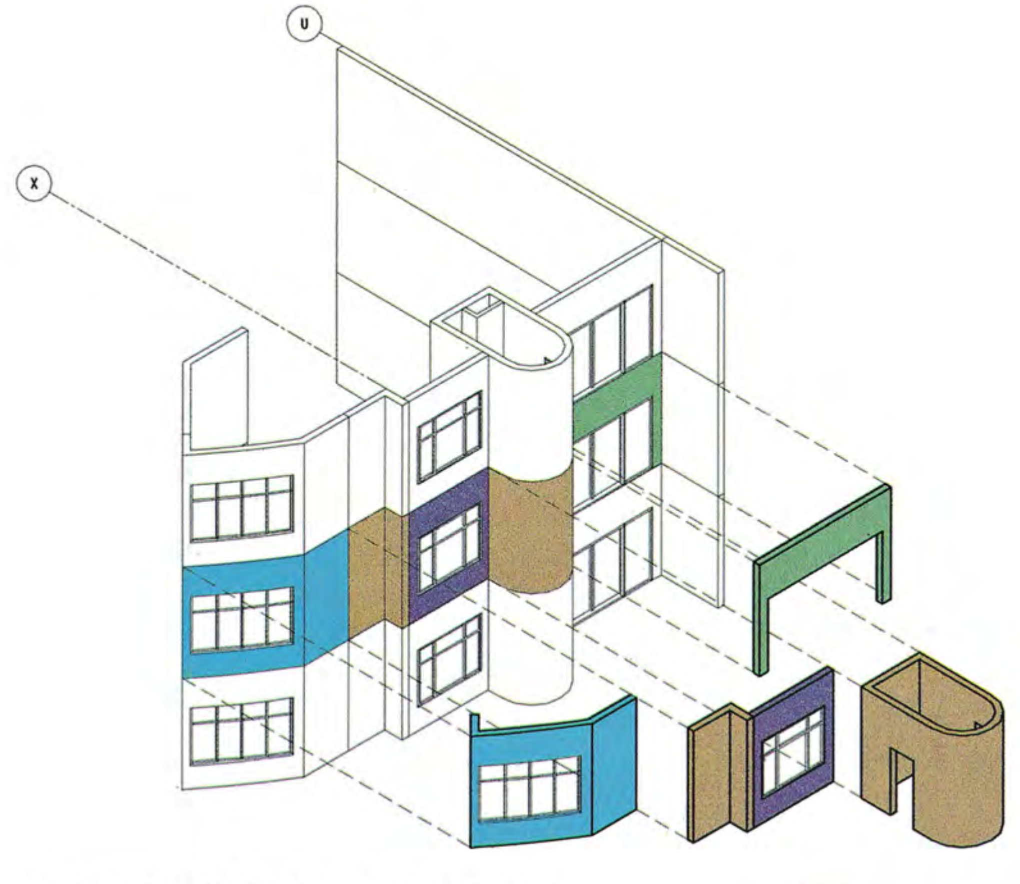
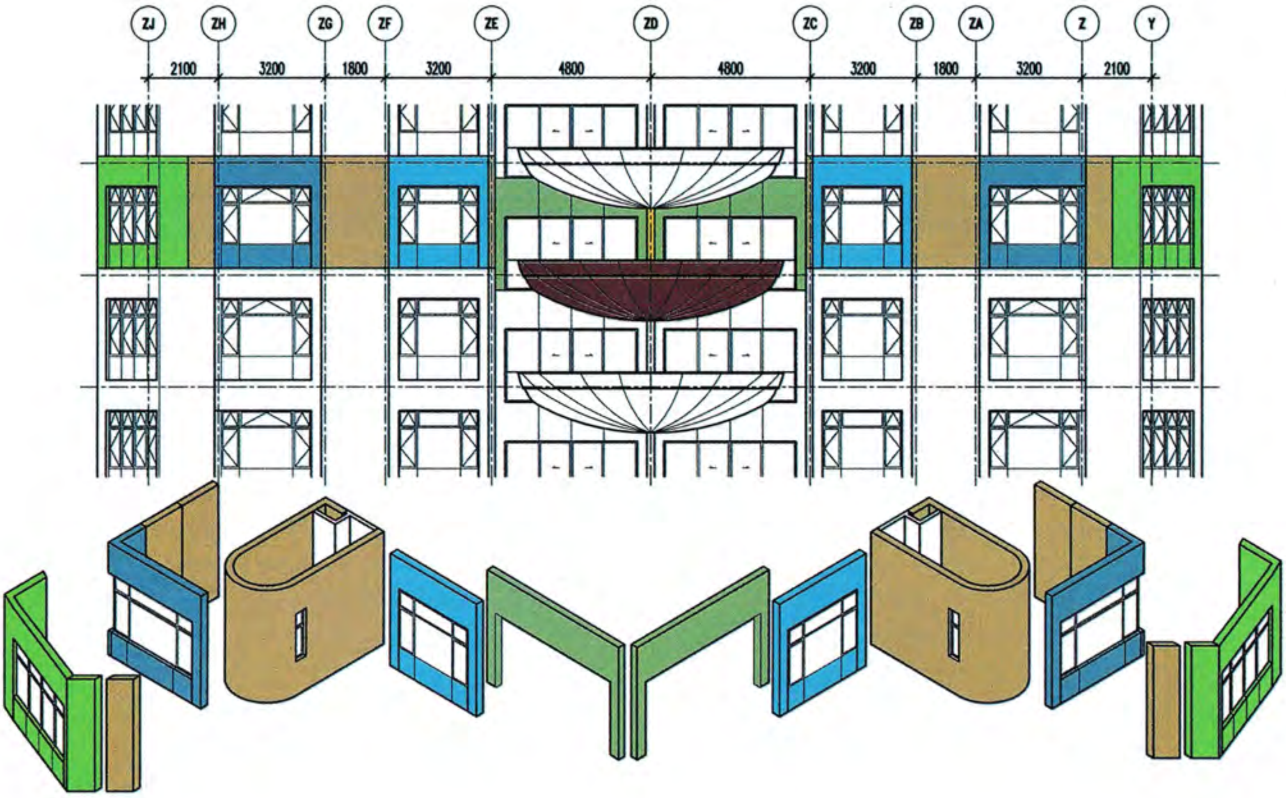
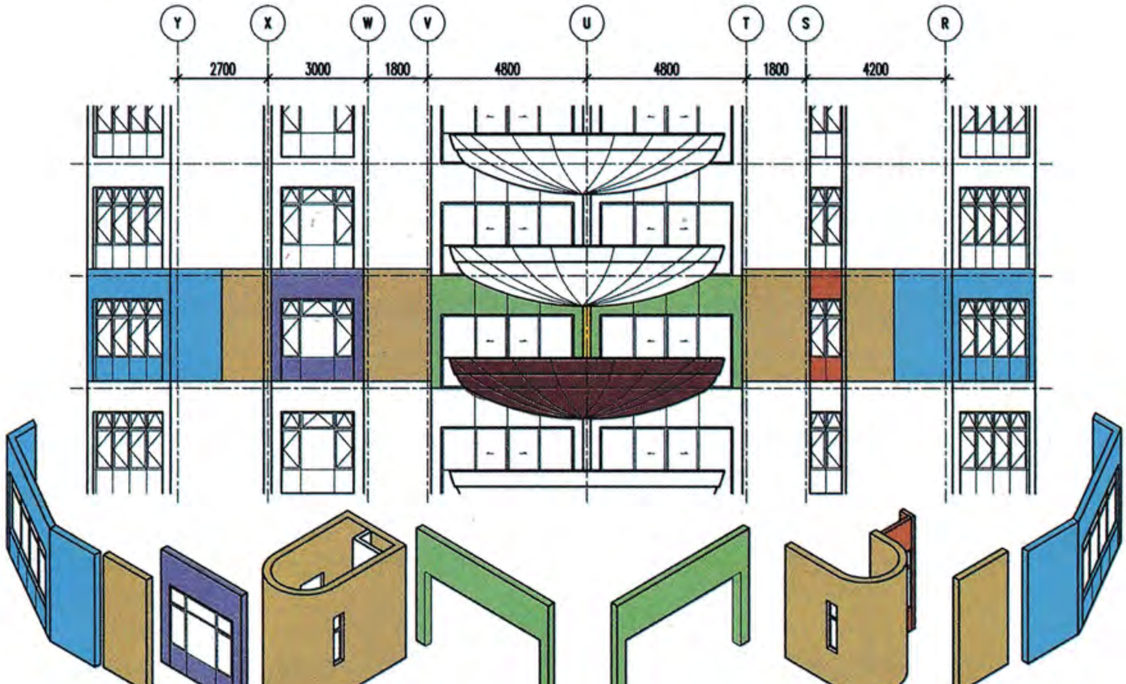


PROPOSED PRECAST CONCRETE PANELS: TYPE 'D'

LEGEND
- PRECAST LOAD BEARING WALL
- PRECAST BEAM
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL



PROPOSED PRECAST CONCRETE ELEVATION: TYPE 'A' & 'B'



PROPOSED PRECAST CONCRETE ELEVATION: TYPE 'C' & 'D'

LEGEND

- PRECAST LOAD BEARING WALL
- PRECAST BALCONY
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
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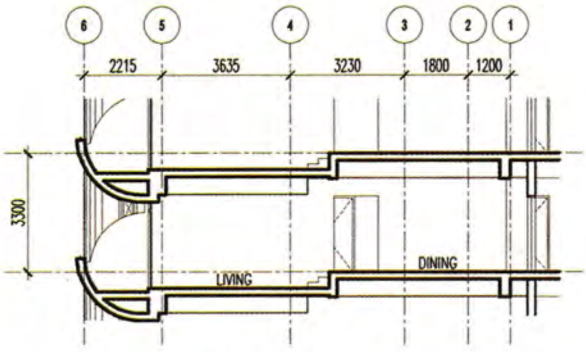
- PRECAST EXTERNAL WALL



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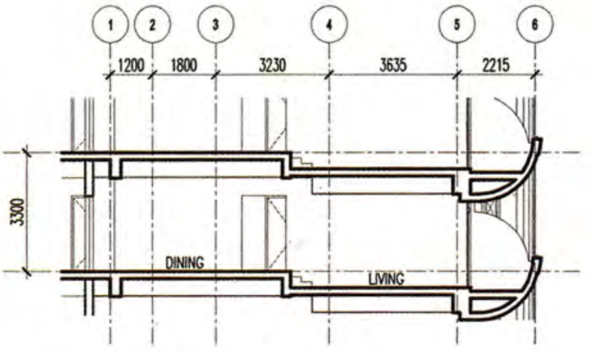

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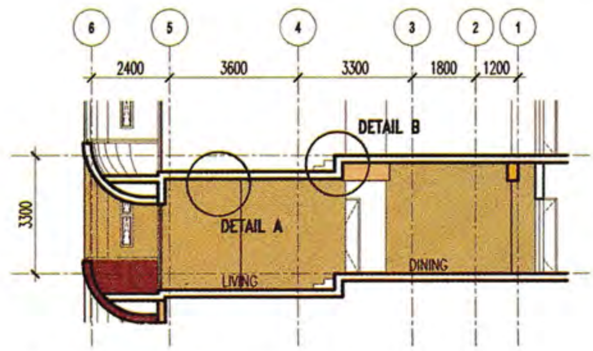

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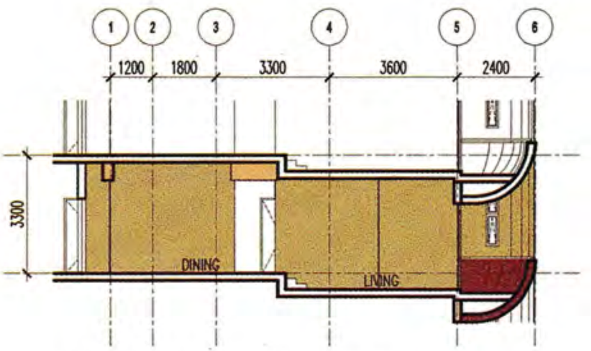

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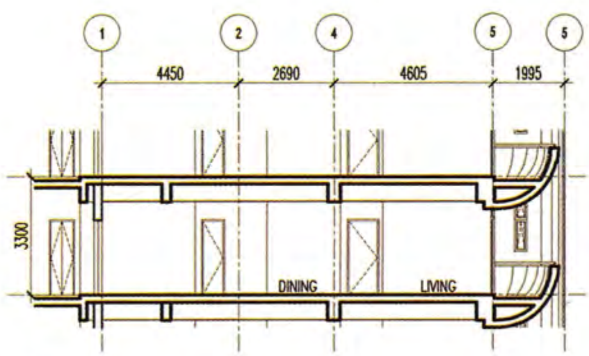

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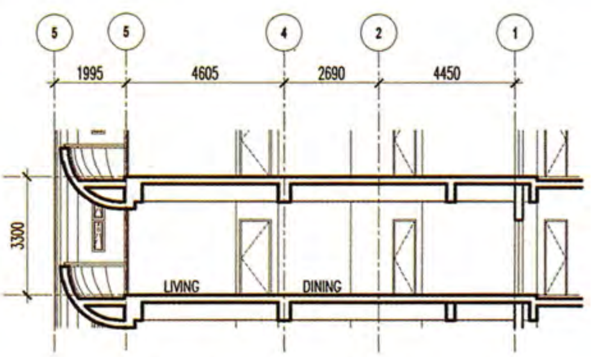

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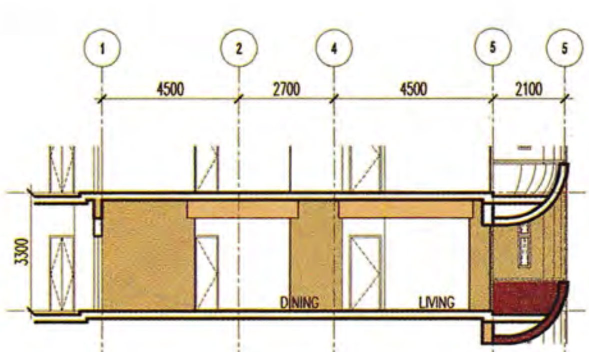
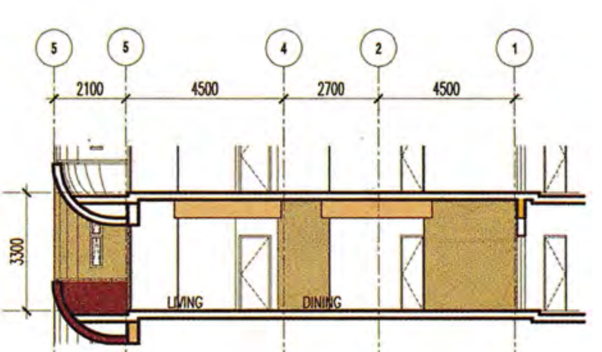
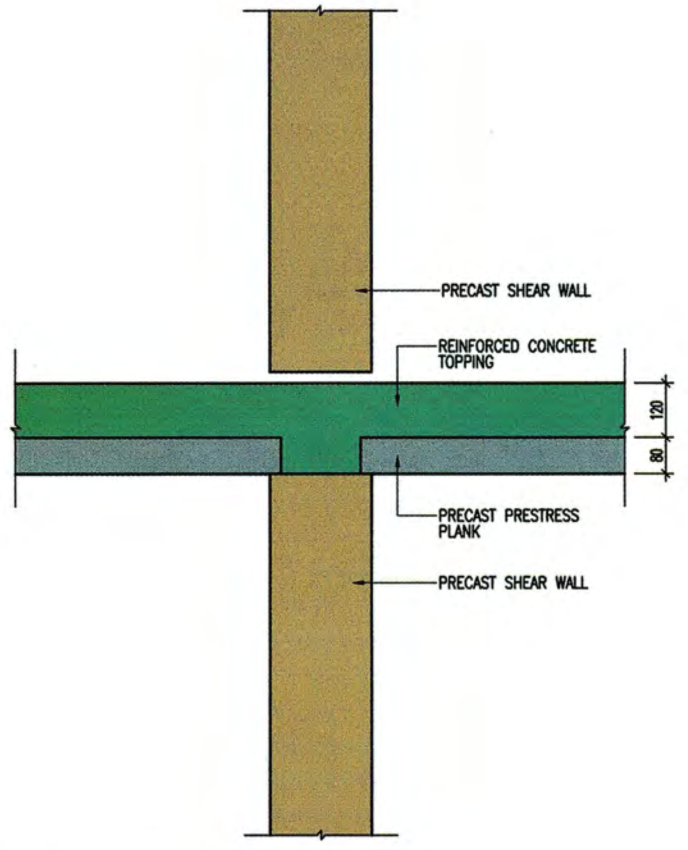


PROPOSED SECTION: TYPE 'C'

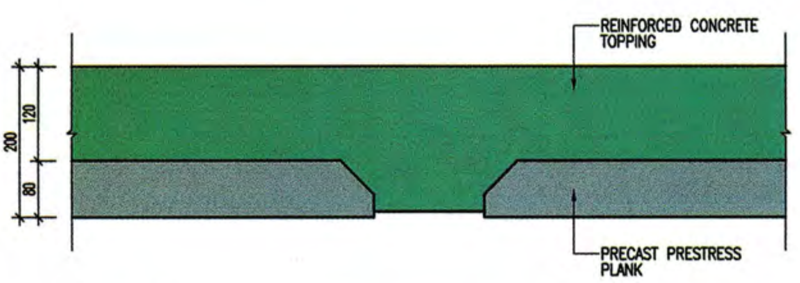


PROPOSED SECTION: TYPE 'D'

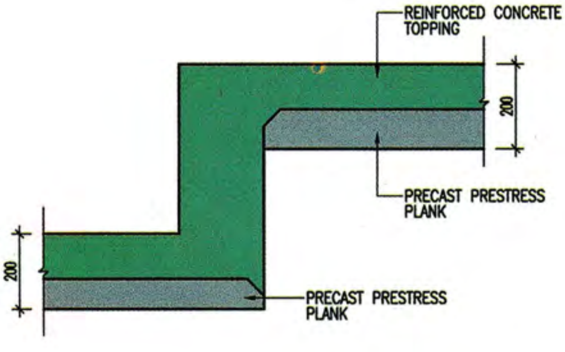
LEGEND
- PRECAST LOAD BEARING WALL
- PRECAST BEAM
- PRECAST BALCONY



DETAIL SECTION A - A: TYPE 'A'



DETAIL A: TYPE 'A'



LEGEND
- PRECAST SHEAR WALL
- REINFORCED CONCRETE TOPPING
- PRECAST CONCRETE PRESTRESS PLANK

DETAIL B: TYPE 'A'

All details shown in drawings are for reference only

1.3 Medium-Rise Residential: The Bayron

1.3.1 The existing building

The following are the data of the existing building:

A. PROJECT DATA

Architect	:	Architects 61 Pte Ltd
Building Type	:	Private Residential
No. of Units	:	96
Building Height	:	Part 12 storey, part 15 storey
Location	:	Devonshire Road / St. Thomas Walk
Site Area	:	5,305.20m^2
Gross Floor Area	:	14,854.56m^2
Plot Ratio	:	2.8
Building Coverage	:	31.33%
Construction Cost	:	$30.5 million
Year of Completion	:	1999
Construction Period	:	19 months (as per tender specifications)

B. EXISTING DESIGN

The project was a conventional in-situ reinforced concrete structure with brickwall and plastering.

C. EXISTING DESIGN FEATURES

The following feature was incorporated into the facade:

- Roof trellis

1.3.2 Proposed precast design of the building

The existing layout plan, its dimensions and structural system are reviewed. It is noted that modular dimensions are adopted in the existing design. No modification to the dimensions is necessary. Due to the site constraints, on-site precasting is not possible.

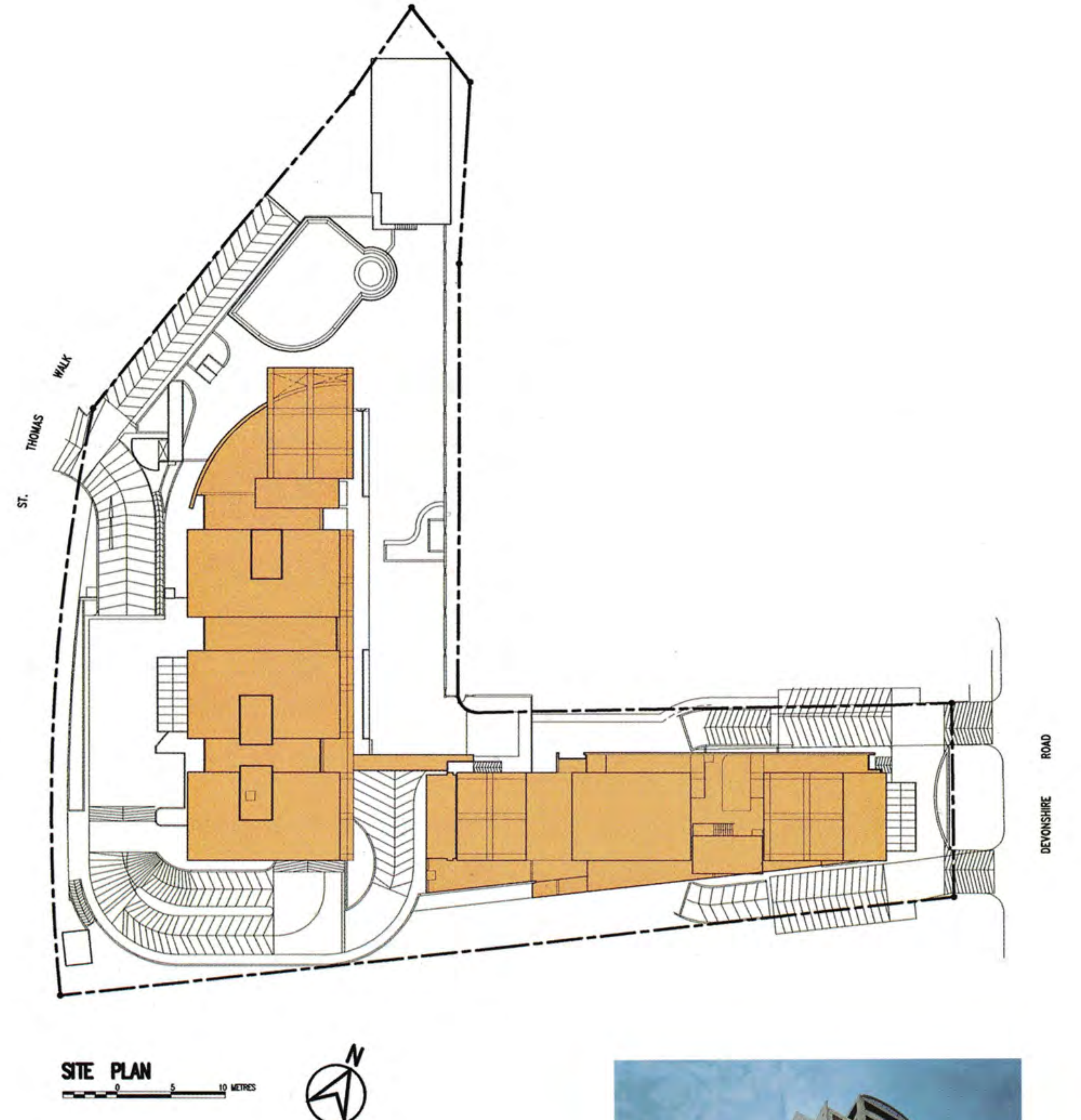
The changes made to the existing design are summarised as follows:

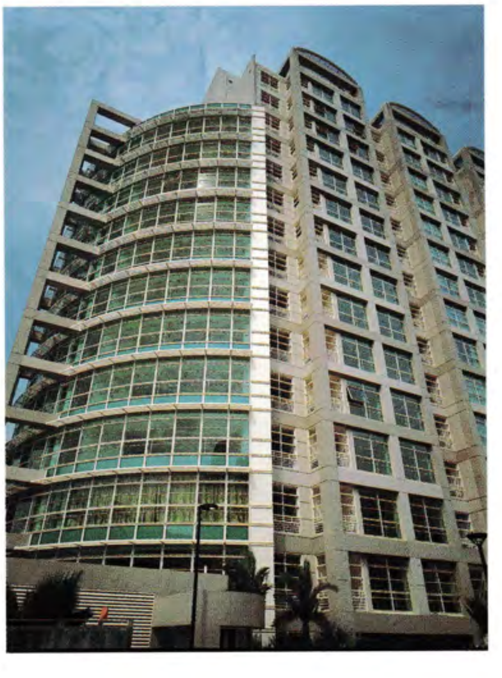
EXISTING DESIGN	PROPOSED PRECAST DESIGN
A. Structural	
i. Basement And 1st Storey Slab:	
(a) In-situ construction.	In situ construction due to high number of reinforced concrete transfer beams at first storey slab over the basement carpark.
ii. 1st Storey Column, 2nd / 3rd Storey And Roof:	
(a) In-situ construction.	Prestressed precast concrete plank 150mm thick + 100mm topping for 8.4m long span. Precast two tiered column and precast beam.
iii. Staircase:	
(a) In-situ staircase	Precast staircase with in-situ landing.
B. Architectural	
i. External Facade And Feature:	
(a) External in-situ concrete column and beam cast with groove lines and indentations. Floor to ceiling aluminium window as infill.	Precast concrete column and beam cast with groove lines and indentations. Floor to ceiling window panel as infill.
(b) Fine textured spray painting.	Water washed fine-sand aggregate textured GRC cladded precast column.
ii. Bathroom:	
(a) Brickwall with tile finished and plasterboard suspended ceiling.	Prefabricated bathroom using steel frame wall panels pre-laid with ceramic tiles.
iii. Internal Wall:	
(a) Brickwall with cement plaster finish.	100mm thick precast wall panel of 600mm module width.
iv. Others:	
(a) In module of 1M.	In module of 1M.
(b) In-situ refuse chute.	Precast refuse chute.

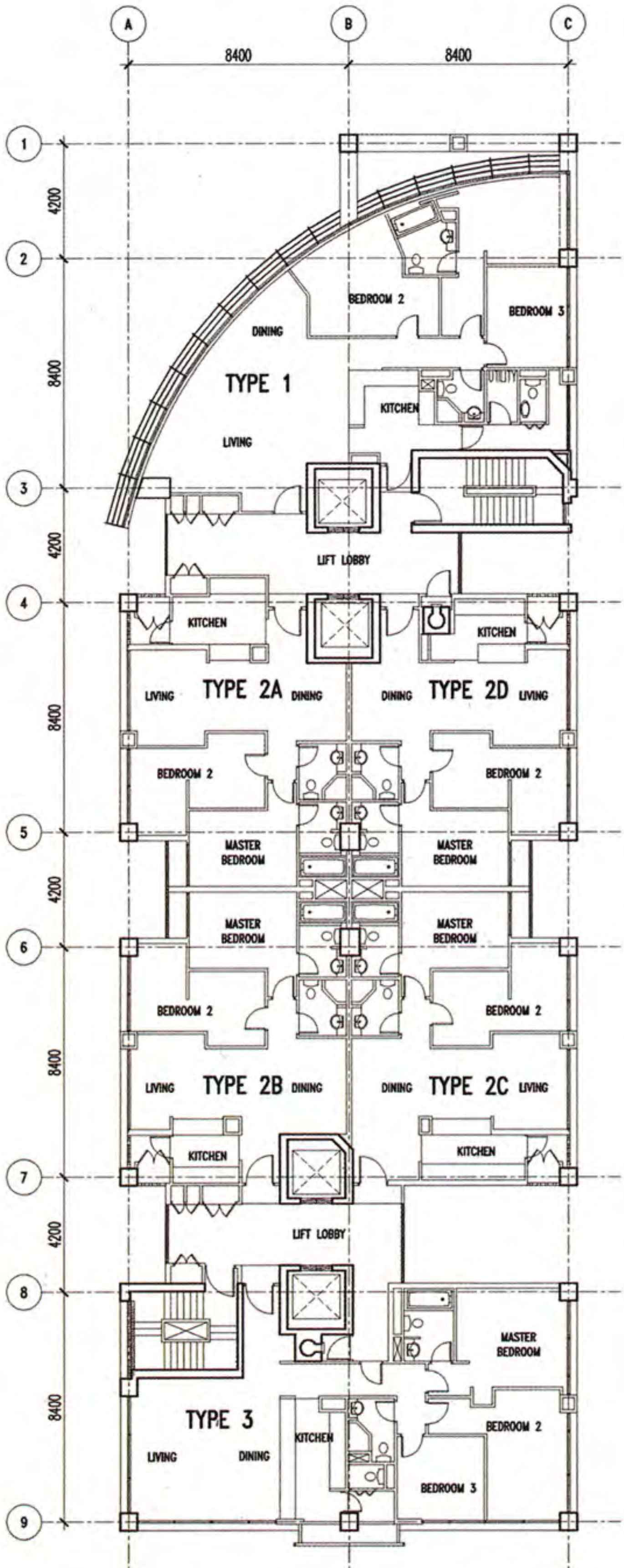
<u>*Notes:*</u>

(i) Due to site constraints, all precast items have to be factory made.

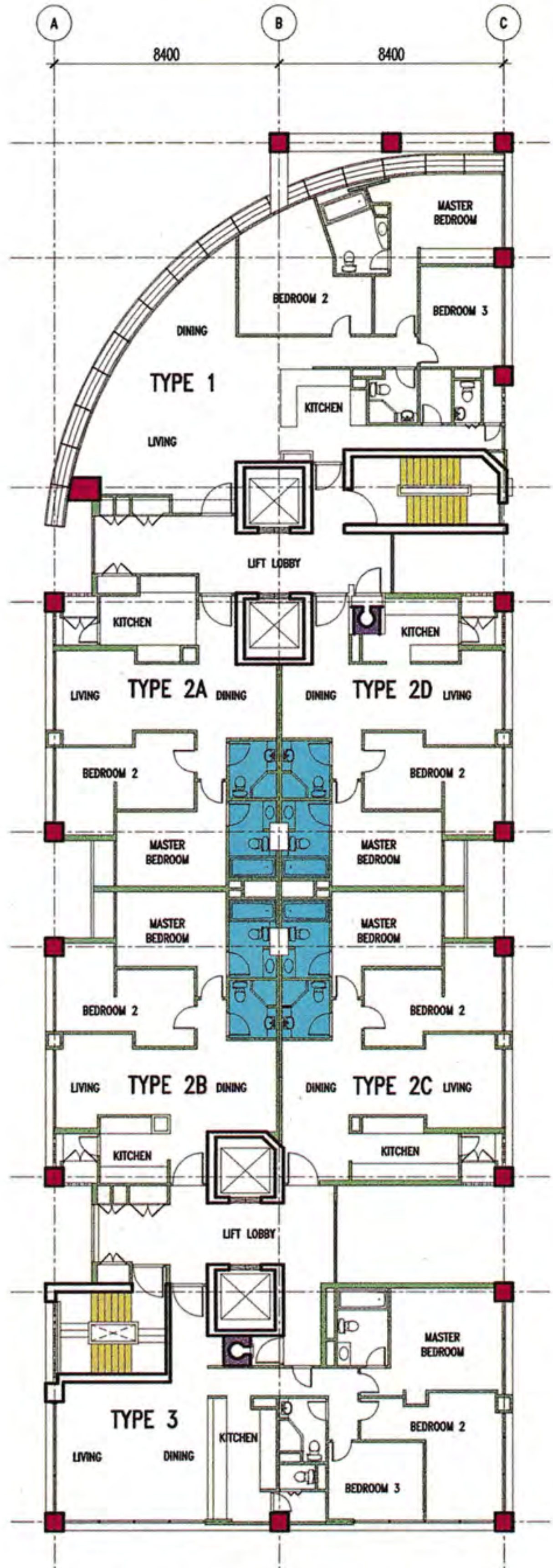
(ii) The modifications under the proposed precast design will not affect the approved planning parameters or the building plan approval.


ST. THOMAS WALK
DEVONSHIRE ROAD
SITE PLAN
0
5
10 METRES
N



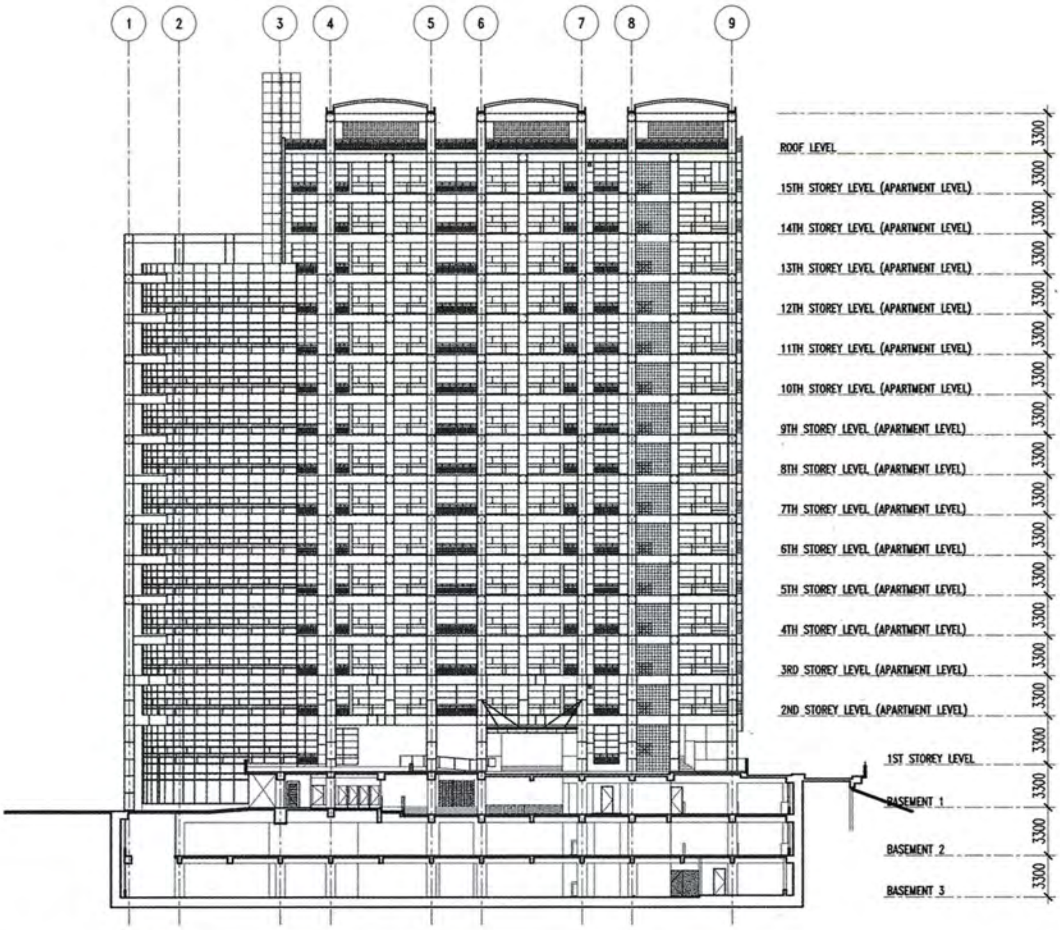


EXISTING DESIGN TYPE '1', '2A', '2B', '2C', '2D' & '3'

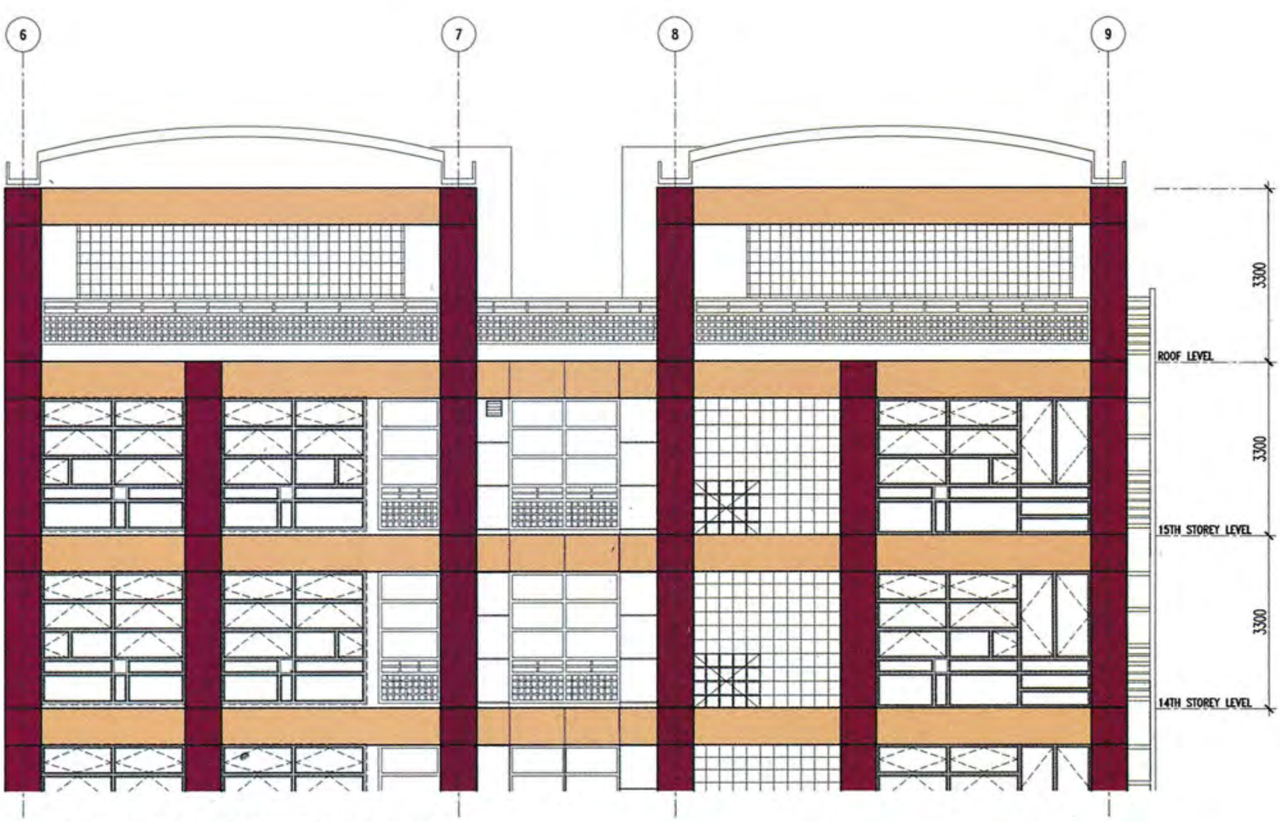


PROPOSED PRECAST DESIGN TYPE '1', '2A', '2B', '2C', '2D' & '3'

LEGEND
- 100 THK LIGHTWEIGHT CONCRETE WALL
- PREFABRICATED TOILET
- PRECAST CONCRETE STAIRS
- PRECAST REFUSE CHUTE
- PRECAST CONCRETE COLUMNS

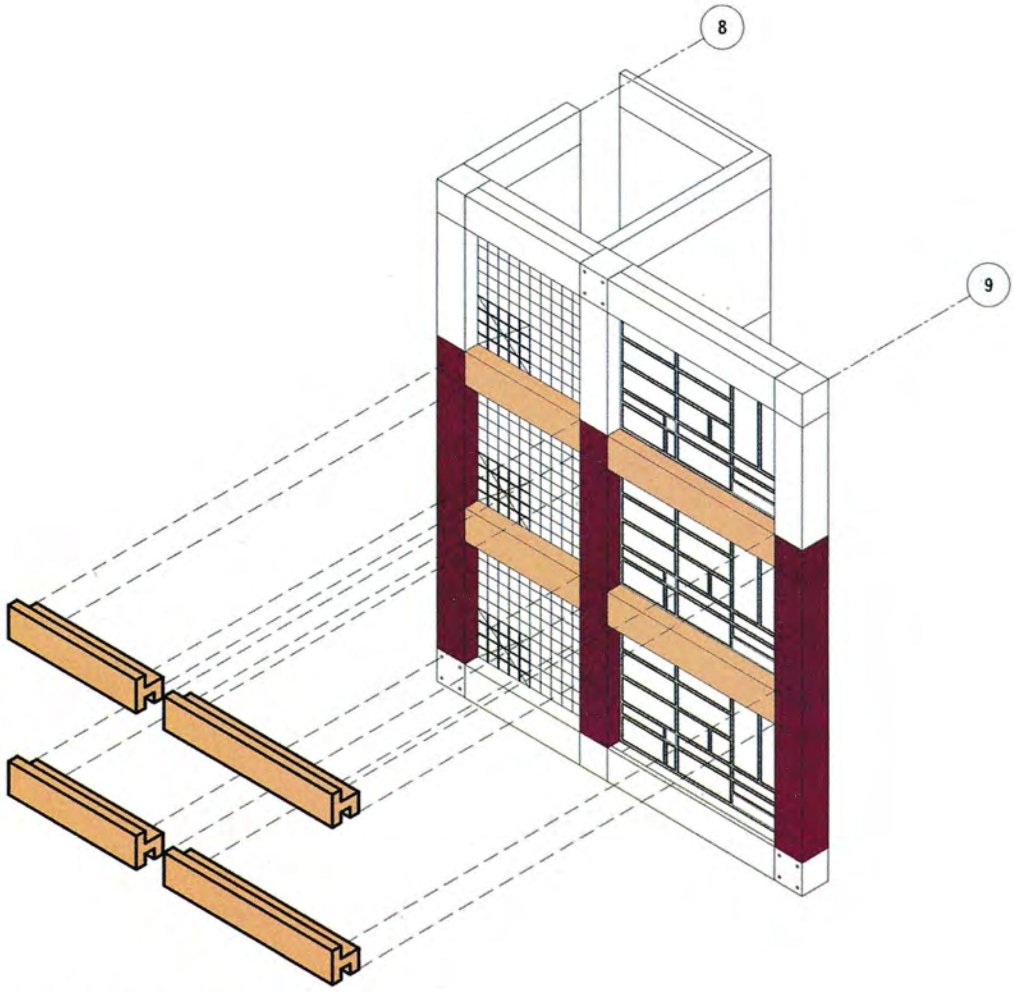


EXISTING ELEVATION

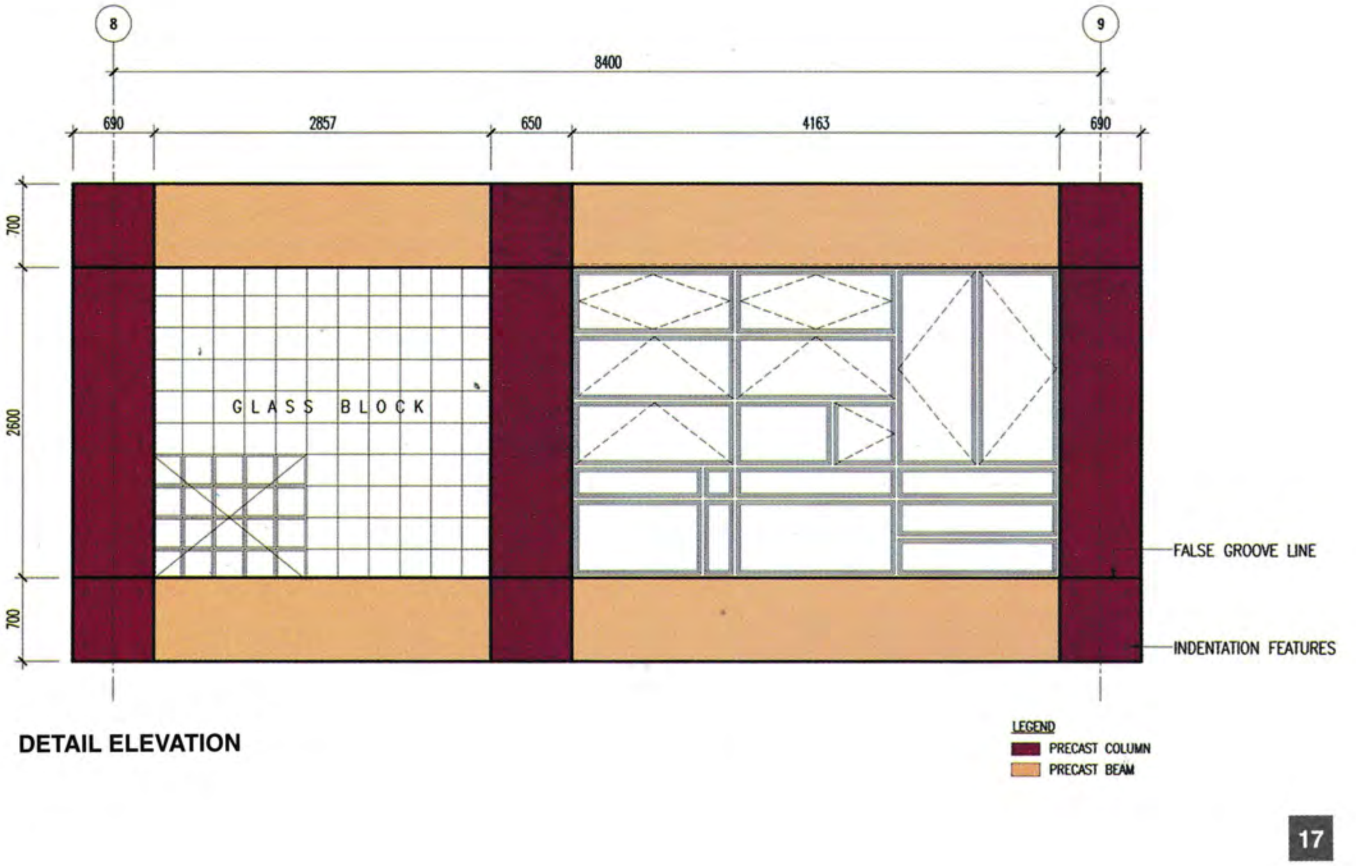


PROPOSED PRECAST CONCRETE ELEVATION

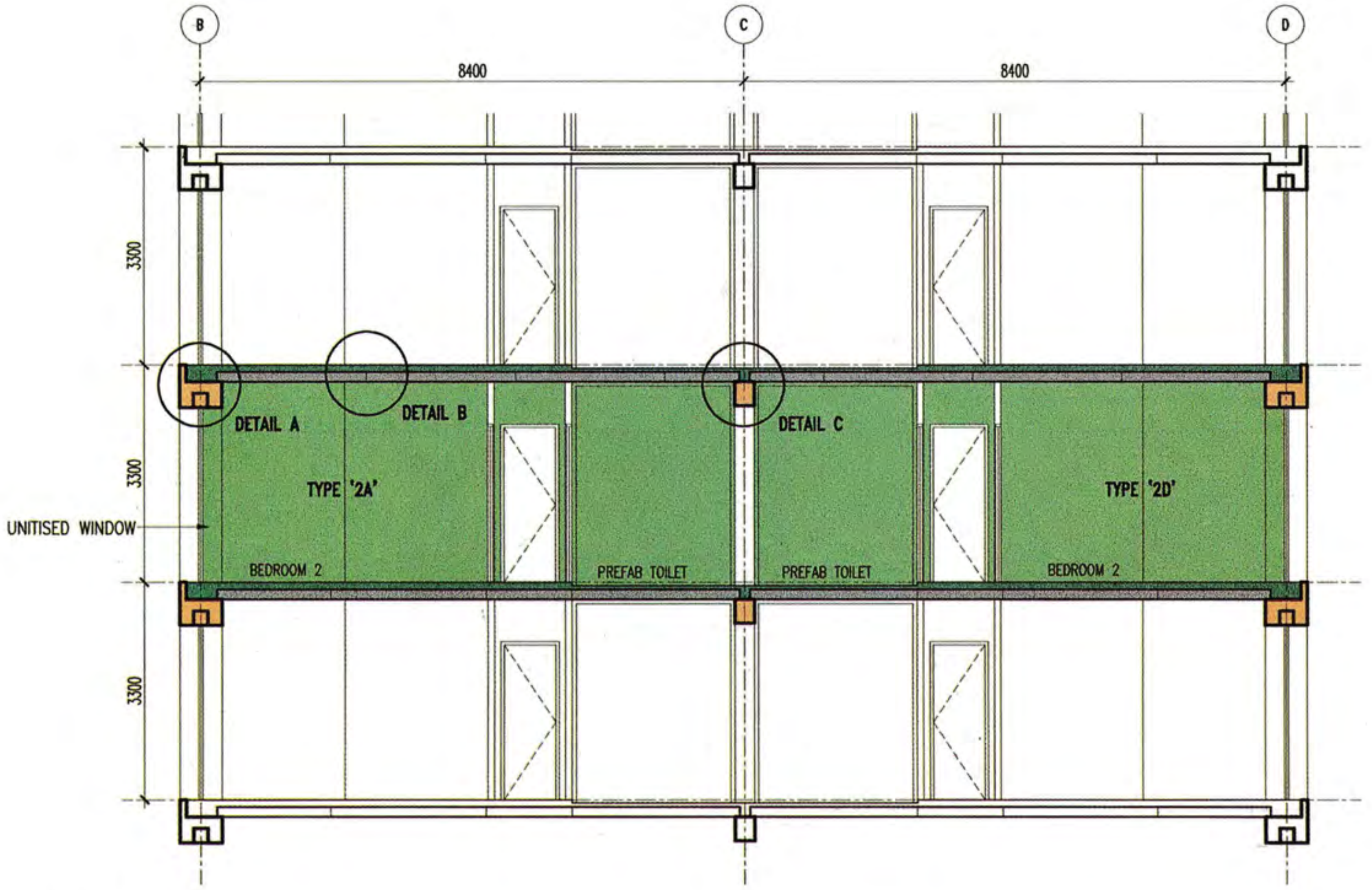
LEGEND
PRECAST 2-TIERED COLUMN
PRECAST BEAM



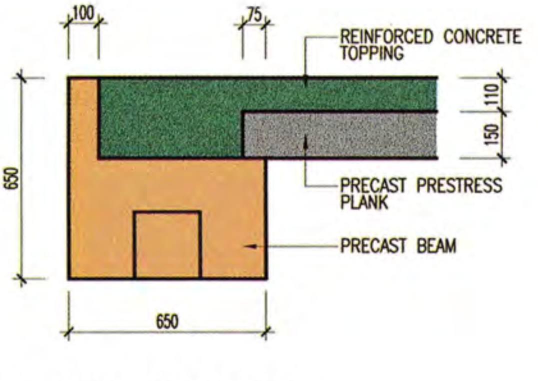
PROPOSED PRECAST COLUMN & BEAM



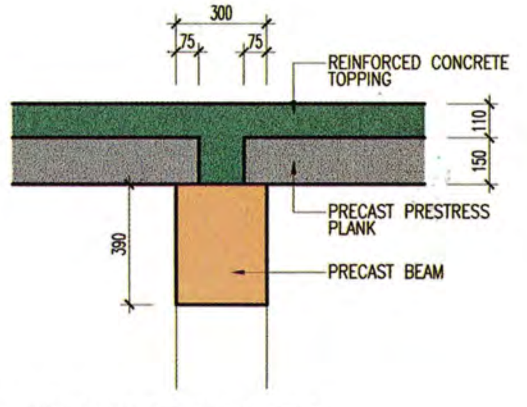
DETAIL ELEVATION



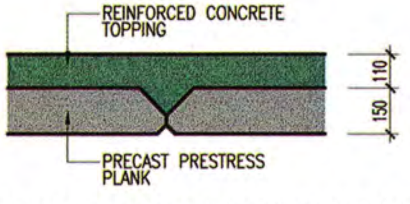
DETAIL SECTION



TYPICAL PRECAST BEAM / PLANK CONNECTION (DETAIL A)

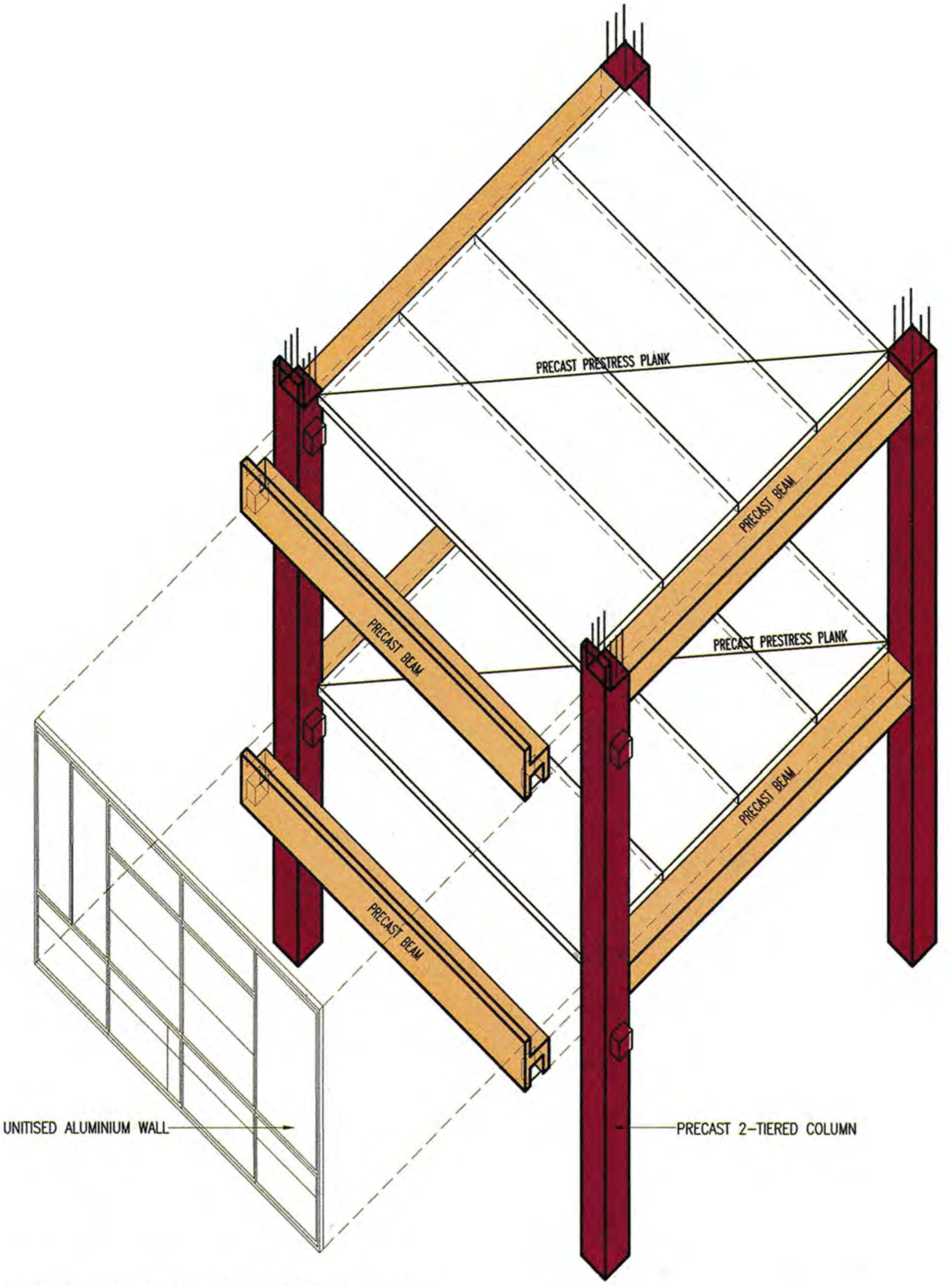


TYPICAL PRECAST BEAM / PLANK CONNECTION (DETAIL C)



TYPICAL PLANK / PLANK CONNECTION (DETAIL B)

LEGEND
- PRECAST BEAM
- PRECAST PRESTRESS PLANK
- REINFORCED CONCRETE TOPPING
- 100 THK LIGHTWEIGHT CONCRETE WALL



ISOMETRIC VIEW OF PRECAST COLUMN, BEAM AND FLOOR CONSTRUCTION

LEGEND
PRECAST BEAM
PRECAST COLUMN

All details shown in drawings are for reference only

1.4 Low-Rise Residential: Casa Pasir Ris

1.4.1 The existing building

The following are the data of the existing building:

A. PROJECT DATA

Architect	Architects Group Associates Pte Ltd
Building Type	Private Residential
No. of Units	58
Building Height	3 Storey with Basement Carpark
Location	201, Jalan Loyang Besar
Site Area	5,744.1m^2
Gross Floor Area	7,225.45m^2
Plot Ratio	1.2
Building Coverage	40.0%
Construction Cost	13.5 million
Year of Completion	1997
Construction Period	10 months (as per tender specifications)

B. EXISTING DESIGN

The project was a conventional in-situ reinforced concrete structure with brickwall and plastering.

C. EXISTING DESIGN FEATURES

The following features were incorporated into the facade:

- Concrete trellis
- Concrete planter box
- Concrete ledge for air-conditioning unit
- Cornice at roof fascia, around window and stair opening
- Rounded edge at corner

1.4.2 Proposed precast design of the building

The existing layout plan, its dimensions and structural system are reviewed. Owing to the tight and irregular site area, the layout plans are designed to maximise utilisation of the site. Changes to its dimensions are difficult without affecting the floor area. However, all the facade components such as planter boxes and concrete trellis are standardised in dimensions. Similarly, the bathrooms are also standardised to reduce the number of types.

The changes made to the existing design are summarised as follow:

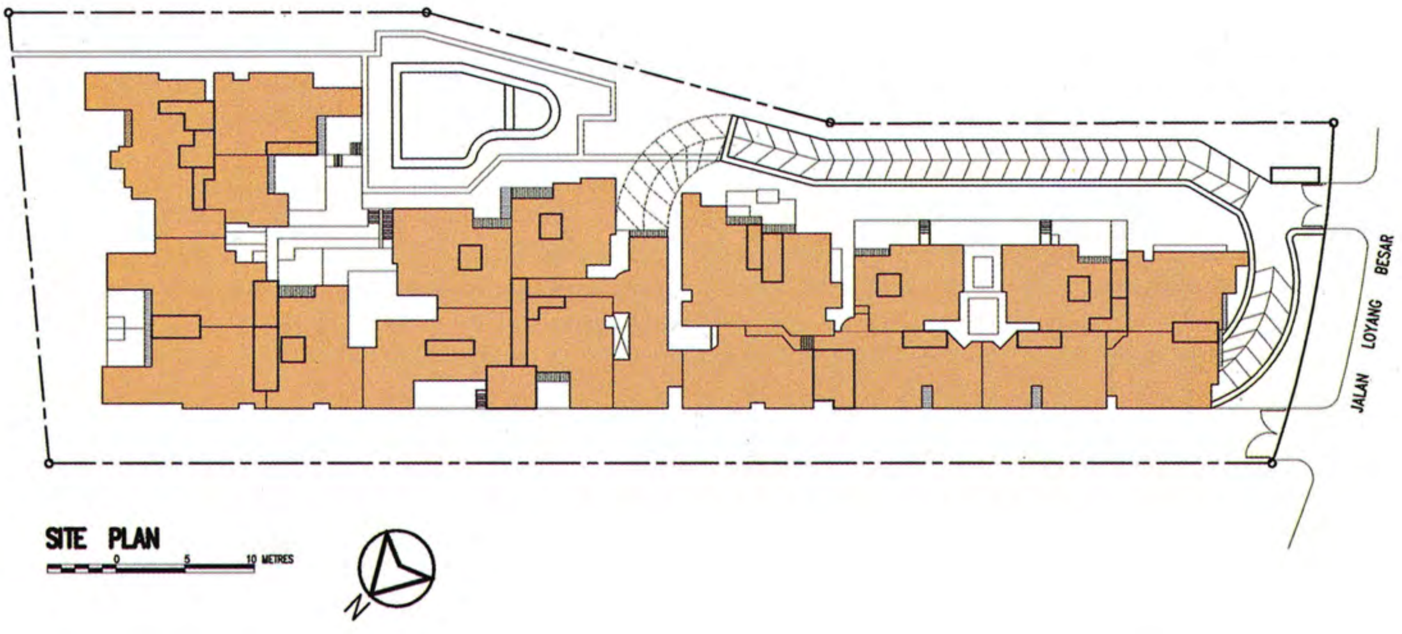
EXISTING DESIGN	PROPOSED PRECAST DESIGN
A. Structural	
i. Basement And 1st Storey Slab:	
(a) In-situ construction	In situ beam and slab construction due to high number of reinforced concrete transfer beams at the first storey slab over the basement carpark.
ii. 1st Storey Columns, 2nd / 3rd Storey And Roof:	
(a) In-situ construction	Reinforced concrete post tension flat plate construction with slab thickness of 200/150mm. In-situ edge beams 200 x 500 mm are proposed. Precast three tiered column with rounded edge corners and 200 x 500mm rectangular column are proposed.
iii. Staircase:	
(a) In-situ staircase	Precast staircase with in-situ landing.
B. Architectural	
i. External Facade And Features:	
(a) Brick infill wall, reinforced concrete beam, column and fascia. Cement and sand plaster to external wall.	Pre-finish wash aggregate precast external wall. Precast roof fascia facade wall, with cornice and window ledge incorporated. Window sizes are standardised to limit the variation of sizes. The following are precast: Concrete trellis, concrete planter box, concrete ledge for air-conditioning unit. Sizes of these precast items are standardised.
ii. Bathroom:	
(a) Brickwalls with tile finished & plasterboard suspended ceiling.	Prefabricated bathroom using steel frame wall panel pre-laid with ceramic tile.
iii. Internal Wall:	
(a) Brickwall with cement plaster finish.	200mm thick precision block for party wall. 100mm thick lightweight concrete panels for all internal walls and 100 mm thick precision blockwall for bathroom and kitchen wall.
iv. Others:	
(a) In-situ refuse chute	Precast refuse chute.

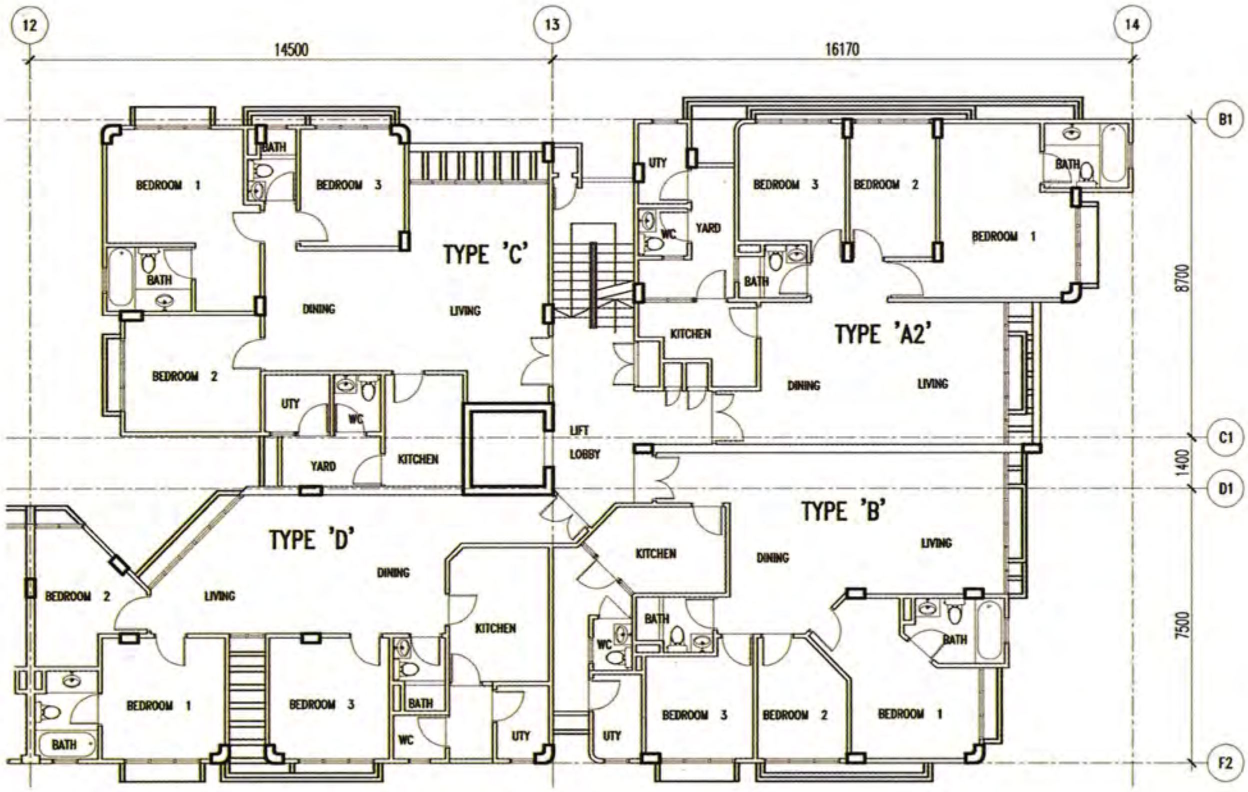
<u>*Notes:*</u>

(i) Core wall for liftshaft - using four precast wall of 200mm thick.

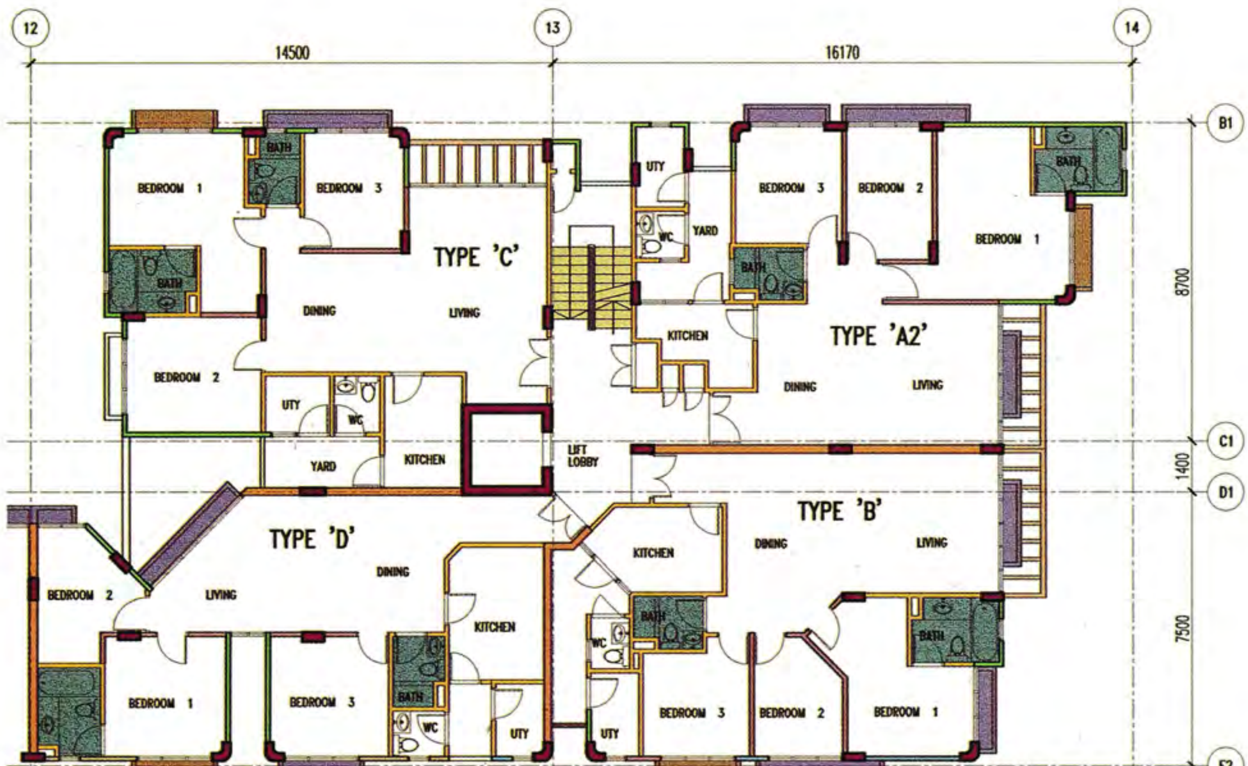
(ii) Due to the compactness of the site, all precast items have to be done off-site.

(iii) The modifications under the proposed precast design will not affect the approved planning parameters or the building plan approval.


JALAN LOYANG BESAR
SITE PLAN
0
5
10 METRES
N



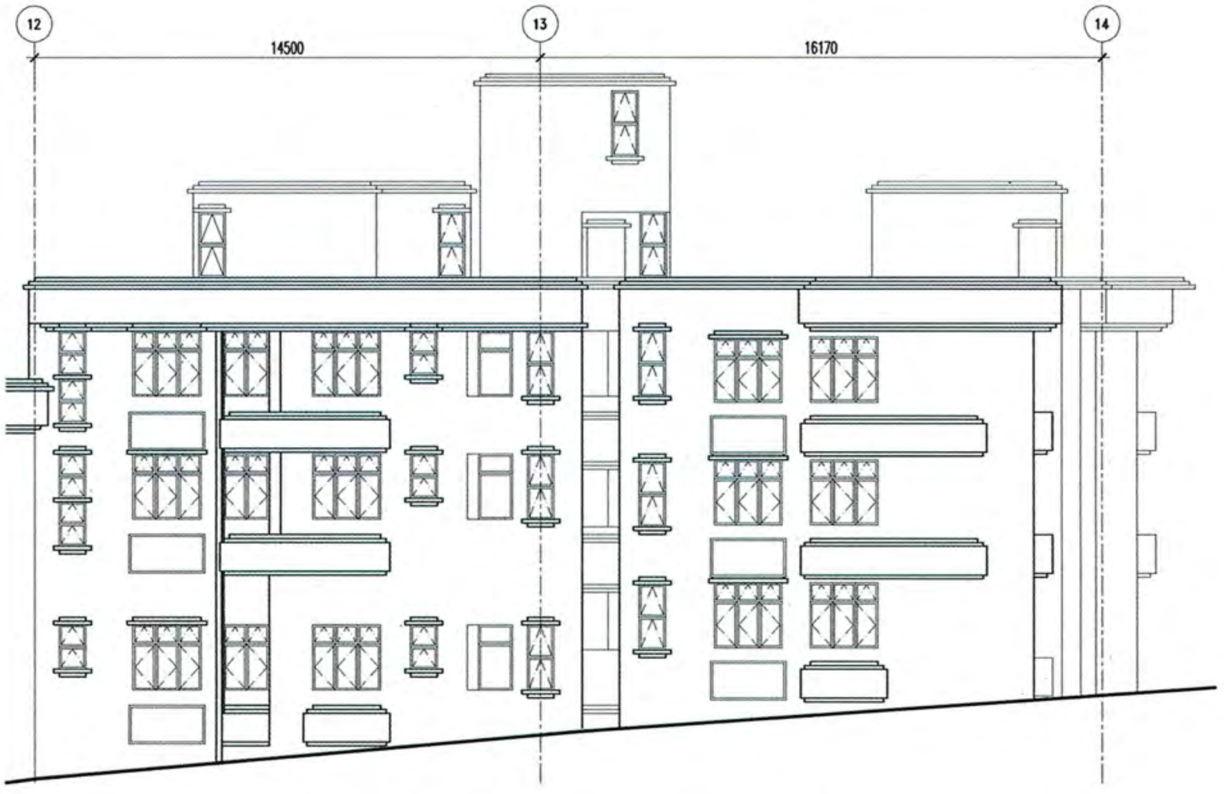
EXISTING DESIGN: TYPE 'A2', 'B', 'C' & 'D'



PROPOSED PRECAST DESIGN: TYPE 'A2', 'B', 'C' & 'D'

LEGEND

- 100 THK PRECISION BLOCKWALL WITH PLASTER AND WALL TILES
- 100 THK LIGHTWEIGHT CONCRETE WALL
- PRECAST STAIRS
- 200 THK PRECISION BLOCKWALL
- PRECAST COLUMNS AND WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST PLANTER/OVERHANG
- PRECAST A/C LEDGE
- PRECAST TRELLIS
- PREFABRICATED TOILET



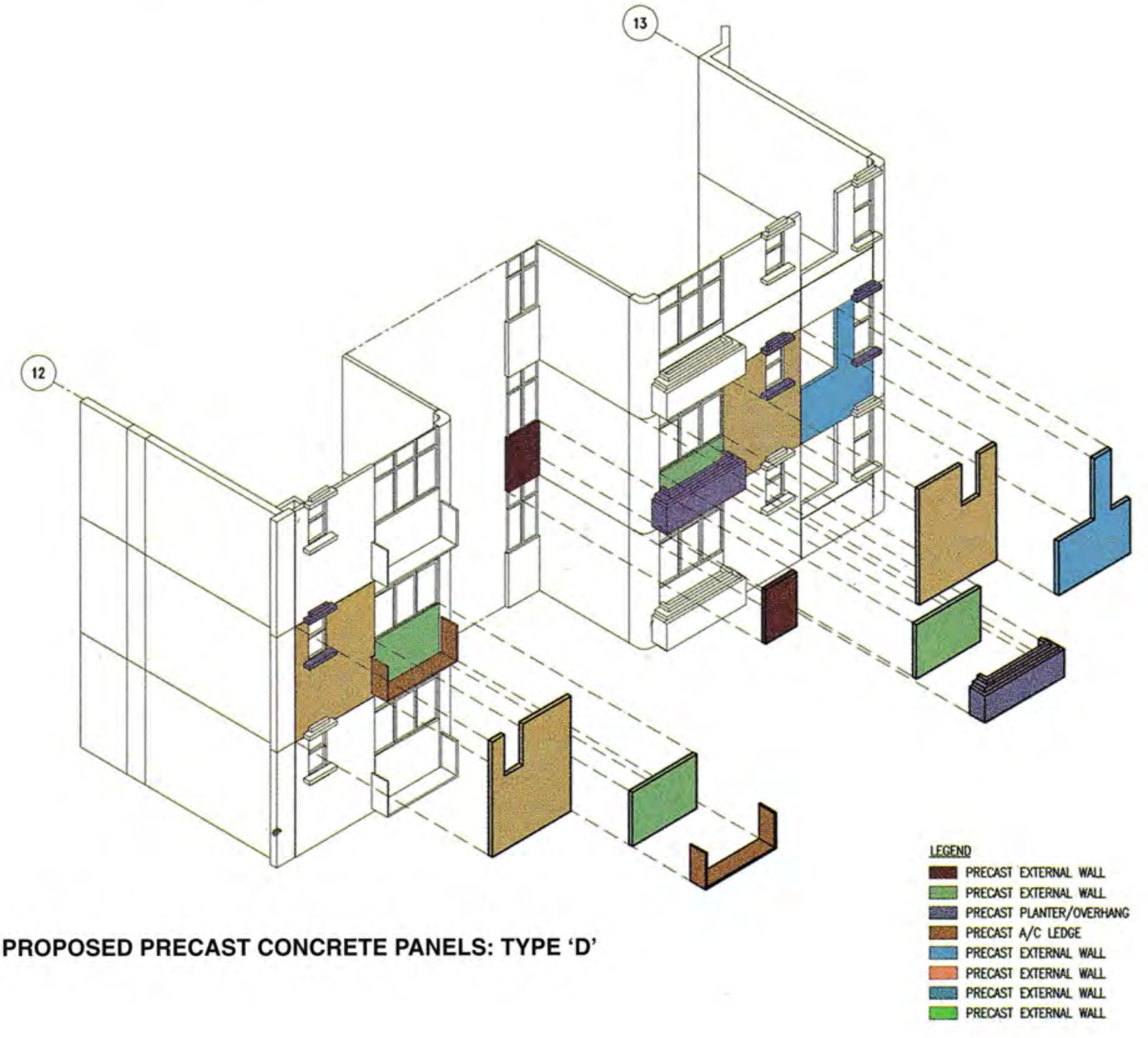
EXISTING DESIGN: ELEVATION (PART 1)

PROPOSED PRECAST DESIGN: ELEVATION (PART 1)

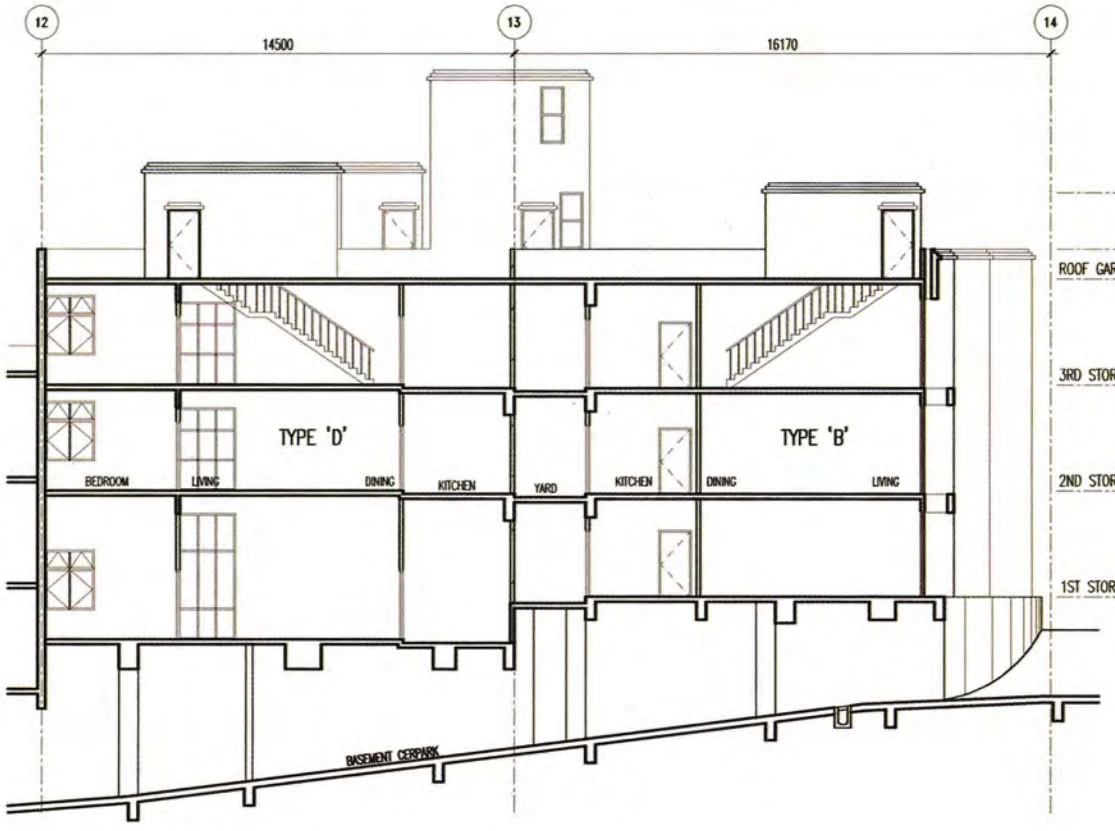
LEGEND

- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST CONCRETE COLUMNS
- PRECAST EXTERNAL WALL
- PRECAST EXTERNAL WALL
- PRECAST CONCRETE PLANTER/OVERHANG
- PRECAST CONCRETE A/C LEDGE

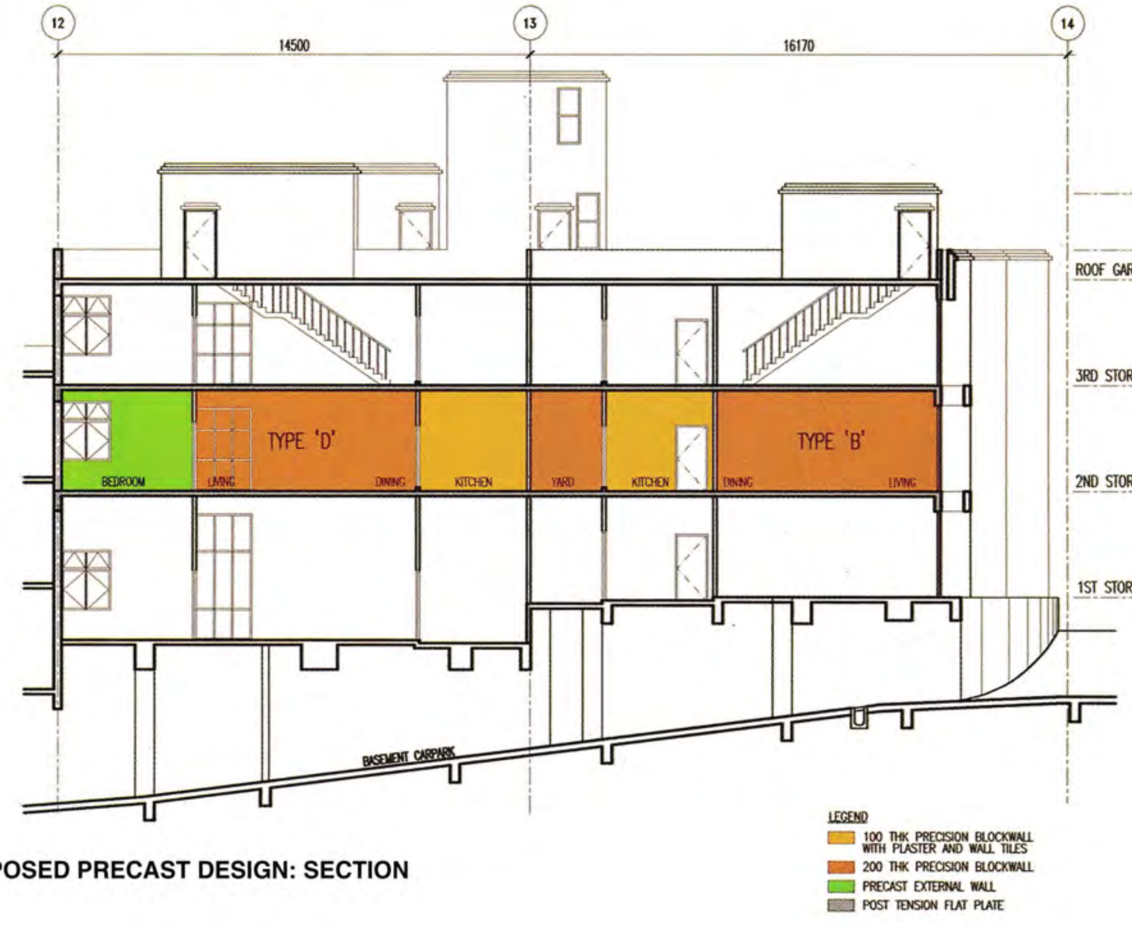
PROPOSED PRECAST CONCRETE PANELS: TYPE 'B'



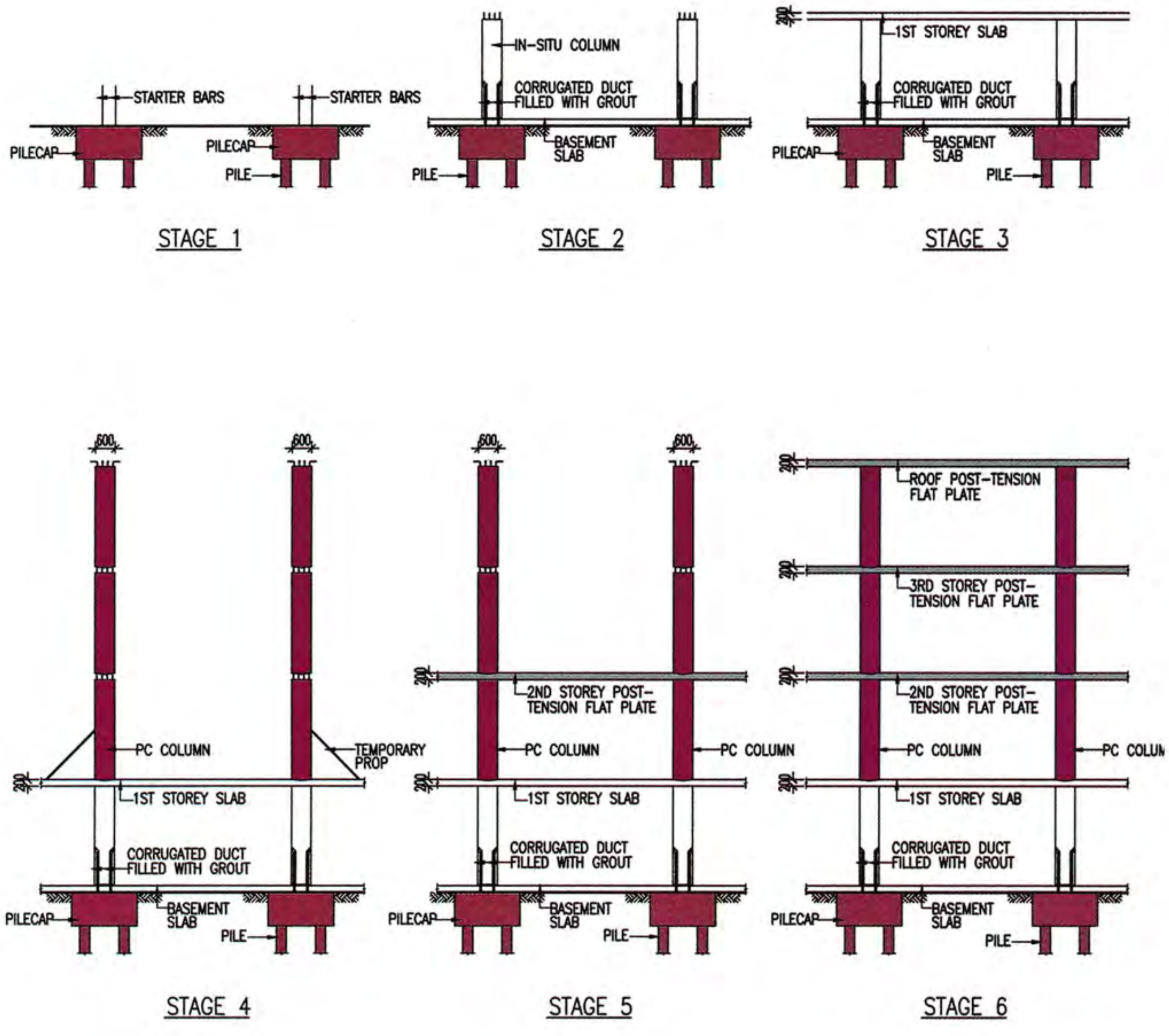
PROPOSED PRECAST CONCRETE PANELS: TYPE 'D'



EXISTING DESIGN: SECTION

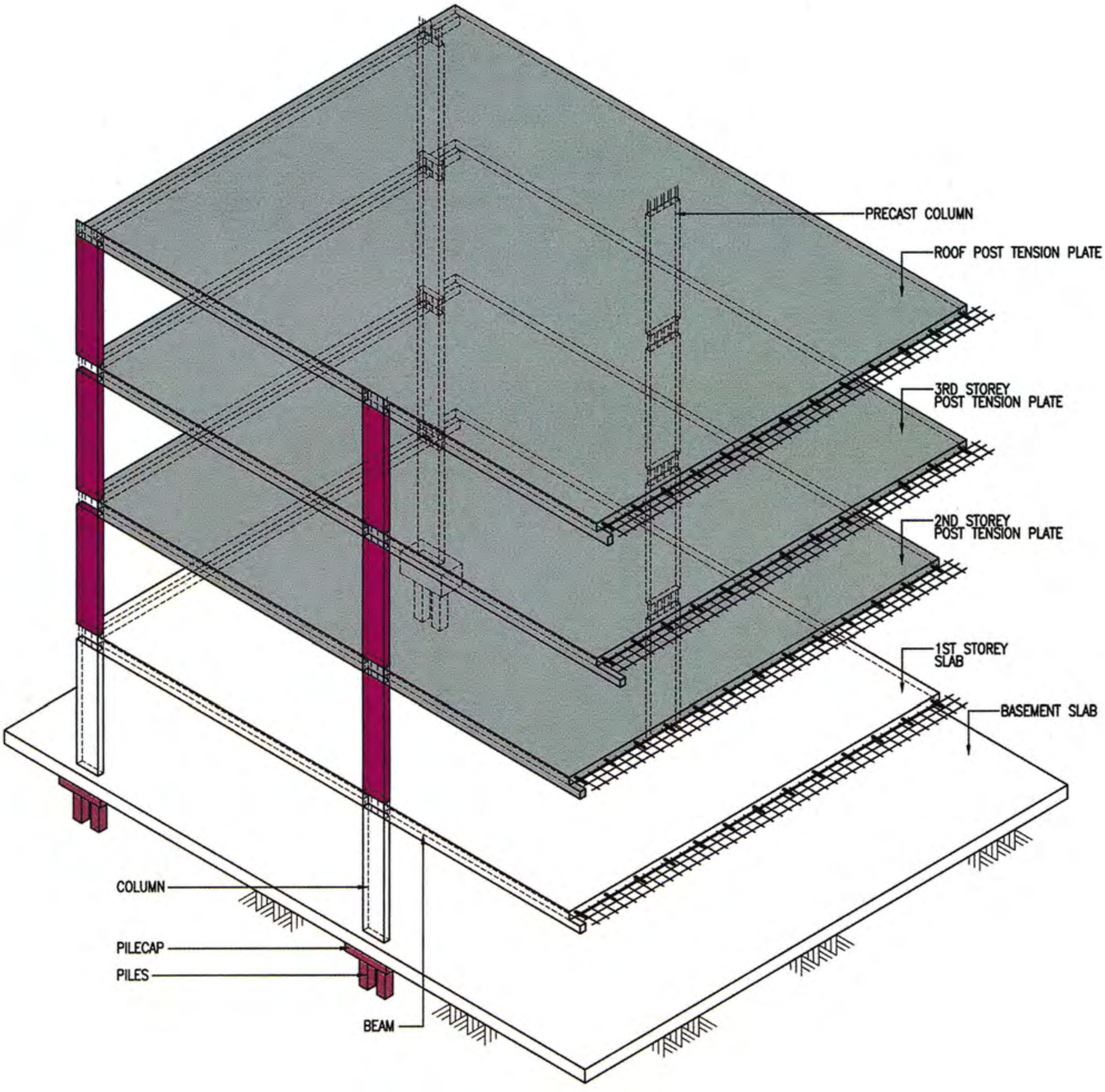


PROPOSED PRECAST DESIGN: SECTION



CONSTRUCTION SEQUENCE FOR THE PROPOSED PRECAST SYSTEM

LEGEND
- PRECAST CONCRETE COLUMNS
- PILECAP
- POST TENSION FLAT PLATE



ISOMETRIC VIEW OF THE PRECAST SYSTEM

All details shown in drawings are for reference only

LEGEND
PRECAST COLUMNS
PILECAP
POST TENSION FLAT PLATE

1.5 Findings Of The Demonstration Projects

From the three demonstration studies, it is concluded that precast construction is a feasible alternative design for private residential projects, be it low-rise, medium-rise or high-rise. In addition, precast design should not be a conversion from cast in-situ projects. It is apparent that the larger the size of the project, the more advantages it will be for the precast construction.

In the demonstration studies, the major challenge is to retain the existing design parameters. Few changes are made to the design of these buildings. This of course will carry a certain cost penalty and constraint in the design of the precast construction and components. It can be concluded that if these projects are designed initially with precast construction discipline, the cost advantage of the precast system will be pronounced even more than results showed by the demonstration studies.

By using more industry standardised components such as staircases, internal and exterior wall panels, etc, as produced by the precasters, the cost for precast components will be reduced. With the constant increase in labour cost due to the shortage of labour, the cost advantage of precast construction will increase.

The traditional method of applying exterior finishes on site can be avoided by using the pre-finished precast concrete components. This will reduce the need to carry out repair work or re-painting commonly required for the in-situ applied finishes. The production of precast components under factory supervision will reduce defects. Repair and rectification work can therefore be greatly minimised. This hopefully will lower the number of litigation between purchaser and developer on workmanship and defects especially for residential development.

In summary, the studies show that precast design:

- Allows architects to explore various design options.
- Enables the existing number of units and unit layouts to be maintained.
- Allows quality and finishes to be improved.
- Improves weathering features which result in lower maintenance costs.
- Reduces construction time.
- Does not compromise existing planning and building requirements.

The conversion from existing cast in-situ design to alternative precast design also increases the buildability scores of the three demonstration projects. The new buildability scores achieved by these demonstration projects are summarised as follows:

Projects	Buildability score of existing design	Buildability score of alternative design
Valley Park	42	84
The Bayron	48	85
Casa Pasir Ris	43	72

CHAPTER TWO
COST ANALYSIS

2.1 General

The cost of precast components is the aggregate of :

- Production Cost
- Transportation Cost
- Installation Cost

Production cost for precast components depends on the type, size and quantity of the precast components. Transportation cost does not only depend on the distance between the site and the precast yard but also on the types and sizes of the components. For production of precast components on-site, transportation cost is avoided, although there are additional costs for setting up temporary site facilities. Installation cost depends on the size and weight of the components besides jointing details. The size and weight of precast components will also determine the capacity of crane required.

As a rule of thumb, the three different types of cost arising from supply, delivery and installation of precast components are:

Production Cost	–	78% to 83%
Transportation Cost	–	2% to 3%
Installation Cost	–	15% to 20%

Selection of type and capacity of crane will depend on size and weight of precast component

Generally, the unit cost of the equivalent in-situ components tends to be slightly cheaper than precast components. However, taking into considerations the shorter construction period and other reduced site expenses, the cost of precast components can be competitive. With careful planning and proper detailing of the precast components, precast construction can be as cost effective as in-situ construction.

2.2 Is Precast More Expensive?

There is a whole range of factors including quality of materials and finishes, price fluctuation, tendering environment and contractor's efficiency that will affect construction cost. Allegations of higher cost in recent years were usually associated mainly with precast construction when the demand for precast components was much higher than supply. It was also a period when the precasters were mainly focusing on the HDB market. In addition, higher cost was partly attributed to conversion of original design to precast construction. The situation has changed drastically in the past two years; prices of precast components are currently very competitive.

On the other hand, the savings were often ignored or unreported. Precast construction results in faster construction and leads to reduced overheads for contractors. The savings in interest due to shorter construction period, fewer number of workers, cheaper house keeping and lesser levies all added up to a significant amount and must be taken into consideration.

The shorter construction period also means lower interest paid on construction and development loans. This enables early occupancy and quicker investment returns for the developers.

The following example shows possible savings for the developer/client if precast is used:

Assume site area is 15,000 m^2 and the development consists of 4 blocks of 10 storey condominium. Each storey has an area of 754 m^2. Land cost = \$4,000/m^2 and construction cost = \$1400/m^2.

(a) Project Cost

i. Land cost	= 15,000m^2 x \$4,000psm	= \$60,000,000
ii. Legal fees and stamp duty	= 4% of land cost	= \$2,400,000
iii. Property tax	= 0.6% of land cost x duration	= \$1,170,000
iv. Construction cost	= 4 x 10 x 754m^2 x \$1,400psm	= \$42,224,000
v. Associated cost	= 8% of construction cost	= \$3,378,000
vi. Marketing and advertising	= 5% of construction cost	= \$2,111,200
vii. GST	= 3% of item iv, v and vi	= \$1,431,400
Total		= \$112,715,000

(b) Construction Period

Conventional construction = 24 months   Pre-construction period = 15 months

Precast construction = 21 months   Pre-construction period = 15 months

(c) Saving In Financing Cost

Interest Rate	= 6%	
For land	= 6% of item i, ii and iii x (39 - 36)/12	= \$953,550
For construction	= 6% of item iv, v, vi and vii x (39 - 36)/12 x 0.5*	= \$368,590
Total		= \$1,322,140

(d) Additional Construction Cost For Precast Construction

Depending on the design, there may be some additional construction cost. This additional cost can be offset by the savings in interest and preliminaries. Refer to Section 2.4 for more details.

* 0.5 is a financing factor used for costing purpose.

In the long term, buildable projects will be more cost competitive as designers and contractors become confident in adopting buildable designs and use precast components more widely. A good example is the standard precast components used in HDB projects. The unit price of precast staircase, precast refuse chute and precast water tank has fallen over the years (refer to the table below).

Prices of Precast Components

Components	Unit Price in 1985	Unit Price in May 1997	Unit Price in Dec 1998	Unit Price in July 1999
Staircase	\$450 - \$500	\$500	\$400	\$400
Refuse chute	\$550 - \$600	\$520	\$480	\$480
Water tank	\$12,000 - \$13,000	\$9,800 - \$12,000	\$8,000	\$8,000

Cost savings arising from fewer site workers through using buildable design will be significant as the trend in developed countries shows that labour cost will increase. The Ministry of Manpower had announced that the foreign worker's levy for construction sector would be raised annually (the recent reduction in foreign worker's levy does not apply to construction sector). At the same time, the man-year entitlement for foreign workers from non-traditional sources had been cut by 10% with effect from 1 April 1999. The man-year entitlement will be further reduced to 50% of 1998 level by year 2010.

Precast projects use fewer workers, cutting down labour cost

The recent increase in the number of lawsuits pertaining to building defects in residential projects has raised concern for the level of workmanship associated with cast in-situ method of construction. The shortage of skilled labour has made it difficult to achieve the desired level of quality demanded by developers and home buyers. It has reached a stage where major developers specify a pre-determined CONQUAS score as one of the contractual obligations to be fulfilled by contractors. There are cases where contractors have been penalised for failure to attain the minimum CONQUAS score.

A clean precast site (above) will have less cleaning costs than a cast in-stu project (right)

Provisions by contractors to cover the high costs of potential litigation and rectification of defects have indirectly added to the overall project development costs. Although precast construction could not eliminate defects totally, better quality of workmanship could be assured. Coupled with the lower costs for housekeeping and safer site conditions, precast construction has gradually gained popularity.

2.3 Savings In Preliminaries

Generally, costs for preliminaries range from 6% – 10% of the total project cost. Besides better quality and shorter construction period, precast construction also reduces the overall costs for site preliminaries.

The costs for cleaning, site hygiene, scaffolding and staging can be very significant for cast in-situ projects. Besides the above factors, overheads such as payment for staff overtime should also be reduced due to shorter construction period. By using precast, the various preliminaries can be reduced substantially, as seen in Table 1 on the next page.

2.4 Case Studies

For the three demonstration projects illustrated in Chapter One, an elemental cost comparison is carried out to establish the differences in cost. For these three cases, the following factors apply:

(a) There is no change to the basement and external works. Only the typical floors and roof are changed from cast in-situ to precast. Concrete grade remains the same.

(b) The existing foundation is adequate for the proposed precast design scheme.

(c) The prefabricated bathrooms have similar finishes to conventional toilets except for Valley Park.

The methodology for the cost comparison is as follows:

(a) The building elements that have been changed from cast in-situ to precast are identified and quantified.

(b) The elements are priced based on second quarter 1999 prices.

(c) The costings have taken into account the increased production efficiency due to modular co-ordination and high level of repetition of components.

(d) The difference in cost is expressed as a percentage of the estimated construction cost for the projects.

Scaffolding and formwork constitute a high percentage of preliminaries for cast in-situ projects

Table 1: Preliminaries for a typical high-rise residential project with significant cost differences if precast design is adopted (percentage in terms of total cost for preliminaries)

No	Item	Cast In-situ project Range	Precast Project Range	Extras / Savings
1	Scaffolding and staging	12% - 18%	2.4% - 6.8%	Savings from 60% - 80%
2	Periodical cleaning and rubbish removal	5% - 17%	1.5% - 4.5%	Savings from 70%- 75%
3	Cleaning on completion	2% - 3%	1% - 2%	Savings from 30% - 50%
4	Pollution, mosquito control and site hygiene	0.5% - 3%	0.5% - 2%	Savings up to 30%
5	Plant and equipment	20% - 36%	26% - 39%	Extras from 8% - 30%

Table 2: Preliminaries for a typical high-rise residential project with no significant cost difference if precast design is adopted (percentage in terms of total cost for preliminaries)

No	Item	Cast in-situ project Range	Precast Project Range
1	Water and electricity	2% - 20%	Same
2	Temporary shoring and strutting*	0% - 10%	Same
3	Setting out	1% - 6%	Same
4	Temporary building#	3% - 3.5%	Same
5	Safety measures	2% - 3%	Same
6	Temporary road and access	0% - 3%	Same
7	Instrumentation and monitoring of surrounding settlement	0% - 3%	Same
8	Temporary drainage system	0.4% - 1%	Same
9	Temporary hoarding	0.3% - 1%	Same
10	Test of material	0.1% - 0.4%	Same
11	Safeguarding of works	<3%	Same
12	Maintenance and use of road	<2%	Same
13	Progress photograph	<2%	Same
14	Fire protection	<1.5%	Same
15	Furniture and equipment	<1.5%	Same
16	Protection of works	<1.5%	Same
17	Mock-ups	<1.5%	Same
18	Fuel for machinery	<1%	Same
19	Co-ordination drawings	<1%	Same
20	As-built drawings	<0.3%	Same
21	Shed	<0.3%	Same
22	Transportation for temporary material/machinery	<0.2%	Same

* Temporary shoring and strutting mainly depend on site conditions. For example, if the site has marine soil and is encroached by existing drainage and cables, the temporary shoring and strutting costs may constitute up to 50% or more of total cost for preliminaries. The normal range is 0% - 10%.

\# Worker accommodation is included in temporary building.

2.4.1 High-rise residential: Valley Park

Elements that have been changed :

Elements	Original Design	Proposed Alternative
Column	In-situ	No columns. Precast shear walls are adopted
Beam	In-situ	Precast
Floor	In-situ	Precast
Staircase	In-situ	Precast
External wall	In-situ/ brick	Precast
Internal wall	In-situ/ brick	Precast
Refuse chute	In-situ	Precast
Bathroom	Conventional	Prefabricated
Balcony	Precast	Precast

Cost Comparison:

Elements	Original Design $/m^2	Proposed Alternative $/m^2	Difference (%)
Preliminary	see note 1	11 (saving in preliminary cost)	see note 1
Column	6	0	-100.0%
Beam	50	9	-83%
Floor	55	67	22%
Staircase	6	7	21%
External wall	68	103	51%
Internal wall	67	97	45%
Refuse chute	12	13	6%
Bathroom	124	142	15%
Balcony	29	28	-2%
Total:	417	455	
Additional Cost		38	
Percentage of construction cost			2.7%

Note:

[1] The preliminaries constitute about 10% of the overall construction cost. Using precast, these can be reduced by 8%. This works out to a saving of about $11/m^2.

The construction cost for apartment based on original design is set at $1,400/m^2. The cost analysis has taken into account the size of the development, number of precast components, number of repetitions, number of storey per block and site area.

As this is a big development, the opportunity for repetition is very high. Therefore the proposed precast alternative is only $38/m^2 or 2.7% more expensive than the original design in terms of the overall construction cost.

2.4.2 Medium-rise residential: The Bayron

Elements that have been changed

Elements	Original Design	Proposed Alternative
Column	In-situ	Precast
Beam	In-situ	Precast
Floor	In-situ	Precast
Staircase	In-situ	Precast
External wall	In-situ/ brick	Precast
Internal wall	In-situ/ brick	In-situ / precision blocks / precast panels
Refuse chute	In-situ	Precast
Bathroom	Conventional	Prefabricated

Cost Comparison:

Elements	Original Design $\$/m^2$	Proposed Alternative $\$/m^2$	Difference (%)
Preliminary	see note 1	11 (saving in preliminary cost)	see note 1
Column	21	20	-5%
Beam	57	62	8%
Floor	51	55	8%
Staircase	6	7	23%
External wall	15	28	87%
Internal wall	78	100	28%
Refuse chute	6	6	8%
Bathroom	97	113	16%
Total:	331	380	
Additional Cost		49	
Percentage of construction cost			3.5%

Note:

[1] The preliminaries constitute about 10% of the overall construction cost. Using precast, these can be reduced by 8%. This works out to a saving of $\$11/m^2$.

The construction cost for apartment based on original design is set at $\$1,400/m^2$. The cost analysis has taken into account the size of the development, number of precast components, number of repetitions, number of storey per block and site area.

As this is a medium size development, the opportunity for repetition is still reasonably high. Therefore the proposed precast alternative is only $\$49/m^2$ or 3.5% more expensive than the original design in terms of the overall construction cost.

2.4.3 Low-rise residential: Casa Pasir Ris

Elements that have been changed

Elements	Original Design	Proposed Alternative
Column	In-situ	Precast
Beam	In-situ	In-situ (perimeter edge beams only)
Floor	In-situ	In-situ (flat plate)
Staircase	In-situ	Precast
External wall	In-situ/ brick	Precast
Internal wall	In-situ/ brick	Precision blocks/precast panel
Refuse chute	In-situ	Precast
Bathroom	Conventional	Prefabricated

Cost Comparison:

Elements	Original Design $/m^2	Proposed Alternative $/m^2	Difference (%)
Preliminary	see note 1	11 (saving in preliminary cost)	see note 1
Column	24	19	-22%
Beam	60	18	-69%
Floor	55	76	39%
Staircase	4	4	23%
External wall	28	111	303%
Internal wall	63	55	-13%
Refuse chute	4	4	8%
Bathroom	156	185	19%
Total:	394	461	
Additional Cost		67	
Percentage of construction cost			4.8%

Note:

[1] The preliminaries constitute about 10% of the overall construction cost. Using precast, these can be reduced by 8%. This works out to a saving of $11/m^2.

The construction cost for apartment based on original design is set at $1,400/m^2. The cost analysis has taken into account the size of the development, number of precast components, number of repetitions, number of storey per block and site area.

As this is a small development, in-situ flat plate for the structural frame is adopted since the number of repetition for precast components is lower. Therefore the proposed precast alternative is $67/m^2 or 4.8% more expensive than the original design in terms of the overall construction cost.

2.4.4 Saving in interest payable

From Section 2.4.1, 2.4.2 and 2.4.3, the extra cost ranges from 9% to 17%. Since the structural cost for a typical project is approximately 30% of the overall construction cost, the overall construction cost increase ranges from 3% to 5%.

However, this additional cost does not take into consideration the saving of interest in financing cost and other benefits of shorter construction period. For the three demonstration projects, a computation of the likely saving in interest is carried out as follows:

(a) The land cost is based on the average market rate in August 1999 and is in terms of $/square foot/plot ratio. The price of the land is dependent on its location and the allowable plot ratio.

(b) Generally, the time needed for design development ranges from 12 months (small project) to 18 months (big projects). For the three demonstration projects, the time for design development is taken to be 18 months. The duration of developing a project is the combination of design time and construction period.

(c) The property tax is 0.6% of land price multiplied by the duration of developing the project.

(d) The total design fees is usually a percentage of the construction cost. For a big project, it is approximately 8% of construction cost. For a smaller project, it is usually higher. For the three demonstration projects, 8% is applied to Valley Park and The Bayron; and 10% to Casa Pasir Ris.

The summary of the computation is shown in Tables 3, 3A, 3B and 3C. Table 3 shows that the saving is more significant for bigger projects like Valley Park. The project is able to reap the benefits of precast and enjoy a saving of 2.3% as compared to the original cast in-situ design.

For a medium size project like The Bayron, the precast design and construction is merely 0.1% more costly than the original in-situ design. One way to reduce cost is to standardise the sizes of the components as much as possible. The cost tends to be lower if the components have fewer different sizes.

The cost increase for a small size project like Casa Pasir Ris which adopts precast design is 4.3%. However, developers should regard this as paying for a better quality building and fewer complaints by home buyers.

Table 3: Project cost for proposed precast design (including savings in interest and preliminaries)

Project	Construction Cost for in-situ design (a)	Extra cost for precast design (savings from preliminaries considered) (b)	Saving in interest[1] (c)	Construction cost for precast design (d) = (b) - (c)	Percentage difference $(e) = \frac{(d) - (a)}{(a)}$
Valley Park	$210,000,000	$215,670,000 (+2.7%)	$10,438,736	$205,231,264	-2.3%
The Bayron	$30,500,000	$31,567,500 (+3.5%)	$1,040,267	$30,527,233	0.1%
Casa Pasir Ris	$13,500,000	$14,148,000 (+4.8%)	$63,409	$14,084,591	4.3%

Note:

[1] see Tables 3A, 3B and 3C

Table 3A: Computation of saving in interest for Valley Park

Basic information

Site area = 43,284 m^2	465,909 sq ft
Rate[1]	$450/sq ft/plot ratio
Plot ratio	2.535
Land cost	$531,485,664

Original in-situ design

A	**PROJECT COST**	
A1	Land cost	$531,485,664
A2	Legal fees and stamp duty (4% of land cost)	$21,259,427
A3	Property tax = 0.6% of land cost x duration	$13,287,142
	SUB-TOTAL (A1 + A2 + A3)	$566,032,233
A4	Construction cost	$210,000,000
A5	Associated costs (8% of construction cost)[2]	$16,800,000
A6	Marketing and advertising (5% of construction cost)	$10,500,000
A7	GST (3% of A4, A5 and A6)	$7,119,000
	SUB-TOTAL (A4 + A5 + A6 + A7)	$244,419,000
B	**DURATION**	
B1	Pre-construction period including piling (in months)	18
B2	Original construction period (in months)	32
	SUB-TOTAL (B1 + B2)	50
C	**INTEREST OF FINANCING COST**	
C1	Interest rate	6%
C2	For land = 6% (A1 + A2 + A3) x duration	$141,508,058
C3	For construction = 6% (A4 + A5 + A6 + A7) x duration x 0.5[3]	$30,552,375
	TOTAL INTEREST:	$172,060,433

Proposed precast design

A	**PROJECT COST**	
A1	Land cost	$531,485,664
A2	Legal fees and stamp duty (4% of land cost)	$21,259,427
A3	Property tax = 0.6% of land cost x duration	$12,436,765
	SUB-TOTAL (A1 + A2 + A3)	$565,181,855
A4	Construction cost	$215,670,000
A5	Associated costs (8% of construction cost)[2]	$17,253,600
A6	Marketing and advertising (5% of construction cost)	$10,783,500
A7	GST (3% of A3 and A4)	$7,311,213
	SUB-TOTAL (A4 + A5 + A6 + A7)	$251,018,313
B	**DURATION**	
B1	Pre-construction period including piling (in months)	18
B2	Revised construction period (in months) (less 10%)[4]	28.8
	SUB-TOTAL (B1 + B2)	46.8
C	**INTEREST OF FINANCING COST**	
C1	Interest rate	6%
C2	For land = 6% (A1 + A2 + A3) x duration	$132,252,554
C3	For construction = 6% (A4 + A5 + A6 + A7)x duration x 0.5[3]	$29,369,143
	TOTAL INTEREST:	$161,621,697
	Saving in interest =	$10,438,736

Note:

1. The land rate depends on location. It can be as high as $700/sq ft/plot ratio for town area and as low as $140/sq ft/plot ratio for suburb area. For this computation, a figure of $450/sq ft/plot ratio is used.
2. Associated costs include professional fees to consultants and site supervision fees.
3. A financing factor of 0.5 is used.
4. By using precast, the construction period can be reduced by 10% to 15%. For this computation, a conservative figure of 10% is used.

Table 3B: Computation of saving in interest for The Bayon

Basic information

Site area = 5,305 m^2	57,103 sq ft
Rate[1]	$600/sq ft/plot ratio
Plot ratio	2.8
Land cost	$95,933,074

Original in-situ design

A PROJECT COST	
A1 Land cost	$95,933,074
A2 Legal fees and stamp duty (4% of land cost)	$3,837,323
A3 Property tax = 0.6% of land cost x duration	$1,774,762
SUB-TOTAL (A1 + A2 + A3)	$101,545,158
A4 Construction cost	$30,500,000
A5 Associated costs (8% of construction cost)[2]	$2,440,000
A6 Marketing and advertising (5% of construction cost)	$1,525,000
A7 GST (3% of A4, A5 and A6)	$1,033,950
SUB-TOTAL (A4 + A5 + A6 + A7)	$35,498,950
B DURATION	
B1 Pre-construction period including piling (in months)	18
B2 Original construction period (in months)	19
SUB-TOTAL (B1 + B2)	37
C INTEREST OF FINANCING COST	
C1 Interest rate	6%
C2 For land = 6% (A1 + A2 + A3) x duration	$18,785,854
C3 For construction = 6% (A4 + A5 + A6 + A7) x duration x 0.5[3]	$3,283,653
TOTAL INTEREST:	$22,069,507

Proposed precast design

A PROJECT COST	
A1 Land cost	$95,933,074
A2 Legal fees and stamp duty (4% of land cost)	$3,837,323
A3 Property tax = 0.6% of land cost x duration	$1,683,625
SUB-TOTAL (A1 + A2 + A3)	$101,454,022
A4 Construction cost	$31,567,500
A5 Associated costs (8% of construction cost)[2]	$2,525,400
A6 Marketing and advertising (5% of construction cost)	$1,578,375
A7 GST (3% of A3 and A4)	$1,070,138
SUB-TOTAL (A4 + A5 + A6 + A7)	$36,741,413
B DURATION	
B1 Pre-construction period including piling (in months)	18
B2 Revised construction period (in months) (less 10%)[4]	17.1
SUB-TOTAL (B1 + B2)	35.1
C INTEREST OF FINANCING COST	
C1 Interest rate	6%
C2 For land = 6% (A1 + A2 + A3) x duration	$17,805,181
C3 For construction = 6% (A4 + A5 + A6 + A7)x duration x 0.5[3]	$3,224,059
TOTAL INTEREST:	$21,029,240
Saving in interest =	$1,040,267

Note:

1 The land rate depends on location. It can be as high as $700/sq ft/plot ratio for town area and as low as $140/sq ft/plot ratio for suburb area. For this computation, a figure of $600/sq ft/plot ratio is used.

2 Associated costs include professional fees to consultants and site supervision fees.

3 A financing factor of 0.5 is used.

4 By using precast, the construction period can be reduced by 10% to 15%. For this computation, a conservative figure of 10% is used.

Table 3C: Computation of saving in interest for Casa Pasir Ris

Basic information

Site area = 5,744 m^2	61,828 sq ft
Rate[1]	$190/sq ft/plot ratio
Plot ratio	1.2
Land cost	$14,096,879

Original in-situ design

A	**PROJECT COST**	
A1	Land cost	$14,096,879
A2	Legal fees and stamp duty (4% of land cost)	$563,875
A3	Property tax = 0.6% of land cost x duration	$197,356
	SUB-TOTAL (A1 + A2 + A3)	$14,858,110
A4	Construction cost	$13,500,000
A5	Associated costs (10% of construction cost)[2]	$1,350,000
A6	Marketing and advertising (5% of construction cost)	$675,000
A7	GST (3% of A4, A5 and A6)	$465,750
	SUB-TOTAL (A4 + A5 + A6 + A7)	$15,990,750
B	**DURATION**	
B1	Pre-construction period including piling (in months)	18
B2	Original construction period (in months)	10
	SUB-TOTAL (B1 + B2)	28
C	**INTEREST OF FINANCING COST**	
C1	Interest rate	6%
C2	For land = 6% (A1 + A2 + A3) x duration	$2,080,135
C3	For construction = 6% (A4 + A5 + A6 + A7) x duration x 0.5[3]	$1,119,353
	TOTAL INTEREST:	$3,199,488

Proposed precast design

A	**PROJECT COST**	
A1	Land cost	$14,096,879
A2	Legal fees and stamp duty (4% of land cost)	$563,875
A3	Property tax = 0.6% of land cost x duration	$190,308
	SUB-TOTAL (A1 + A2 + A3)	$14,851,062
A4	Construction cost	$14,148,000
A5	Associated costs (10% of construction cost)[2]	$1,414,800
A6	Marketing and advertising (5% of construction cost)	$707,400
A7	GST (3% of A3 and A4)	$488,106
	SUB-TOTAL (A4 + A5 + A6 + A7)	$16,758,306
B	**DURATION**	
B1	Pre-construction period including piling (in months)	18
B2	Revised construction period (in months) (less 10%)[4]	9
	SUB-TOTAL (B1 + B2)	27
C	**INTEREST OF FINANCING COST**	
C1	Interest rate	6%
C2	For land = 6% (A1 + A2 + A3) x duration	$2,004,893
C3	For construction = 6% (A4 + A5 + A6 + A7)x duration x 0.5[3]	$1,131,186
	TOTAL INTEREST:	$3,136,079
	Saving in interest =	$63,409

Note:

1 The land rate depends on location. It can be as high as $700/sq ft/plot ratio for town area and as low as $140/sq ft/plot ratio for suburb area. For this computation, a figure of $190/sq ft/plot ratio is used.

2 Associated costs include professional fees to consultants and site supervision fees.

3 A financing factor of 0.5 is used.

4 By using precast, the construction period can be reduced by 10% to 15%. For this computation, a conservative figure of 10% is used.

2.5 Achieving Overall Cost Effectiveness

Maximum efficiency and economy can be achieved by mass production in factories. For mass production of precast components to be viable, there should be a high-level of standardisation and dimensional co-ordination resulting in inter-changeable components that are suitable for a wide range of building types. Besides improved design and production efficiency, the contractor must have good management skills to ensure that the precast project is on schedule.

2.5.1 Improved design

(a) Design

To ensure that precast construction is cost effective and comparable with in-situ construction, precast components must be designed to achieve maximum and efficient use of moulds.

For precasting to be effective, the following items must be taken into consideration during design stage:

- Identify components that can be precast.
- Identify components that can be bought "off-the-shelf", for example, precast staircase.
- Standardise the components sizes.
- Adopt repetitive design.
- Involve precasters at early design stage.
- Adopt modular co-ordination.

The design of joints and the fixing method will affect the speed of erection. Simple joint details and fixing method must be adopted to improve the ease and speed of erection, resulting in lower cost.

(b) Standardisation

Standardisation of precast components would reduce the types of component. It would enable precasters to obtain economical production to offset high capital investment in equipment and mould. It could also enable precasters to minimise the time taken in producing shop drawings.

Economical production method is associated with repetition and productivity. As a rule of thumb, for simple components, the minimum number of repetition required is around 50-60 times. For more intricate design, the minimum number of


Standardising the staircase requires only one mould

repetition required would be around 100 times. The minimum number of repetition also depends on a supplier's overheads i.e. supplier with lower overheads will require lower minimum number of repetition. Designers are therefore advised to check with different suppliers to obtain the best deal.

(c) Modular co-ordination

Modular co-ordination would allow the same components to be manufactured by different suppliers. It also encourages suppliers to be more competitive in their pricing. Modular co-ordination will allow components to be inter-changeable without excessive wastage. This will result in lower production costs.

Modular co-ordination facilitates precasters to produce off-the-shelf precast components which can be used for a wide range of projects. Examples are precast staircases and parapet walls.

(d) Optimum size

The cost of transportation is generally proportional to the distance travelled and the components' weight. The size and weight of precast components are generally governed by the limitations in transportation. Thus, exceptionally big or wide components can increase the cost greatly due to safety provisions such as police escort.

When the precaster's yard is too far from the site, it may be viable to adopt on-site precasting, provided there are adequate space at the site.

(e) Dead load

The use of precast does not necessarily mean heavier dead load and additional piling costs, although some individual precast components may be heavier than in-situ components. The use of high strength concrete will reduce the precast components' sizes and results in saving of piling work.

(f) Simple connection

The installation methods also affect the time and labour required for erection. Simple fixing methods will reduce erection cost.

2.5.2 Enhanced production efficiency

(a) Cost of production

The production cost of precast components can be sub-divided into the following elements :

- Design Cost
- Material Cost
- Mould Cost
- Labour Cost
- Factory Overheads
- Storage Cost

As a rule of thumb, the cost per unit of a precast component will fall as the quantity increases. This is mainly due to multiple re-use of the moulds. Bulk purchase of concrete, sand, steel bars and associated fixings can also reduce production cost.

As more projects in recent years have adopted precast components, the demand for precast components has increased. This will lead to even greater economy of scale in production as the industry moves toward higher level of standardisation of precast components.

The size of a project will also affect the opportunity for precasting. With standardisation and modular dimensions, bigger projects will tend to have better economy of scale for precast construction.

To lower the cost of production, the following factors have to be considerated during the design stage:

No.	Item	Purpose
(i)	Standardise the components to be used.	To increase repetition so as to reduce the mould cost per unit.
(ii)	Adopt simple details.	To reduce mould cost, labour cost and erection cost.
(iii)	Maximise re-use of moulds.	To minimise alteration.
(iv)	Reduce dead load of components.	To reduce handling cost.
(v)	Co-ordinate delivery to site.	To reduce storage space at yard and at site.
(vi)	Adopt on site precast.	To eliminate transportation cost and lower production cost.
(vii)	Use off-the-shelf components.	To reduce component cost.

(b) On-site precasting

A recent trend in precast construction is to produce the components on site instead of purchasing the components from precast suppliers. One of the main reasons is to eliminate transportation cost. Other advantages and disadvantages of on-site precast and off-site precast are tabulated as follows :

On-Site Precast	Off-Site Precast
<u>Advantages</u> • Saving on transportation cost • Better control of construction schedule	<u>Advantages</u> • Better quality finishes • No issue on availability of site space
<u>Disadvantages</u> • Quality of finishes may be affected • Additional space on site for precasting • Additional temporary site facilities such as gantry cranes and machineries for site precasting	<u>Disadvantages</u> • Transportation cost • Tight control of the delivery schedule • Waiting area for trucks • Temporary storage area for precast components

Generally, plain and relatively simple units can be cast economically on site. On the other hand, components with intricate designs such as keystones, arches, fins are better suited for off-site casting under controlled conditions.

The new trend: On-site precasting

The cost components for on-site precasting are as follows:

(i) Moulds

The quantity for each type of component must be evaluated to determine the number and types of mould required. To minimise costs, moulds must have the flexibility for modifications to meet the different designs of the components.

A simple method to compute the cost effectiveness of precast mould is as follows:

[assume the material cost (concrete and reinforcement) remains the same and the mould is new]

Cost of mould = \$5,000

Area of 1 panel, say 3m by 3m = 9 m^2

No. of panels produced by 1 mould = 100

Therefore cost of production = \$5,000/(100 x 9)

= \$5.50/m^2

Compared with the formwork (\$28/m^2) and plastering (\$12/m^2) for cast in-situ construction, there will be substantial savings. However, there will be other expenses such as cost for setting up temporary facilities, additional design and drawings (if applicable) which need to be taken into consideration.

(ii) Production

Besides the cost of mould, labour and material costs (reinforcement, concrete etc.) also add up to the production costs.

(iii) Temporary facilities

Costs for temporary facilities include gantry crane, rebar cutter and bench, forklift, generator and so on.

Stack casting of wall panels reduces formwork and storage costs

The contractor may need to lease the land from nearby lots temporarily for the production and storage of precast components for projects which have limited site area. This will add to the cost for site precasting.

Storage of precast components on site requires careful planning

(iv) Design and drawings

There should be no additional design cost for projects which are planned and designed for precast right from the start. This is more common in projects where the contractor proposes to convert from cast in-situ to precast. In such cases, the contractor will need to engage its own design and drafting team to carry out the conversion. This will be translated into additional costs to the contractor.

Besides cost factor and availability of space on site, the decision to carry out on-site precasting or purchase off-site also depends on the contractor's management, planning and experience in site precasting. A contractor must work out the pros and cons and decide the best construction method for each individual project.

2.5.3 Better site management

For any construction project, it is crucial that the contractor possesses good management and site planning skills. This is even more so for precast projects. Many precast projects were delayed because the contractor did not plan and schedule the delivery and installation of precast components properly.

For a contractor who is handling a precast project, especially for the first time, it is prudent that he engages site personnel who are experienced in administrating precast project schedule including coordination with other trades. With good site management and planning, precast construction will have a shorter construction period. The amount of saving in the construction period varies from 10% to 15%.

CHAPTER THREE
PLANNING AND DESIGN GUIDELINES

3.1 Method And Design Approach

3.1.1 General

The successful implementation of precast concrete projects requires careful planning and good co-ordination among the architect, the engineer, the precaster and the contractor.

Efficient production schedule through good co-ordination

It is recommended that early consultation with precaster be made in order to achieve the best results. Consultants are to ensure that the design inputs by the precaster are properly considered and integrated with the overall design of the project.

In precast concrete construction, the architect and the engineer remain the lead persons in the design and detailing of a project. However, they should be receptive to alternative solutions from the precaster, in order to get the maximum benefit from the precaster's knowledge in design and factory production.

At the initial stage, there are several possible approaches, depending on the requirements of the project. For a simple project, the architect can develop the initial design, then seek the advice of the precaster. For a more complex project, an appropriate approach is to establish a design team which includes a precast specialist at the conceptual design stage to avoid abortive work.

At the final design stage, the engineer can develop the details of the precast components together with the precaster for practical erection consideration.

A systematic approach and a high degree of standardisation should be adopted in the architectural design in order to achieve maximum economy and optimum quality in precast construction. The architect should lead the consultant team and firm up the design in the early stage before work commences on site. The co-ordination of architectural, structural, mechanical and electrical applications warrants special attention and must be incorporated into the precast elements.

3.1.2 Factors that influence design concept

The following points are to be considered in the design process:

- The architect should interact with the engineer and precaster to obtain suggestions concerning good practices, production details, and manufacturing capabilities. This should take place at the initial design phase of the project.
- For connection designs, the architect/engineer is advised to work together with the precaster to ensure that the connections are practical and facilitate ease of production and erection. This will help to reduce abortive work.

- It is recommended that reference samples be used to determine product characteristics and quality, rather than explicit specifications by the architect which may prohibit the precasters from using a process that offers the best solution for producing the desired components.

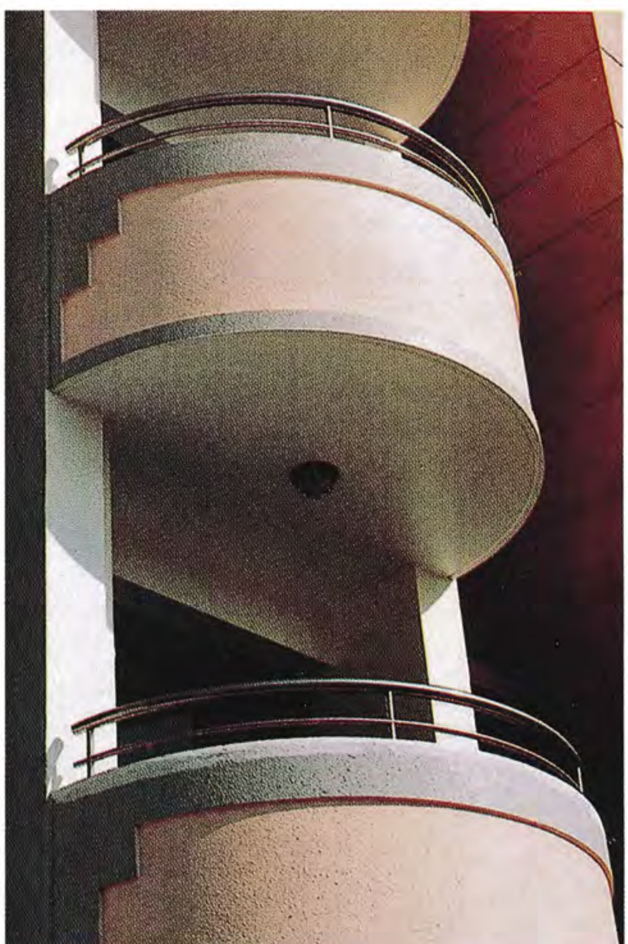
Mock up sample

- Quality of precast components tend to be better than that of the in-situ. However, designers must be careful with the interfacing or fixing details between precast components and in-situ structure. Appropriate tolerance in dimension must be allowed.
- Good planning and sufficient lead-time given to the production of precast components will result in savings in the production cost and achieve a better quality end product.
- Transportation limitations imposed by product dimensions and weights must be considered during the design process. However this will not be a problem for projects where the precast components are cast at the site.

3.1.3 Architectural considerations

The following points are to be considered in the architectural design:

- Modular co-ordination: A modular grid of 300mm or 3M (where M = 100 mm) is recommended as a basis of design for horizontal dimensions and 0.5M for vertical dimensions. Modular design is a useful and effective way to achieve better productivity and a higher degree of standardisation.
- Layout design: Gridlines should be set out on a uniform pattern with majority of walls line-up. Avoid staggered arrangements.
- Sub-module layout: The overall design layout can be arranged as an assembly of many similar sub-modules or clusters in order to create possible repetition in precast element design.
- Decorative features and motifs: Where appropriate, they could be standardised and constructed as 'add-on' attachments to the basic plain facade design.



Decorative curved balcony

- Site accessibility and topography: Good accessibility and sufficient space for manoeuvring crane and trailer within the site are important.
- Size and weight: To facilitate handling and erection, the maximum height and weight of each precast component must be considered.

Lifting precast components

3.1.4 Structural considerations

The following are the two major systems in the structural consideration:

- Combined system: Structural precast system can be considered together with the architectural precast components such as precast load bearing internal wall and facade.
- Separate system: Structural and architectural precast elements are separately designed and constructed. Examples may be precast or in-situ frame structure with non-load bearing precast facade.

3.1.5 Mechanical and electrical services considerations

The following points relating to mechanical and electrical services are to be considered during the design of precast concrete components:

- The routes and locations of mechanical and electrical services should be considered early in the design stage. Electrical conduits can be buried within the precast floor topping or incorporated into the precast walls. Conduits may also be placed in the voids of hollow core slabs with outlets for lights or other fixtures.
- Various methods can be used for fixing air-conditioning ducts and services pipes to the underside of the precast slab. Several types of fastening method such as power-activated fasteners and cast-in inserts can be used.
- Penetrations or openings in precast walls and floors can be incorporated during the factory production of these components.
- Lightning conductor and gondola guide insert can also be cast into the precast panels.
- For precast construction, the design for mechanical and electrical services must be finalised early and made available to the precaster to avoid delays in production.

3.2 Modular Co-ordination And Standardisation

3.2.1 General

Modular co-ordination was first studied in Singapore when metrication was introduced in the early seventies. The Housing & Development Board implemented the concept in 1973 in the new generation flats. Architects in Singapore, in general, are familiar with the concept of modular co-ordination and standardisation.

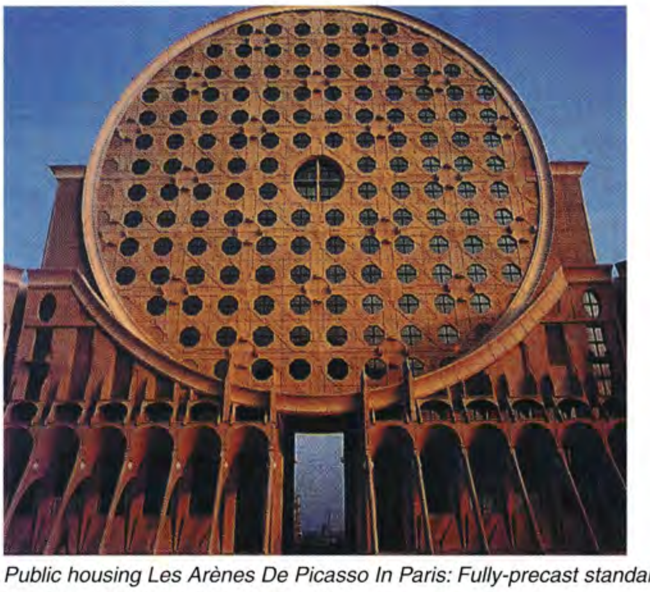
Harvis Osaka office and hotel mixed development in Japan: Modular co-ordinated design
Architect: Takenaka Corporation
Photographer: Shinkenchiku-sha

Public housing at Yishun Street 20: Modular co-ordinated design

Modular co-ordination and standardisation are used as a planning tool to achieve systematic work and economy for the structural and architectural works. However, in precast concrete construction, the benefit is even more pronounced.

For precast construction, modular co-ordination should be used throughout the project. This applies to the planning as well as the design of standardised units, elements, details and systems. The use of non-standard solutions and details should be kept to a minimum. In mass production, modularisation is most desirable as it lowers the cost of the precast elements.

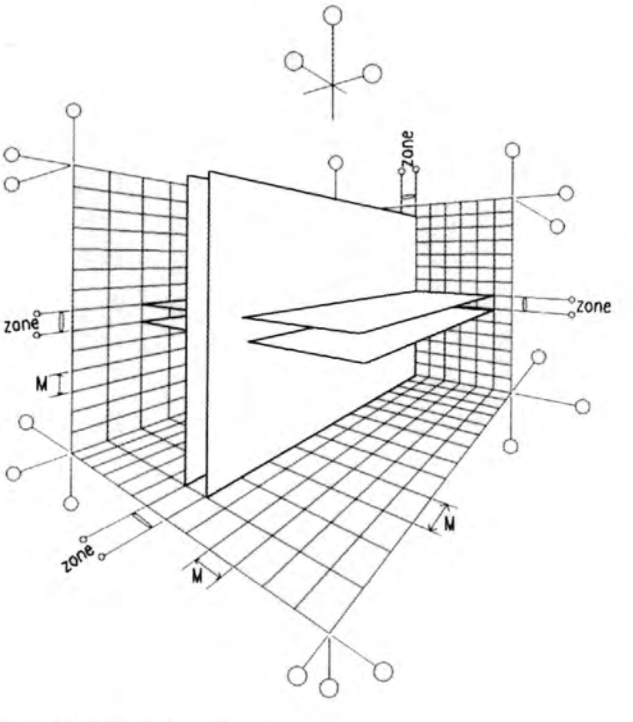
In the past, the stereotype architectural precast concrete facade was flat, featureless and relatively monotonous. However, today, it is unjustifiable to criticise precasting for its lack of flexibility since each project is usually designed as a 'one-off' for which new moulds always have to be made. Precast facade units can be as flexible as any other building product in the market.



Public housing Les Arènes De Picasso In Paris: Fully-precast standardised architectural facade
Architect: Manolo Nunez Yanowsky
Source: Omnium Technique OTH

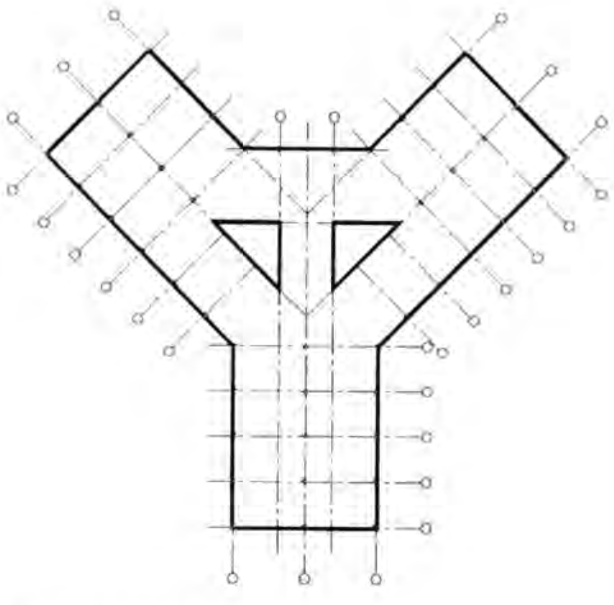
3.2.2 Definition of modular co-ordination

Modular grids should be chosen in accordance with the basic rules in the Modular Co-ordination Handbook published by BCA. Modular co-ordination starts in the architectural design stage. The basic modular grid will define the major planning grid where the structural components for the building are being co-ordinated. This will determine the placing of the main structural components such as columns, beams and floor slabs. Thereafter, the architect must decide where to place the architectural components. For example, the wall panels may be placed on the outer part of the grid or in-line with the grid. The architect can consider the whole building or part of it as a standard module to be repeated, with sub-module for the smaller components, which could be turned, or mirrored to form the desired architectural expression.



Modular reference system

The shape or layout of the building does not necessarily need to be rectilinear. The diagram below illustrates different examples of possible shapes and configurations using modular grids.



Example of modular co-ordination on grids

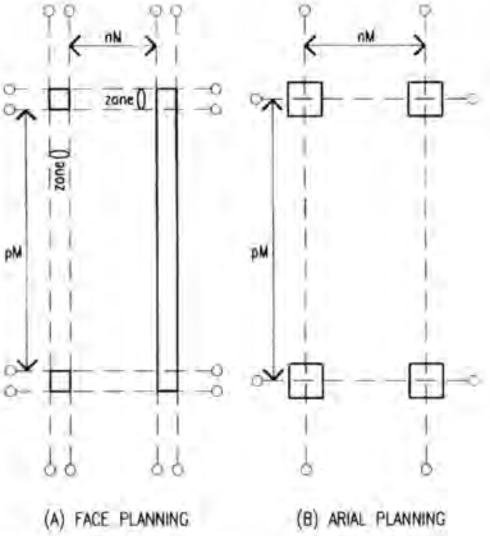
3.2.3 Benefits of modular co-ordination

The benefits for adopting modular co-ordination especially in precast concrete construction technology are enormous. These include:

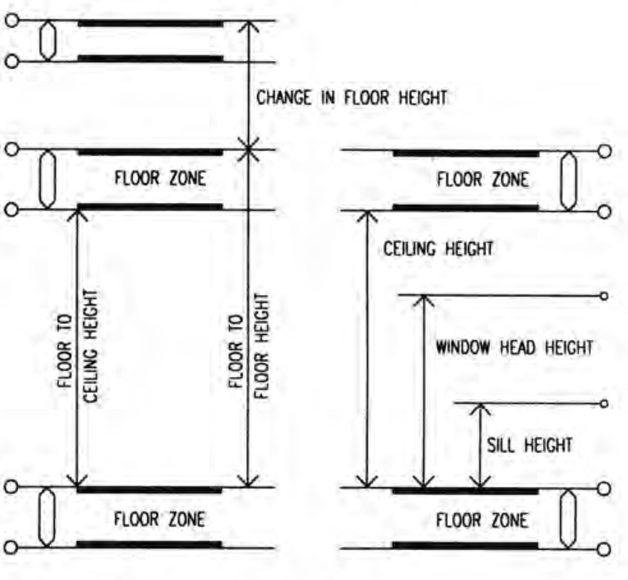
- Better co-ordination in the design and construction stage.
- Reduction in design time, especially with the use of standard details and dimensional co-ordination.
- Facilitate the use of computer-aided design and drafting.
- Increase the speed of production and manufacturing of components.
- Improve structural and architectural quality of the building.
- Reduce wastage of labour and materials.
- Increase the speed of erection of standardised components and joint details.

3.2.4 Recommended modular planning grids for private residential buildings

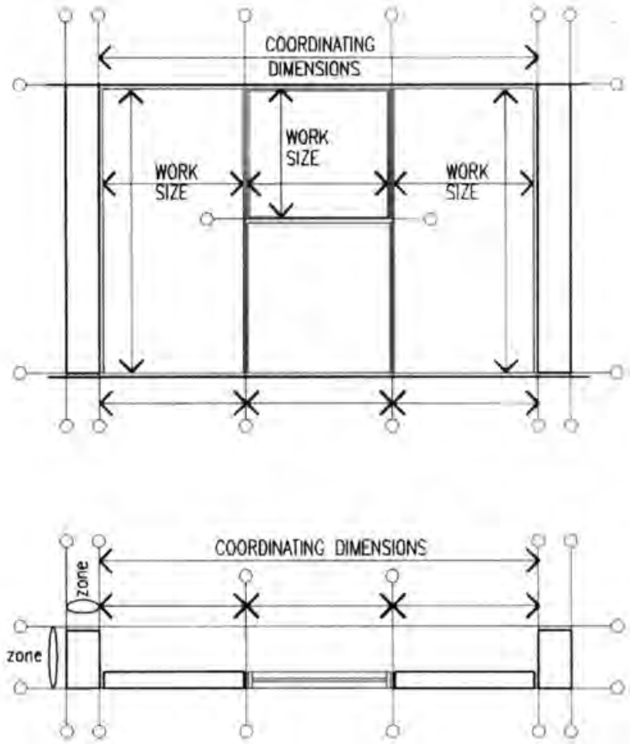
The basis for modular planning is to select a suitable grid, where the building is planned relative to the main axis. The modular distance between the grid lines shall, as far as possible, be equal. This will limit the number of non-standard components to be manufactured and simplify the detailing. The whole planning process then becomes much more efficient.



Horizontal controlling dimensions



Vertical controlling dimensions



The building component and controlling planes

The most common module of a basic planning grid is 300mm or 3M (where M = 100mm). For the planning of private residential buildings, 3M is recommended for the horizontal multi-module and 0.5M for the vertical multi-module.

The following are the recommended modular dimensions which will provide sufficient flexibility in the design of private residential buildings :-

Basic module	:	M (M = 100mm)
Horizontal multi-module	:	3M
Vertical multi-module	:	0.5M
Structural grid	:	12M
Column size	:	0.5M
Beam size	:	0.5M
Door width	:	3M
Door height	:	1M
Window width	:	3M
Window height	:	1M
Floor thickness	:	0.5M

It is possible to introduce sub-modular increments of 0.25M or 0.5M for the above components.

3.3 Selection Of Precast Structural System

3.3.1 General

The selection of the types of precast structural system for a building depends on the architectural layout, span of structural components and the architectural concept of the interior space. The decision will also be influenced by site constraints and building heights.

The most common basic precast concrete structural systems are:

1. Precast frame and skeletal system
2. Precast load bearing walls and facade system
3. Precast cell system
4. 'Mixed' construction
5. Precast floor
6. Precast roof

Precast column: Changi Airport Terminal 2

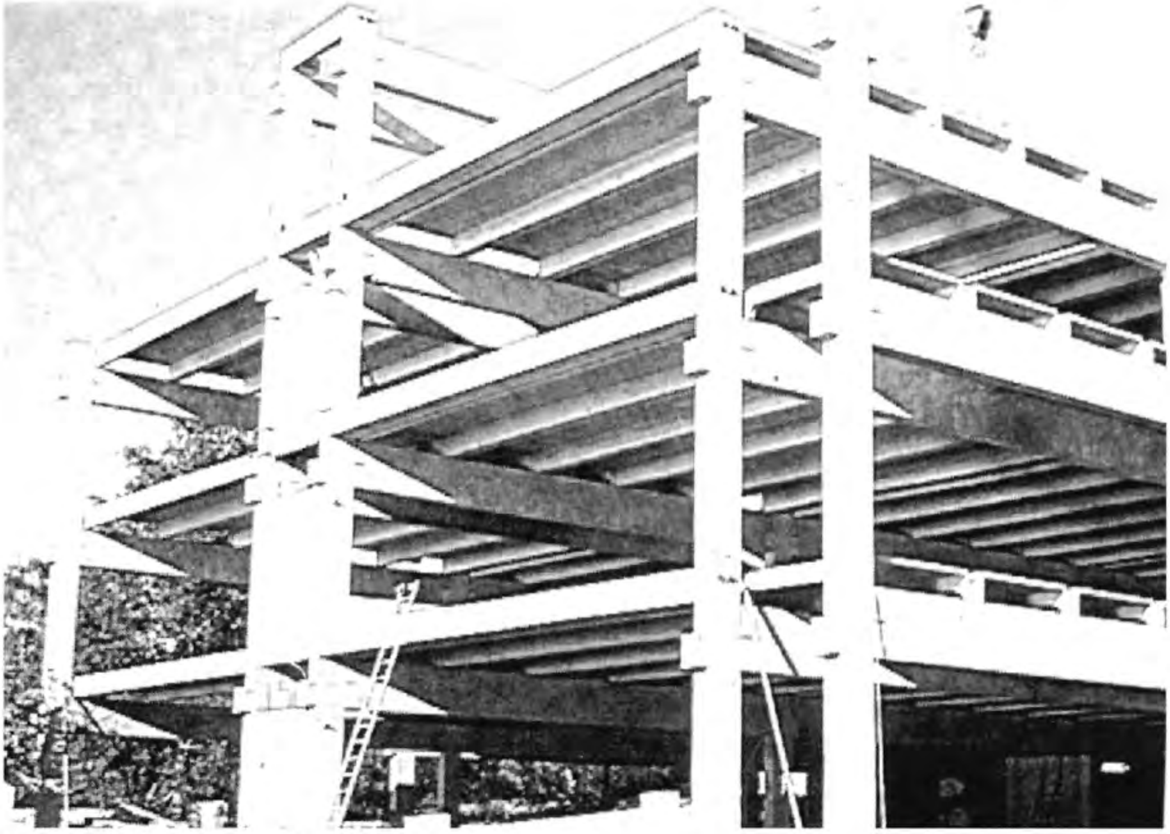
3.3.2 Precast frame and skeletal system

The precast frame and skeletal system is selected mainly on the possibility of achieving large span and open spaces without interfering walls. It is suitable for buildings requiring a high degree of flexibility like industrial building, shopping mall, car parking building, sports complex and large office building. This concept gives flexibility for changes of floor space and gives architects a broad choice of facade claddings.

Precast concrete buildings with frame and skeletal system may come in different forms as follows :

- Single storey building – comprises a series of basic portal frames.

Single storey industrial building



Low-rise building with precast frames and ribbed floors

Multi-tiered precast columns

Precast H-shaped unit

- Low-rise building – the precast columns can be in the form of 1-storey height or up to 3-storey height per section.
- High-rise building – for high-rise building, precast concrete frames can be constructed with columns and beams of different shapes and sizes. Beams are normally single-spanned and simply supported. Precast floor slab is normally used.

3.3.3 Precast load bearing wall and facade system

Precast load bearing walls can appear as cross-walls, walls in shafts and cores, and load-bearing facades.

Precast cross-walls are used commonly in residential apartments. The advantage is to create free open space between the load-bearing walls. Lightweight partition can be used for the internal walls.

Very often the use of loading wall system eliminates the need of internal beams. This system is therefore highly suitable for residential buildings.

Load-bearing facades have a dual function in being both decorative and structural. The need for external columns, beams and shear walls can be reduced. If built-in windows are incorporated into the facade, it will be possible to make the building water-tight at an earlier construction stage.

Non-load bearing facade panel can also be used in combination with the load-bearing wall structural system.

The Bayshore Condominium: (Above) Load bearing precast wall (Below) Completed building

3.3.4 Precast cell system

Entire precast cells, such as precast bathroom, civil defence shelter, lift core, and staircase core may be used to form part of a building.

Precast cell system has large in-plane stiffness and strength. The disadvantage is the limitation in size because of its weight.

Precast refuse chute

Precast service balcony

Precast cores for lift and staircase

3.3.5 Mixed construction

Mixed construction refers to a combination of precast concrete with cast in-situ concrete, steel, or masonry. This term must not be confused with 'composite' construction which combines precast concrete with another material as an integrated component. Examples of mixed construction are as follows:

- Precast floors, roofs and facades are combined with cast in-situ concrete or steel frames.

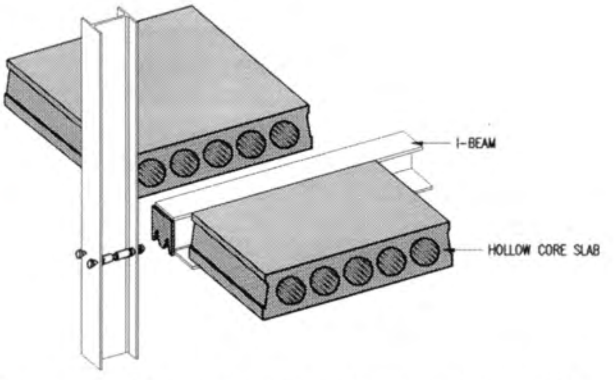
- Precast construction usually starts at the second level onwards, while in-situ construction is adopted for the lowest floors, including the basement. This is done to allow the lead-in time required for precasting.

Shangri-la Hotel, Jakarta
(Above) Precast facade, supported by in-situ concrete structural frame, is cast to room module to facilitate early start on interior work
(Below) Completed building

Trellis Towers: Precast load-bearing walls are adopted for third storey onwards

Exterior view of The National School of Civil Engineering and Geographic Sciences, Paris

Increasingly, more buildings are constructed of structural steel frames for rapid assembly on site. Avoiding the need for downstand beams is also desired for ease of M&E service routes. One solution to this is to have H steel columns (filled with concrete for the fire rating) connected by asymmetrical I steel beams with wider flange at the bottom to support precast and prestressed hollow core floor slabs. The rigidity of the structure is ensured by in-situ compression topping which transfer horizontal stresses to the lift cores and gable walls, acting as windbracing element.



Asymmetrical I Beam and hollow core slab used in the school design

Interior view of the school

Precast polished concrete facade on steel structure: Palaise De congress
Architect: Christian de Portzamparc, Paris

3.3.6 Precast floor

Precast floors are classified into fully precast and partially precast. The latter comprises a precast element with a cast in-situ structural screed.

The precast floor systems commonly available are:

- Hollow core floor

Hollow core floor panels are precast reinforced or pre-stressed concrete planks with different edges, and lengths (maximum 9m and 12m respectively). Some of these are used as internal wall panels.

Installing hollow core floor

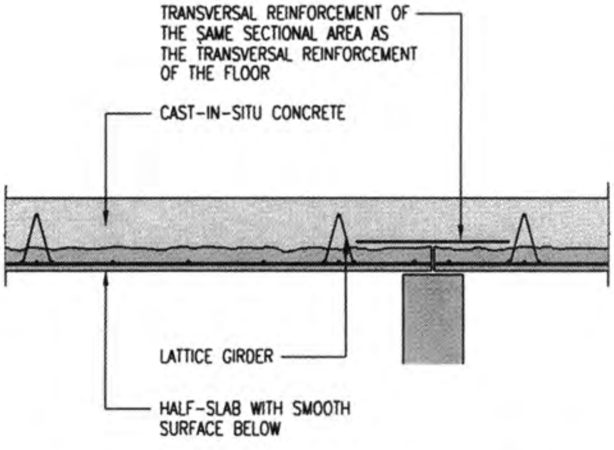
- Ribbed soffit floor

The ribbed soffit precast concrete panels are in the form of single T or double T. They are in fact a combined beam and slab structure. Maximum span is approximately 22m. The panels have excellent stability and load-bearing capacities.

Double-T floors ready for delivery in a Belgium factory

- Composite half-slab floor

Typically, they are thin precast slabs combined with in-situ reinforced concrete topping to achieve a robust composite floor. Precast slabs are 0.6 to 2.4m wide and 40 to 100mm thick. In-situ topping is between 40 to 100mm thick. The precast slabs can be reinforced or pre-stressed concrete and have smooth underside with joints filled up with sealant.



Composite half-slab with joints concealed over partition wall. Lattice girders and tie bars are shown

Hazel Park: (Above) Lifting the room-size precast half-slab
(Below) Precast half-slabs ready for installing over precast beams

To ensure good bonding, the precast slabs are normally cast with protruding lattice girders which improve stiffness during transportation and erection. In apartment buildings, these slabs could be precast to the size and shape of a room so as to conceal the soffit joints above the partition walls.

- Composite hollow core and ribbed soffit floor

The concrete topping for these precast floor panels ranges from 50 to 100mm. Mesh reinforcement is usually used in the topping to prevent cracking. The thicker topping allows pipes and conduits to be concealed within the topping.

Composite hollow core floor

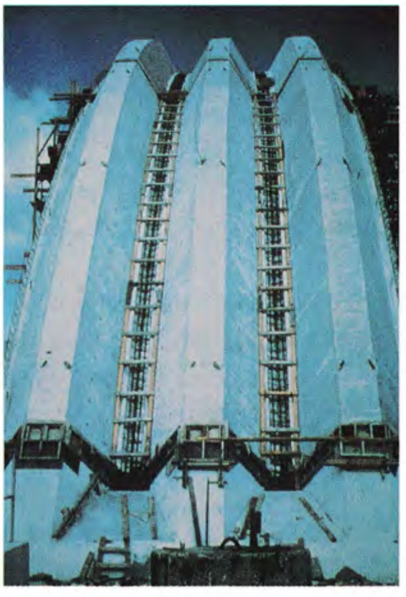
Composite double-T floor

3.3.7 Precast roof

For precast concrete roof, water tightness and thermal insulation are to be considered. Water tightness is normally achieved with waterproofing membrane such as an elastromeric membrane laid over the topping of the composite roof slab. The topping is laid to fall with a minimum thickness of 40mm.

Large-span arched, folded plate or shell roofs can be precast in sections and assembled to give column-free spaces.

Segment of the arched precast roof



Long-span precast arched roof

Precast segmental linings to underground Mass Rapid Transit System in Antwerp

Precast and prestressed roof beams: Anderlecht Stadium in Brussels

Precast roofs to carpark building: KK Women and Children Hospital Singapore

3.4 Design Efficiency And Consideration

3.4.1 General

The shape, size, colour and texture of architectural precast components have to be considered carefully in the design of a project. A successful design would maximise the qualities, performance, utility and appearance for each component.

At an early design stage, the architect, with the help of the precaster, should develop some mockup samples to establish the quality, colour and finishes required.

Precast cladding in three dimensional shape

Precast cladding component

Curved facade

3.4.2 Shapes

In establishing the shape, the architect must consider the proper thickness of the panel to allow for positioning inserts for handling and connection. Other factors that need to be considered are the ease of production, adequate cover of reinforcement and the sizes of aggregate to be used. Before the shape of a precast concrete unit is finalised by the architect, the finishes must be considered. It must be recognised that many finishes cannot be achieved with equal visual quality on all faces of the unit.

The shape of the precast concrete cladding units is related to:

- Panel web thickness:
  In practice the web thickness is governed by the requirements of concrete cover for the reinforcement.
- Horizontal support and restraint nibs:
  The load bearing and fixing requirements determine the depth of horizontal support nib. The most important consideration is that there must be a minimum bearing of 100mm on the structural slab plus an allowance of 25mm for any inaccuracies in the edge of the slab and any danger of spalling.
- Vertical strengthening nibs:
  The depth of the vertical strengthening nibs is related to the span between the supports. Sufficient depth is often necessary to accommodate the elements of open-drained joints.

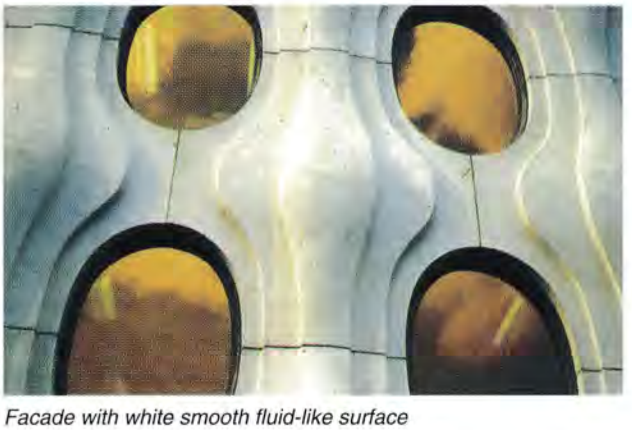
3.4.3 Textures

Besides the shape, the next element that needs immense consideration is the texture of the panel. The four factors that need to be considered with regard to texture are:

- The area of the surface to be covered.
- The effect desired at a viewing distance.
- The aspect of the particular elevation.
- The shape and surface characteristics of the aggregates.

Surface texture also affects colour. A mat finish will appear in a different colour from a smooth finish. Texture helps to give a visual definition of a wall panel.

Special aggregates for the facade finishes include naturally occurring aggregates such as selected gravel, granites, traprock, marble, limestone, and quartz, quartzite, feildspar and obsidian. The back of the precast facade panels may



Facade with white smooth fluid-like surface

Facade with smooth and water washed concrete

be given an exposed aggregate, screed, broom, float, trowel or stippled finish. If the finish is to be painted, a stippled concrete finish will normally be the most economical.

It should be noted that the larger the aggregate, the more difficult it will be to accommodate edges and returns. The smaller the aggregates, the more cement and water are required in the mix, thus increasing the shrinkage of the concrete and the possibilities of hairline cracks.

3.4.4 Corners and drip details

The design of corners in buildings demands special attention. It is recommended that all edges of precast concrete be designed with a reasonable radius or chamfer, instead of leaving them as sharp corners. Fine aggregates will be collected if the edge is detailed as a sharp edge. This will weaken the edge, causing it to chip during handling and erection. Chamfered or radial edges are stronger and will help to mask irregularities in the alignment of precast panels.

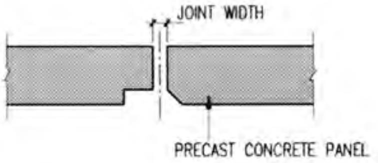
Fragile edge details should be avoided. They can increase the handling costs. The panels should be shaped so that they would be sufficiently stiff in the direction of handling-induced stresses.

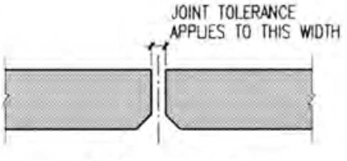
The architects must bear in mind that mitred corners are difficult to manufacture and erect. Jointed corners may appear weak. The problem can be avoided by using L-shaped panels that return around the corner, giving a strong solid edge.

Precast cladding with window

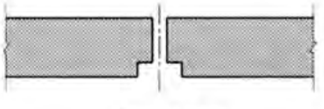
Streaking on the facade panel is usually caused by rainwater trapping on the surface. To reduce this problem, rainwater must be thrown off the building. Water drips will reduce streaking due to the uneven washing of a backward-sloping surface when the drips are correctly dimensioned and placed close to forward edge. Drips should be 20 – 25mm wide and from an angle of 40 – 45 degrees. At the upper levels of a facade, horizontal projections need to be at least 250 – 300mm deep to throw water off.

Concrete frames at window heads must be designed with drip details so that rainwater does not splay down and back toward the frame and cause streaking on the sides. The drip section must be designed in relation to the slope of the concrete surface. To avoid a weakened section that is likely to chip, the drip must not be located too close to the edge of the precast unit.

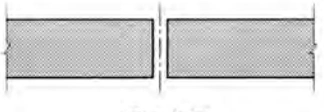




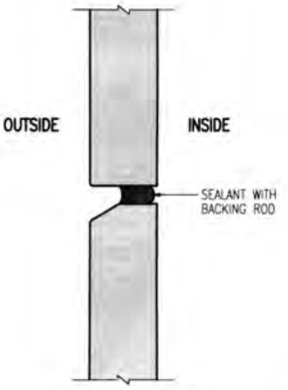
Chamfered joint



Reveal joint

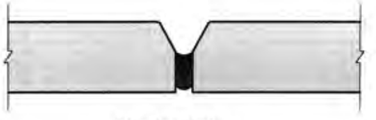


Butt joint

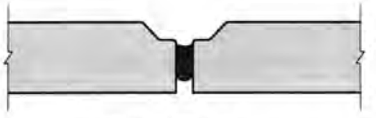


Horizontal joint

Alternative joint



Vertical joint



Alternative joint

3.4.5 Joints details

The joints between precast concrete panels or between panels and other building materials must be considered as the weakest link in the overall water-tightness of the wall. The design and execution of these joints are therefore of the utmost importance and must be accomplished in a rational, economical manner. The joint treatment also has an effect on the general appearance of the project and must be considered during the design development stage.

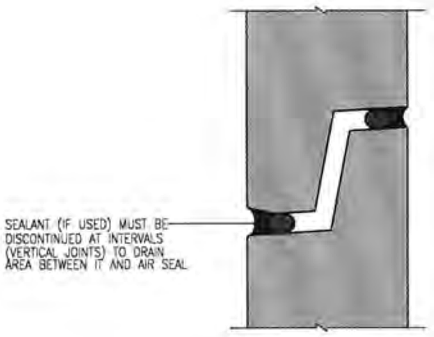
Design criteria for the joints include:

- Water-tightness and weather protection
- Structural and thermal movement
- Architectural appearance

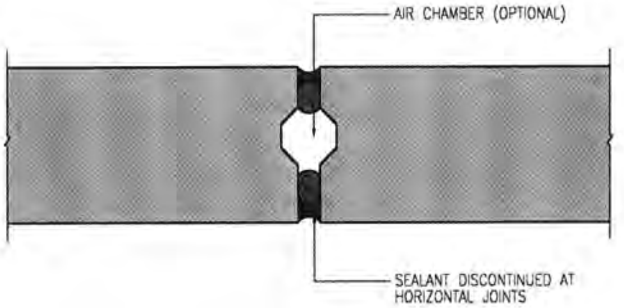
Items affected by joint design are:

- Panel size and dimensional accuracy
- Weathering
- Tolerance
- Transition between adjacent material
- Location of opening

Joints are required to accommodate structural movement, prevent water and air penetration through the building envelope.

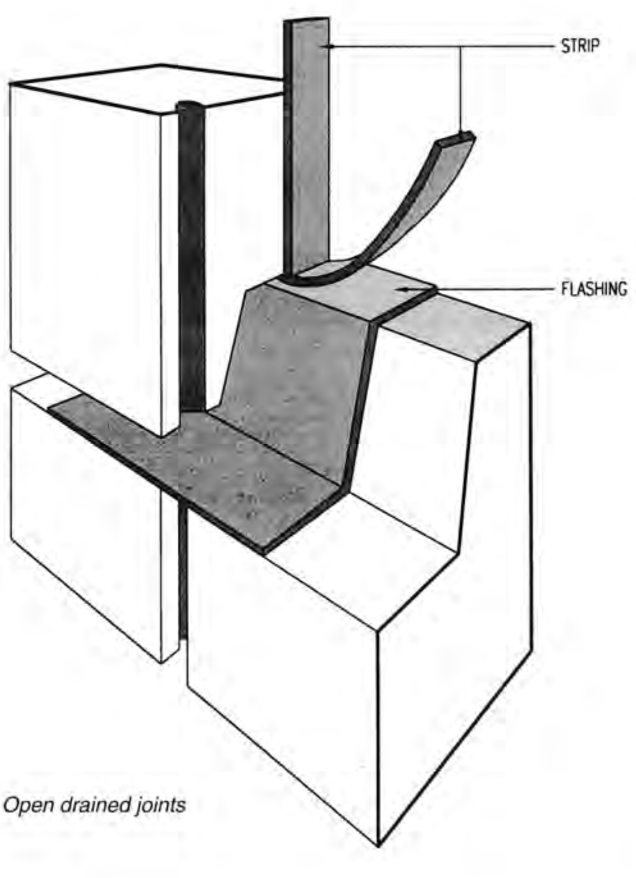


HORIZONTAL JOINT



VERTICAL JOINT

Double sealed joint: Using field - molded sealants



Open drained joints

Materials for expansion joints must be chosen for their ability to absorb appreciable structural movement while performing their primary function to control the movement of moisture and air.

- Face - Sealed Joints

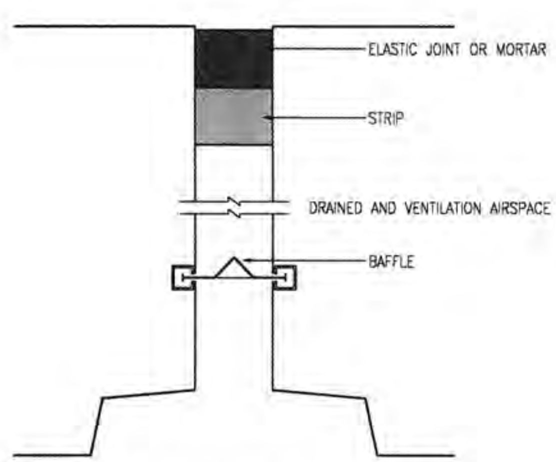
Sealing of joints between precast concrete panels is usually done with a face - sealed joint. Examples of the single sealed joints are shown in the diagrams.

Although single sealed joints are the most economical with regard to initial cost, local precasters normally adopt the double sealed joints. The double sealed joints have two lines of defence for waterproofing. A typical joint has a rain barrier seal at the exterior face and an air-seal at the interior face. Between the two seals is an air chamber that must be vented and drained to the outside. Face - sealed joint is directly exposed to weathering. It is recommended that the sealant be set back into the joints by using recessed joints so that the sealant is protected from rain, wind and UV light.

- Open Drained Joints

In the open drained joints, a baffle is inserted to throw off rainwater. A drained and ventilated air space traps any water or moisture and discharges it. The water-tightness of open-drained joints depends critically upon the integrity of the air-seals at the rear of each joint.

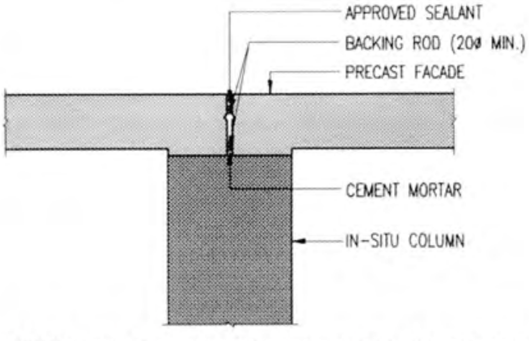
Special care is needed at the intersection of vertical and horizontal joints, as these are the weak points of the system. Open drained joints and gaskets require relatively thick panels and complex edge details. Repair of leaking joints is always not easy.



Example of open drained joint

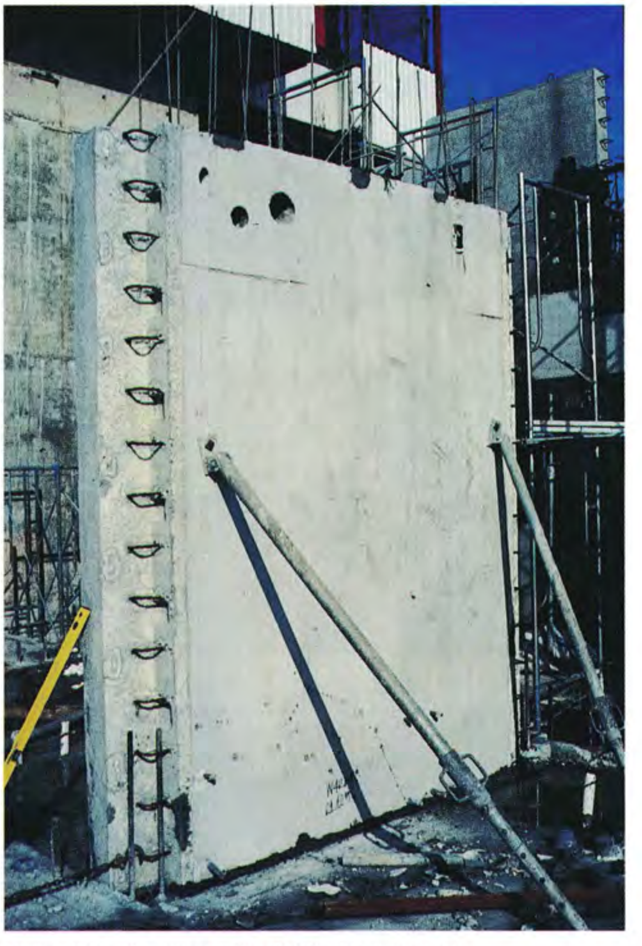
• Sealant

Polysulphide and polyurethane sealants are commonly used as joint seals. Silicone sealant is not recommended due to staining problem unless it is a modified silicone. Both polysulphide and modified silicone have good elongation property and are suitable for movement joint. However they cannot be painted over. Polyurethane is suitable for non movement joint and wet joint which can be painted over. The recommendation from the sealant manufacturer on mixing, surface preparation and application must be strictly adhered to. Sealant manufacturers normally give 5 years warranty for the materials. However they may be prepared to give warranty up to 7 years if requested.



Typical HDB detail of a precast facade wet joint at in-situ column

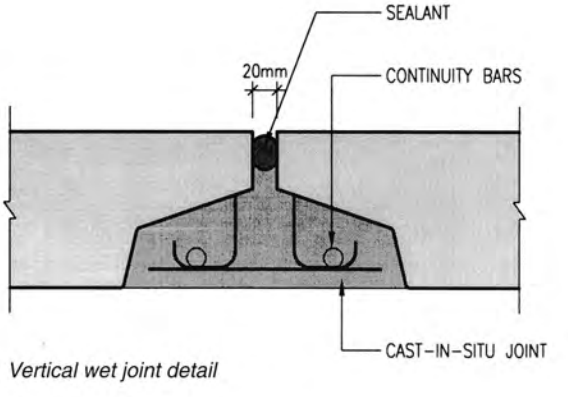
HDB precast facade being prepared for 'Wet' joint connection with in-situ column



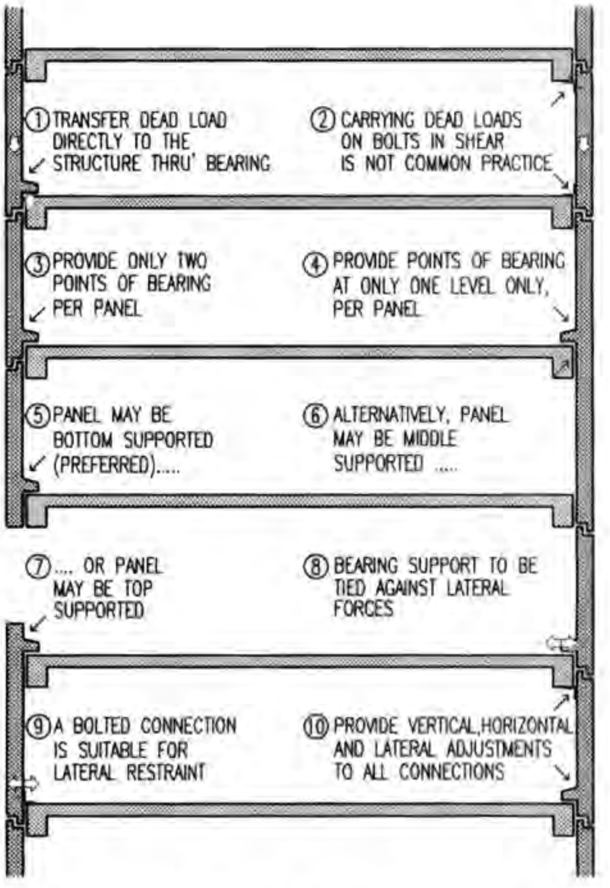
Precast facade prepared for 'Wet' joint connection

• 'Wet' Joints

The face-sealed joints and open drained joints discussed above entail precision and highly accurate assembly and fixing of precast panels on site. Local public housing constructions, which have a large percentage of precast components, tend to use 'wet' or cast in-situ joint and connections. These wet joints and connections are easier to fix on site due to a higher tolerances allowed. They minimise the use of sealant and are therefore more reliable for waterproofing. Some examples of wet joints and connections are shown in the diagrams.



Vertical wet joint detail



Design principles for cladding connections: Ten basic principles

3.4.6 Connection details

Connections are very important in precast construction as they connect the precast units together and transfer stresses from their point of application to the stabilising structure. The design of connections for precast concrete components is a major factor influencing safety, performance and economy.

Precast concrete connections must also meet design and performance criteria. These include:

- Structural strength and loading
- Durability
- Fire resistance
- Constructability

3.4.7 Precast panel connections

The main purposes of a panel connection are to transfer load to the supporting structure and to provide stability. A precast panel can be supported by concrete nibs cast integrally with the panel or by steel angles fixed to the back of the panel. Unless the steel element is protected by concrete, galvanised, painted or epoxy coated, stainless steel angles should be used.

Ten basic principles for panel connections to the main structure are shown in the diagram.

The preferred method of support is to cast the panel with an integral nib that rests on the structure. Restraint fixings are usually metal angles bolted between the panel and the structure.

Connections could jeopardise the structure's stability if weakened by fire. As such, it should be protected to the same fire rating as the members that they connect. This can be easily achieved by embedding the fixings in in-situ concrete or by the use of a proprietary board or spray.

3.5 Handling And Erection Consideration

3.5.1 General

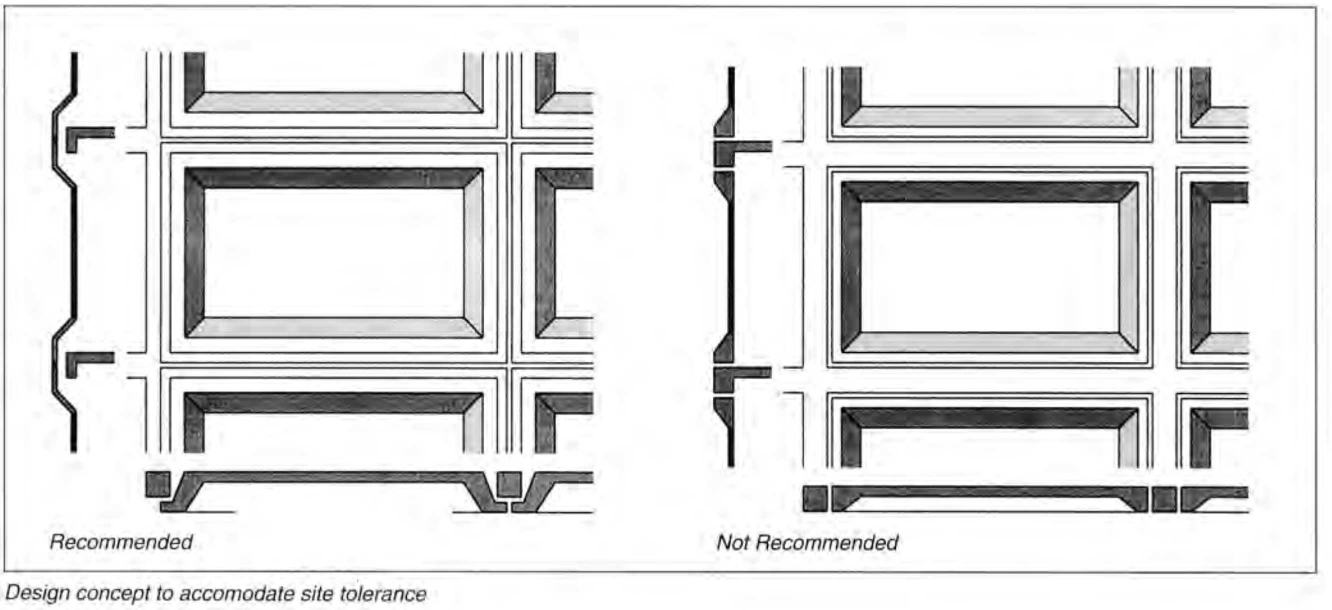
At the design stage, the architect should, with the help of precaster, consider the tolerance, handling, transportation and erection of the precast components. Considerations for efficient and economical plant manufacturing of precast components alone may not be enough. Considerations must also be given to handling and erection operations as they affect the overall efficiency and economy.

3.5.2 Tolerance

The precast components must be designed with sufficient tolerance for manufacturing and erection. Adequate tolerance is essential in order to avoid irregularities such as tapered joints (panel edges not parallel), movement at intersection and non-uniform joint widths. It also helps to maintain uniform opening dimensions and aligns the vertical faces of the units to avoid offset. By careful planning, cumulative effect of dimensional inaccuracy can be prevented through providing escape areas where dimensional inaccuracy or production errors can be absorbed.

Tolerance in the manfacturing for the precast concrete components is generally in accordance with BS 8110: Part 1:1985, Section 6, Subsection 11.3. As a guide, the permissible deviations are as follows:

Types of Tolerance	Size of Panel	Deviations(±)
Width and height	Up to 3m	3mm
	3m to 4.5m	4.5mm
	4.5m to 6m	6mm
Cross section	Up to 500mm	3mm
	500mm to 700mm	4.5mm
Straightness or bow	Up to 3m	4.5mm
	3m to 6m	6mm
	6m to 12m	9mm
Squareness (deviation of the shorter side from perpendicular taken from longer side)	Up to 1.2m	3mm
	1.2m to 1.8m	4mm
	1.8m to 2.4m	5mm
	2.4m to 4m	6mm
	More than 4m	7mm
Twist (any one corner in relation to other corners)	Up to 600mm wide and up to 6m long	3mm



Design concept to accomodate site tolerance

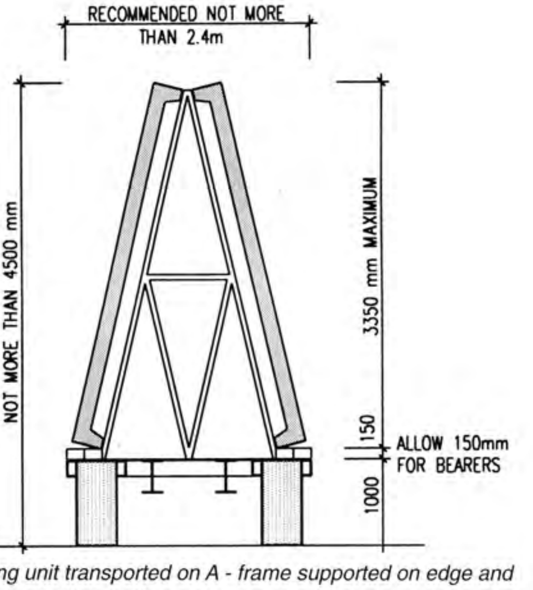
3.5.3 Handling and transportation

One of the major advantages in precasting is that precast components pre-finished with elaborate details and various shapes can be produced under optimal conditions in factories or protected site casting yards.

If the pre-finished components are erected without damages, the repair works on the buildings will be reduced to an absolute minimum. The advantages of construction speed, minimum waste of material, reduction of labour and good durable finishing quality can be achieved with good handling and erection. On the other hand, the advantages of the precast will be reduced if extensive making good is required due to handling and erection damages.

Site casting and handling

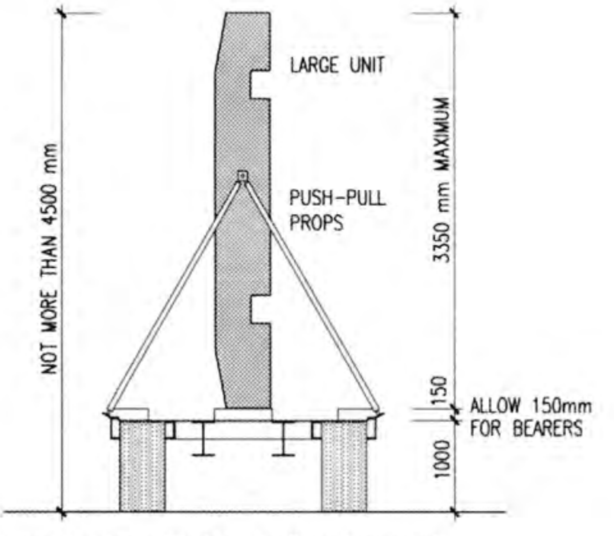
Wall panels transported by a low trailer



Cladding unit transported on A - frame supported on edge and mounted on a low trailer

Precast components are subjected to stresses during the production, transportation and erection. As such, it is important to understand the stresses at each stage and design the element that can withstand such stresses. In addition, the concrete strength is also different in each of the stages.

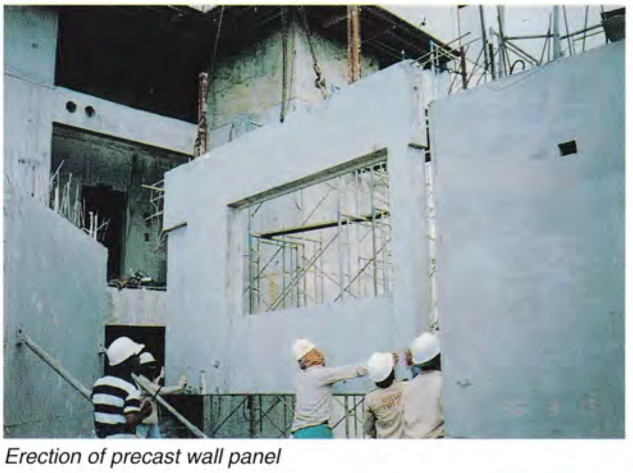
For the ease and safety in the handling of the precast concrete components, lifting hooks and inserts are incorporated into the components during manufacturing. Lifting hooks and inserts must be carefully assessed in relation to their bearing capacities and the precast components. The safety measures should apply from the first lift out of the mould until the component is permanently installed in the construction.



Large cladding unit held vertically and mounted on a low trailer

Precast concrete components should be stored in a vertical position similar to their final position in the building. This procedure has the advantage that the prolonged storage of the components will cause it to weather as it would in its final position.

Considerations must also be given to the height, width, length and weight limitations of the precast components in relation to transportation.



Erection of precast wall panel

Erection of precast H-shaped unit

Lifting of precast panel

3.5.4 Guidelines for erection

Proper planning of the construction process is essential for efficient and safe erection. The sequence of erection must be established early. After erection, each panel must be stable and can withstand wind load, accidental load and load imposed due to other construction operations. Provision should be made for both the panel and the support system to permit immediate temporary bracing of the panels. Such temporary bracing should not interfere with adjacent erection and other construction operation. The temporary bracing must be maintained until permanent connections are accomplished.

The precast concrete erector must conduct a survey of the building as constructed and check the position of the cast-in-place brackets before setting out the joint locations prior to actual erection. Any discrepancies between site conditions and shop drawings which may cause problems during erection (such as structure out of alignment, hardware improperly installed, errors in bearing elevations or location, and obstructions caused by other trades) must be noted. Erection should not proceed until discrepancies are corrected or until erection requirements are modified.

Temporary support for precast wall panel

3.6 Building Codes And Regulations And Design Responsibilities

3.6.1 Building codes and regulations

Local building codes and regulations for conventional buildings also apply to precast buildings. There is no specific codes and regulations published in Singapore for precast buildings.

In the submission of the drawings and calculations for a precast building by Qualified Person (QP) to the Building Authorities, reference is made to the British Standard 8110 (The Structural Use of Concrete), or American Standard under PCI (Precast Concrete Institute) Code of Practice. British Standard 8297 :1995-Code of Practice for Design and Installation of Non-load Bearing Precast concrete Cladding is also used.

Currently, the Singapore Building Control Regulations 1990 Edition and the Code of Practice for Fire Precautions in Buildings 1997 are also applicable to precast concrete building.

3.6.2 Design responsibility

The parties involved in the design and construction of a precast building include the owner, architect, engineer, general contractor, precaster, erector and site inspector.

In general, the architect selects the cladding material for appearance, specifies the requirement for weatherproofing, tolerances for proper interfacing with other materials, and general performance characteristics. The structural engineer designs the structure, designates connection points and evaluates the effects of structural movement on the performance of the elements. The precaster designs the precast components for handling, erection and fulfil the performance specification. Full co-operation amongst all parties is absolutely essential for the success of the project.

It is important that the responsibilities of the architect, engineer, general contractor and precaster are clearly defined and understood. If part of the design responsibility is vested with the precaster, close co-ordination between the architect and the precaster is necessary in finalising the architectural design.

3.6.3 Responsibilities of architect and engineer

The basic responsibility for both the architect and the engineer when specifying precast concrete design should be as follows:

- Provide design drawings and specify the aesthetic, functional and structural requirements with dimensions.
- Specify the architectural and structural performance requirement of the precast concrete units.
- The performance specifications shall specify all limiting factors such as minimum and maximum thickness, depths, weights and any other limiting dimensions.

3.6.4 Responsibilities of precaster

A precaster can be either a material supplier or a sub-contractor to the general contractor.

Many precasters can design the precast components to be manufactured by them, if this task is specified in the contract. Similarly, connection designs may be carried out by the precaster, if the connection forces are provided by the engineer.

The architect may, in the specifications, leave the responsibility for erection of precast concrete components to the general contractor. He may also specify erection be under the responsibility of the precaster. In general, precaster prefers that the erection be under the responsibility of the general contractor except for architectural precast components.

Their responsibilities will also include:

- Producing samples, shop drawings and establish installation procedures.
- Analysing and designing the precast concrete components for handling (stripping, storage, transportation and erection) stresses or temporary loading imposed on them prior to and during final erection.

3.6.5 Responsibilities of main contractor

The main contractor's responsibility is to build the structure in accordance with the contract documents.

He is responsible for administration of the project schedule, co-ordination with all other construction trades and developing adequate construction means, methods, techniques, sequences and procedures of construction.

The main contractor should be responsible for:

- Co-ordinating all information necessary for the precast concrete manufacturer to produce the precast concrete components.
- Reviewing and approving or obtaining approval for all precast concrete shop drawings, including the method statement for handling, transporting and erection.
- Co-ordinating of dimensional interfacing of precast concrete with other materials and construction trades.
- Ensuring that proper tolerance is maintained to guarantee fit and overall conformity with precast concrete shop drawings.
- Establishing and maintaining at convenient locations, control points and benchmarks in an undisturbed condition for use by the erector until final completion and acceptance of the project.

CHAPTER FOUR
ARCHITECTURAL PRECAST COMPONENTS

4.1 Architectural Precast Concrete Facade

4.1.1 General

Architect has a plethora of options when designing architectural precast concrete. A wide range of shapes, profiles and textures are available. It is possible to capitalise on the expertise of the precasters. By utilising the experience of precasters and the creativity of architect, innovative design solutions could be generated.

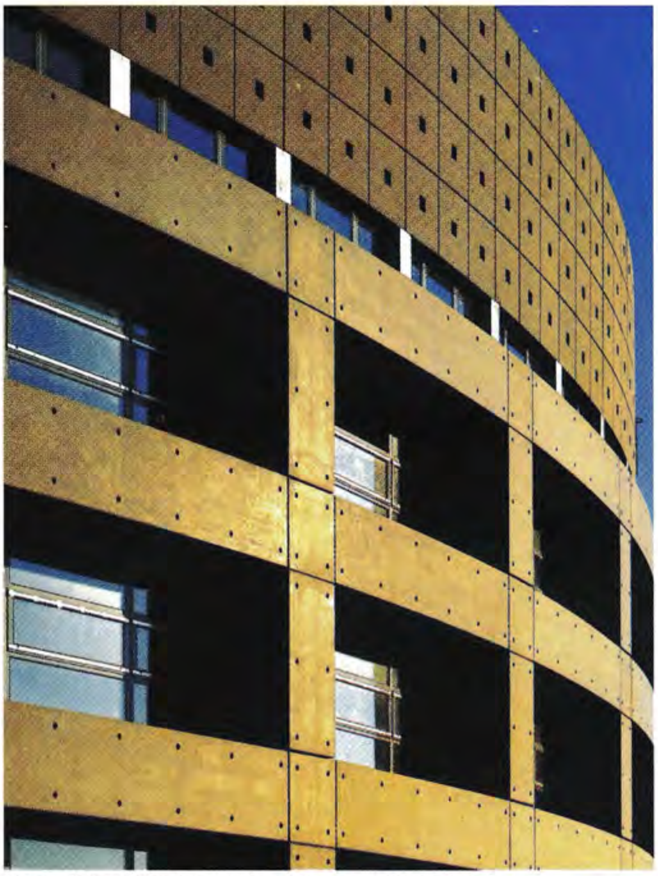
The benefits of precast concrete facade are as follows:
- Design of three-dimensional curved form for the facade panel is possible. Complex and innovative designs are achievable with high quality moulds.
- Precise and quality finishes under factory controlled production.
- High strength concrete can be used to achieve lasting quality.
- Excellent fire and acoustic performance.

For external facade, architect has the option to select the design of the precast concrete cladding as either load bearing or non-load bearing. One major advantage of the load-bearing wall design is the cost saving for combining both the structure and the wall element. However, greater effort is needed to ensure design, production, delivery and installation, integration of services are carefully planned and coordinated.

The non-load bearing precast wall, being a non-critical path item in the construction process, can be designed, developed, prefabricated independent of the critical structural elements.

Sculptured precast wall reflects the plasticity of concrete

A plain and articulated precast facade
Architect: Ricardo Bofill



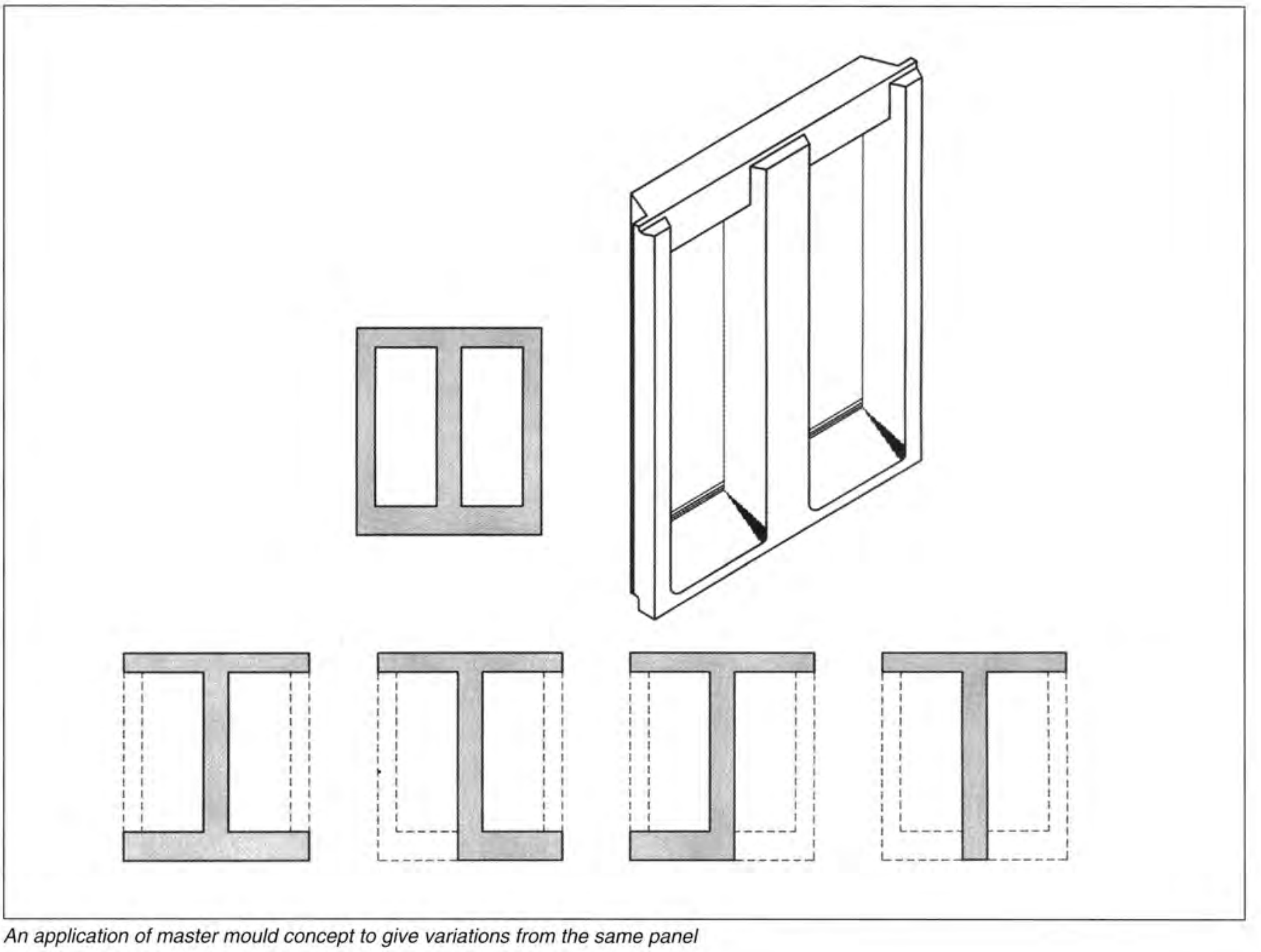
Curved facade using precise precast concrete panels
Architect: Christian Hauvette

4.1.2 Types of mould

By using largest panel as a master mould concept, different section of the panel is being cast or blocked off

The understanding of the mould design plays an important role in achieving the final shape and finishes of the precast concrete products. Precasters often adopt a master mould concept to optimise their production. The concept is simply to design the largest possible panel mould for a particular facade panel, whereby several variations from the same mould can be produced by varying mould component accessories. Architect can capitalise on this concept with the precaster to create varieties in design using the master mould.

Most moulds are designed to have face-down casting to achieve flatness and fewer pinholes on the concrete surface. Vertically cast moulds are being used by contractors. Condominium project such as Floravale had adopted this method to achieve finished surface on both sides of the facade.

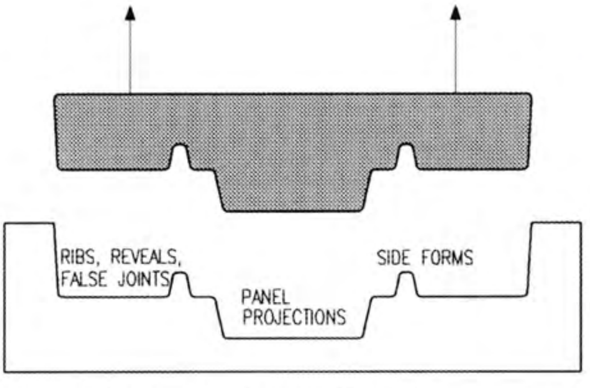


An application of master mould concept to give variations from the same panel

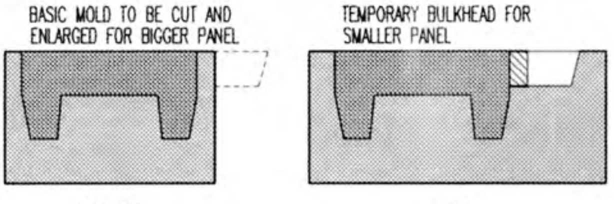
There are various types of mould material:

- Steel mould
  Local precasters prefer the use of steel mould for its robustness and precision. With the availability of plasma cutting technology, steel mould can be cut and assembled with relative ease. A well-constructed steel mould can be used for casting up to 150 times with only minor repair and cleaning. However, owing to storage problem, most non-standard moulds are not stored for future use. One major cost saving possible is to adopt standard moulds, or to maximise repetition in mould usage.


Vertical cast steel mould

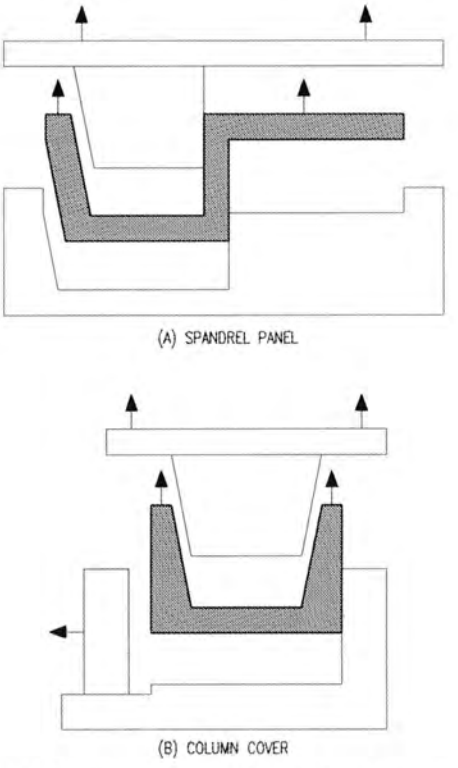


Total envelope mould - minimum positive draft

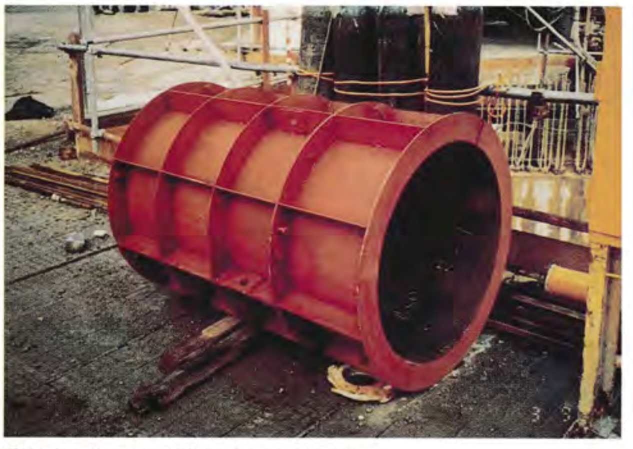


DON'T **DO**

Master mould concept



Example of face and back forming for deeply sculptured panels


Circular steel mould for round column


A recessed window precast facade using steel mould, aluminium window frame is cast together to provide a weather-tight joint

- Timber mould

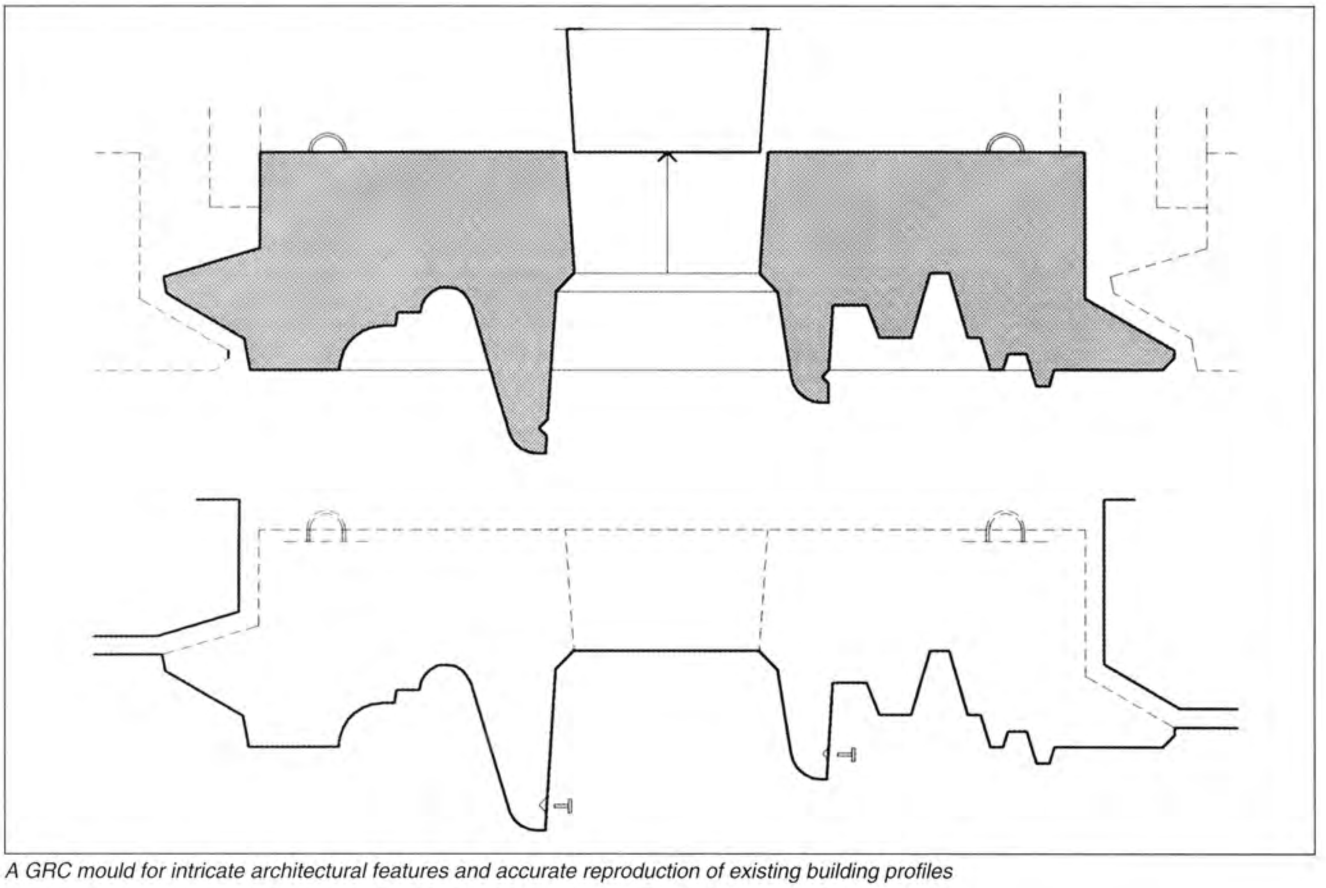
  Timber mould is commonly used in overseas countries due to the availability of good quality softwoods and skilled craftmen. Timber mould can be easily made and worked upon. For example, in France, a master timber mould is often made to allow for modifications and for casting into a variety of different panel designs.

- GRC mould

  The number of casting for GRC mould is fewer as compared to steel mould. Even though the cost of production is higher, GRC mould is most appropriate for three dimensional structures.

A mould for a large precast parapet wall panel under construction. In France, moulds are frequently constructed from high grade softwood which allows substantial alterations to be made relatively easily

A GRC mould for a relatively complex corner feature for King's Centre Development Singapore



A GRC mould for intricate architectural features and accurate reproduction of existing building profiles

- Polystyrene mould
  Special stone effect on precast wall can be created using pre-designed polystyrene mould. This technique is relatively new and costlier as the mould can only be used one time after casting. Colours and textures can be applied to the stone-effect wall to create a realistic natural effect.

A stone-effect precast wall using polystyrene mould technique which has a range of surfaces to choose from and is available from local precasters

4.1.3 Surface finishes

There is a wide range of possible surface finishes that can be explored by architects. The common finishes are derived from the use of aggregates (crushed stones, granites chips or gravels) of varying sizes and shapes. With the experience gained over the last twenty years, precasters are now able to have a good control over the finishes.

A full prototype sample is necessary to confirm the uniformity of the surface and its texture effects. It is highly recommended for precasters to stock pile aggregates or coloured cement to minimise inconsistencies of the finishes. Architect and client must recognise the difficulties in achieving colour consistency in very large panel and panel with highly polished surface.

The methods or treatments used to achieve surface finishes can be divided into two broad categories:

(a) Modeling
Modeling uses techniques like sand blasting, acid washing, polishing and honing, hammering and chipping to create the required architectural effects. There is an increase use of polished concrete surface and the quality of finish is comparable to that of granite and natural stone. With more research into these applied finishes in the future, architects could have more confidence to achieve their inspirations.

One of the exceptional attributes of concrete is the almost unlimited diversity of surface finishes and colour
Architect: Arata Isozaki & Associates, Team Disney Building, Florida 1991
Photographer: Yasuhiro Ishimoto
Used by permission from Disney Enterpises, Inc., USA

The surface modeling treatment can be further divided in the following:

- Off-form

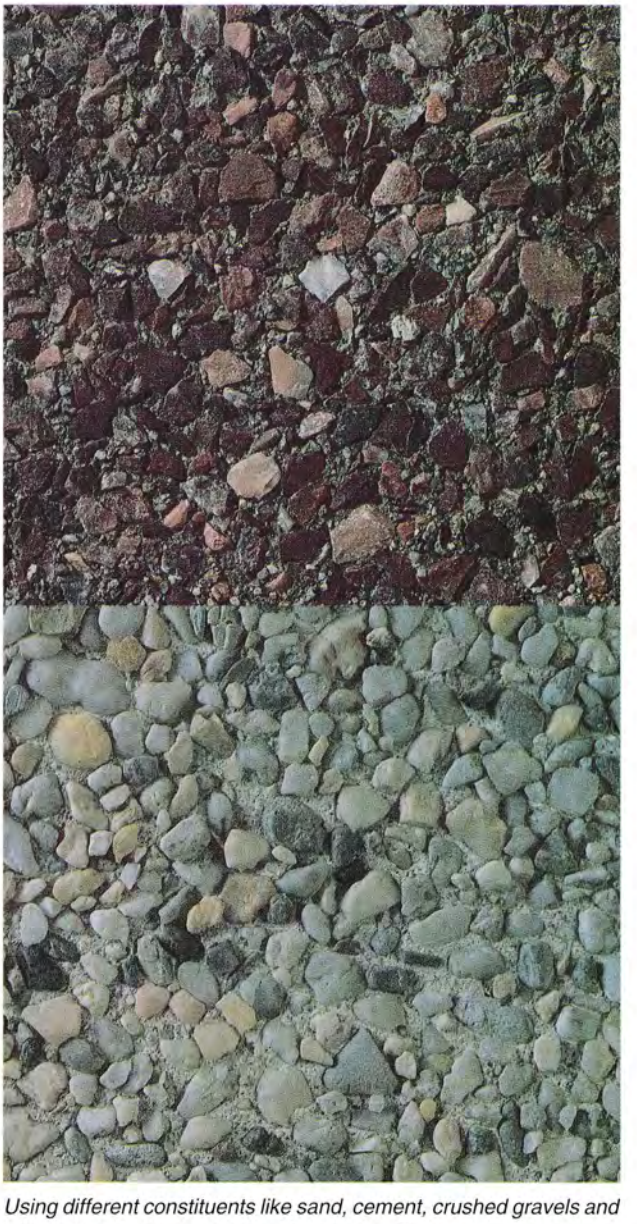
With the recognition of the beauty of concrete as a plastic material, its off-form raw colour finish is widely used. However, care is to be taken to treat the off-form finish with appropriate protective coatings to prevent weathering and staining due to its surface porosity.

- Exposed aggregate

Chemical retardants are applied to concrete panel to expose the sizes and colours of the granite chips, stones and gravels.

Application of this technique is limited to face-down casting or vertical casting often involving the surface details. The selection of a suitable retardant is dependent upon the depth of exposure of the aggregates required by the designer. The purpose of chemical retardant is to delay the cement at the surface of the precast element to set too early.

Off-form finish requires attention to mould precision, casting, demoulding and surface protective coating



Using different constituents like sand, cement, crushed gravels and stones to achieve an exposed textured surface

- Reveals and grooves

Elastomatic rubber moulds or formliners are used to achieve specific patterns such as reveals and grooves. Designer can select a wide range of prescribed surface textures and patterns from manufactures catalogue like Reckli. The profile thickness of the formliner varies from 7mm to 50mm.

- Acid retardant

The acid retardant will expose the round aggregates surface on the panel. In Europe, "silographic" images can be etched on flat concrete surfaces. Large graphic images are now possible to be printed on to the concrete surface.

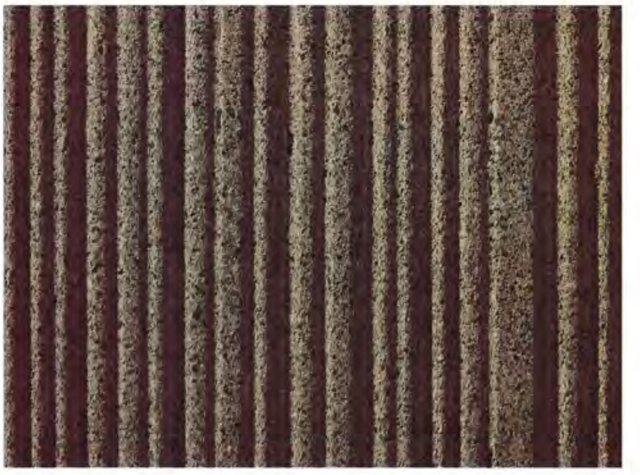
- Water washed

This is the most economical method of concrete surface treatment. It requires a large quantity of clean water. The recycling of the water is highly recommended for this process.

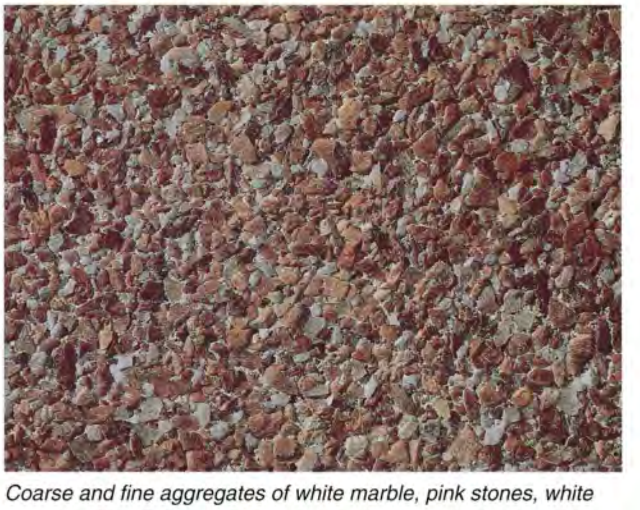
- Acid etched

Similar to acid retardant, this method requires the use of strong acidic liquid to treat the precast concrete surface. Environmental care must be taken to prevent acid from getting into the underground water and soils. The treated surface is usually a matt, stable surface, which has long lasting qualities.

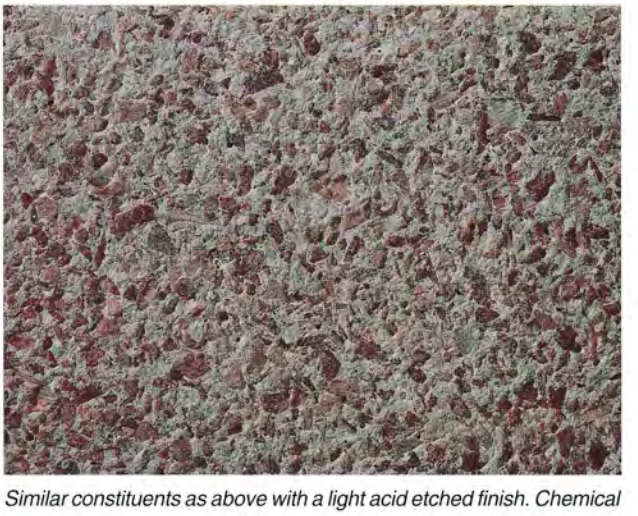
In short, modeling of architectural precast concrete offers a myriiad expressions and possibilities that cannot be accomplished with other matarials. The examples are not design alteratives but serve to help architects by pointing out those available options.



Elastomatic rubber mould produces a striated effect



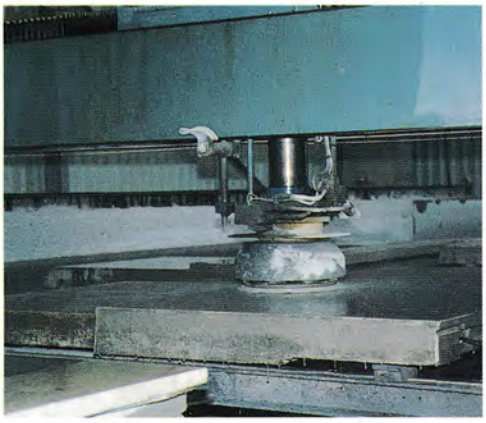
Coarse and fine aggregates of white marble, pink stones, white cement with a light retardant



Similar constituents as above with a light acid etched finish. Chemical retarding agents are available to produce a range of retarding effects to provide light, medium or heavy surface expose levels


Sand blasting to precast concrete surface


Sand blasting in factory-controlled environment


Polishing of concrete panel to give a highly polished surface similar to stonework


Final hand polishing to a polished concrete staircase

(b) Texture

The textured treatment of concrete surface is achieved with a tooling process. The processes are as follows:

- Sand blasting is an abrasive process using medium such as water, sand or grit to "chip off" the surfaces to give a more durable and self-cleaning appearance.

- Rope and hammered nib process is relatively laborious and requires highly skilled workers. The design of the end walls for Forum Gallery at Orchard Road utilised this technique.


Rope and hammered nib textured surface

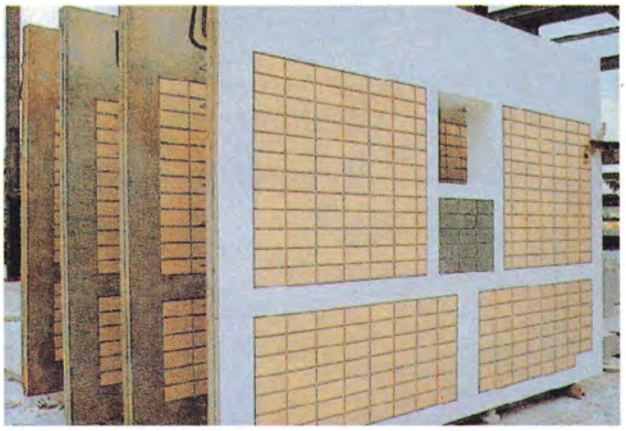
- Sophisticated honed finish is a level of grinding that produces a smooth but matt finish.

- Polished concrete is similar to polished natural granite and stones. This technique uses a high-tech polishing machine to create a highly glossy and evenly flat surface.

(c) Mixed finishes

- Brick-in-laid or tiled panels

  Many public housing projects employ such surface treatment. The bond of the surface materials such as bricks or tiles to the concrete panels are much stronger when cast together.


Brick-in-laid precast wall panel

Stringent pull-out tests are to be carried out in factory to prevent any possible de-bonding of in-laid materials.

- Granite or marble finish panel

The combination of natural granite or marble slabs cast together with precast concrete in factory provide an enduring and sophisticated exterior for owners and architects. The stainless steel pin inserts incorporated into the precast panels under factory environment ensure the much needed safety.

- Reconstituted stone

The increased availability of the artificial manufactured stones will offer architects a wider selection of finishes when used with precast panel. Tests must be carried out to determine the strength of the bonding with concrete.

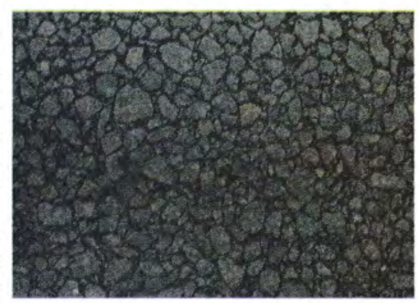
For architect to specify precast facade, perhaps the most important issue is to recognise and appreciate the variations which must be expected and determine the level of acceptance.

Two approaches are as follows:

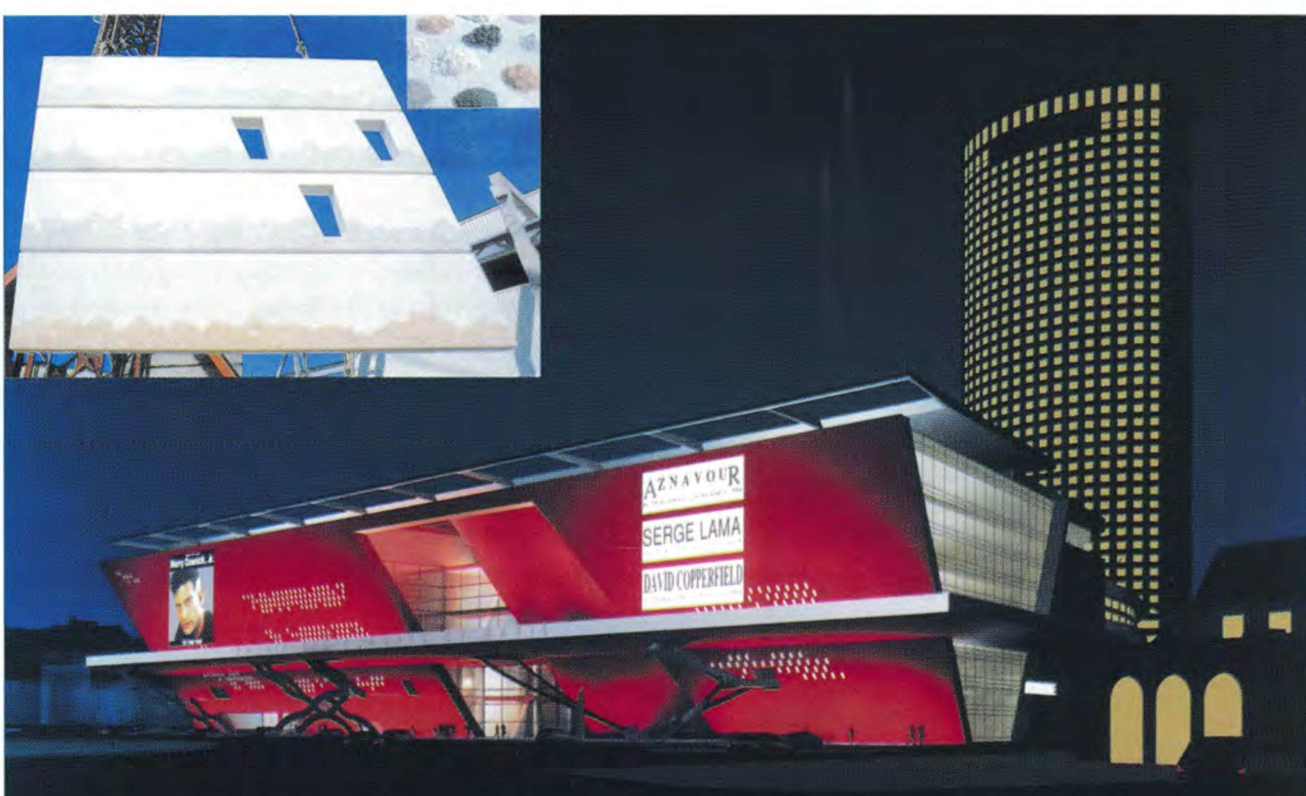
- Looking at buildings with similar mixes and finishes.
- Discuss with the precaster at the conceptual stage of the design.

Machine polishing a two-tone precast concrete panel

A machine polished finish
<u>Cement</u>
white
<u>Fine aggregate</u>
crushed white marble
<u>Coarse aggregate</u>
white marble



A machine polished finish
<u>Cement</u>
gray
<u>Fine aggregate</u>
crushed mahogany granite
<u>Coarse aggregate</u>
mahogany granite
<u>Pigment</u>
dark gray



Inclining 30º over Porte Maillot is dramatic and existing. The new precast facade measured 160 metre long 30 metre high.
Above insert shows the two-tone wavy line polished precast facade
Architect: Christian de Portzamparc, Palais de Congress

Inland Revenue House Singapore: The ribs are solid granite inserts to create a patterned feature. Different coloured granites have been used to add visual interest to the external precast wall

Ministry of Home Affairs Complex: Granite in honed and polished finish in precast facade. The full prototype panel incorporates aluminium frame to achieve weather-tight joints

4.1.4 Colour

The colours for precast concrete panels can be derived from either aggregates, cement or pigments.

- Aggregates

Aggregates can provide colour as the final finishes.

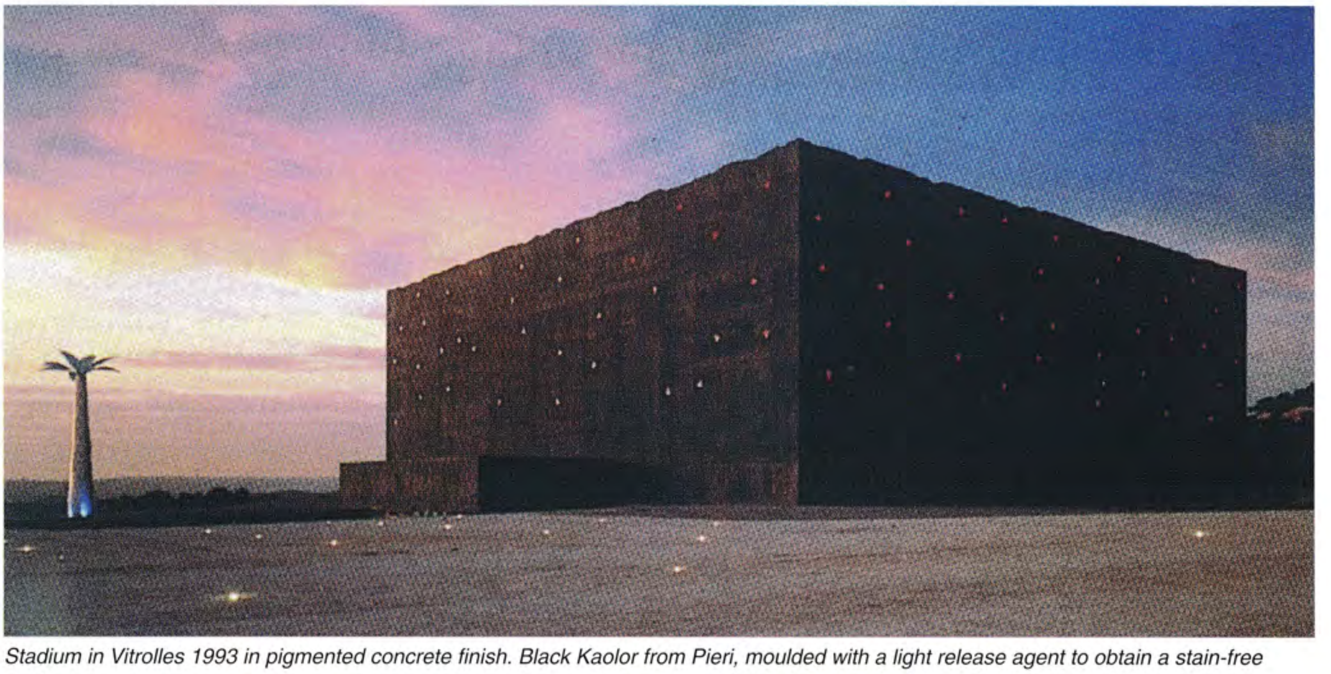
- Colour cement

Cement with different colours can provide the desired colour effects. Good quality control is essential to achieve consistency in colours.

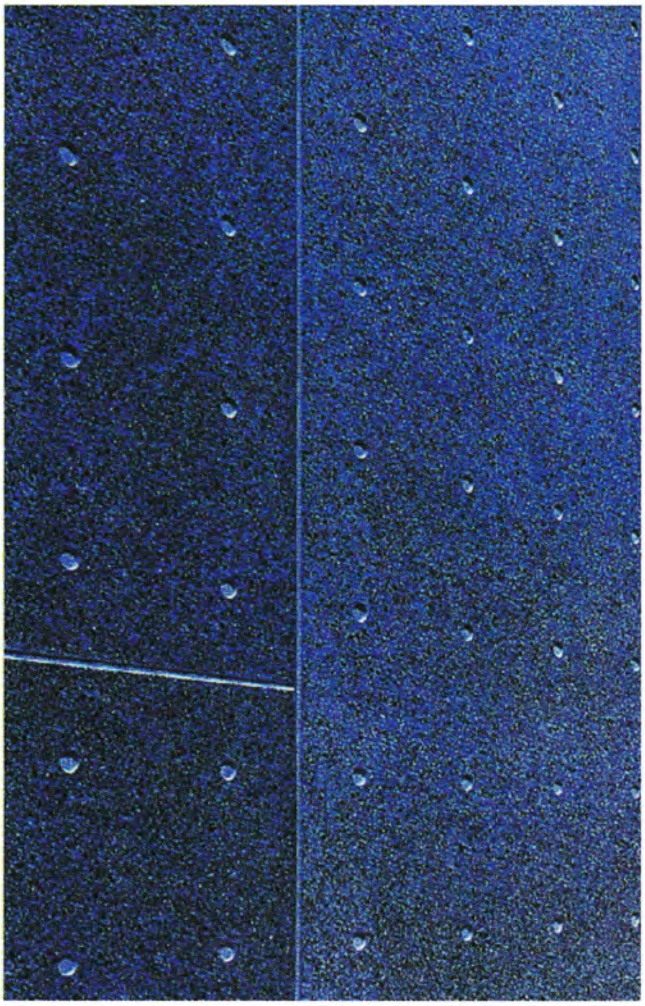
Full scale samples are needed to ascertain the colour consistency and effect from the viewing distance of the building.

The selection of appropriate colour must be made by referencing to suppliers' literature and recommendations followed by sample panel trials. Sample panel trials are encouraged to determine the right colour tone and surface detail. Full prototype will allow evaluation of final appearance which may lead to a re-design of the element.

Coloured concrete are from metallic oxides. Iron oxide for black, oxide for blue red and yellow chromium for green cobalt
Natural organic pigments are relatively cheap but colours are not consistent



Stadium in Vitrolles 1993 in pigmented concrete finish. Black Kaolor from Pieri, moulded with a light release agent to obtain a stain-free surface
Architect: Rudy Ricciotti



Blue coloured pigment concrete wall with a surface water repellent treatment to protect exposed surface from water and atmospheric pollution. Usine des eaux de joinville Le Pont
Architect: Jacques Ferrier

Kaolor blue pigment

- Coloured oxide pigments

Coloured oxiding pigments have gained wider acceptance to provide colour and finishes for concrete. A good selection of coloured pigments in powder or granular forms is now available. The concreting colour pigments being metallic oxides are predominantly in the shades of green, blue, yellow and brown. In application, the colour may be throughout the full thickness of the precast panel or restricted to the face of the panel, like a veneer. The veneer approach may be appropriate if the mix contains an expensive aggregate, such as granite, and white or off-white cement. The homogenous effect of coloured pigment provides a uniform and almost flaw-less, durable surface.

Time and wider applications of the above techniques will certainly help to make these exciting repetiore of finishes to be common place in Singapore architecture for many years to come.

4.2 Precast Internal Wall Partition System

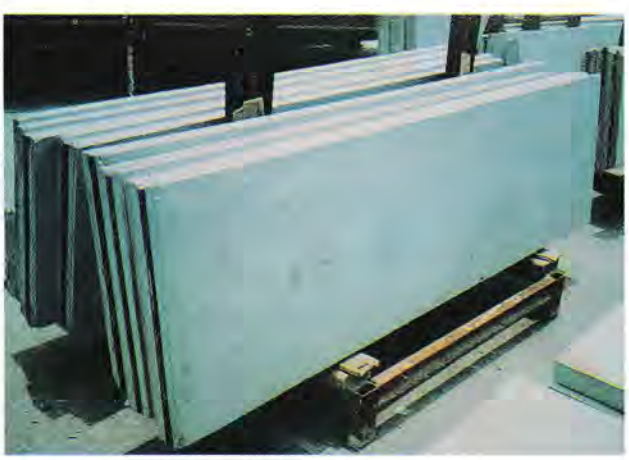
4.2.1 General

There are various types of precast internal wall partition systems available in the construction industry. The different systems range from composite gypsum dry wall systems to lightweight concrete panels and other composite wall panel systems.

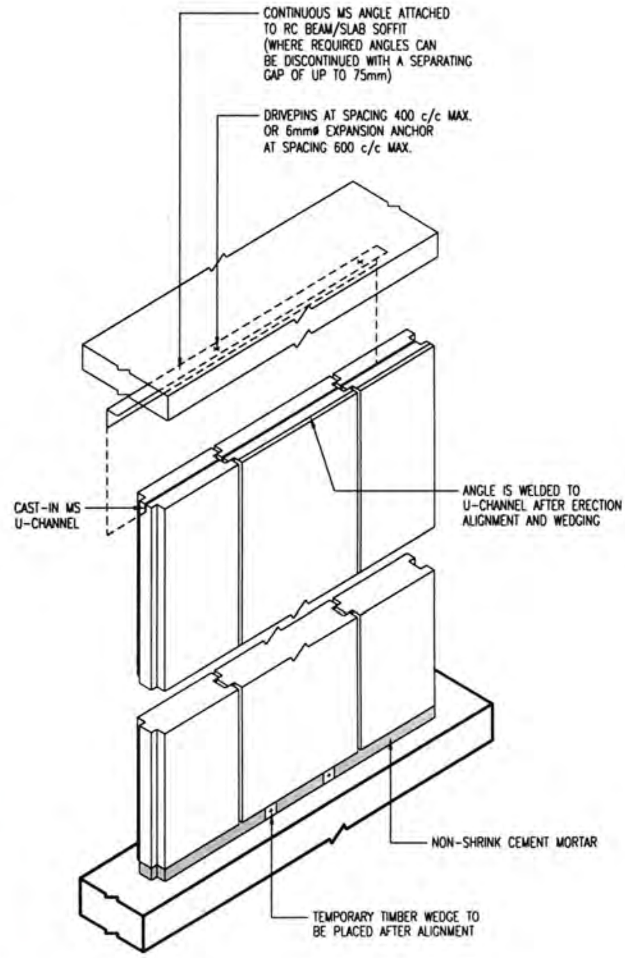
For this study, the reviews are made only on the relevant materials suitable for the Singapore residential building culture. Currently there are two types of precast internal wall partition systems commonly used in residential projects in Singapore:
(1) Precast solid lightweight concrete panel system
(2) Precast hollow core lightweight concrete panel system

4.2.2 Precast lightweight concrete panel system

Precast lightweight concrete panel is the oldest standardised internal wall system in Singapore and has been used extensively by the Housing & Development Board in public housing.



Stacking of precast internal wall panels



Precast lightweight concrete panel

(a) Material Specification
Precast lightweight concrete panel system has two different thickness; 75mm and 90mm. The standard widths are 300mm and 600mm. Notwithstanding the standard production module, transport facilities and the availability of lifting equipment dictate the maximum dimensions of the panel.

Dimensional specification and weight of the panel are as follows:

Length	2.4 m to 3.6 m
Width	600 mm
Thickness	75 mm
Weight	160 kg to 240 kg

(b) Guidelines for Installation

The sequence of installation for the wall partition is as follows:

(i) Align the precast panel in desired position. Alignment of panels shall allow for skimming so as to flush with the adjoining reinforced concrete structure.

(ii) Mild steel angles and expansion bolts are used to secure the panel.

(iii) The top of the panel has a recess or gap formed by a cast-in mild steel C channel placed centrally. The panel is erected and fixed into required position by fitting the top angle into the recess/gap and held on firmly by timber wedges slotted in at the bottom of the panel.

(iv) A bottom galvanised steel L-shaped steel plate shall be fixed to the bottom of the first and last of the panel. The galvanised steel plate is then secured into the structural floor by masonry drive pins.

(v) The vertical joint between the panels should be maintained at 10mm ± 2mm.

(vi) The gaps between the beam soffits or ceiling soffits and the top of the partition should be 25mm. The bottom gaps between the structural floor and the bottom of the partition should not be more than 35mm.

(vii) Joints are patched up using non-shrink grout. (joints include top, bottom and sides).

(viii) The surface of the partition is skim coated.

Installation of precast concrete lightweight panel

4.2.3 Precast hollow core lightweight concrete panel system

(a) Material Specification

Hollow core lightweight panel is a composite consisting of cement, cellulose fibre, limestone, chemical additives and water. It is an extruded lightweight concrete panel. The dimension of the panel comes in 600mm width, 80mm or 100 mm in thickness and cut length up to 5850mm. The joints can be concealed with similar composite material.

Cutting and fixing of the panel can be achieved with normal tools such as saw, wood chisel, and wood drills. The ease of installation increases the productivity and fewer workers are needed.

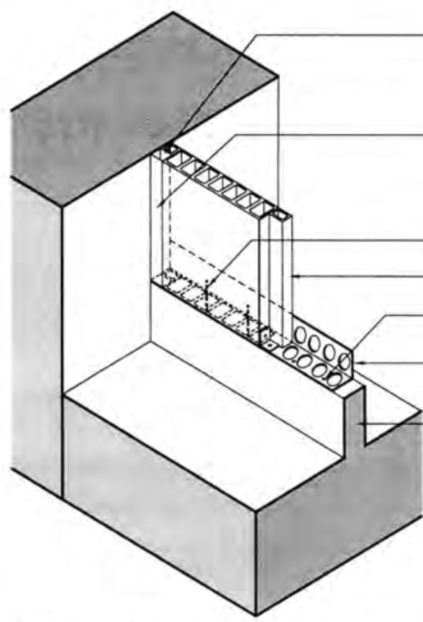
The profile of the panel allows easy concealment for mechanical and electrical services. The sound insulation level of the panel is equivalent to brickwall.

Profile of hollow core panel

Dimensional specification and weight of the panel are as follows:

Length	Up to 5.85 m
Width	600 mm
Thickness	80 mm or 100 mm
Weight	68 kg/m^2 for 100 mm thick panel

(b) Guideline for Installation



Hollow core lightweight concrete panel

The sequence of installation for hollow core lightweight concrete panel is generally as follows:

(i) Align panel to the desired position in accordance to the architectural drawings.

(ii) The accurate location of the tongue and groove of each panel shall be such that the offset between adjacent panel is within 2mm on both faces and width of the resultant joint between any two adjoining panels is 10mm (±) 2mm.

(iii) In general, the permanent connections shall be made before the partitions are erected and aligned. Mild steel dowel bars of size 16mm diameter and mild steel angle are fixed into the concrete slab and ceiling respectively at every alternate panel for bottom and top fixing. A gap of minimum 20mm is provided at the top between ceiling and panel and in-fill with polystyrene foam for vertical movement.

All vertical joints shall be sealed with one layer of jointing compound. The sealing of the vertical joints shall be in accordance to the manufacturer's procedures and instructions.

Installation of precast hollow core panel: Using temporary angle as a guide for alignment of wall

4.2.4 Integration of other building services

Vertical electrical trunkings should be incorporated into the panels during casting. However, the 75mm thickness of the precast lightweight solid panel presents problems in concealing trunkings and pipings for air-conditioning, water and gas. Generally, mechanical and electrical services may be concealed in the beams, floor slabs or by providing some form of architectural box up.

The hollow core lightweight panel system can easily incorporate mechanical and electrical services both horizontally and vertically. Openings for services can be formed by using a coring machine. The panel can also be cut to accommodate openings and lintel support.

Finished precast internal wall

4.3 Precast / prefabricated bathroom

4.3.1 General

In housing, hotel and hospital projects, bathroom is one of the most labour intensive elements in terms of finishes and accessories installation. Good standards and workmanship are normally expected owing to maintenance and potential water-tightness problems. Very often complaints during handing over and maintenance of these projects centre on the bathrooms. Thus, in order to achieve a more buildable and zero-defect building, precast/prefabricated bathrooms should be considered. The bathroom concept can shorten the construction period, as factory can proceed production in parallel with the worksite activities. These 'Unitised' bathrooms in the form of precast/prefabricated components or cells are being used increasingly especially in Europe, Japan and Korea.

4.3.2 Types of precast / prefabricated bathroom

Generally precast / prefabricated bathroom come in the following forms:

(1) Precast concrete cell with finished wall and floor pre-assembled prior to delivery to site.

(2) Precast concrete finished walls and floor panels separately lifted and assembled at location.

(3) Lightweight prefabricated finished cell with wall, ceiling and floor pre-assembled prior to delivery to site. Masonry or partition walls are required outside the wall panels.

(4) Lightweight prefabricated finished wall separately lifted and assembled at location with similar floor to sit on in-situ concrete slab.

(5) Lightweight prefabricated finished wall and ceiling pre-assembled off-site with precast concrete pre-finished floor as a cell.

Examples illustrated here are propriety products from Finland, Japan and Korea. Modified products for Singapore's adaptation are shown in examples of HDB projects and private condominium, Trellis Towers.

Generally, the ceiling to these unitised bathrooms can also be prefabricated with various lightweight materials.

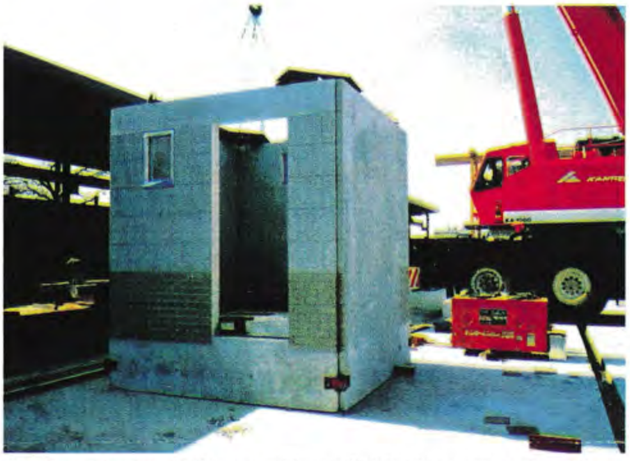
Gaps for tolerance are provided between the unitised bathrooms and supporting structural slab or walls for ease of installation, concealed piping, wiring, and maintenance.

The interior of the European example of precast concrete bathroom

An example of precast concrete bathroom in Europe

Pre-assembled bathroom cell prior to delivery

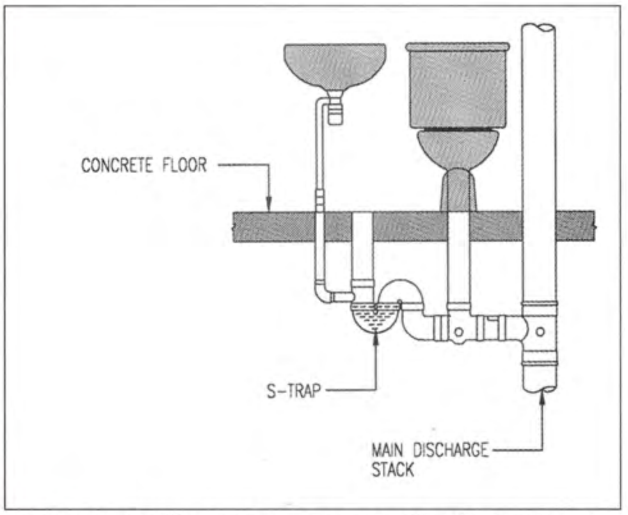
Conventional or 'shallow' floor traps can be used in unitised bathrooms, but the latter is preferred as it eliminates the core holes required through concrete slab.



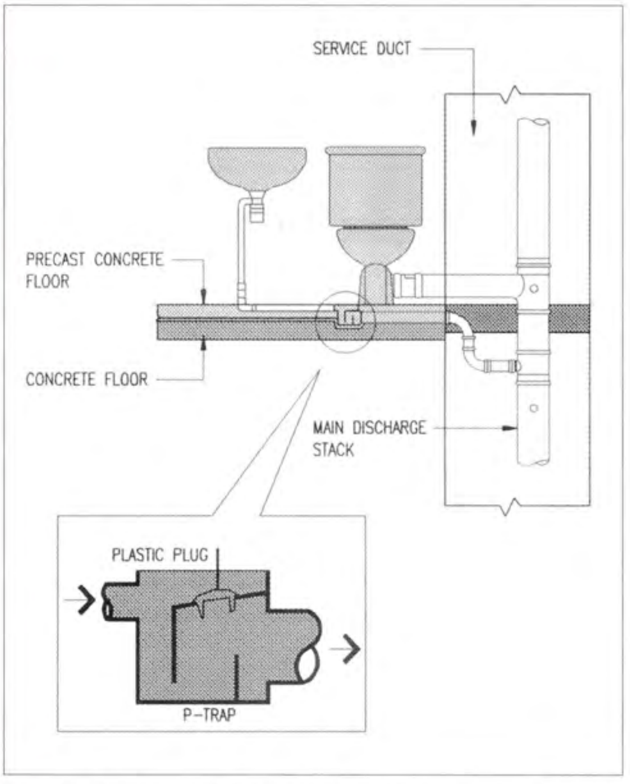
Precast concrete bathroom with pre-finished concrete external wall in Japan

Prefabricated finished walls separately lifted and assembled at location

During design stage, consideration should be given to the weight of the panel or cell. The location of the bathroom on the floor plan also affects the hoisting of the unit into its position.



Conventional sanitary system makes use of the S-trap which goes about 600mm below the floor



The new P-trap used in the prefabricated sanitary system is at floor level, thus making for easy maintenance. The compactness of the P-trap also means no pipes can be seen protruding into the ceiling of the unit below

4.3.3 Case study one

Trellis Towers

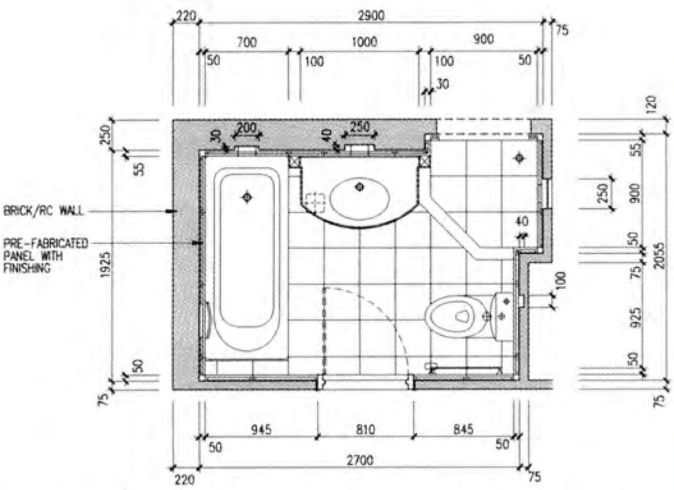
The first private residential project to use the prefabricated bath system is this 30-storey project with total 384 apartments at Lorong 1, Toa Payoh.

Trellis Towers

The project was awarded based on the coventional design and built contract. The contractor Shimizu Corporation proposed to convert the cast in-situ shear walls to precast walls to improve quality and reduce construction time. One innovative addition was the introduction of the Unit Bath System. Shimizu in its value engineering assessment had identified that finishing work to bathrooms was the most difficult task in a residential development, and decided to bring in a new toilet system marketed by National Matsushita from Japan.

Panel walls were prefabricated steel frames with marble or tiles and complete with sanitary, mechanical and electrical fittings. The finished panels were hoisted into their final position to be mounted on block walls.

The precast technology reduces dependence on skilled workforce on site as well as cutting down dirty wet work. Conventional floor traps were used for the unit baths as no approval was granted for shallow floor traps when construction work started. In-situ concrete floor slab was cast to receive marble or tiles.



Trellis Towers prefabricated bathroom layout: Lightweight concrete blockwalls give support to prefabricated panels


Completed interior of Trellis Towers prefabricated bathroom

4.3.4 Case study two


HDB housing at Hougang Avenue 1

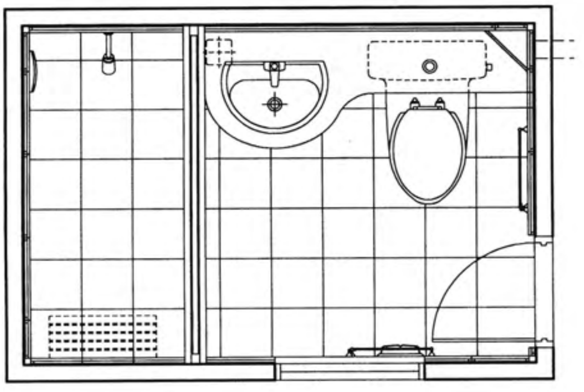
HDB Projects at Hougang Neighbourhood 1

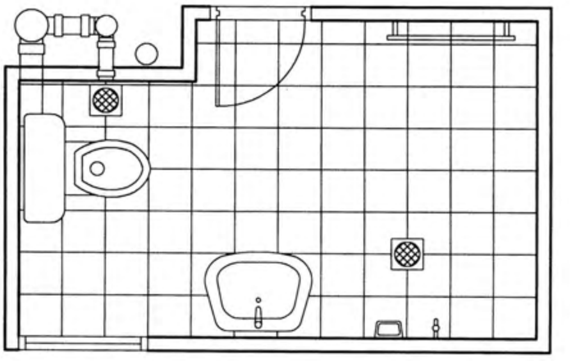
The first public residential project to use the prefabricated bathroom system was completed in November 96 to Blocks 158 to 161 at Street 11. They were the 'Pre-assembled' and precast toilet units. The second type was completed in November 97 to Blocks 168 to 173 at Avenue 1. They were "Pre-assembled" toilet units.

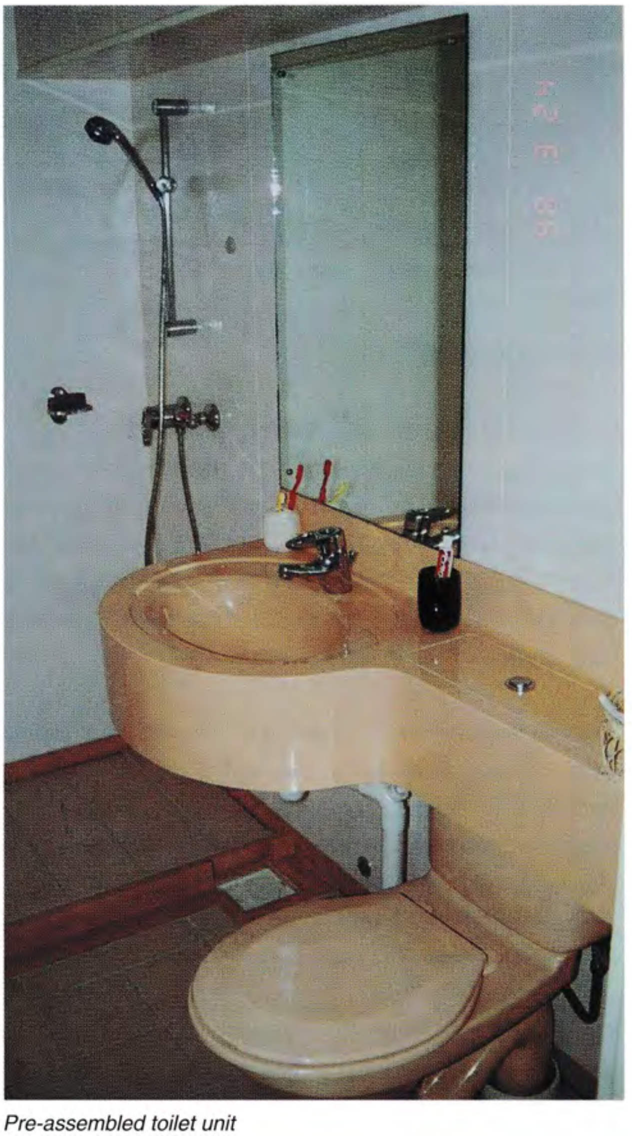
The first type of 'Precast' toilets was the product of Parma from Finland. They were assembled in Malaysia and delivered to site as complete cells with PVC coated galvanised steel wall finished with floor and wall tiles. Each unit had a 100 mm thick precast concrete floor with cast-in P-type shallow floor trap. The entire cell was hoisted to sit on in-situ floor slab. The weight of a unit was about 2 tonnes.

The second type of 'Pre-assembled' toilets was imported from Japan. These consist of fibreglass floor panel pre-laid with tiles, laminated cement board wall panels pre-laid with tiles and steel sheet ceiling panel. These panels were delivered to site as individual panels and assembled on site with fittings. The floor panel was laid on in-situ concrete slab and connected to conventional S-type floor trap.

The new shallow floor trap was approved by Ministry of Environment for use in HDB and PWD's camp projects, with the requirement to modify the floor trap with mosquito plug. Locally made product will be available soon.







Pre-assembled toilet unit

Precast toilet unit

To assist users in HDB pilot projects, a user's manual was issued. Most useful information includes the maintenance of the new P-type floor trap and notes on modifications and renovations.

HDB also carried out user survey in 1998. Less desirable features named were the hollowness of the walls and smallness of the windows. However, almost all residents found it easy to maintain the floor traps. It confirmed that P-strap is working just as well as the conventional S-trap. In terms of concealed piping and wiring as well as aesthetics, these two systems scored high points with the residents.

Hoisting of prefabricated toilet unit

Pipings ready for the pre-assembled toilet unit

For the two prototypes experimented, the cost is very close to the new generation HDB flats with concealed wiring and piping. Certainly, HDB is moving towards this new direction for their future projects especially with cost coming down when they are locally manufactured.

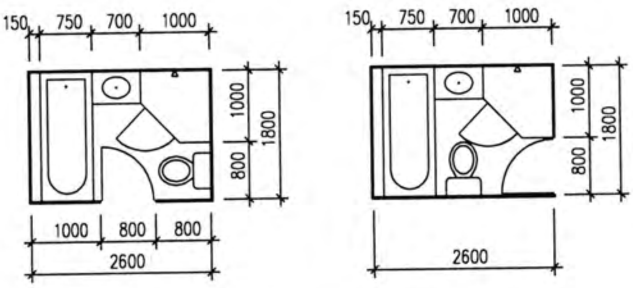
Standard imported prefabricated bath units from Japan and Korea are not suitable for use in local private residential projects as they normally use smaller oriental sitting bath instead of standard European/American long baths commonly used in Singapore.

Connections to soil stack

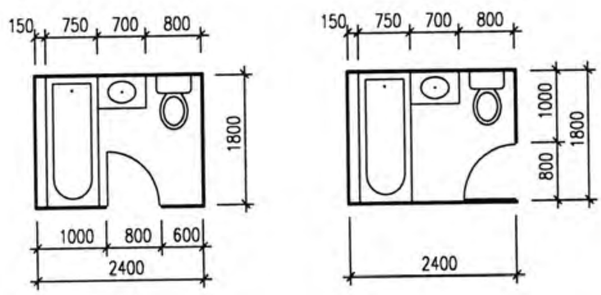
4.3.5 Recommended bathroom layout

This section suggests some typical layouts and dimensions for the various types of bathrooms commonly used in private residential projects in Singapore. These can be mass-produced to the similar standard used by HDB in Hougang pilot project.

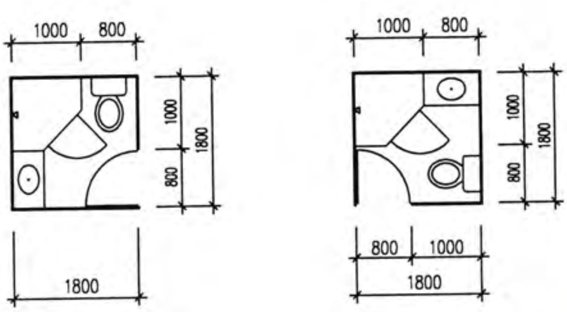
- All horizontal dimensions indicated are internal. A steel-framed tiled wall is normally 50mm thick, and a marble-tiled wall is normally 55mm thick. Allow 20-60 mm tolerance between these wall panels and masonry (or concrete) wall behind.
- Internal ceiling height to be 2400mm. Heaters may be installed above ceiling.
- All long bath side ledges are 150mm wide.
- All shower doors are 600mm wide. All shower screens are frameless with tempered glass.
- Steel door frame shall be in 25mm wide, thus allow clear door width of 750mm.
- All vanity counters are 450mm deep.
- The maid's basins are 300mm deep.
- Internal finishes and fittings may be modified to meet different levels of desired quality and budget.



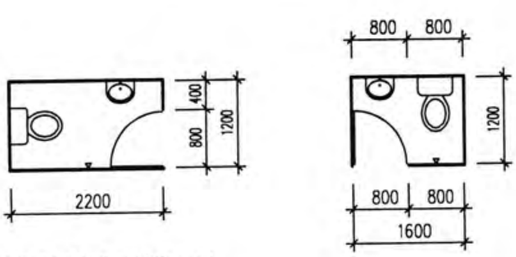
Recommended master unit with long bath and shower



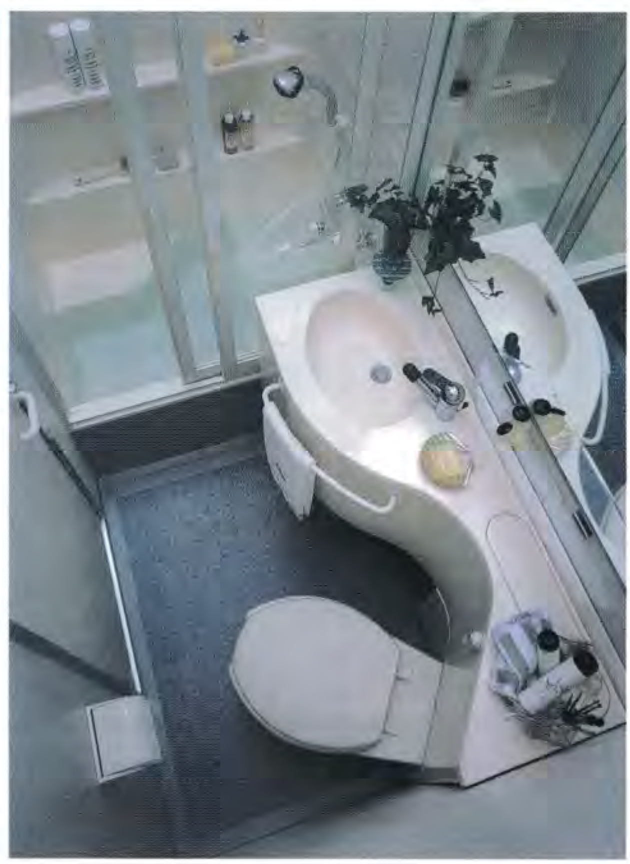
Recommended master unit with long bath



Recommended common unit with shower



Recommended maid's unit



Interior of a typical Japanese fully finished and fitted prefabricated bathroom available from catalogues

Bathtub: FRP (Fibre Reinforced Plastic)

Vanity Top : Artificial marble

Floor : FRP Base laid with resin-coated crushed stone moulded into the surface

Wall : Moisture and Heat Resistant Cement Board

Wall Coating: 3 layers coating for superb properties

Ceiling : Decorative PVC-coated steel panels

4.4 Precast Staircase

4.4.1 Standardised dimensions recommended for precast staircase

Precast staircase is well developed in the Singapore market. Precast staircases may be fabricated in a form of curved or straight and even in spiral profile. The prefabrication mould is limitless and malleable to the imagination.

Curved profile precast concrete staircase

Precast concrete staircase

Based on the Building regulations, precast staircases can accommodate tread size between 225mm to 250mm and riser between 150mm to 175mm.

Metal mould

Currently most precasters have to custom-make the mould to accommodate the specific dimension required. Following is a chart showing the various riser dimensions and their corresponding floor to floor height:

Riser Dimension (mm)	18 Risers Floor to Floor Height (mm)	20 Risers Floor to Floor Height (mm)	22 Risers Floor to Floor Height (mm)
150	2700	3000	3300
155	2790	3100	3410
160	2880	3200	3520
165	2970	3300	3630
170	3060	3400	3740
175	3150	3500	3850

The size of the thread as stipulated in the fire code must not be less than 250 mm. The optimum dimension of the risers would be 165mm and 175mm. At 175mm riser height, the floor to floor height is 3150mm for 18 risers. At 165mm riser height, the floor to floor height is 3300 mm for 20 risers. The two floor to floor height of 3150 mm and 3300 mm will be very suitable for most private residential developments.

Recommendation:

The two standardised precast concrete staircases recommended for private residential buildings are:

(i) Precast staircase with 165mm riser and 250mm thread.

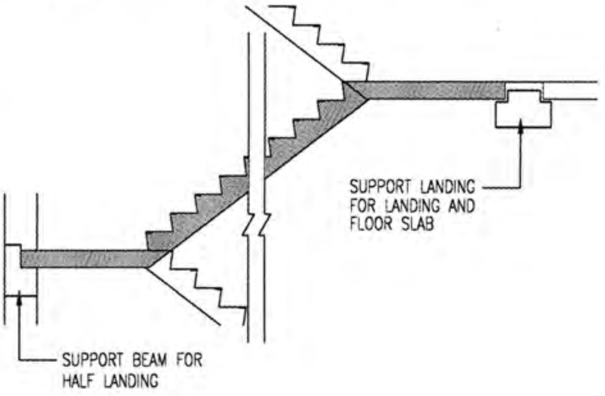
(ii) Precast staircase with 175mm riser and 250mm thread.

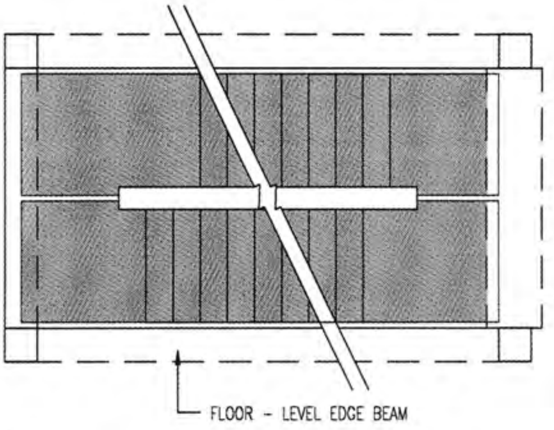
Lifting technique

4.4.2 Guideline for installation

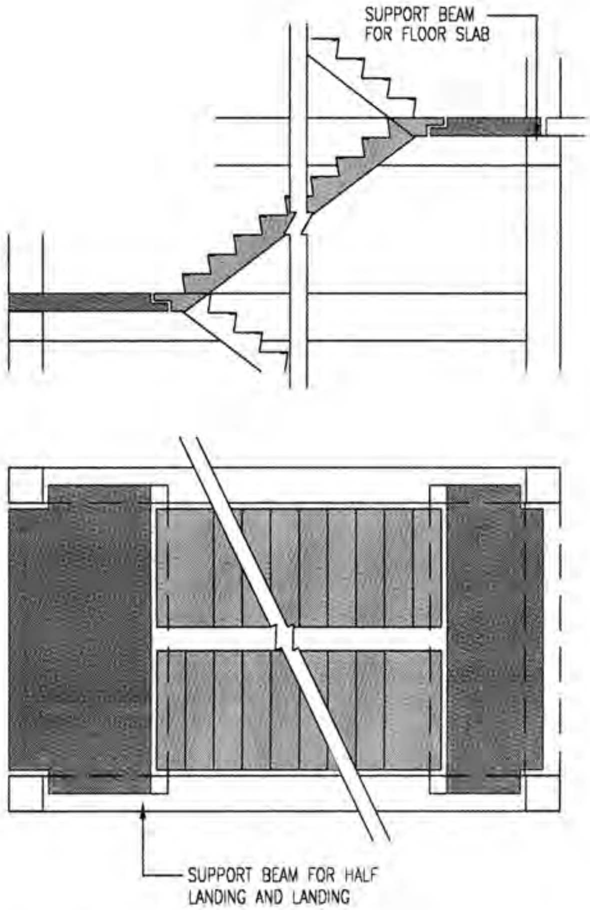
Currently there are two predominant fixing methods. The staircase can be prefabricated together with landing as a complete unit. Alternatively, the staircase is prefabricated without the landing. The landing may be prefabricated separately or cast in-situ with the structural member. The landing is first secured to the structural member, then the prefabricated staircase can be fixed.

The advantage of producing only the precast staircase flight is that it can accommodate some construction errors while the installation of precast staircase with flight and landing produced as a single unit requires good construction accuracy.





Combined landing, flight and half-landing units



Separate landing, flight and half-landing units

The sequence of installation for precast staircase is generally as follows:

(a) Support at both ends of the component is required during erection.

(b) The support can be beam or slab in precast or cast in-situ construction. If the bearing support does not cater for permanent loads, temporary propping underneath the supporting structure is required.

(c) The correct position and level for the staircase seating are to be checked and marked.

(d) Bearing pads for the seating of precast staircase panel are to be provided.

(e) Staircase panel is lifted by crane into staircase well.

(f) Staircase panel is adjusted to correct position and placed into recess.

(g) The erection of the staircase component can be either on the critical path or non-critical path of the construction sequence.

4.5 Precast Civil Defence Shelter For Residental Development

4.5.1 Statutory requirements

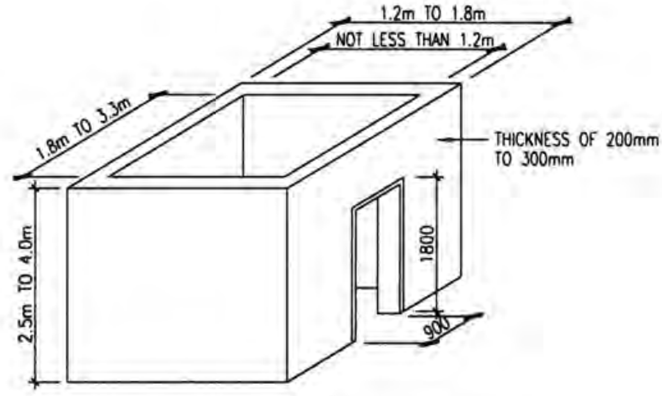
The statutory requirements are contained in the following publications:

(a) Technical Requirements for Household and Storey Shelter 1997.

(b) Administrative Procedures for Compliance by Qualified Person (QP) in the Design, Construction and Commissioning of Household and Storey Shelters.

(c) Construction and Commissioning Requirements of Household and Storey Shelters.

Building plans including detail structural drawings and clearance applications are to be submitted to the Civil Defence Shelter Engineering Department, Building and Construction Authority.

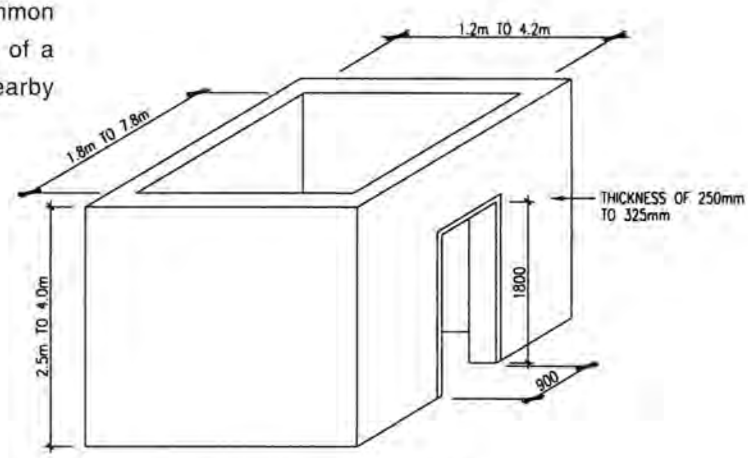


Household shelter: Internal floor area 2.0m² to 4.8m²

4.5.2 Types of shelter

(i) Household Shelters – This is located within each residential unit.

(ii) Storey Shelter - This is located beside the common circulation area (eg. lift lobby) at each storey of a residential block. The shelter is shared by nearby residential units.



Storey shelter: Internal floor area up to 32m²

(i) Household Shelters (HS)

The internal floor area shall be $2.0m^2$ to $4.8m^2$ and the maximum HS size shall be $4.8m^2$. The minimum HS size shall be in accordance to the Table below ;

Gross Floor Area (GFA) Of Dwelling Unit	Minimum Internal Clear Floor Area Of HS	Nominal Occupancy Of HS (No. Of Persons)
$GFA \leq 45m^2$	$2.0m^2$	2
$75m^2 \geq GFA \geq 45m^2$	$2.4m^2$	3
$140m^2 \geq GFA > 75m^2$	$3.2m^2$	4
$GFA > 140m^2$	$4.0m^2$	5

HS Wall Thickness

The HS wall thickness shall be as follows:

HS Clear Height Below Structural Slab (Ht)	Setback Distance Of HS Wall From External Building Line	Wall Thickness Required
$2.5m \leq Ht \leq 2.65m$	Less than 6m but more than 2m	250mm
	6m or more	200mm
$2.65m < Ht \leq 3m$	Less than 6m but more than 2.2m	275mm
	6m or more	225mm
$3m < Ht \leq 3.5m$	Less than 6m but more than 2.5m	300mm
	6m or more	250mm
$3.5m < Ht \leq 4m$	Less than 6m but more than 2.7m	300mm
	6m or more	250mm

(ii) Storey Shelter (SS)

The SS size should be calculated on the basis of at least $0.8m^2$ per person. The nominal occupancy of various sizes of dwelling units used to calculate the minimum SS size is given in Table below:

Gross Floor Area (GFA) Of Dwelling Unit	Nominal Occupancy Of Dwelling Unit (No. of Persons)
$GFA \leq 45m^2$	2
$75m^2 \geq GFA > 45m^2$	3
$140m^2 \geq GFA > 75m^2$	4
$GFA > 140m^2$	5

Its internal clear floor area shall be the product of $0.8m^2$ and the sum of the nominal SS occupancy loads of all the dwelling units served by the SS. For example, if the SS is to serve 2 dwelling units, one with GFA equals to $44m^2$ and the other with GFA equals to $46m^2$, then the minimum SS clear floor area to be provided shall be:

$0.8m^2 \times (2 + 3) = 4.0m^2$. The maximum net area (excluding the walls) of the SS shall be $32m^2$.

SS Wall Thickness

The SS wall thickness shall be as follows:

HS Clear Height (Ht)	Setback Distance Of SS Wall From External Building Line	Wall Thickness Required
$2.5m \leq Ht \leq 2.65m$	Less than 6m but more than 2.2m	300mm
	6m or more	250mm
$2.65m < Ht \leq 3m$	Less than 6m but more than 2.4m	300mm
	6m or more	250mm
$3m < Ht \leq 3.5m$	Less than 6m but more than 2.6m	300mm
	6m or more	250mm
$3.5m < Ht \leq 4m$	Less than 6m but more than 2.8m	325mm
	6m or more	275mm

4.5.3 Precast shelter

Except for the public housing sector, there has been no attempt by the private sector developers to construct precast shelters. All precast joint details have to be validated in full-scale explosive tests. The HDB experience, which is limited to household shelters and only to the wall elements of the shelter are shown in (ii) to (v) as follows:

(i) Single precast unit

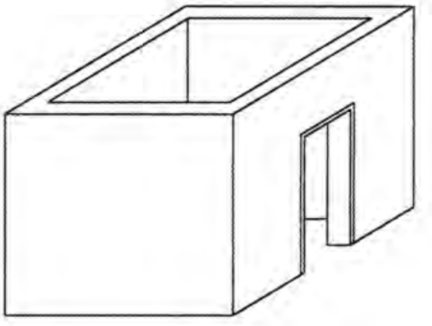
- All four walls done as a single precast unit.
- Due to the thickness of the concrete wall, this precast unit is about 20 tonnes and is too heavy to be lifted by normal site lifting equipment.

(ii) C Shape wall units

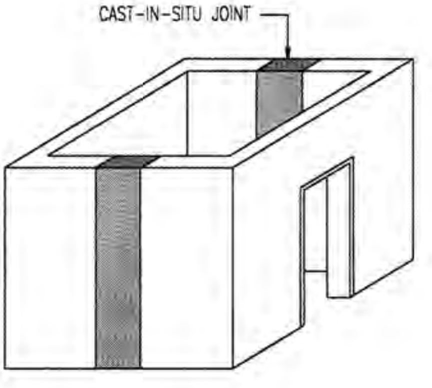
- Two numbers of precast C shaped wall units with cast-in-situ joints.
  Note: Joint details have not been validated in full scale explosive tests.

(iii) Semi-precast unit

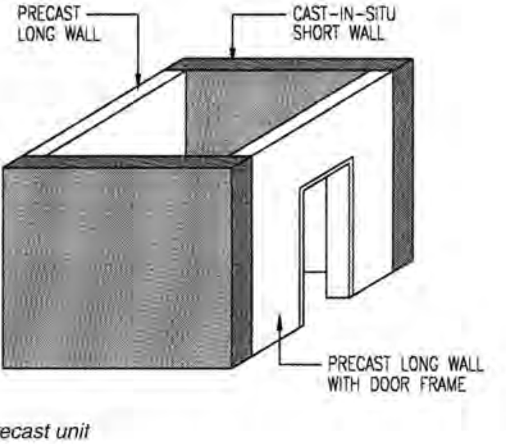
- Two numbers of precast long walls with cast-in-situ short walls.
- Details of the semi-precast shelter including validated joint details can be obtained from BCA. Please note that these approved details were developed by HDB for household shelters of 2.8m floor to floor height. Precast details for storey heights above 2.8m to 3.6 m are acceptable in principle for implementation so long as the precast connections are in accordance with the overall structural framework of the approved joint details for household shelter with storey height of 2.8m. As reinforcement contents for the walls depend on the shelter clear heights, detailed structural drawings with precast connections have to be submitted to the Civil Defence Shelter Engineering Department of the Building and Construction Authority for approval.



Single precast unit



C shape wall unit

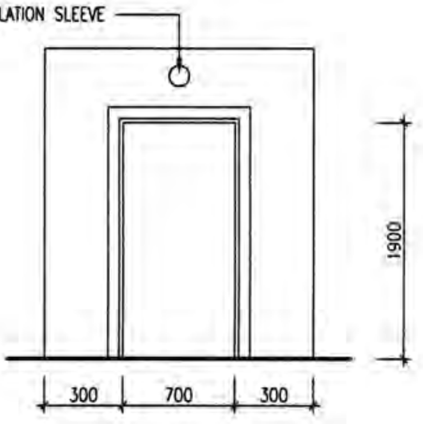


Semi-precast unit

(iv) Precast door frame panel with ventilation sleeve
This becomes a standard component for shelters of various sizes. The details of the shelter with precast door frame panel and validated joint details can be obtained from BCA. As the details are for house-hold shelter of 2.8m floor to floor height, the same requirements for modification to 2.8m to 3.6m height as described in (iii) above is applicable.

(v) Precast concrete cell with hollow walls
As the precast shelter shown in (i) above is too heavy for lifting by normal site equipment, a precast cell with hollow wall can be handled by lifting equipment on site.

The precast concrete cell can be lifted into place and the hollow wall filled up with in-situ concrete. The precast cell should come complete with the steel door frame and ventilation sleeves. The details of the precast cell for 2.8m floor to floor height is available from BCA. For modification to 2.8m to 3.6m floor to floor height, the same requirements described in (iii) above is applicable.

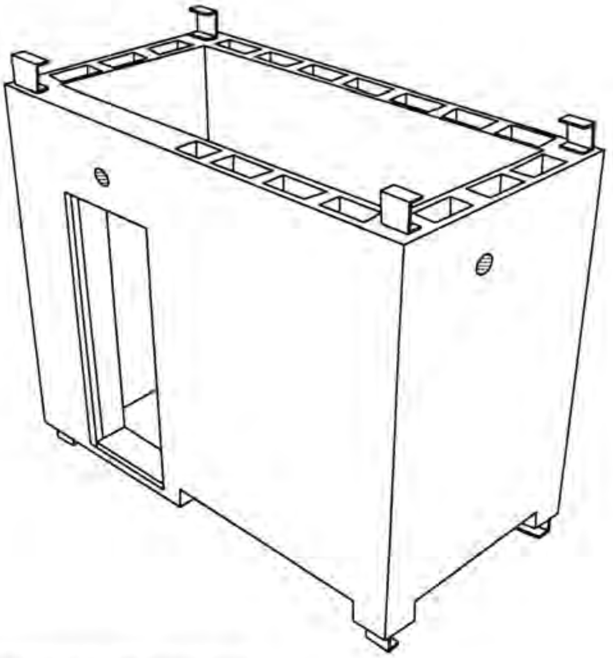


Precast door frame unit

4.5.4 Installation of fixtures in precast shelter

As with in-situ shelter construction, all proposed fixtures and services to be cast in or mounted on the internal and external walls of the precast shelter also need to be submitted to the Civil Defence Shelter Engineering Department, Building and Construction Authority for approval before implementation.

The electrical installation and communication system in the shelter shall include lighting, power, telephone, radio and television outlets.


Precast cell with hollow wall

4.5.5 Standardised shelter component for household shelter

(i) Semi-precast unit / precast concrete cell

The following table shows the recommended internal dimensions for the various sizes of household shelters.

These recommended dimensions can be applied to floor plan layouts where the setback distance of the household shelter wall from the external building line is less than 6m but more than 2m. The internal clear height of 3m will be suitable for floor to floor height of 3.15m where floor slab thickness is 150mm. If a higher floor to floor height for the dwelling unit is desired, the same internal height of 3m for the shelter can be retained by dropping the reinforced concrete ceiling panel over the shelter or by raising the reinforced concrete floor level of the shelter.

Two sets of recommended internal dimensions are given for dwelling units with gross floor area of more than $140m^2$. The higher height of 3.3m can be used for landed residential house where the floor to floor height is generally higher.

Gross Floor Area (GFA) Of Dwelling Unit	Minimum Internal Clear Floor Area Of HS	Nominal Occupancy Of HS (No. Of Person)	Recommended Internal Dimensions Of HS (W)x(L)x(H)	Thickness Of Wall
GFA $\leq$ 45 m^2	2.0 m^2	2	1.2 x 1.8 x 3.0	275 mm
$75m^2 \geq$ GFA $> 45\ m^2$	$2.4m^2$	3	1.2 x 2.1 x 3.0	275 mm
$140m^2 \geq$ GFA $> 75\ m^2$	$3.2m^2$	4	1.5 x 2.4 x 3.0	275 mm
GFA $> 140m^2$	$4.0m^2$	5	1.5 x 2.4 x 3.0	275 mm
			1.5 x 2.4 x 3.3	300 mm

Precast door frame unit

These recommended internal dimensions, if adopted extensively, will enable precasters to stock a range of standarised shelter components for the semi-precast unit and precast concrete cell with hollow walls as shown in 4.5.3 above.

(ii) Precast door frame panel with ventilation sleeve

Installing a civil defence door frame to in-situ surrounding walls is a difficult process. The precast door frame panel will resolve this problem. This standard component can be used for shelters of various sizes where the shelter walls are cast in-situ.

LIST OF SUPPLIERS

List Of Suppliers For Architectural Prefabricated Components

Name of Precaster	Contact		Range of products: Facades	Internal dry walls	Prefabricated bathroom	Precast staircase	Precast CD shelters
Eastern Pretech Pte Ltd	Address: Tel: Fax:	15 Sungei Kadut Street 2 Singapore 729234 3681366 3682256	✔	✔	✔	✔	✔
Fermold Pte Ltd	Address: Tel: Fax:	3 Tuas Basin Close Singapore 638798 8618836 8612909	✔		✔	✔	✔
Hong Leong Asia Ltd	Address: Tel: Fax:	7A Tuas Avenue 13 Singapore 638979 8623501 8610674	✔		✔	✔	✔
L&M Precast (Tuas) Pte Ltd	Address: Tel: Fax:	28 Tuas Crescent Singapore 638719 8613988 8612284	✔			✔	✔
Lightweight Concrete Pte Ltd	Address: Tel: Fax:	11 Kwong Min Road Singapore 628713 2615522 2644141	✔	✔		✔	
Prime Structures Engineering Pte Ltd	Address: Tel: Fax:	Blk 4016, #02-528 Ang Mo Kio Industrial Park 1 Singapore 569632 4540822 4540877	✔	✔			
Poh Cheong Concrete Product Pte Ltd	Address: Tel: Fax:	48 Sungei Kadut St 1 Singapore 729377 2691447 3685604	✔	✔		✔	✔
Redland Precast (Singapore) Pte Ltd	Address: Tel: Fax:	P O Box 541 Serangoon Central Post Office 2896541 2844279	✔			✔	

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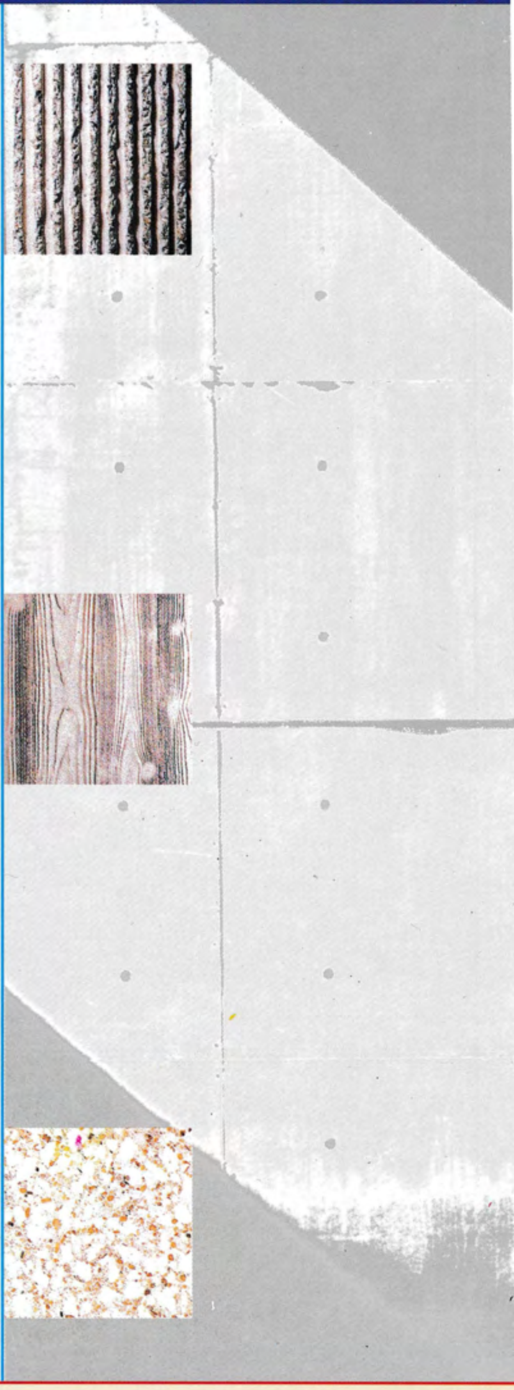

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