III. Stairs and staircases

III.1. Stairs and their types

Stairs lead from floor to floor. They are of several types. The common ones are:

(*a*) a sloping slab spanning from one floor to a landing or another floor
(*b*) a sloping slab carried on sloping beams from one floor to another or to a landing.

Typical reinforcement details are given for these staircases on Sheet Nos III.1 and III.2. As seen there are several variations in the presentation of the structural detailing of staircases. In all situations the staircases have landings and waste as shown in the key diagram (i) on Sheet No. III.2. The dimensions are established in III.3. The rise of the stair does not usually exceed 150 mm and the tread 250 mm including a nosing of about 25 mm beyond the vertical surface of the rise. The load for which these staircases is designed varies with the type of building. In all circumstances, the detailer must check specifications with the structural engineer prior to carrying out reinforcement details.

III.1.1. Specifications and basic data on staircases

A stair is constructed with steps rising without a break from floor to floor, or with steps rising to a landing between floors, with a series of steps rising further from the landing to the floor above. There are three basic ways in which stairs are planned:

(*a*) a *straight flight stair*, which rises from floor to floor in one direction with or without landing
(*b*) a *quarter turn stair*, which rises to a landing between floors, turns through 90°, then to the floor above
(*c*) a *half turn stair*, which rises to a landing between floors, turns through 180°, then rises, parallel to the lower flight, to the floor above. This type of stair is sometimes called 'dog-leg' or 'scissor-type stair'.

III.1.1.1. Geometric stairways

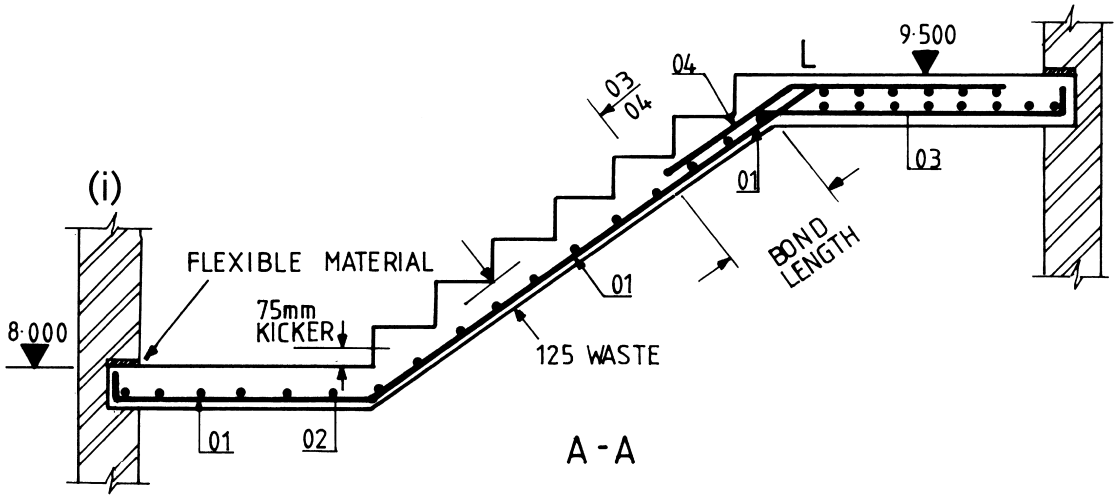
The stairs mentioned above are generally freestanding ones. In addition to these, stairs known as geometrical stairs can be designed into spiral, helical, circular, elliptical and other shapes. They can all be in concrete, steel, timber or combination. The stairs are sometimes described as open well stairs where a space or well exists between flights.

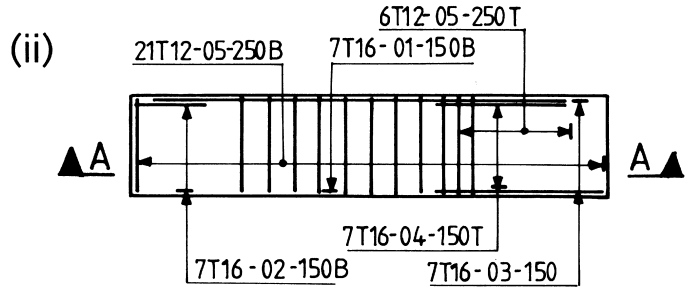
Again, in free-standing stairs the main types are:

(*a*) type 1: those supported transversely or across the flight — stringer beams are needed on one or both sides
(*b*) type 2: those spanning longitudinally along the flight of steps either on walls or on landing beams or on wall beams
(*c*) type 3: cantilever type projecting from walls or wall beams with each step acting as a cantilever

STAIRCASE REINFORCEMENT **SHEET NO. III.1**

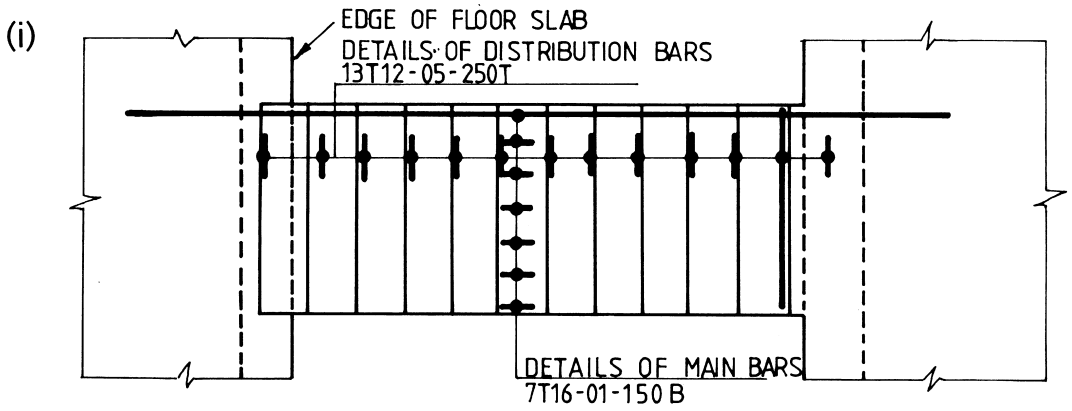
(a) Straight stairflight supported on brickwork

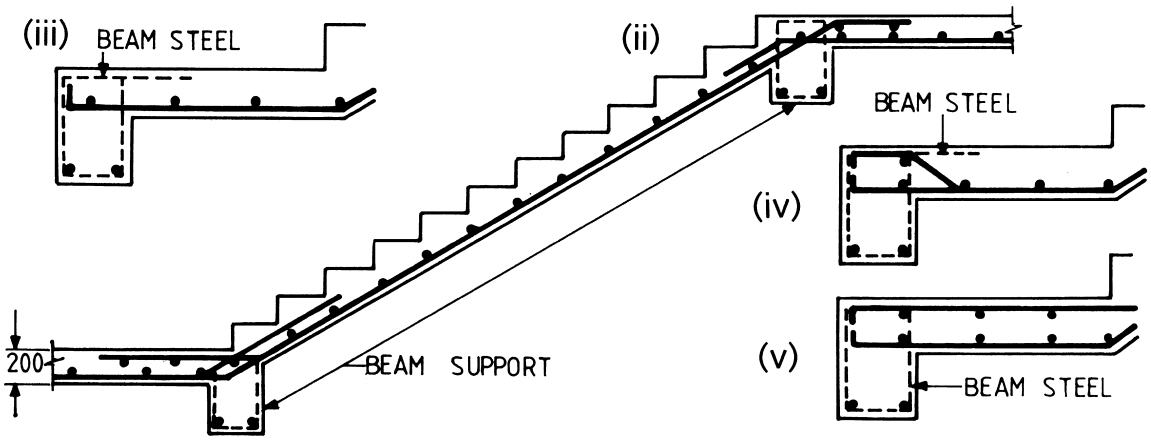




PLAN (Small scale)

(b) Straight stairflight on beam supports

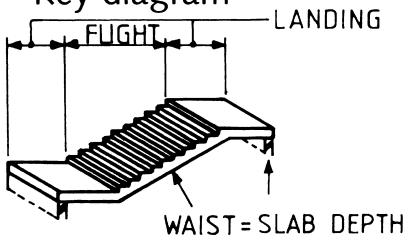




STAIRCASE WITH SLAB CONSTRUCTION

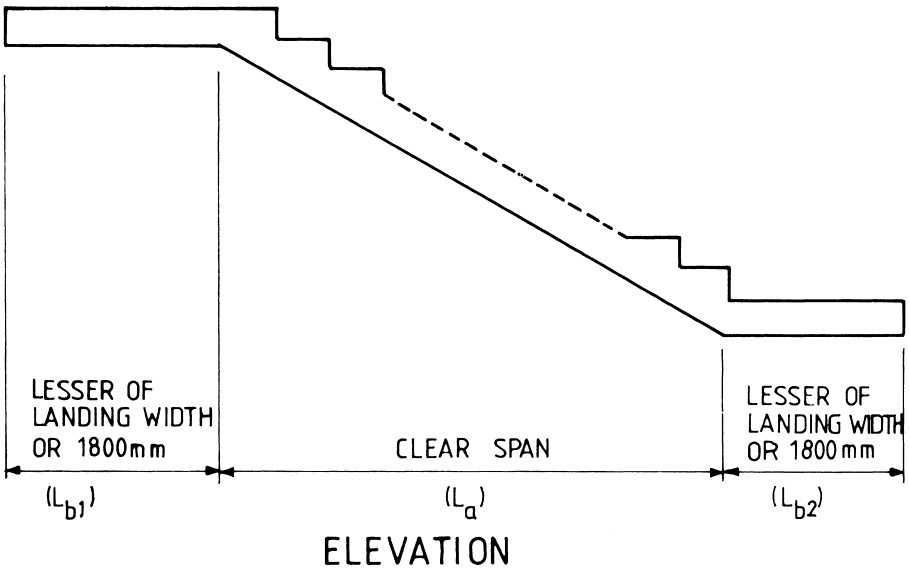
SHEET NO. III.2

(i) Key diagram



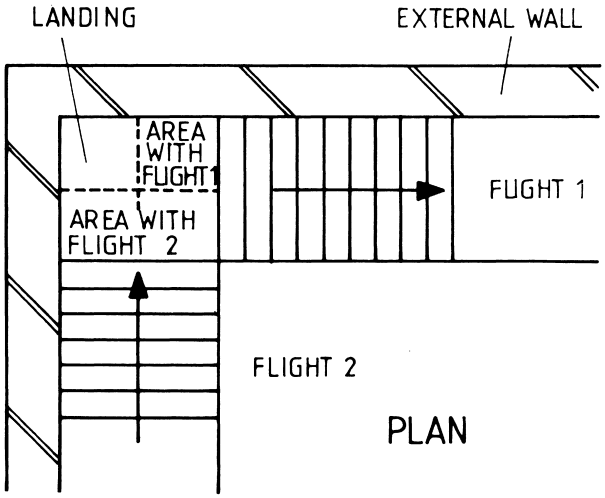
(a) Slab construction

(i)



ELEVATION

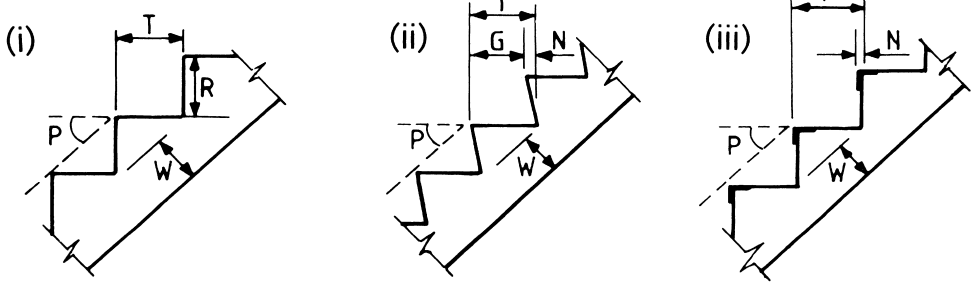
(ii)



PLAN

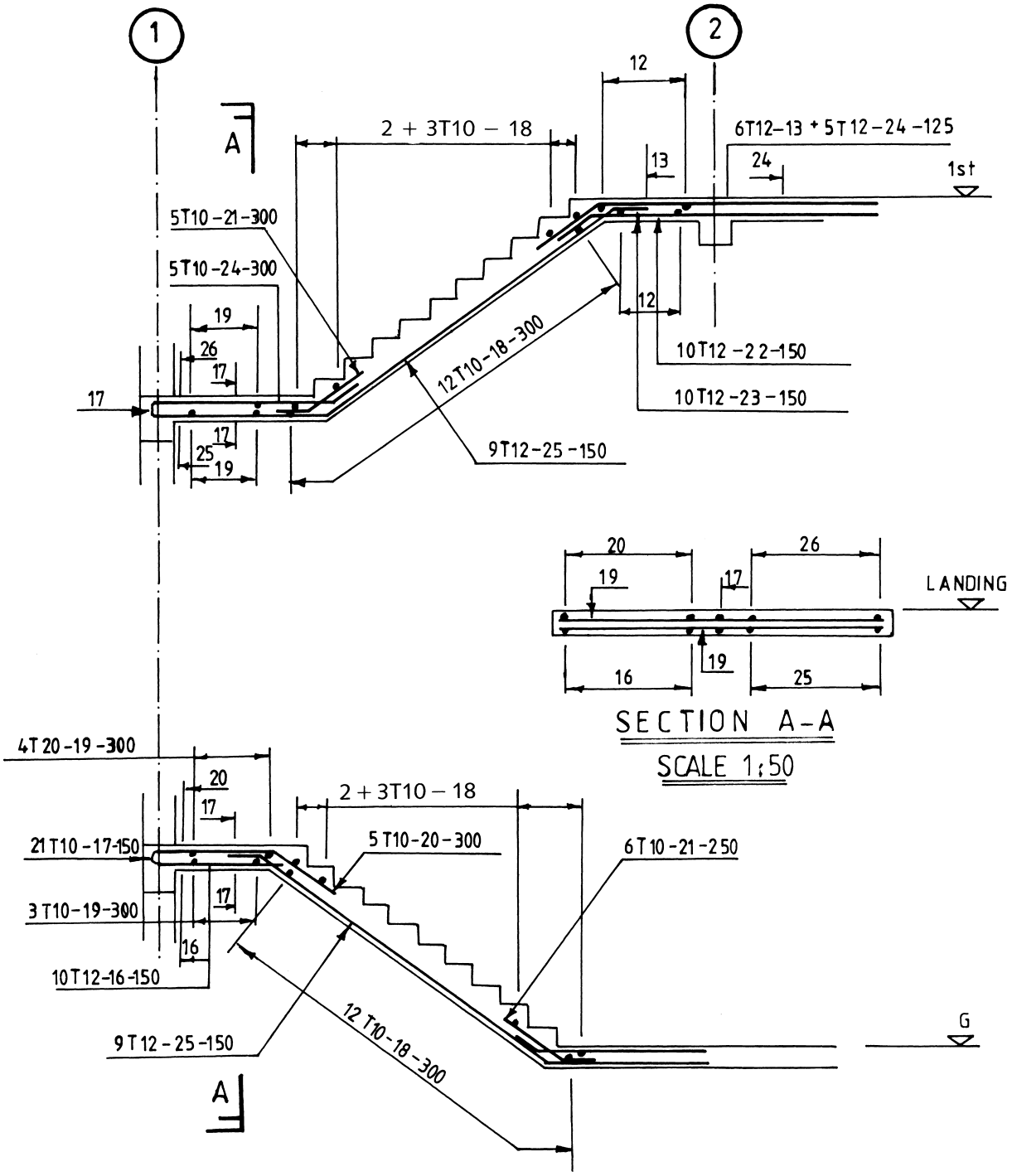
G - GOING
N - NOSING
P - PITCH
R - RISE
T - TREAD
W - WASTE

(b) Parts of a staircase



STAIRCASE ELEVATION

SHEET NO. III.3



(*d*) type 4: combination of type 2 and type 3 — every 4th or 5th step is cantilevered with sloped soffit with a slab continuous between two *steps*.

III.1.2. Stairway layouts

Stairway layouts depend on several factors including building type and its layout, choices, material, etc. Comfortable stairways should be designed in relation to the dimensions of the human figure. The British Standard on stairs BS 5395 (1977) defines some of these dimensions in Figure 1.6. The British and the European practices use the following criteria for width, length and headroom, etc.

(*a*) Flats — two storey to four storey $w_F = 900$ mm; more than four storey $w_F = 1000$ mm.
(*b*) Public buildings using each floor — under 200 persons $w_F = 1$ m; 200 to 400 persons $w_F = 1{\cdot}5$ m; in excess of 400 persons 150 mm to $w_F > 3$ m. Where the width is 1·8 m or over, the width should be divided by a handrail.
(*c*) The length and rise a minimum of three steps and a maximum of 16 steps. There must not be more than 36 rises in consecutive flights without a change in the direction of travel of 30° or more. The total rise must not exceed 6 m.

III.1.2.1. Landings, landing beams and flights

A quarter space landing in wood is generally supported by a newel post carried down to the floor below. In small houses quarter or half turn stairs are sometimes constructed with winders instead of quarter or half space landings. Winders are triangular shaped steps constructed at the turn from one flight to the next. The landing beams are designed as rectangular or flanged beams, for the reactions from the two flights or steps on one side and the landing on the other.

III.1.2.2. Strings or stringers

These are available in steel, concrete, timber and composite. There are two types of wood string, namely, the open (cut) and the close (closed) strings. In wood their top edges project some 50 to 60 mm above the line of nosing or tread. Wall strings are closed ones. The outer strings, particularly those made in timber, are cut to the profile of the treads and risers and are secured by wood bearers screwed to both strings and treads or risers in the underside of the flight.

III.1.3. Additional basic layouts and data

Sheet No. III.4 gives additional basic layouts and data for various parameters required for the planning and design of staircases.

The dimensions and other specifications are derived from the general layout of the building or structure where the stairs are to be used. Two typical layouts given on Sheet No. III.5 show the exact positioning of these staircases with respect to grid work and floor levels. Sheet No. III.4 gives beam/slab/column reinforcement layouts with respect to a staircase. Sheet No. III.5 gives a beam/slab/column plan on a section showing levels and grid work.

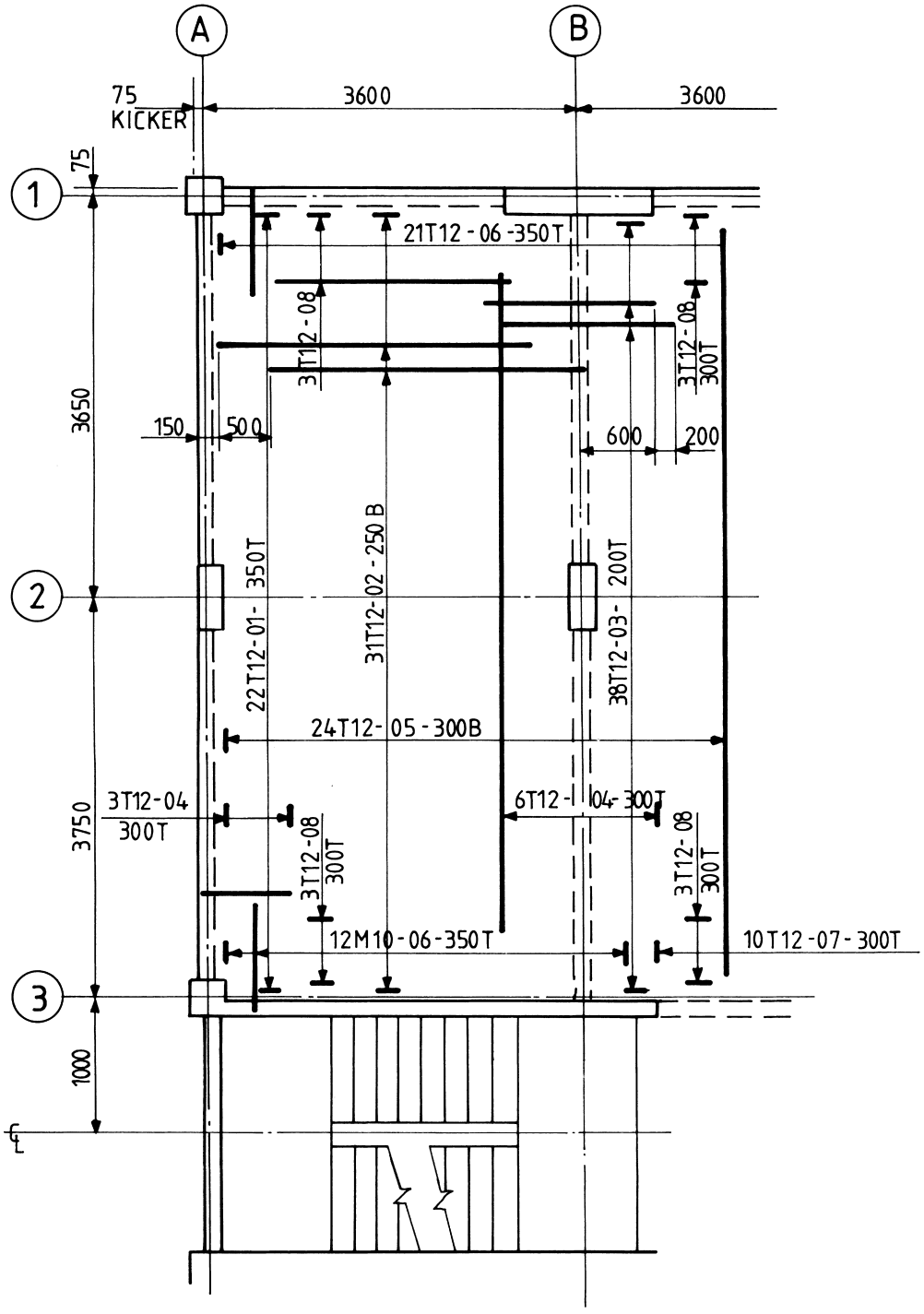
These staircases will have the reinforcement details as outlined on Sheet Nos III.1 and III.2.

There are a number of other types, such as stairs cantilevered from a side wall, spiral stairs with sides cantilevered out from a central column and free-spanning spiral stairs. They can be easily designed and detailed. Geometrical stairs are described on Sheet No. III.6.

Precast concrete staircases have recently become very popular and a number of companies are involved in producing them. In this book Birchwood

STAIRCASE WITH THE BEAM SLAB ARRANGEMENT

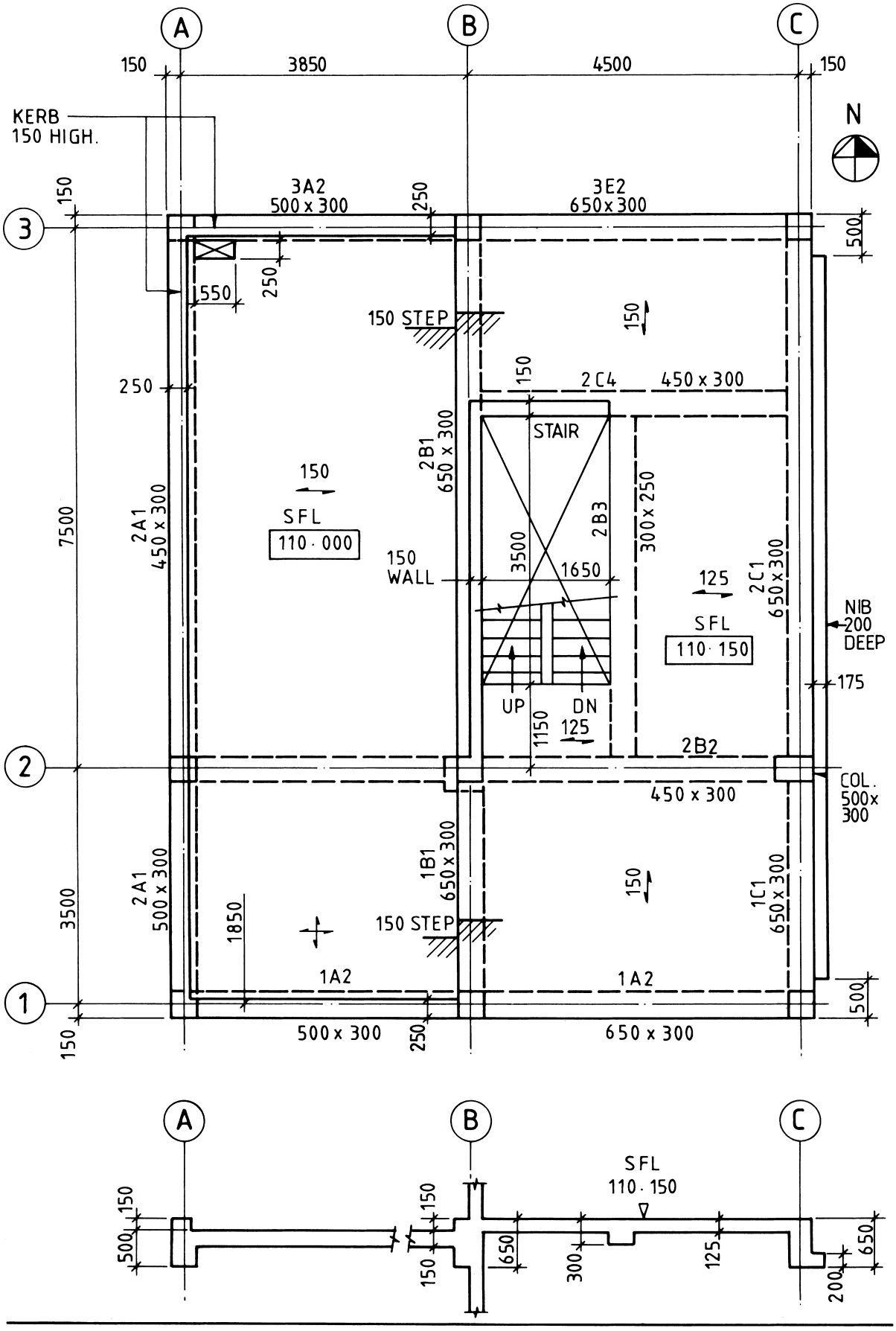
SHEET NO. III.4



PLAN

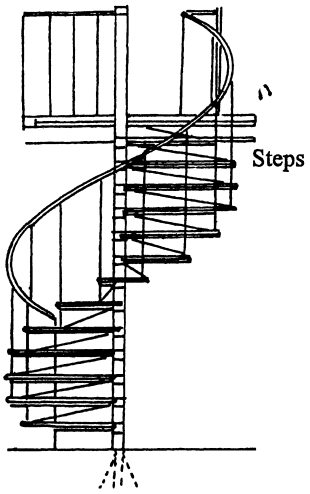
For staircase reinforcement
details see Sheet Nos. III.1 and III.2.

GENERAL ARRANGEMENT PLAN FOR CONCRETE STRUCTURES SHEET NO. III.5

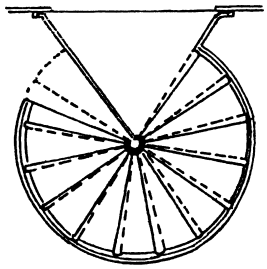


GEOMETRICAL STAIRS

SHEET NO. III.6

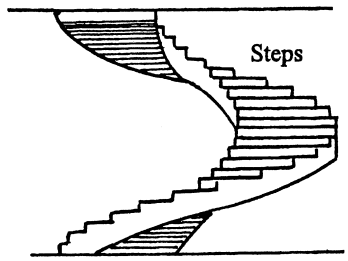


i. Elevation

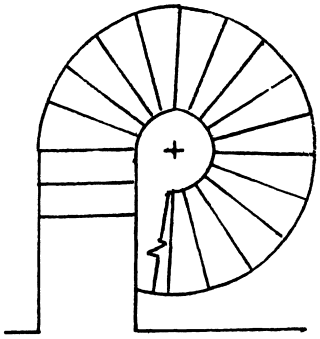


ii. Plan

a) Spiral stair

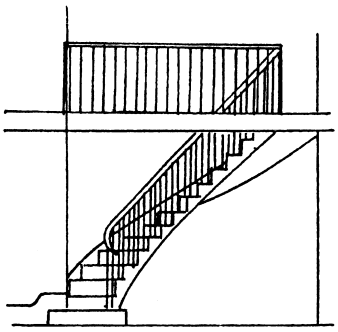


i. Sectional elevation

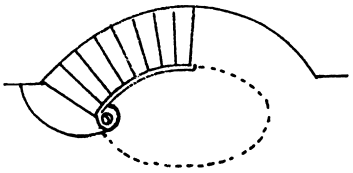


ii. Plan

b) Helical staircase

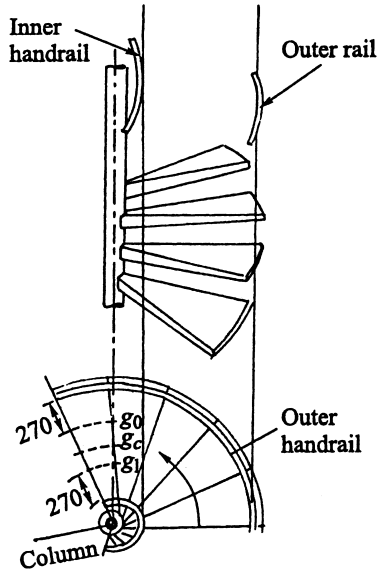


i. Elevation

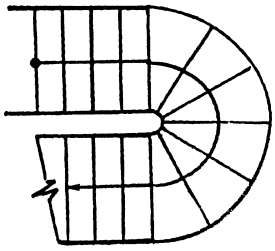


ii. Plan

c) Elliptical staircase



d) Details of a spiral staircase



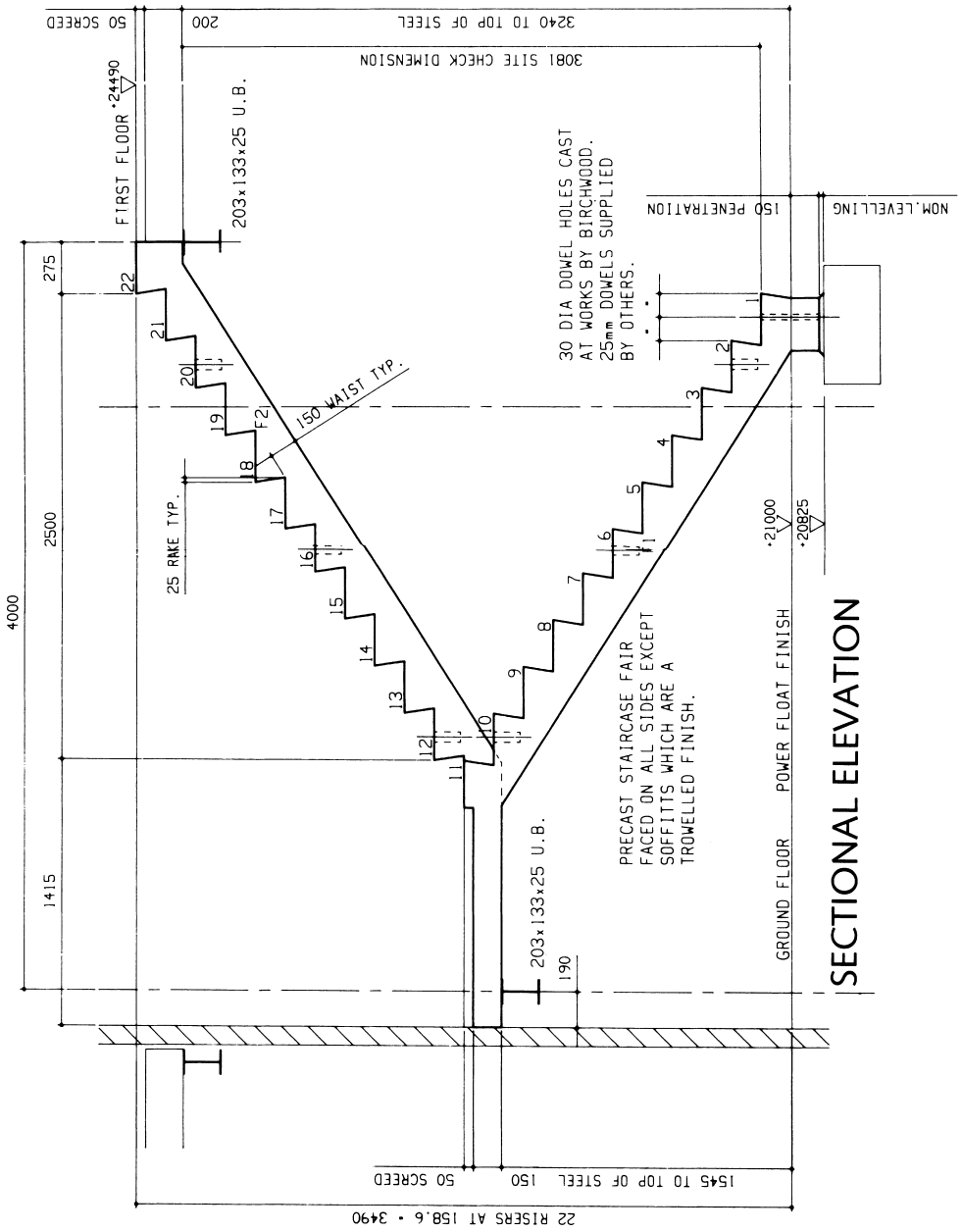
e) Part circular plan with straight flights

prestressed concrete staircases are shown on Sheet Nos III.7 to III.10. Sheet Nos III.7 and III.8 give sectional elevations and plans of staircase details. The stairs are connected to precast concrete floor units which themselves are connected to cross-landings and bearings. Sheet Nos III.9 and III.10 show typical reinforcement details for stairs, bearings and landings. Loading and material specifications are given on each drawing. The standard accepts vinyl tiles, sheet or carpet direct. Where any two or more members join, it is recommended to use site-applied screed to the landing. Dimensions and details for the rise and going for these stairs are given below in Table III.1.

Table III.1. Dimensions and details for the rise and goings of staircases (information abstracted from Building Regulations 2000 and International Building Code 2000)

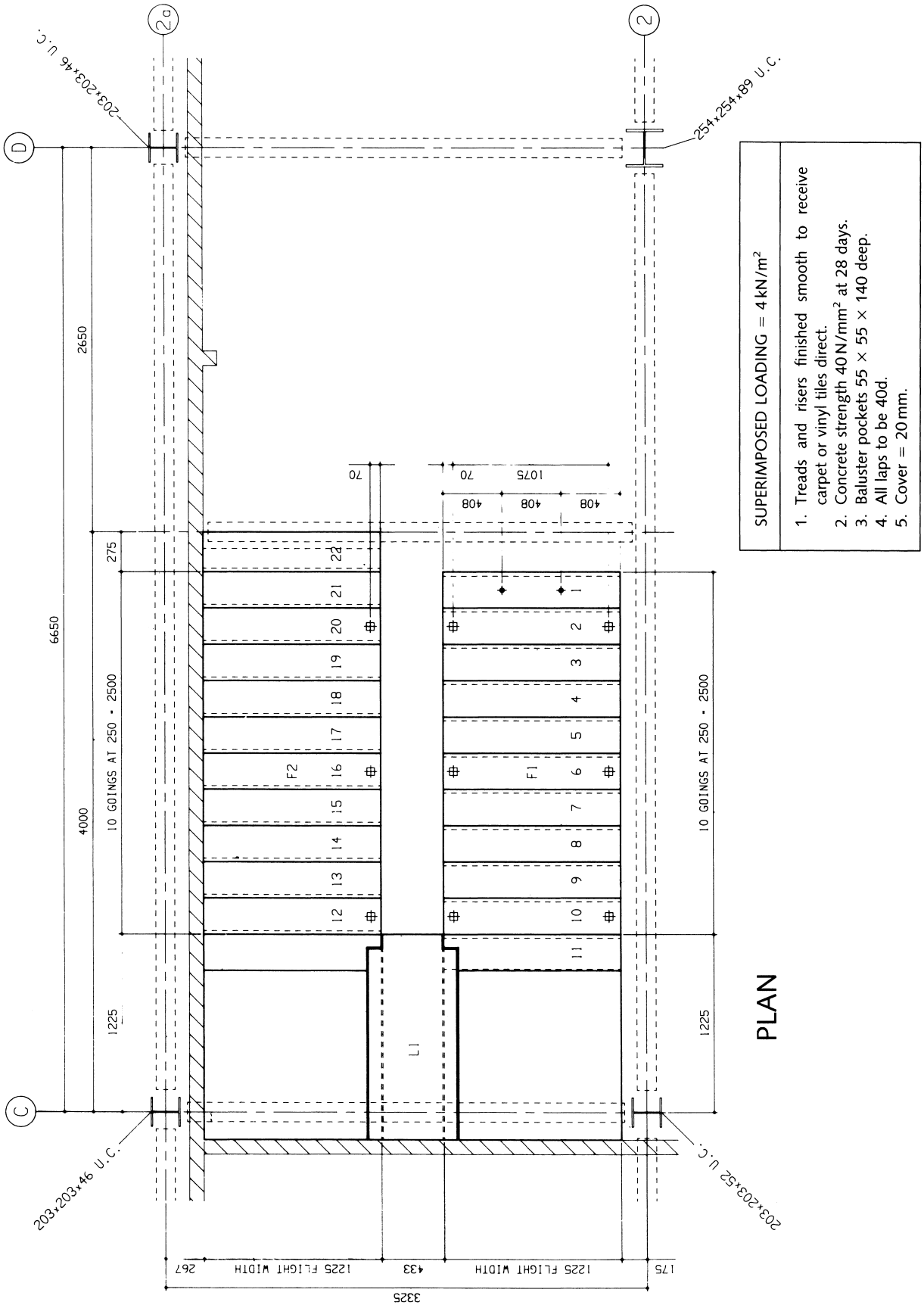
Staircase type	Rise (max.)	Going (min.)
Private—giving single access	220	220
Common—giving joint or multi-access	190	240
Disabled	170	250
Institutional and assembly buildings	180	250
Any type not described	190	250

BIRCHWOOD PRECAST CONCRETE STAIRCASE SHEET NO. III.7



BIRCHWOOD PRECAST CONCRETE STAIRCASE

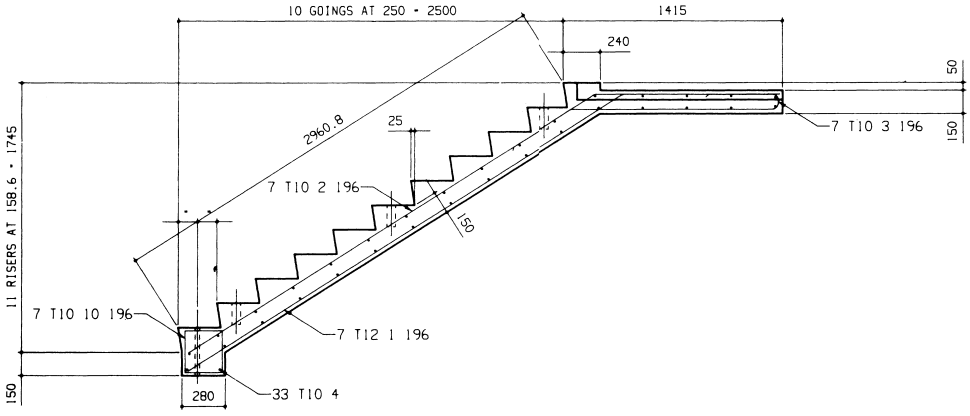
SHEET NO. III.8

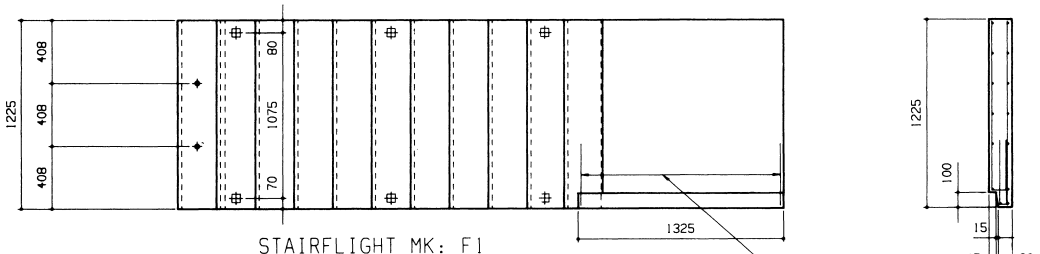


PLAN

SUPERIMPOSED LOADING = 4 kN/m²	1. Treads and risers finished smooth to receive carpet or vinyl tiles direct. 2. Concrete strength 40 N/mm² at 28 days. 3. Baluster pockets 55 × 55 × 140 deep. 4. All laps to be 40d. 5. Cover = 20 mm.

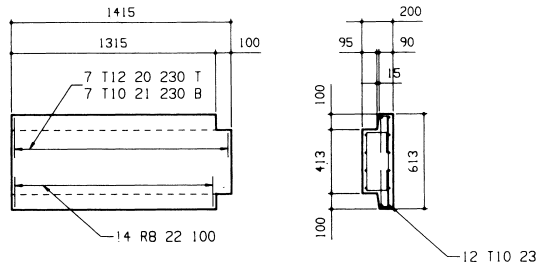
BIRCHWOOD PRECAST CONCRETE STAIRCASE — SHEET NO. III.9
Reinforcement Details — 1





STAIRFLIGHT MK: F1
1 No. required
Volume of Concrete = 1.12 cubic metres
Total Weight of Flight = 2.771 tonnes

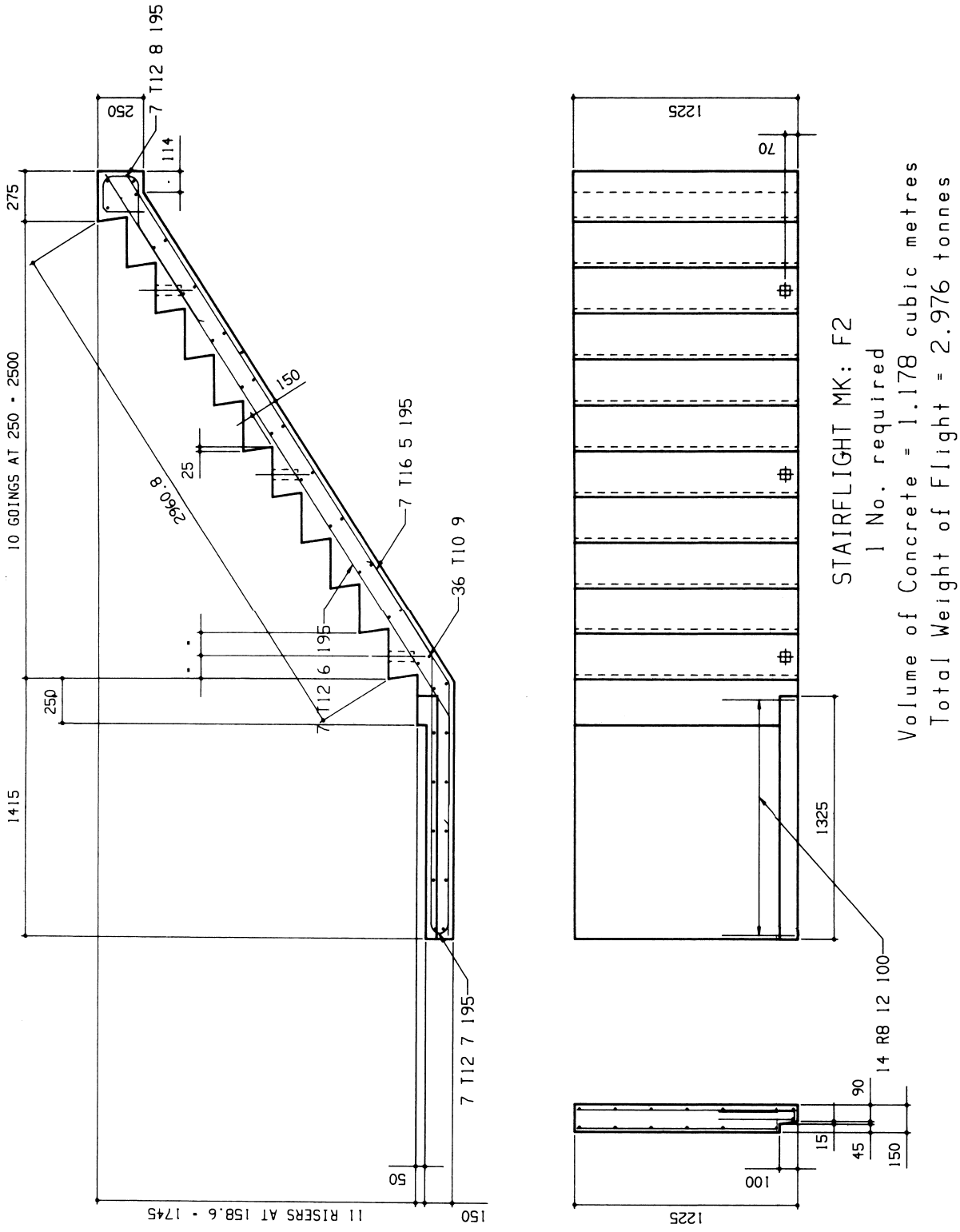
SUPERIMPOSED LOADING = 4 kN/m²
1. Treads and risers finished smooth to receive carpet or vinyl tiles direct. 2. Concrete strength 40 N/mm² at 28 days. 3. Baluster pockets 55 × 55 × 140 deep. 4. All laps to be 40 d. 5. Cover = 20 mm.



LANDING MK: L1
1 No. required
Volume of Concrete = 0.169 cubic metres
Total Weight of Landing = 0.406 tonnes

BIRCHWOOD PRECAST CONCRETE STAIRCASE **SHEET NO. III.10**

Reinforcement Details—2



III.1.3.1. Data for geometric stairways

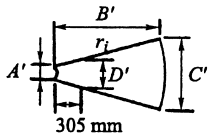
A brief introduction to these staircases is given in Section I.1. It is vital to give brief data on spiral/helical staircases. These staircases are manufactured in a variety of diameters. The most common materials for tread and platform are steel, aluminium and wood. Steel and aluminium can be smooth plate, checker plate, pan or tray type and bar. A variety of hardwoods can be used. For exterior or wet area interiors, zinc-chromated rust inhibitor, black acrylic enamel and black epoxy are usual. Platform dimensions usually are 2 in. (50 mm) larger than the stair radius. Table III.3 in Sheet No. III.11 gives specifications for spiral and helical stairs. Where horse-shoe shapes are involved, the data for helical stairs circular in plan are modified include the geometry of the inclined straight arms. The data collected are from countries such as Britain, Spain, USA, Germany, Sweden, Pakistan, India, Italy, Turkey and Japan. A reference is made to some structural details of various geometric stairways given on Sheet Nos III.12 to III.17.

SPIRAL/HELICAL STAIRS: PARAMETERS AND FRAMING DIMENSIONS

SHEET NO. III.11

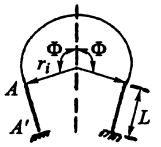
Table III.2. Specifications for spiral/helical stairs parameters.

Diameter (cm)	101.1	121.9	132.0	152.4	162.6	182.9	193.0	223.5	243.8
Centre column (cm)	10.1	10.1	10.1	10.1	10.1	10.1	10.1	16.8	16.8
Weight (kg)	93.9	99.8	106.6	113.4	120.2	140.6	147.4	197.3	220.0
Tread detail A' (cm)	10.1	10.1	10.1	10.1	10.1	10.1	10.1	16.8	16.8
Tread detail B' (cm)	45.7	55.9	61.0	71.1	81.3	86.4	91.4	106.7	121.9
27 tread detail C' (cm)	23.5	28.3	30.8	32.7	37.8	42.5	44.8	52.0	56.7
27 tread detail D' (cm)	19.4	20.3	21.0	22.2	21.6	21.9	21.0	25.4	26.7
30 tread detail C' (cm)	26.7	31.9	34.6	39.7	42.5	48.0	50.5	58.4	63.8
30 tread detail D' (cm)	21.6	21.9	22.2	22.5	22.9	23.5	23.8	28.9	29.2
Landing size (cm)	55.9	66.0	71.1	81.3	86.4	96.5	101.6	116.8	132.0

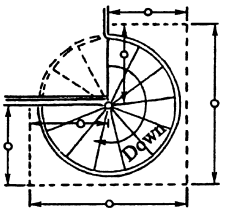


a) Sector in plan

b) Circular in plan



c) Horse-shoe in plan

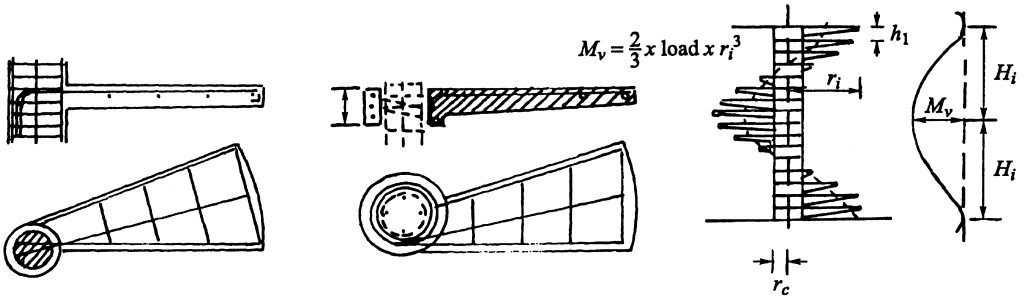


d) Framing dimensions

Framing dimensions (cm)

Stair diameter	2.54	5.08	7.62	10.16	12.70
40	50.8	50.8	67.0	111.8	111.8
48	67.0	67.0	71.1	132.0	132.0
52	66.0	66.0	76.2	142.2	142.2
60	76.2	76.2	68.4	162.6	162.6
64	81.3	81.3	91.4	172.7	172.7
72	91.4	91.4	101.6	193.0	193.0
76	96.5	96.5	106.7	203.2	203.2
88	111.8	111.8	121.9	233.7	233.7
96	121.9	121.9	132.0	254.0	254.0

27 riser table			30 riser table	
Finish floor height (cm)	Number of steps	Circle degree	Finish floor height (cm)	Number of steps
228.6-243.8	11	297	215.9-241.3	9
246.4-264.2	12	324	243.8-264.2	10
266.7-284.5	13	351	266.7-289.6	11
287.0-304.8	14	375	292.1-312.4	12
307.3-325.1	15	405	315.0-337.8	13
327.7-345.4	16	432	340.4-360.7	14
348.0-365.8	17	459	363.2-386.1	15
368.3-386.0	18	486	388.6-408.9	16
388.6-406.4	19	513	411.5-434.3	17
408.9-426.7	20	540	436.9-457.2	18



e) Reinforcement details of treads and columns

Formulae

$\overline{G}$ (outer going) $= 2(r_i - 270°) \sin \theta/2$

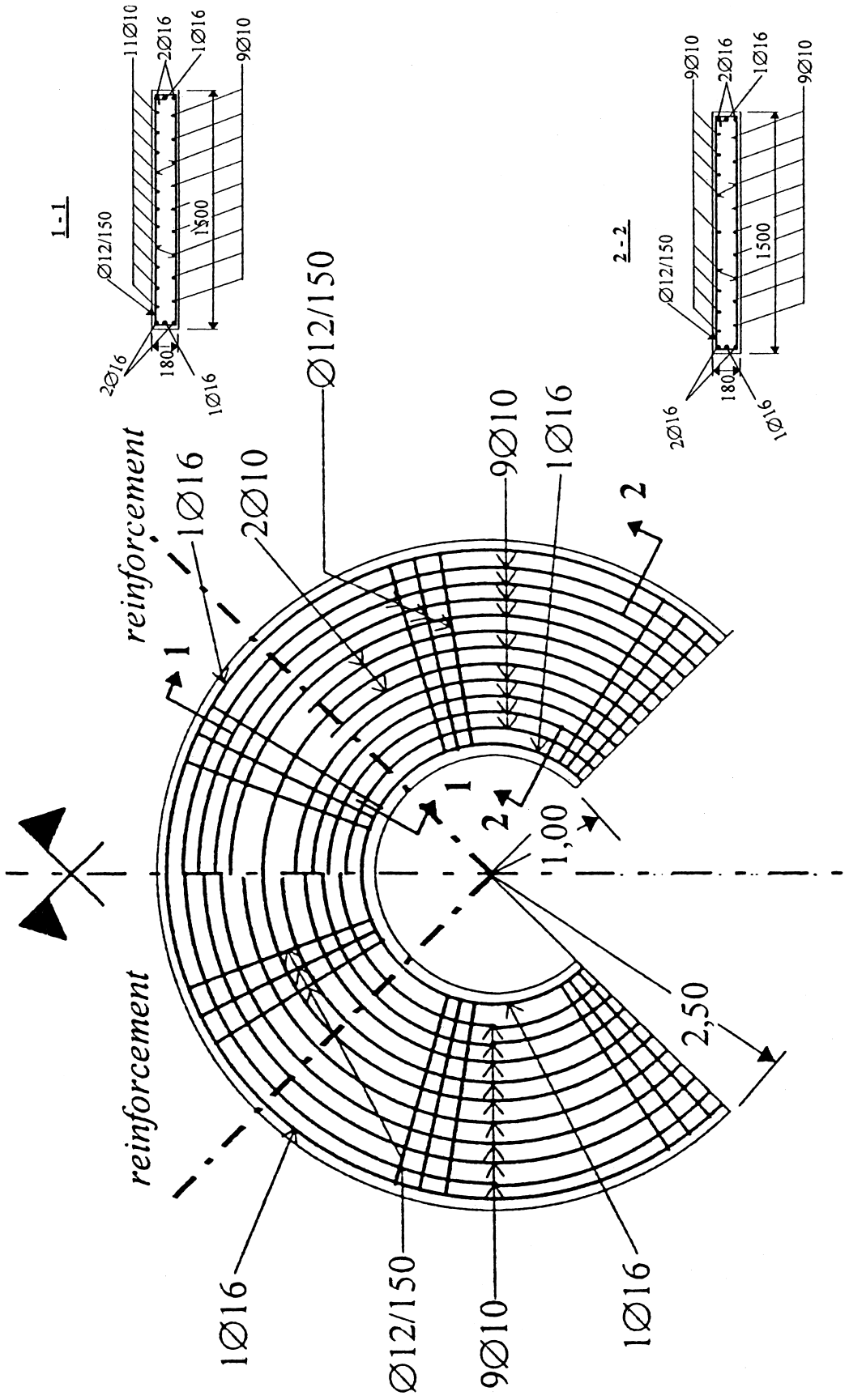
Clear headroom $= r_i - r_c$, where r_c is the radius of the column or post at the centre.

$\overline{G}$ (inner going) $= 2(r_c - 270°) \sin \theta/2$

Clear headroom: $2H_i = h_1(\phi/\theta) - t_L$, where ϕ = the angle of rotation at a distance along radius, θ = the angle of taper of tread, h_1 = the rise, t_L = the thickness of landing.

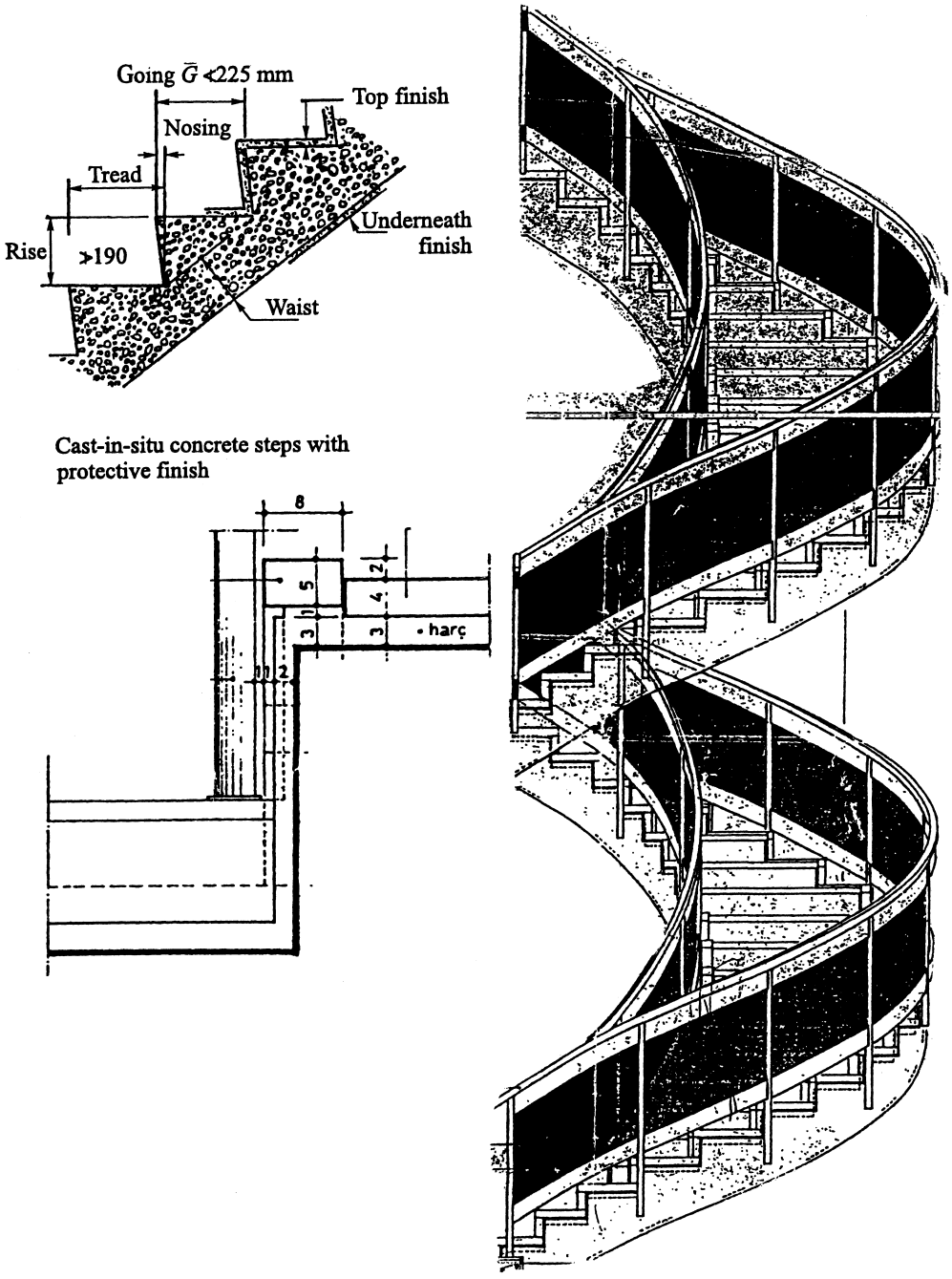
Minimum splayed straight length $L = B' + 2/3 \times$ bearing.

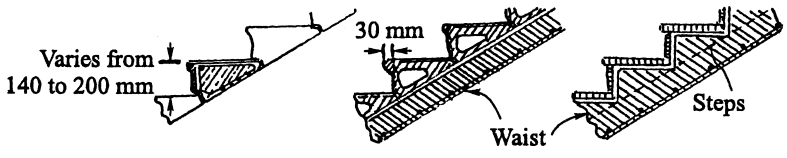
HELICAL STAIRS — PLAN SECTIONS (BASED ON EC2) **SHEET NO. III.12**
RC DETAILING



HELICAL STAIRS (BASED ON EC2)

SHEET NO. III.13



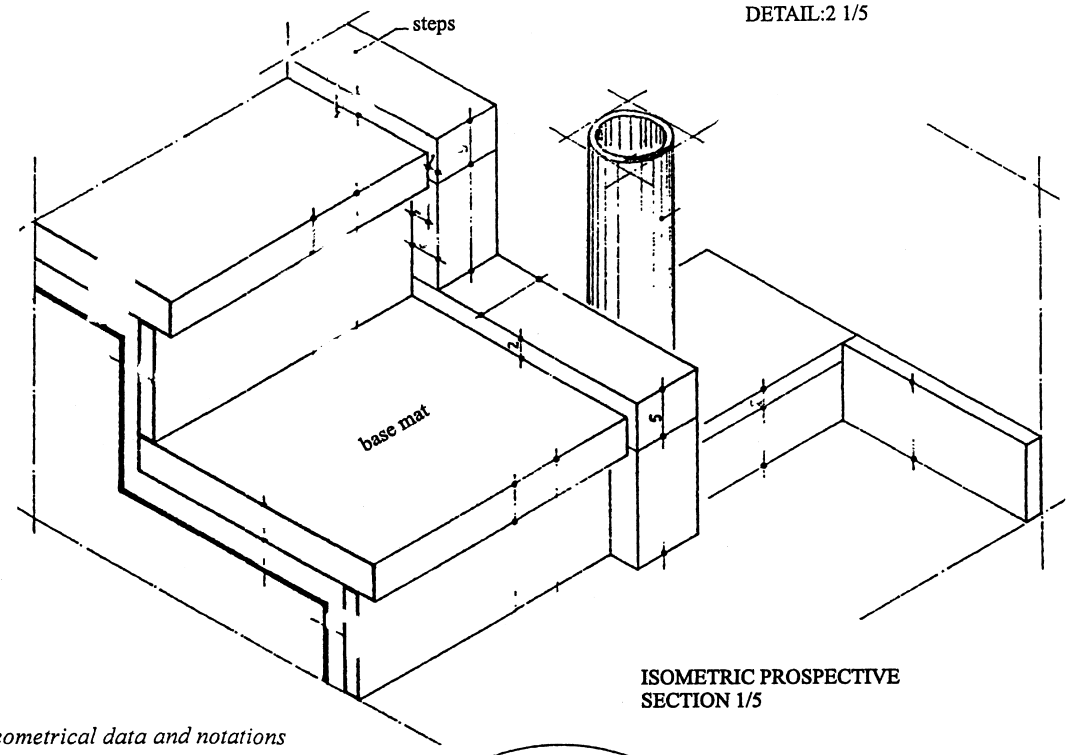


Precast concrete steps

BASE MATS AND STEPS (HELICAL STAIRS) (BASED ON EC2)

SHEET NO. III.13 (contd)

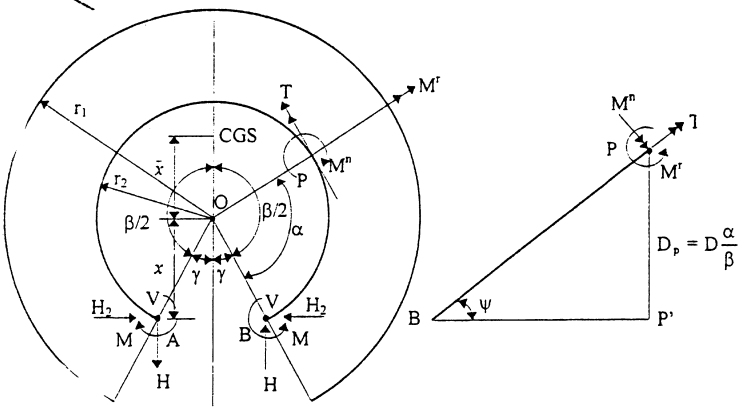
DETAIL:2 1/5



ISOMETRIC PROSPECTIVE
SECTION 1/5

Geometrical data and notations

r_i- internal radius of the slab;
r_e- external radius of the slab
b_w- width of the slab;
D- the level's high;
β- the unfolding slab's angle;
γ- the supports angle;
h- the slab's thickness h=200 mm
h_t- the step's height; h_t=150 mm
b_t- the step's width. b_t=300 mm



Geometrical Elements

The load's centre line:
r_1 = 1,85 m

The slab's centre line:
r_2 = 1,75 m

The slab's angle:
tg ψ = 0,5
ψ = 26,6°

(Section)	α (°)	T_{Sd} (kNm)	M^r_{Sd} (kNm)	M^n_{Sd} (kNm)	V^r_{Sd} (kN)	V^n_{Sd} (kN)	N_{Sd} (kN)
0	0	-37,8	0,0	75,6	-48,3	-48,1	78,0
1	45	-19,6	-32,0	123,8	0,0	-16,0	84,3
2	90	-1,3	-9,3	93,8	48,3	-1,7	54,8
3	135	0,0	8,0	0,0	68,3	0,0	0,0

Loading Assessment

Dead load (weight of the slab and steps h_{med}=220 mm, γ_b=25 kN/m^3):
G_k=5,50 kN/m^2

Live load:
Q_k=3,00 kN/m^2

Materials Resistance

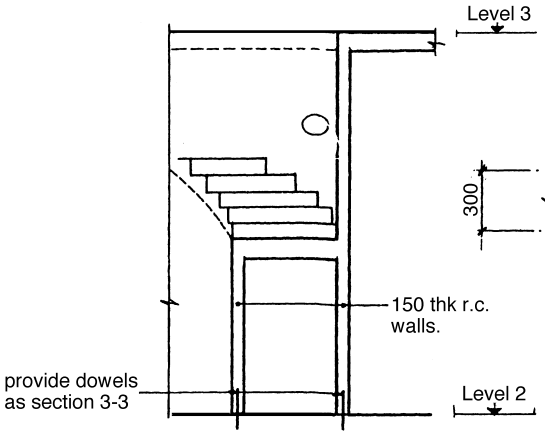
concrete C20/25: f_{ck}=20

γ_c=1.5; $f_{cd} = \frac{20}{1,5} = 13,33$ MPa

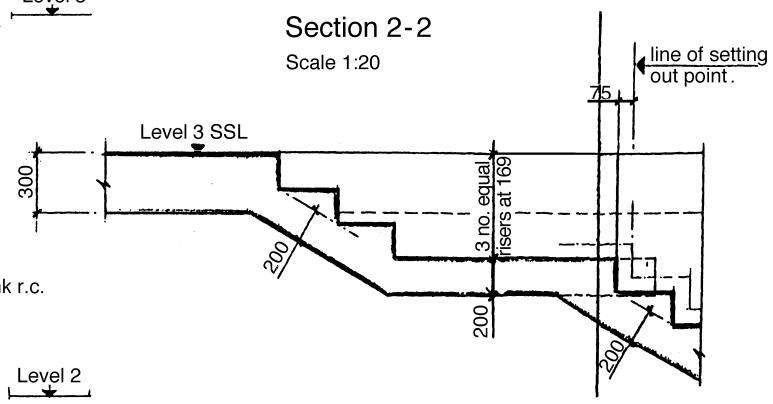
Steel longitudinal bars: on the axis of symmetry
f_{yk}=500 MPa, γ_s=1,15; directed horizontal reaction:

$H=H_A=H_B=68,3$ kN

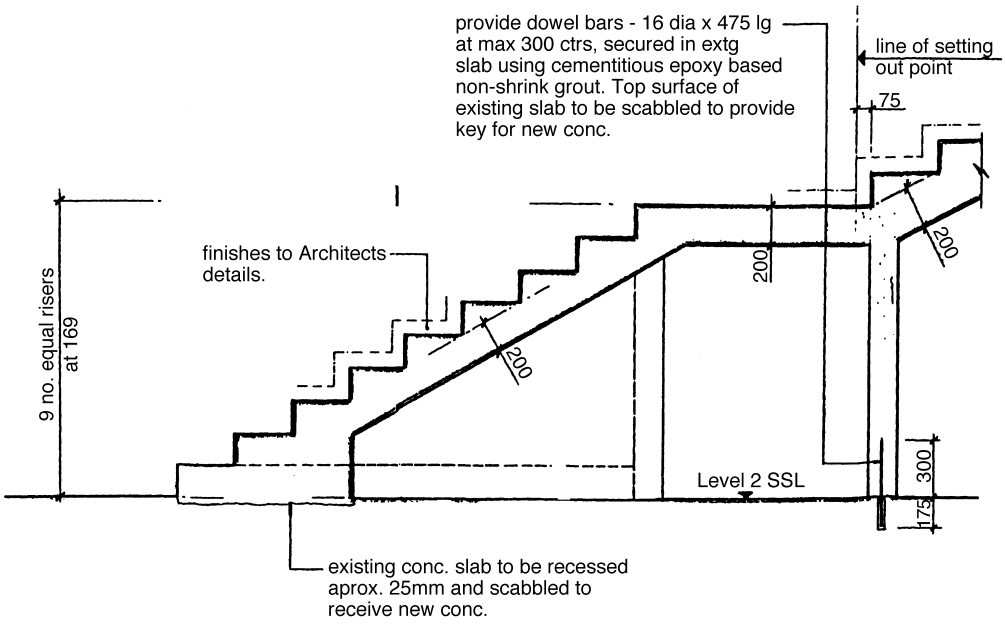
MIXED RC STAIRCASE (BRITISH CODES) SHEET NO. III.14

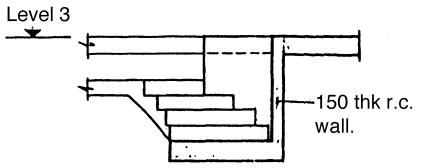


Section 1-1
Scale 1:50

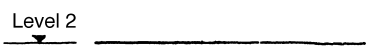


Section 2-2
Scale 1:20

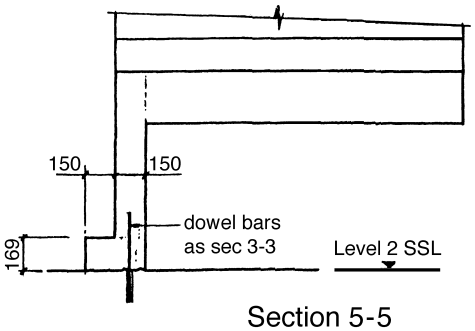




Section 3-3
Scale 1:20

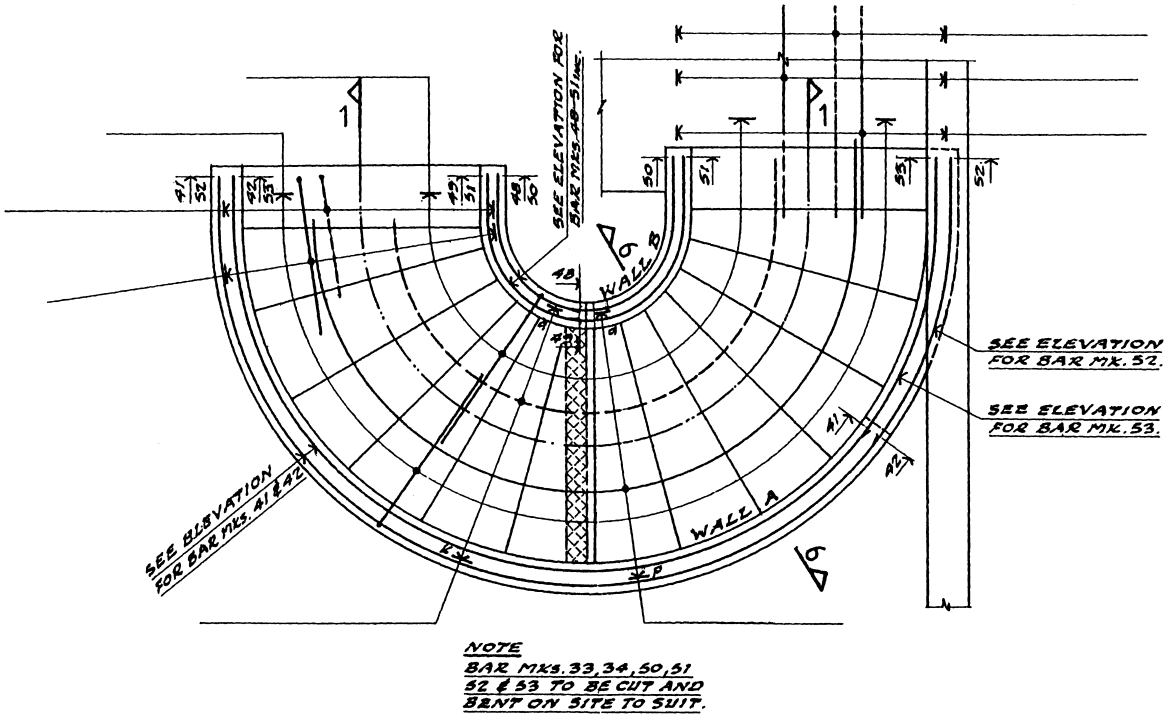


Section 4-4
Scale 1:50

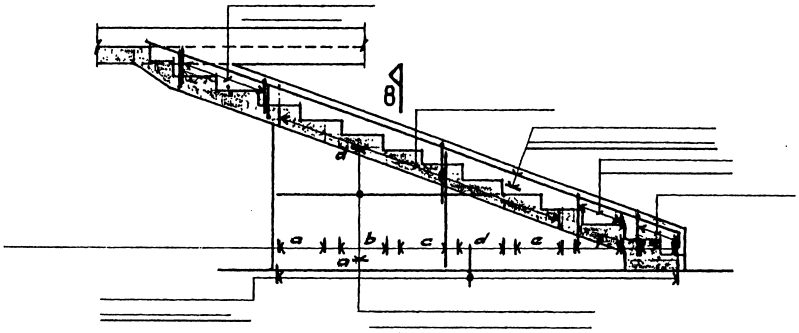


Section 5-5
Scale 1:20

SHEET NO. III.14 (contd)



Plan on Flight A

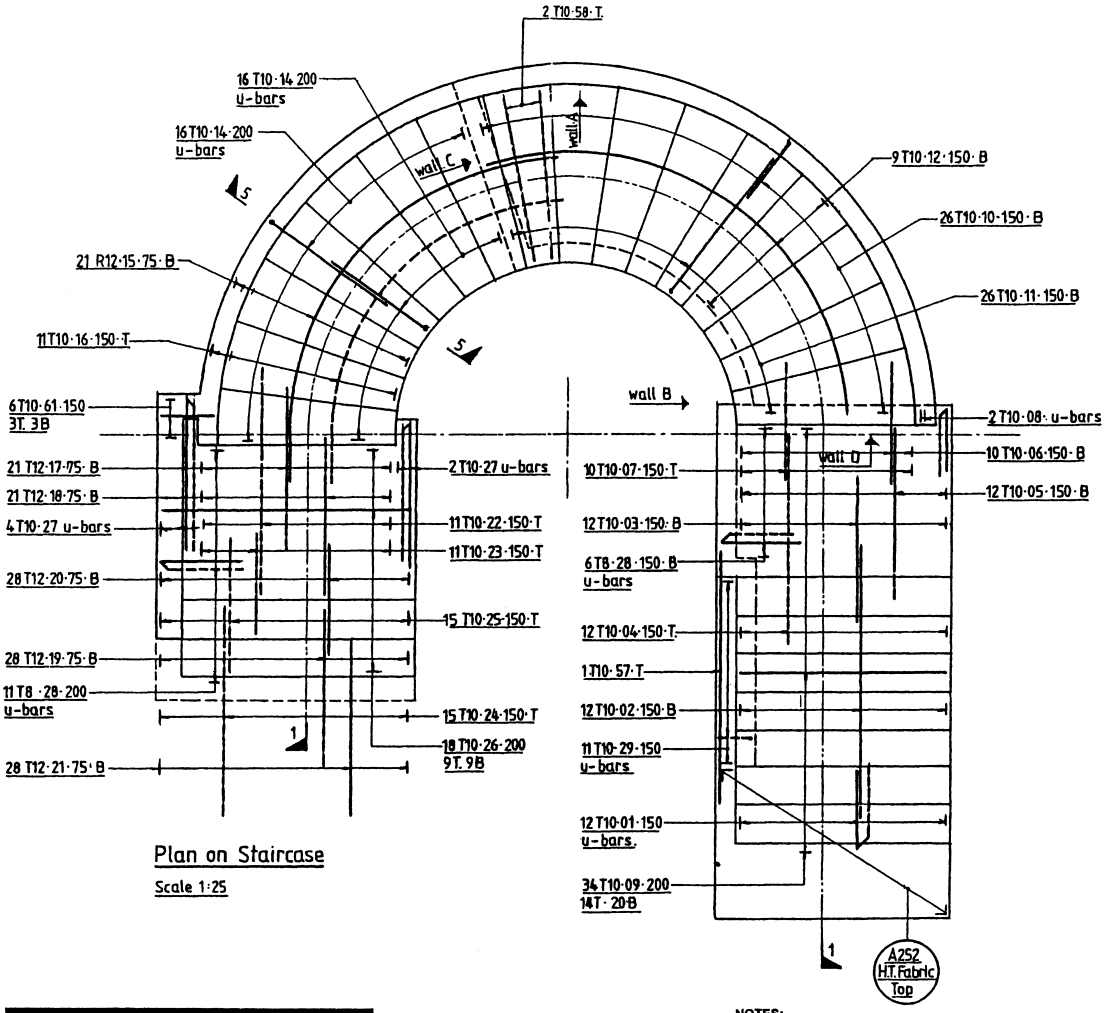


Elevation of Wall A
(Developed)
(SCALE 1:50)

WARD + COLE consulting engineers 1, old lodge place, st. margarets, twickenham, middlesex tw1 1rq tel. 081-744-0900 fax. 081-744-0902	drawing title Proposed Structural Work. Tax Office Stair R. C. Details.	drawing no. 30/127/400 rev. O scale 1:50, 1:20 date AUG. 93 drawn by D.P.

Mixed staircase – Straight-cum circular/helical (Ward & Cole, London) (British practice).

SHEET NO. III.14 (contd)



Plan on Staircase

Scale 1:25

WARD :: COLE
consulting engineers
1 old lodge place st margarets twickenham
middlesex tw1 1rq
tel 0181 744 0900 fax 0181 744 0902

drawing title

R.C. Details of Staircase & Walls
Central Staircore - Level 2 to 3

scale | date: | drawn by | checked by

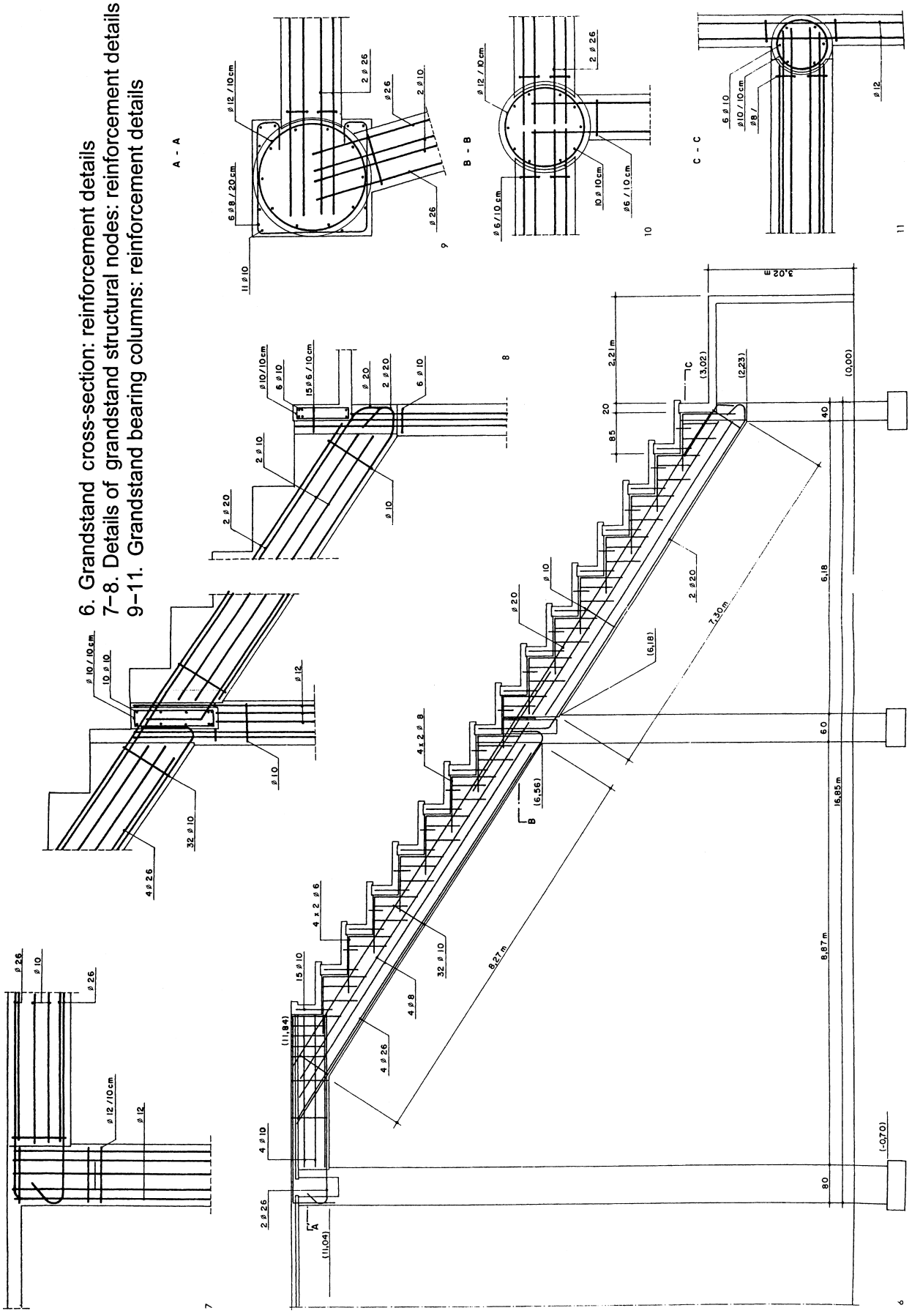
NOTES:

1. For general notes refer to Ward + Cole drawing no 30/127/313.
2. For general arrangement refer to Ward + Cole drawing no: 30/127/355.
3. Concrete to be grade C35 with 20mm max. size of aggregate.
   All concrete to be in accordance with BS.8110
4. High yield steel, prefixed "T" on drawing and delivery tags, to be in accordance with BS.4449 OR BS. 4461.
   Mild steel, prefixed "R" on drawing and delivery tags, to be in accordance with BS 4449
   High yield fabric to be in accordance with BS 4483
5. Minimum laps to reinforcement:
   T8 - 325
   T10 - 350
   T12 - 425
6. Concrete cover to reinforcement to be:
   Staircase - 35mm U.N.O.
   Walls - 25mm U.N O.
7. The Engineer is to inspect the fixed reinforcement prior to pouring concrete. Contractor to give Ward + Cole min. 48 hours prior notice.

Mixed staircase – Straight-cum circular/helical (Ward & Cole, London) (British practice).

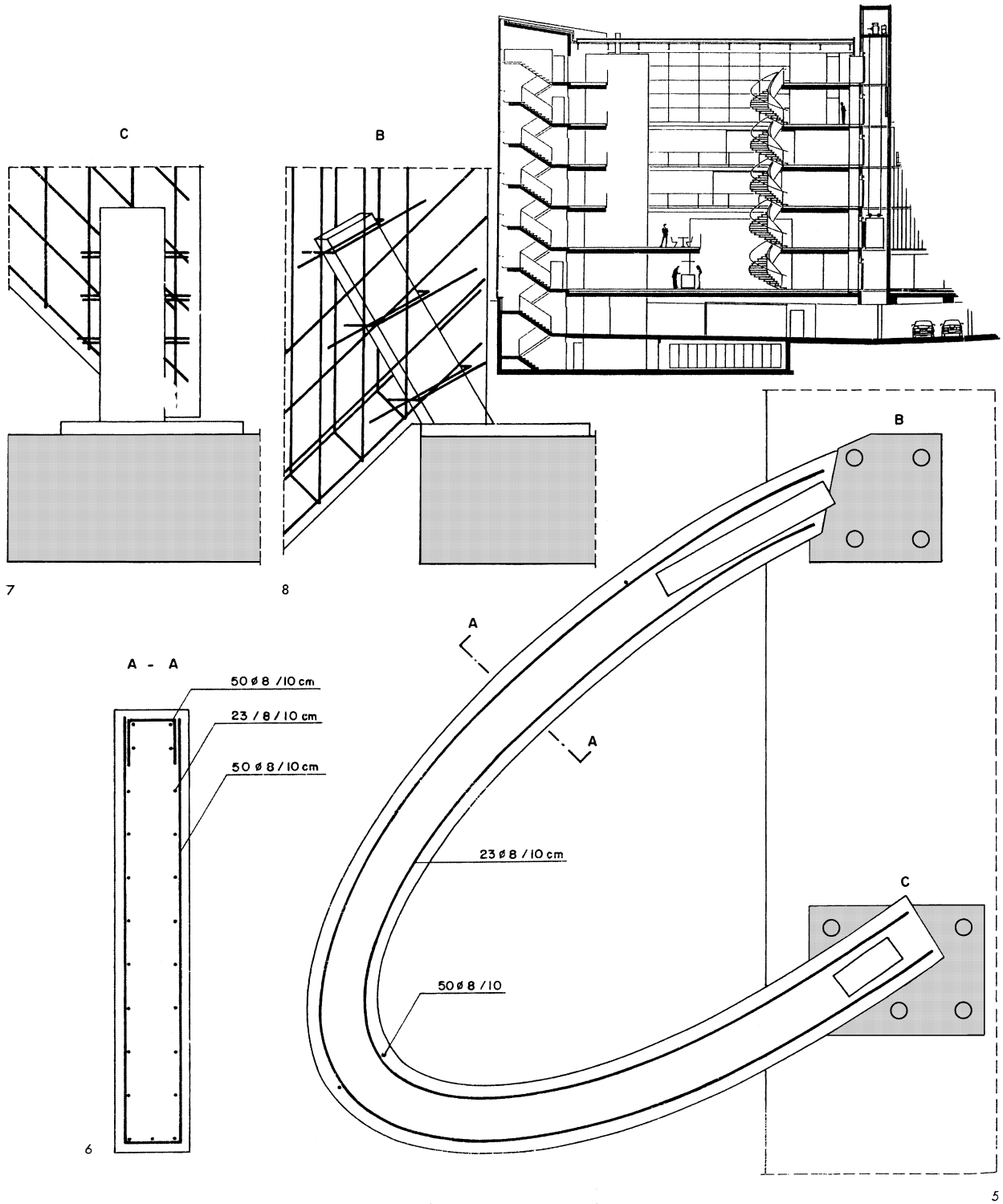
GRANDSTAND STAIRS (BASED ON EC2)

SHEET NO. III.15



6. Grandstand cross-section: reinforcement details
7–8. Details of grandstand structural nodes: reinforcement details
9–11. Grandstand bearing columns: reinforcement details

HELICAL STAIRCASE DETAILS (BASED ON EC2) SHEET NO. III.16



5. Horizontal section of the stair upright: reinforcement; 6. Vertical section: reinforcement; 7. Lower fitting of the upright; 8. Upper fitting of the upright.

CANTON ADMINISTRATION BUILDING (MORGES) SWITZERLAND (BASED ON EC2)

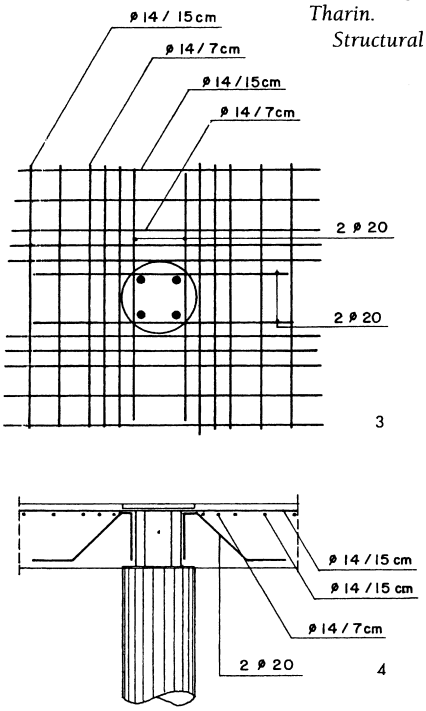
SHEET NO. III.17

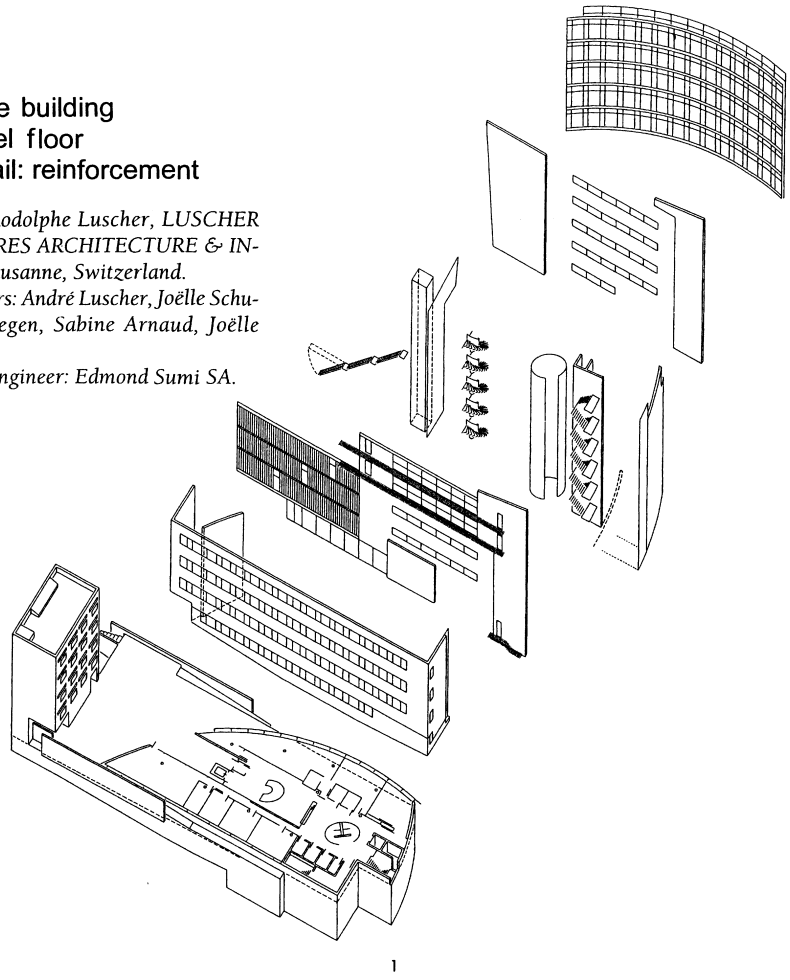
1. Axonometric view of the building
2. Plan of the second level floor
3–4. Foundation and detail: reinforcement

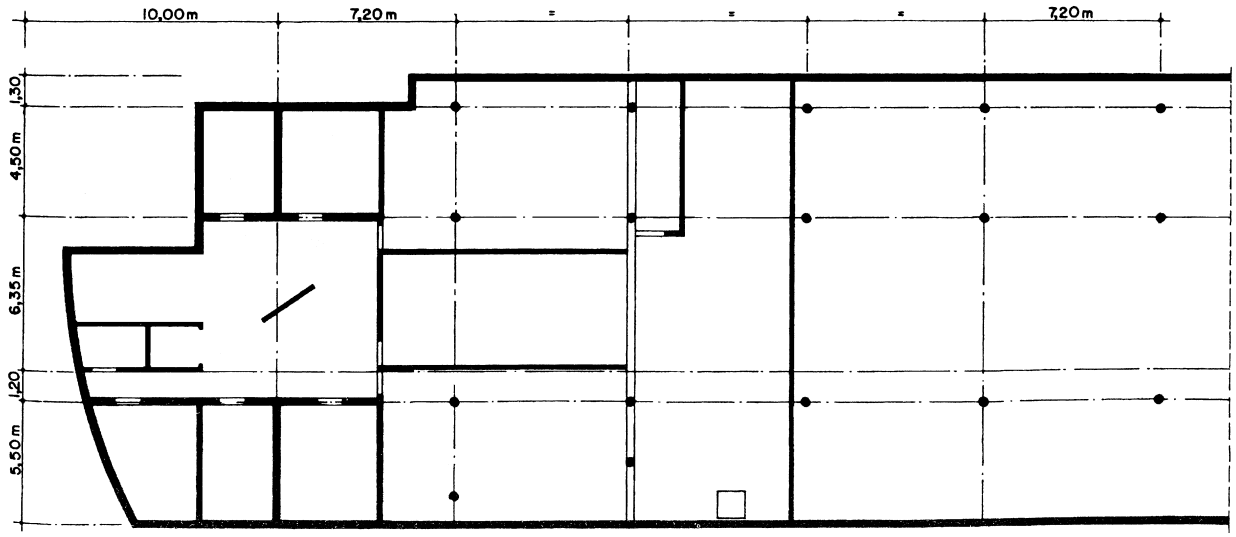
Architect: Rodolphe Luscher, LUSCHER & PARTENAIRES ARCHITECTURE & INGENIERIE, Lausanne, Switzerland.

Collaborators: André Luscher, Joëlle Schumann, Jürg Degen, Sabine Arnaud, Joëlle Tharin.

Structural engineer: Edmond Sumi SA.







III.1.3.2. Loads and load combinations

Loads and their combinations vary from one country to another. The partial safety factors associated with these loads vary as well and they largely depend on whether the stairs are analysed by the elastic, limit state, strength reduction and other concepts. In general, it is easy to compute dead loads and loads due to self weight and finishes. The disagreements are on the imposed loads (3 kN/m^2 to 5 kN/m^2) and the partial safety factors for loads and materials. Several examples in the text will indicate this dilemma. The general opinion is that steps should be loaded also with concentrated loads. The British practice is to check individual treads by placing on them two loads of 0·9 kN at 300 mm spacing and placed symmetrically about the centre line of the tread. For details, individual codes should be consulted.

III.1.3.3. Materials and stresses

For materials and their allowable stresses, individual codes are referred to.

III.1.3.4. Additional specifications for the reinforcement of concrete stairs

Reinforcement size

A standard range of bars and sizes is available for use in reinforced concrete. They may be hot-rolled (mild steel, high yield steel) or cold worked (high yield steel). Bars are made in a range of diameters from 8 to 40 mm. Special sizes of 6 and 50 mm are seldom available. The specification for steel covers chemical composition. Tensile strength, ductility, bond strength, weldability and cross-section area can be found in various codes.

Fabric

Fabric reinforcement is manufactured to BS 4483 and to ASTM 1992 requirements. There are four types of fabric made from hard drawn mild steel wire of $f_y = 485$ N/mm^2 or from cold-worked high yield bars.