STANDARD PRECAST STAIRCASES

CHAPTER 3

Highly skilled workers are required to construct staircases in-situ because the step configuration of staircases could not be possibly made without skilled carpentry. The result is longer construction duration.

Using precast staircases will shorten the construction duration. It also allows operational access instantly to all floor areas. When constructed as non-critical structural components, stairwells can be used as access for the delivery of construction materials.

3.1 Architectural Design Considerations

The proposed standard precast concrete staircase is designed for use in residential, commercial and institutional developments. It is possible for an architect to specify standardised precast staircases according to Architectural Reference Sheet ST01, instead of detailing staircases. Once the floor to floor height is determined, the architect would merely have to indicate the type of staircase components on the drawings and the contractor can then buy these components off the shelf from the precaster. Using precast components would also eliminate the frequent construction errors in riser height in in-situ construction.

3.2 Structural Design Considerations

Precast stair slabs are usually designed to span longitudinally into the landings at right angles to the stair flights or span between supporting beams. In monolithic construction, the stair slab can be designed with continuous end restraints over the supports. But in instances where staircases are precast, the construction is generally carried out after the main structure, with pockets or recesses left in the supporting slabs or beams to receive the stair flights. With no appreciable end restraints, a precast stair slab could therefore be designed as simple slab between supports.

In design, the dead load is calculated along the sloping lengths of the stairs but the live and finishing loads are based on plan area. If the risers were to be covered with finishes, additional loads would have to be added in the design.

The effective span is measured horizontally between the centres of the supports or the actual horizontal length of the precast stair slab where dry connections are used at the supports. The thickness of the waist is taken as the slab thickness.

The basic span-effective depth ratio may be increased by 15% to 23 (=20 x 1.15) if the stair flight occupies at least 60% of the span. This will apply to precast stair slabs without landings.

The supporting nibs of the precast stair slab may be constructed with either dry or wet connections (extended bearings). The design of reinforcement of the nibs can be based on:

- Simple bending
- Strut and tie force model
- Shear friction

Theories and examples of the various design approaches can be obtained in the *Structural Precast Concrete Design Handbook* by BCA. Small diameter rebars should be used at the nibs as a result of the structural dimensions adopted.

3.3 Standard Precast Staircase Dimensions

In practice, the number of risers and the riser height of a staircase have always been dictated by the storey height of a building. This would result in different riser dimensions. Prefabricating stair flights with many different riser dimensions would not be economically viable.

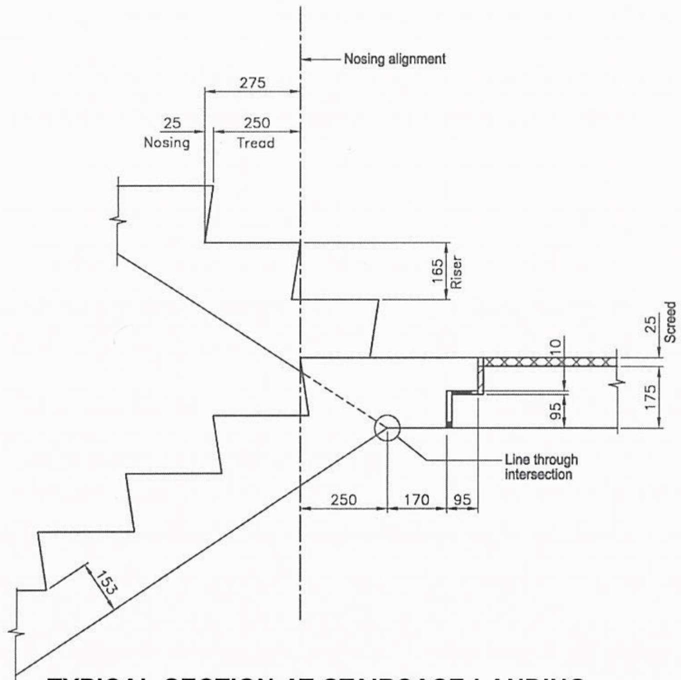
Standard precast staircases for residential projects have already been developed by Housing and Development Board (HDB) and the private sector. The main difference between HDB housing and private housing is the variation in floor to floor height. As most private developers prefer higher headroom, the number of risers and the riser height would vary accordingly.

The Committee considered the design aspects related to the aesthetic, fabrication, handling and erection of precast staircases and incorporated the following two distinct architectural features in the standard precast concrete staircase:

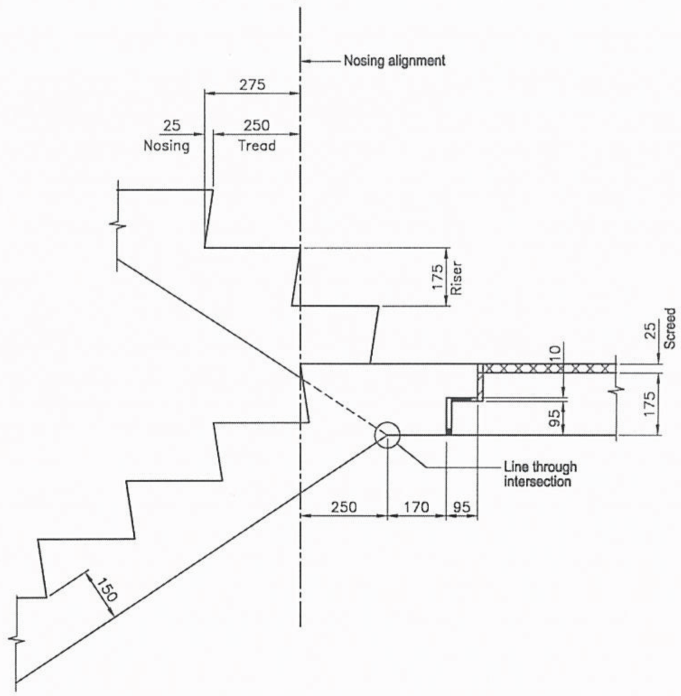
- Alignment of nosing of the first flight flushed with the nosing of adjacent flight.
- Simple and lined through intersection at the soffit of staircases where the flights and landings meet.

The Committee also proposed to limit the riser height to 165mm and 175mm, with a tread dimension to 250mm. These dimensions are suitable for fire escapes. For school development projects, 150mm riser with 300mm tread (instead of 250mm) are recommended dimensions required by the Ministry of Education, for safety reasons.

The following sketches show the recommended staircase dimensions for private housing and commercial developments.



TYPICAL SECTION AT STAIRCASE LANDING
Riser = 165mm, Tread = 250mm



TYPICAL SECTION AT STAIRCASE LANDING
Riser = 175mm, Tread = 250mm

Architectural Reference Sheet ST01 provides the recommended riser flight combinations, which could be used as reference for designers to select the appropriate floor height dimensions. For example in residential developments, a designer could use staircases with 175mm riser for a floor to floor height of 3,150mm, for fire escape. In luxury residential developments, staircases with a 165mm riser would be appropriate for a floor to floor height of 3,300mm.

The recommended width of standard staircase is ideally set to allow for a 1,000mm clearance between handrails and edging kerb. In addition, it allows designers to include or exclude an edging kerb (or buffer zone) of 75mm width to one side of the staircase. The provision is intended for the fixing of balustrades, which could be welded to the base plate, cast in the welding pocket, or bolted to the concrete surface by cast in socket.

3.4 Prefabrication and Labelling

Precast concrete staircases are cast on their sides or face down using precision-engineered steel mould and off-formed finished with nosing groove lines. The quality of end product is therefore assured. Dimensions such as the tread and riser should be fixed, to maximise the general usage of standard moulds. The Committee encourages designers to adopt the recommended dimensions as in Table 1, 2 and 3 of Reference Sheet ST01 in their designs.

The Committee also recommends designers to make use of the dimensions and details presented in the Architectural Reference Sheets. The labelling system for Stair Flight Type based on the following system,

ST10	/	150

is defined as:

ST	-	Standard Precast Stair Flight
10	-	Number of Risers per Stair Flight
150	-	Riser dimension (in mm)

3.5 Reference Sheets

RECOMMENDED DIMENSIONS FOR STANDARD PRECAST STAIRCASE

Table 1 150mm riser staircase.

Stair Flight Type	1st Flight (Riser Nos.)	2nd Flight (Riser Nos.)	Floor to floor Height (mm)
ST10/150	10	10	3000
ST11/150	11	11	3300
ST12/150	12	12	3600

Note: Standardised 300mm tread, recommended for school development projects.

Table 2 165mm riser staircase.

Stair Flight Type	1st Flight (Riser Nos.)	2nd Flight (Riser Nos.)	Floor to floor Height (mm)
ST10/165	10	10	3300

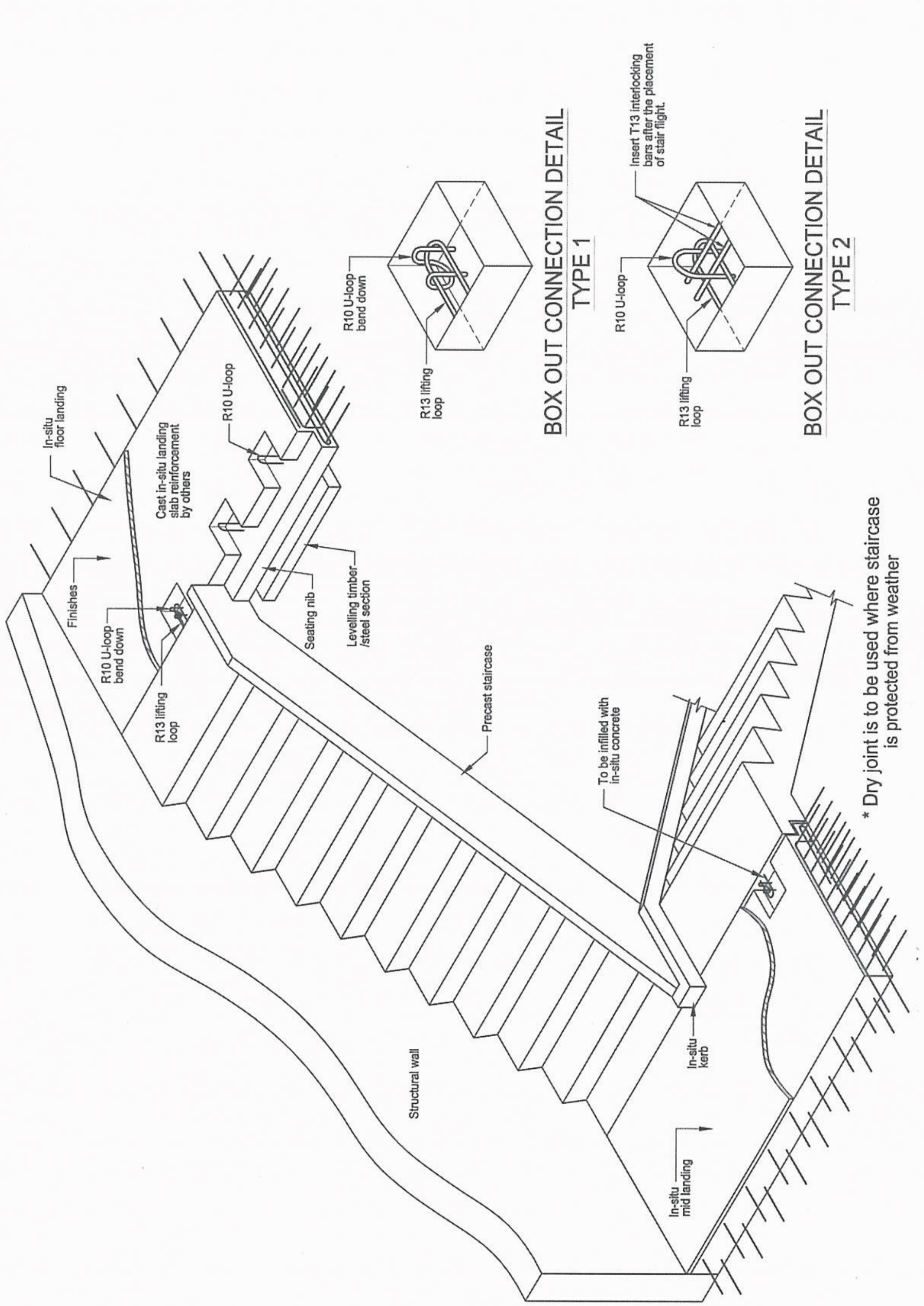
Note: Standardised 250mm tread.

Table 3 175mm riser staircase.

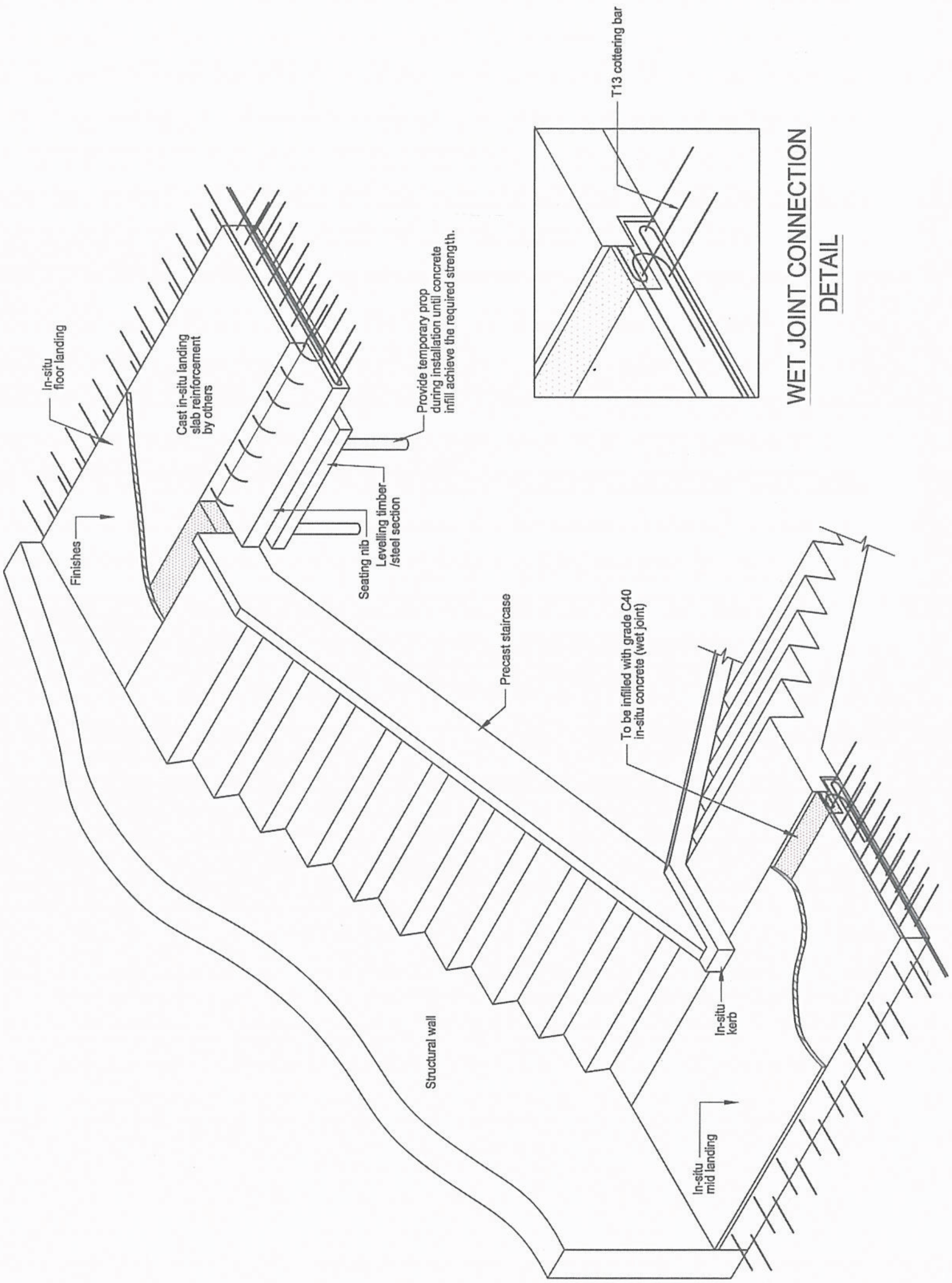
Stair Flight Type	1st Flight (Riser Nos.)	2nd Flight (Riser Nos.)	Floor to floor Height (mm)
ST8/175	8	8	2800
ST9/175	9	9	3150
ST10/175	10	10	3500
ST11/175	11	11	3850
ST12/175	12	12	4200

Note: Standardised 250mm tread.

ISOMETRIC VIEW OF STANDARD PRECAST STAIRCASE (DRY JOINT)



ISOMETRIC VIEW OF STANDARD PRECAST STAIRCASE (WET JOINT)

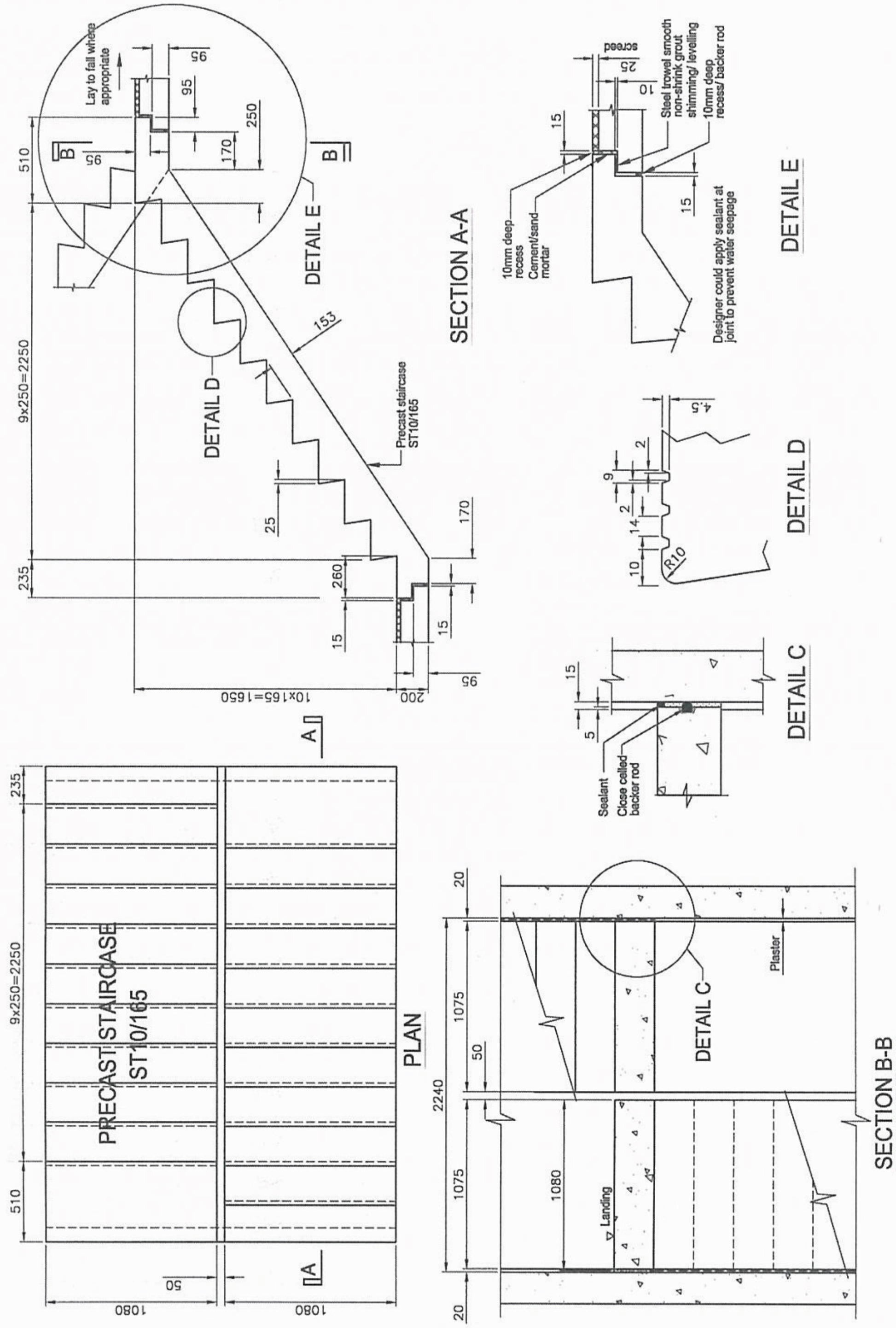


GENERAL NOTES FOR STANDARD PRECAST STAIRCASE

1. In practice, the number of risers and the riser height of a staircase have always been dictated by the storey height of a building. This would result in different riser dimensions. Due to the cost of mould, prefabricating stair flights with many different riser dimensions would not be economically viable.
2. The Committee recommends designers to limit the riser height to 165mm and 175mm, with a tread dimension to 250mm. For school development projects, 150mm riser with 300mm tread (instead of 250mm) are recommended dimensions required by the Ministry of Education, for safety reasons.
3. The architectural features of the proposed precast staircase are:
   - Alignment of nosing of the first flight flushed with the nosing of adjacent flight.
   - Simple and lined through intersection at the soffit of staircases where the flights and landings meet.
4. The proposed precast staircase would be suitable for fire escape. However, it could be modified by Qualified Person to suit the intended usage.
5. The recommended width of the standard staircase is ideally set to allow for a 1,000mm clearance between handrails and edging kerb of 75mm to one side of the staircase for the fixing of balustrades.
6. Precast concrete staircases are cast on their sides or face down using precision-engineered steel mould and off-formed finished with nosing groove lines.

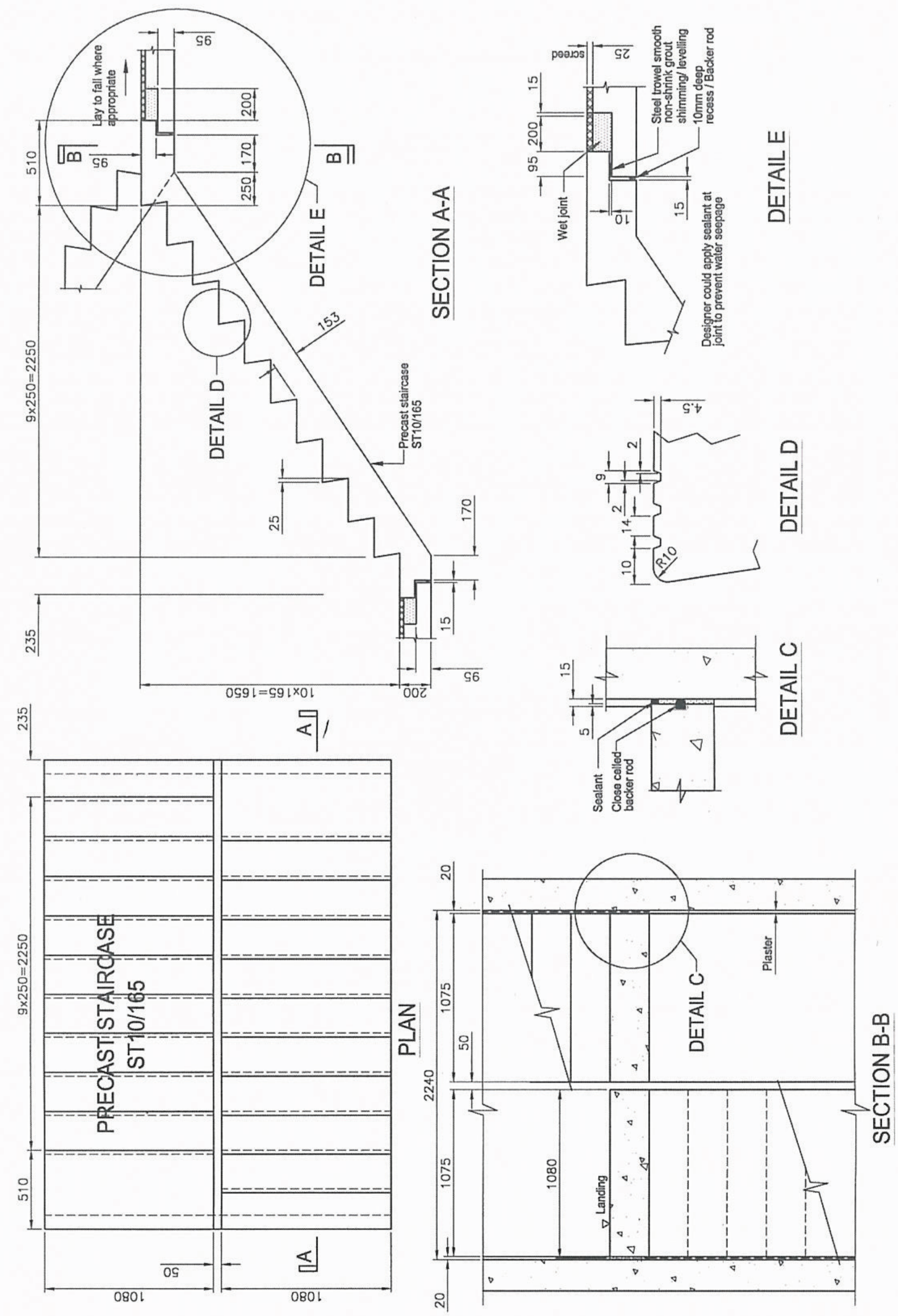
STANDARD PRECAST STAIRCASE DETAILS (DRY JOINT)

TYPE: ST10/165

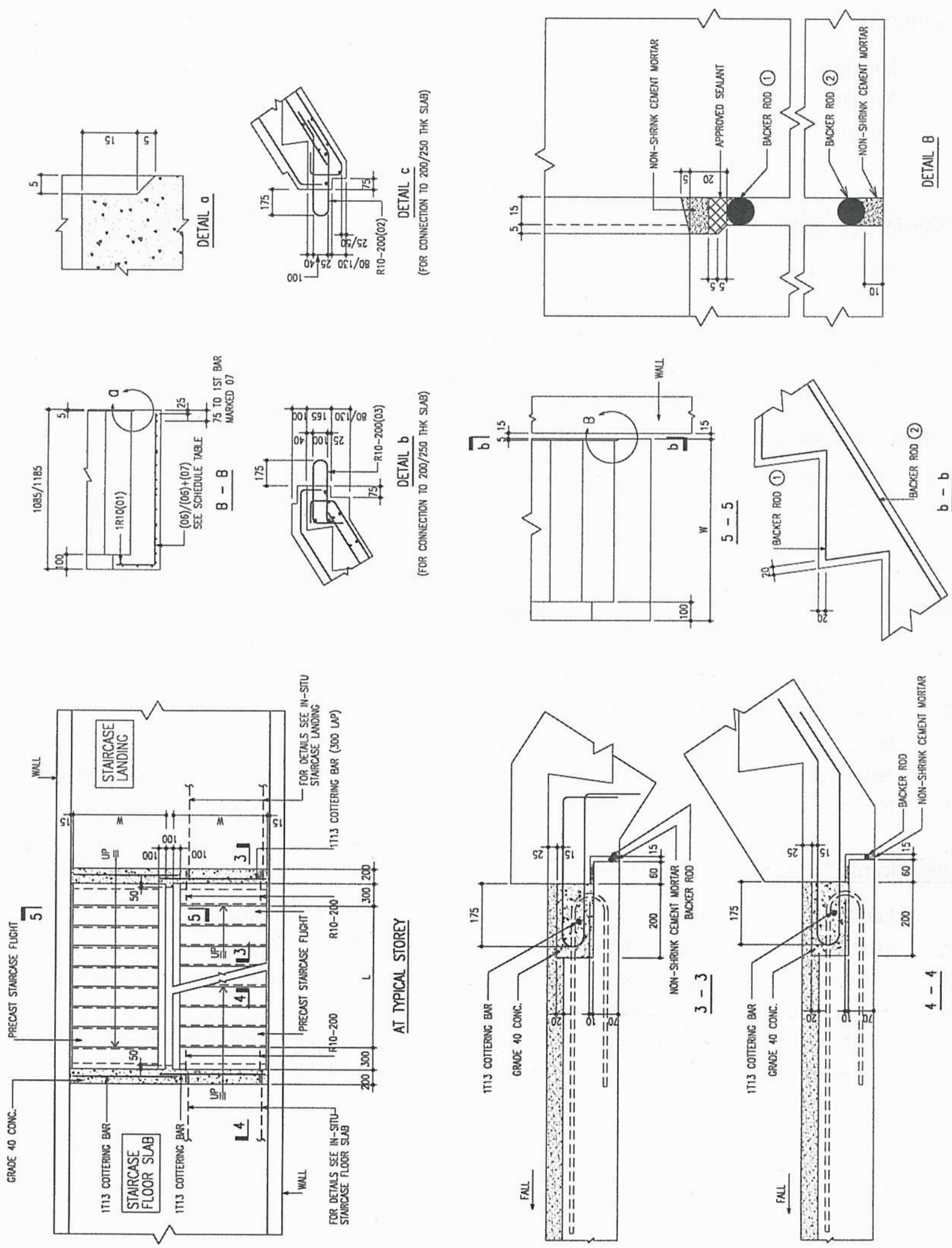


STANDARD PRECAST STAIRCASE DETAILS (WET JOINT)

TYPE: ST10/165



HDB'S PRECAST STAIRCASE DETAILS



GENERAL NOTES FOR STANDARD PRECAST STAIRCASE (DRY AND WET JOINT)

Concrete

1. Minimum grade of concrete in all reinforced concrete elements shall be C40, normal weight concrete.
2. Nominal cover to reinforcement shall be 25mm.
3. Surface finishes shall be off-form.
4. It shall have a minimum fire rating of two hours.

Reinforcement

1. All reinforcement shall conform to the latest BS4449 with a minimum yield stress:
   - T - Denotes 460 N/mm^2 high yield deformed bar, Type 2
   - R - Denotes 250N/mm^2 for mild steel bars
2. All steel fabric shall conform to the latest BS4483 with a minimum yield stress of 485N/mm^2.

Design Considerations

1. Walls shall be designed in accordance with the provisions of BS8110.
2. Precast stair flight was designed as simply support slab between landings.
3. When completed, stair flight shall be restrained by cast in-situ landing.

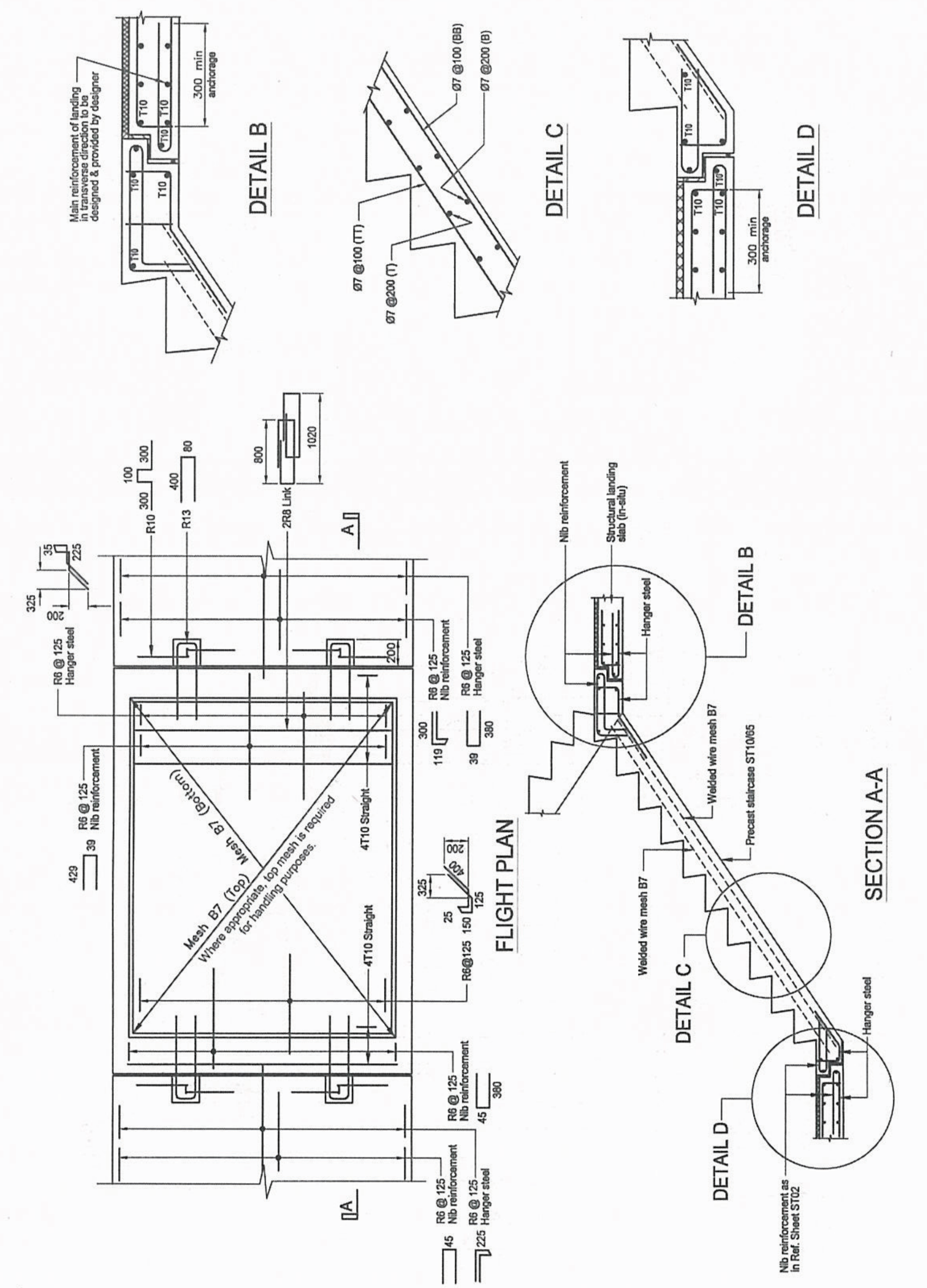
Dry Joint Construction Sequence

1. Landings shall be cast in-situ before the placement of precast stair flights.
2. Levelling timber or steel section shall be used, to ensure flushed soffit when completed.
3. When dry joint is to be adopted at seating nib, U-loops at landings and ends of stair flight shall be bent and interlocked with each other after the placement of stair flight. Alternatively, interlocking rebars could be inserted after the placement of stair flight on landings. (Reference Sheet ST02)
4. Nominal stair flight / landing contact bearing shall be 75mm.

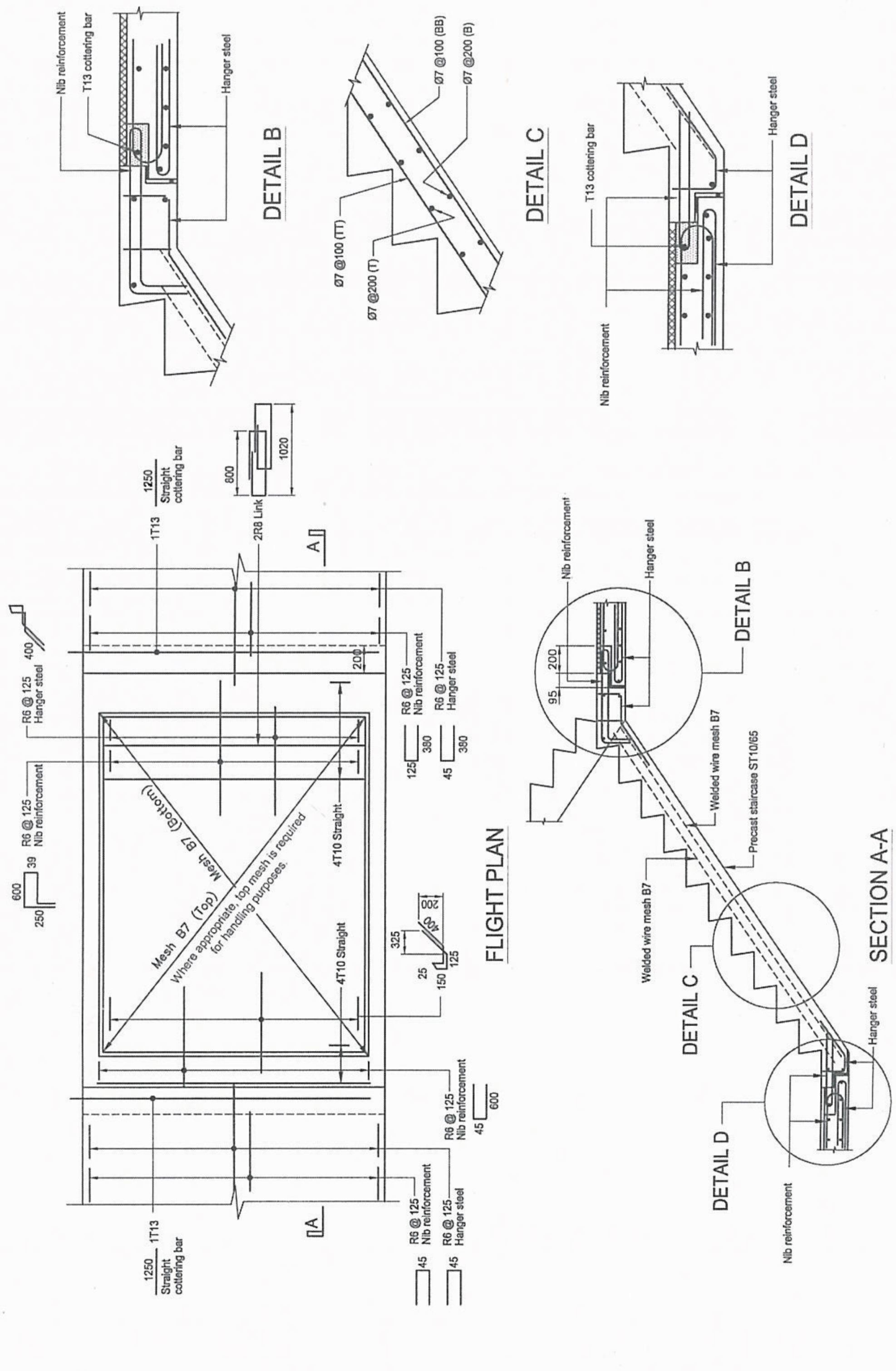
Wet Joint Construction Sequence

1. Landings shall be cast in-situ before the placement of precast stair flights.
2. Levelling timber or steel section shall be used, to ensure flushed soffit when completed.
3. The cast in-situ strip will prevent water seeping through the joint, suitable for staircases subjected to wetting and drying. (Architectural Reference Sheet ST03)
4. Temporary props / levelling timber or steel sections shall be used to ensure cast in-situ concrete infill achieve the required strength during installation.
5. Nominal stair flight / landing contact bearing shall be 75mm.

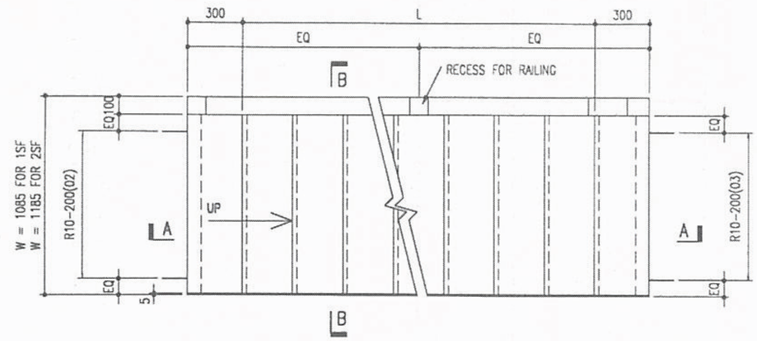
STANDARD PRECAST STAIRCASE REINFORCEMENT DETAILS (DRY JOINT)
TYPE: ST10/165

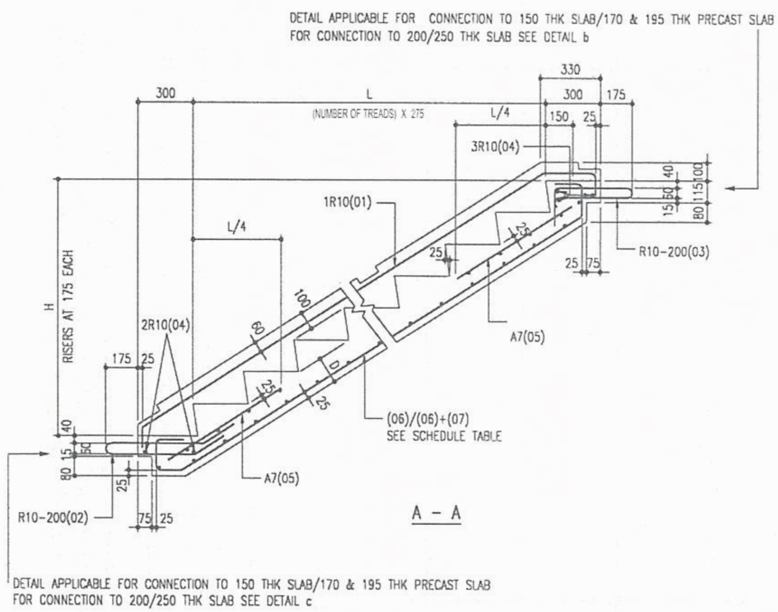


STANDARD PRECAST STAIRCASE REINFORCEMENT DETAILS (WET JOINT)
TYPE: ST10/165



HDB'S PRECAST STAIRCASE REINFORCEMENT DETAILS





BAR SCHEDULE TABLE

WAIST(D)	BAR MARK	BAR SIZE	SHAPE	QTY.
100	06	B8	MESH	1
	07	-	-	-
125	06	B10	MESH	1
	07	-	-	-
150	06	B12	MESH	1
	07	T10	X2	5
175	06	B12	MESH	1
	07	T10	X2	5

BAR SCHEDULE TABLE

BAR MARK	BAR SIZE	SHAPE	QTY.
01	R10	140 X1 280 140	1
02 (FOR 1SF)	R10	60/100 525 450 200 200	5
02 (FOR 2SF)			6
03 (FOR 1SF)	R10	150 425 60/100	5
03 (FOR 2SF)			6
04 (FOR 1SF)	R10	1035	5
04 (FOR 2SF)	R10	1135	5
05	A7	MESH	2

TYPE	No. OF RECESS	FLIGHT DIMENSIONS (mm)				BAR LENGTH (mm)	
		LENGTH (L)	No. OF TREADS (T)	HEIGHT (H)	WAIST (D)	X1	X2
1SF 2SF	3	1375	5	1050	100	1710	-
		1650	6	1225		2035	-
		1925	7	1400		2360	-
		2200	8	1575	125	2685	-
		2475	9	1750		3010	-
		2750	10	1925		3335	-
		3025	11	2100		3560	-
	4	3300	12	2275	150	3985	3855
		3575	13	2450		4310	4180
		3850	14	2625	175	4635	4505
		4125	15	2800		4960	4830

DESIGN TABLE - PRECAST STAIRCASE FLIGHT AND NIB
Live Load = 2.5kN/m² and 3.0kN/m²

Type	Main Reinforcement: Live Load (2.5kN/m²)	Main Reinforcement: Live Load (2.5kN/m²) + Finishes	Nib Reinforcement	Main Reinforcement: Live Load (3.0kN/m²)	Main Reinforcement: Live Load (3.0kN/m²) + Finishes	Nib Reinforcement
ST10/150	- / B8	- / B9	R6 @ 150	- / B9	- / B9	R6 @ 125
ST11/150	B6 / B9	B6 / B10	R6 @ 125	B6 / B10	B7 / B10	R6 @ 125
ST12/150	B8 / B10	B8 / B12	R6 @ 125	B8 / B12	B8 / B12	R6 @ 100
ST10/165	- / B6	- / B7	R6 @ 150	- / B7	- / B7	R6 @ 150
ST8/175	- / B6	- / B6	R6 @ 150	- / B6	- / B6	R6 @ 150
ST9/175	- / B6	- / B7	R6 @ 150	- / B7	- / B7	R6 @ 150
ST10/175	- / B7	- / B7	R6 @ 150	- / B7	- / B7	R6 @ 150
ST11/175	- / B7	- / B8	R6 @ 150	- / B8	- / B8	R6 @ 125
ST12/175	- / B9	- / B10	R6 @ 125	- / B10	- / B10	R6 @ 125

Note:

1. Design parameters: f_{cu}=40N/mm²; Cover=35mm
   f_y=485N/mm²(mesh); f_y=460N/mm²(T-bars); f_y=250N/mm²(mild steel)
2. Finishes are taken as 1.2kN/m².
3. | |
   |---|
   | B9 |
   | B10 |

   - B9 - Denotes Top reinforcement using B9 mesh
   - B10 - Denotes Bottom reinforcement using B10 mesh
4. The proposed standard precast concrete staircase is designed for peacetime use. Nevertheless, where there is only one staircase leading to household shelters, the Professional Engineer or Qualified Person would have to carry out a detailed design in compliance with Civil Defence requirements.

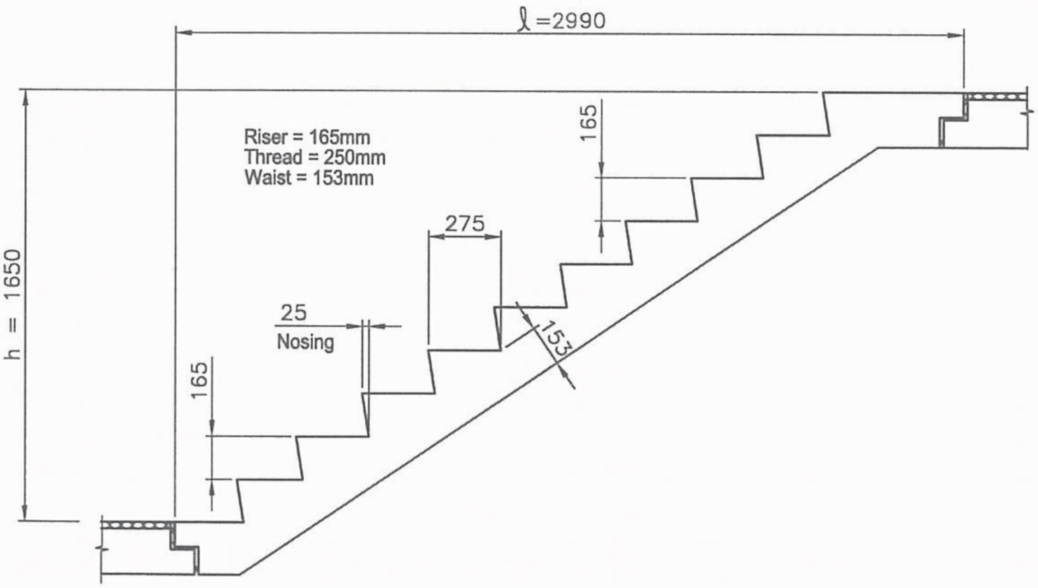
DESIGN TABLE - PRECAST STAIRCASE FLIGHT AND NIB
Live Load = 4.0kN/m² and 5.0kN/m²

Type	Main Reinforcement: Live Load (4.0kN/m²)	Main Reinforcement: Live Load (4.0kN/m²) + Finishes	Nib Reinforcement	Main Reinforcement: Live Load (5.0kN/m²)	Main Reinforcement: Live Load (5.0kN/m²) + Finishes	Nib Reinforcement
ST10/150	-	-	R6 @ 150	-	-	R6 @ 100
	B9	B10		B9	B9	
ST11/150	B7	B6	R6 @ 100	B6	B7	R6 @ 100
	B10	B12		B12	B12	
ST12/150	B8	B8	R6 @ 100	B8	B8	R6 @ 100
	B12	B12 + T10@200		B12 + T10@200	B12 + T10@100	
ST10/165	-	-	R6 @ 125	-	-	R6 @ 125
	B7	B7		B7	B7	
ST8/175	-	-	R6 @ 150	-	-	R6 @ 150
	B6	B7		B6	B7	
ST9/175	-	-	R6 @ 150	-	-	R6 @ 125
	B7	B8		B7	B7	
ST10/175	-	-	R6 @ 125	-	-	R6 @ 125
	B7	B8		B8	B8	
ST11/175	-	-	R6 @ 125	-	-	R6 @ 100
	B8	B9		B9	B10	
ST12/175	-	-	R6 @ 100	-	-	R6 @ 100
	B10	B12		B12	B12	

Note:

1. Design parameters: fcu=40N/mm²; Cover=35mm
   fy=485N/mm²(mesh); fy=460N/mm²(T-bars); fy=250N/mm²(mild steel)
2. Finishes are taken as 1.2kN/m².
3. | B9 | - Denotes Top reinforcement using B9 mesh |
   |---|---|
   | B10 | - Denotes Bottom reinforcement using B10 mesh |
4. The proposed standard precast concrete staircase is designed for peacetime use. Nevertheless, where there is only one staircase leading to household shelters, the Professional Engineer or Qualified Person would have to carry out a detailed design in compliance with Civil Defence requirements.

DESIGN EXAMPLE - PRECAST STAIRCASE ST10/165



Design Data:

Material

Concrete	fcu	=	40N/mm^2
Welded Mesh	fy	=	485N/mm^2
Mild Steel	fy	=	250N/mm^2
Cover to reinforcement		=	25mm
Fire Rating		=	2 hours

Loading

Design Live Load	=	4.0kN/m^2

Consider per metre width of staircase

Slope length of stair	=	$\sqrt{(1.65^2 + 2.99^2)}$
	=	3.415m
Weight of waist plus steps	=	(0.153 x 3.415 + 0.275 x 0.165 x 10÷2) x 24
	=	18.00kN/m
Live Load	=	4.0 x 2.99
	=	11.96kN/m
Ultimate Load, F	=	1.4 x 18.00 + 1.6 x 11.96
	=	44.34kN/m

Bending Reinforcement

Assuming no effective restraint at support.

Ultimate BM at mid-span $= \frac{F \times L}{8}$

$$M = \frac{44.34 \times 2.99}{8}$$

$$= 16.57\text{kNm/m}$$

Effective depth, $d = 153 - 25 - 10 \div 2$

$$= 123\text{mm}$$

Use $d = 120\text{mm}$

$$z/d = 0.5 + \sqrt{(0.25 - M \div (0.9bd^2fcu))}$$

$$= 0.5 + \sqrt{(0.25 - (16.57 \times 10^6 \div (0.9 \times 1000 \times 120^2 \times 40))}$$

$$= 0.967$$

Use $z/d = 0.95$

Therefore $z = 114\text{mm}$

$$As = \frac{M}{0.95 \times fy \times z}$$

$$= \frac{16.57 \times 10^6}{0.95 \times 485 \times 114}$$

$$= 315\text{mm}^2\text{/m}$$

Use welded mesh type B7

(Main reinforcement 7mm dia. @100mm c/c, secondary reinforcement 7mm dia. @ 200mm c/c)

Therefore, provided As $= 385\text{mm}^2\text{/m}$

Deflection

$$\frac{M}{bd^2} = \frac{16.57 \times 10^6}{1000 \times 120^2}$$

$$= 1.15$$

$$fs = \frac{2}{3} \times fy \times \frac{As_{reqd}}{As_{Prov}}$$

$$= \frac{2}{3} \times 485 \times \frac{315}{385}$$

$$= 265N/mm^2$$

Tension modification factor, Φ

$$= 0.55 + \frac{(477 - fy)}{120\left(0.9 + \frac{M}{b \times d^2}\right)}$$

$$= 0.55 + \frac{(477 - 265)}{120\,(0.9 + 1.15)}$$

$$= 1.41$$

Clause 3.10.2.2, Part 1, BS8110 (1997), basic span / depth ratio of staircase flight

$$= 20 \times 1.15$$

$$= 23$$

Minimum effective depth, d

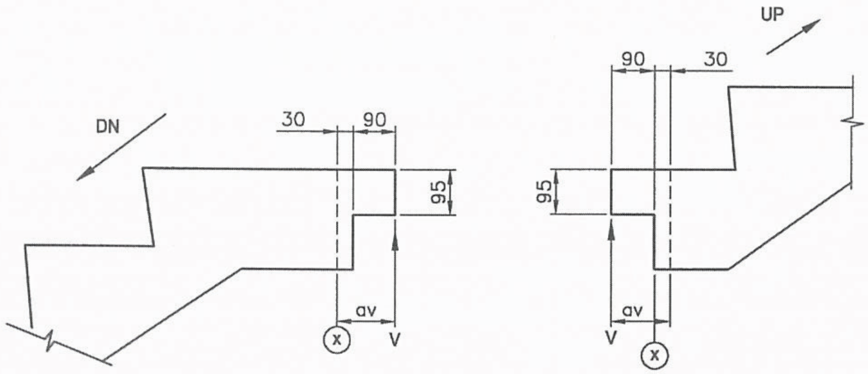
$$= \frac{L}{\Phi \times \text{Span/Depth Ratio}}$$

$$= \frac{2990}{1.41 \times 23}$$

$$= 92mm < 120mm$$

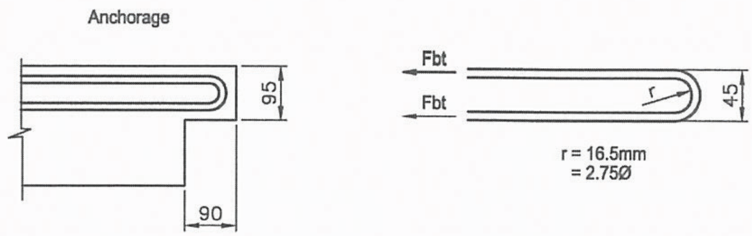
Therefore, **OK**

Design of Supporting Nibs



Reaction at supporting nibs,	V	=	44.34 x 0.5
		=	22.17kN/m
	a_v	=	90 + 30
		=	120mm
Bending Moment,	M	=	V x a_v
(At Section X)		=	22.17 x 0.120
		=	2.66kNm/m
Effective depth,	d	=	95mm - 25mm - 5mm
		=	65mm
	z/d	=	$0.5 + \sqrt{(0.25 - M \div (0.9bd^2fcu))}$
		=	$0.5 + \sqrt{(0.25 - (2.66 \times 10^6 \div (0.9 \times 1000 \times 65^2 \times 40)))}$
		=	0.98 (< z/d = 0.95)
Therefore,	z	=	61.8mm
Use mild steel,	As	=	$\frac{M}{0.95 \times fy \times z}$
		=	$\frac{2.66 \times 10^6}{0.95 \times 250 \times 61.8}$
		=	$181mm^2/m$
Use R6 @ 150mm c/c,	As	=	$188mm^2/m$

Check Anchorage

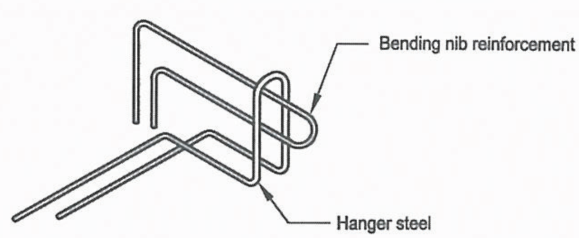


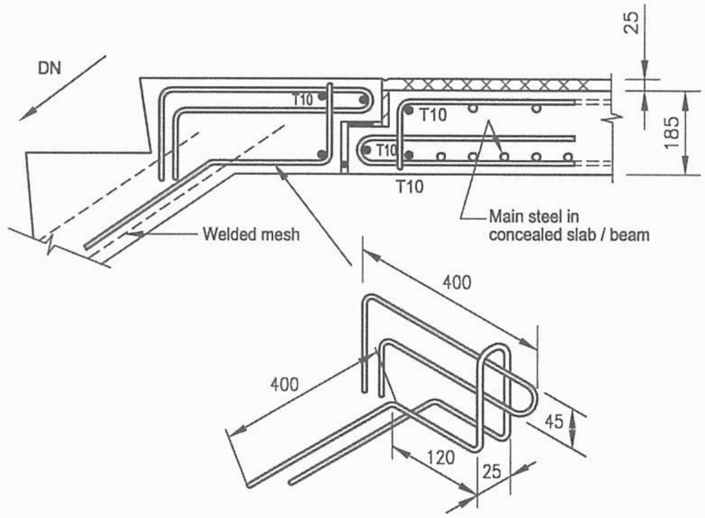
	F_{bt}	=	0.95 fy As
		=	$0.95 \times 250 \times 28 \times 10^{-3}$
		=	6.65kN
Minimum bending radius,	r	≥	$\frac{F_{bt}}{Ø} \times \frac{1 + 2(Ø \div a_b)}{2\,fcu}$
Where	Ø	=	6mm
	a_b	=	150mm
	fcu	=	$40N/mm^2$
Therefore	r	≥	$\frac{6.65 \times 10^3}{6} \times \frac{1 + 2(6 \div 150)}{2 \times 40}$
		≥	14.9mm
		≥	2.5 Ø
Provide	r	=	2.75 Ø > 2.5 Ø Therefore, **OK**

Check Hang-up Reinforcement

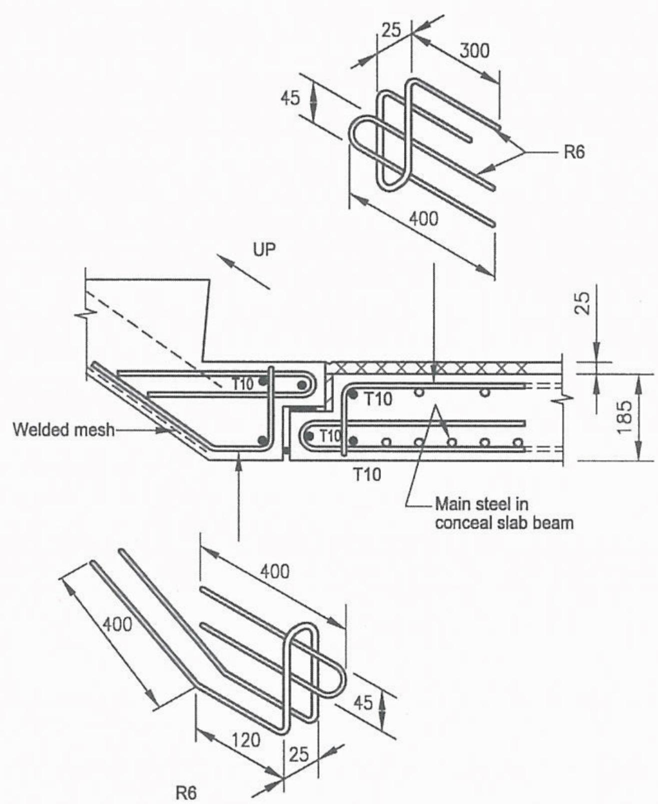
Hang-up reinforcement,	A_{sh}	=	$\frac{V}{0.95\,fy}$
		=	$\frac{22.17 \times 10^3}{0.95 \times 250}$
		=	$93mm^2/m$

For practical reason, provide at every R6 nib reinforcement a looped R6 as hanger steel, as below.





TYPICAL REINFORCEMENT DETAILS AT UPPER FLIGHT



TYPICAL REINFORCEMENT DETAILS AT LOWER FLIGHT

Check Shear

Shear force, $V = 22.17\text{kN/m}$

$$v = \frac{22.17 \times 10^3}{1000 \times 65}$$

$$= 0.34\text{N/mm}^2$$

$$r_S = \frac{188 \times 100\%}{1000 \times 65}$$

$$= 0.29\%$$

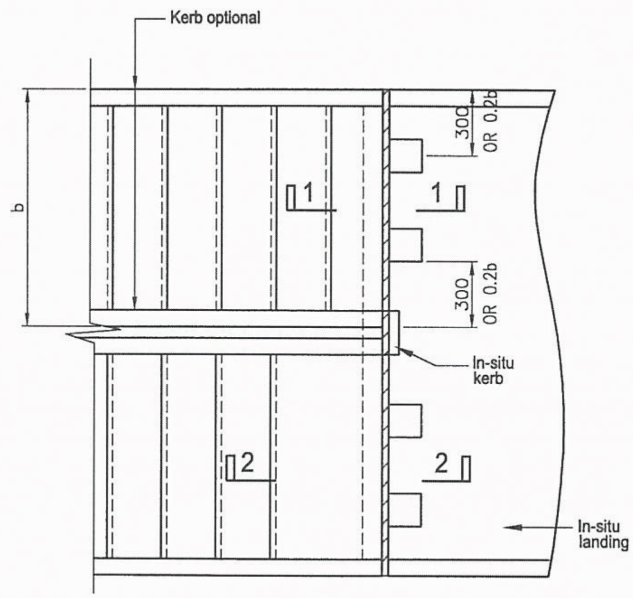
$$v_C = \frac{0.79\,(r_S)^{1/3}\,(400/d)^{1/4}\,(fcu/25)^{1/3}}{\gamma_m}$$

$$\gamma_m = 1.25$$

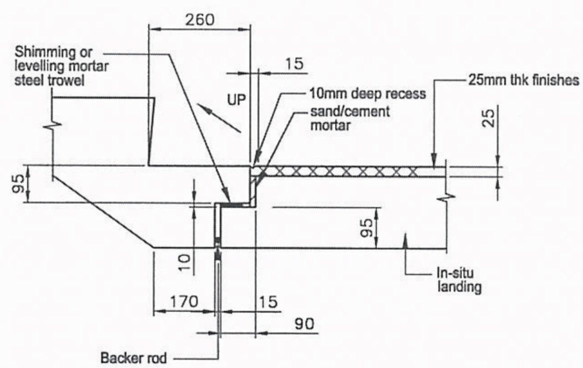
$$v_C = \frac{0.79\,(0.29)^{1/3}\,(400/65)^{1/4}\,(40/25)^{1/3}}{1.25}$$

$$= 0.77\text{N/mm}^2 > 0.34\text{N/mm}^2$$

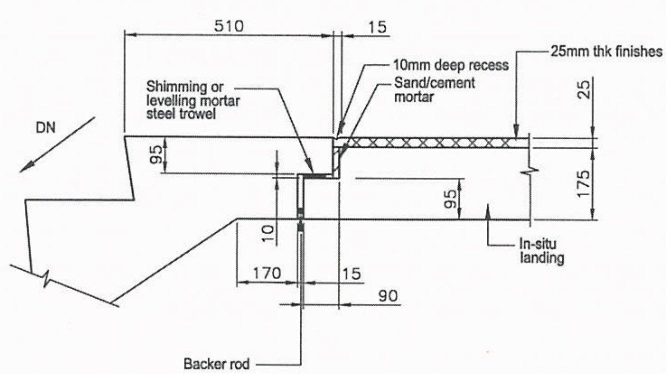
Therefore, **OK**



PLAN



SECTION 1-1



SECTION 2-2