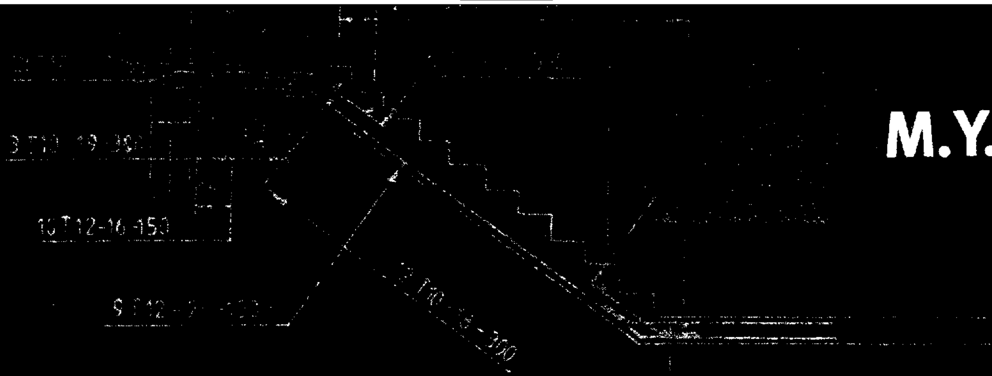
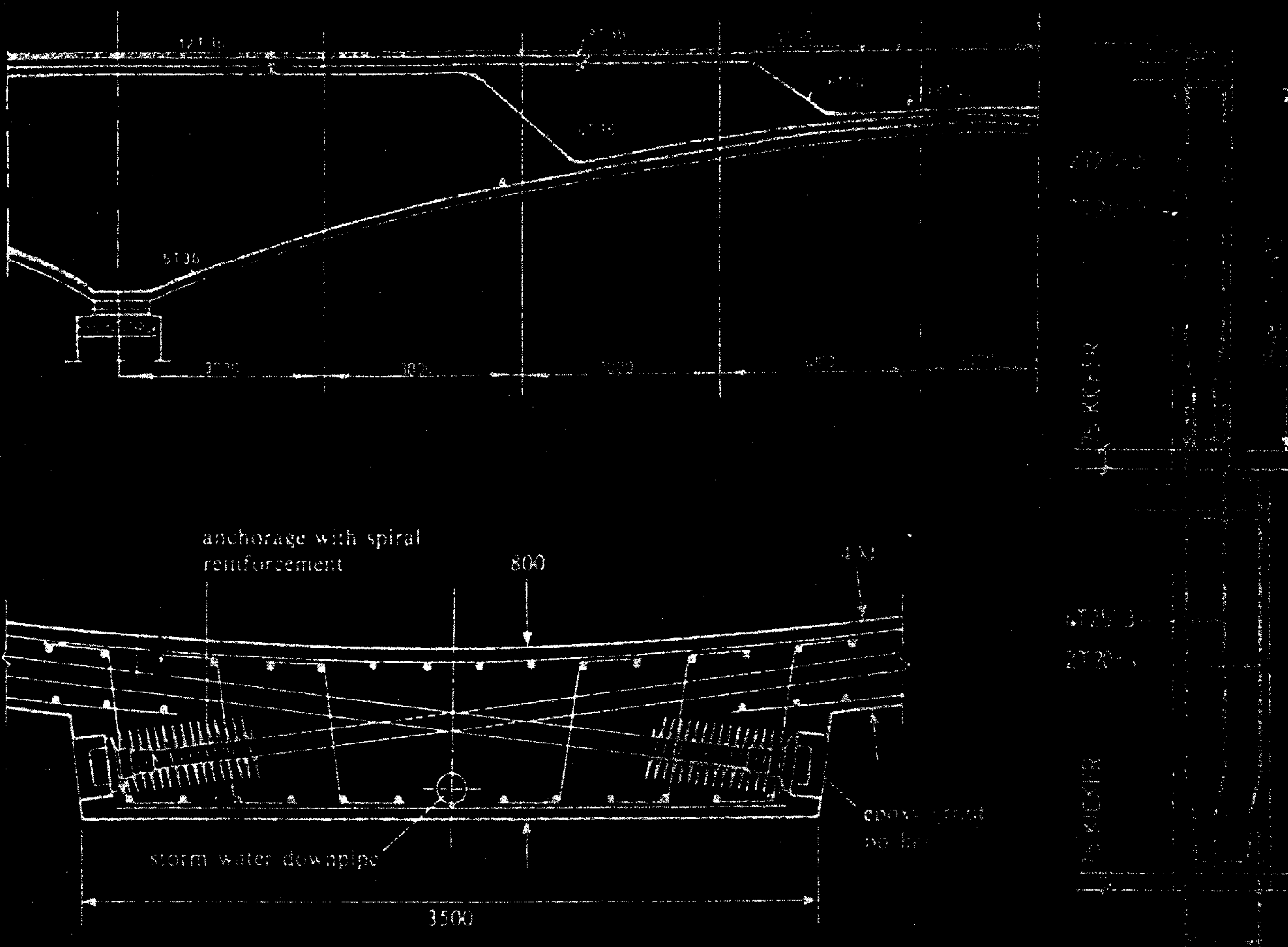
M.Y.H. Bangash



Structural Details in Concrete



Structural Details in Concrete

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Contents

Preface

A number of books on various aspects of concrete design and detailing have been published but this is believed to be the first comprehensive detailing manual. The aim of this book is to cover a wide range of topics, so simplifying and reducing the work required to prepare structural drawings and details in reinforced, prestressed, precast and composite concrete.

The book initially provides a list of extracts from relevant codes and current practices. Where drawings are carried out using imperial units, a conversion table is provided to change them into SI units.

The book is divided into eight sections: Section I deals with the general requirements for structural detailing in concrete, basic drafting criteria and the properties of materials. Section II is devoted entirely to the structural detailing of beams and slabs. Section III covers reinforced concrete detailing of stairs and staircases. A comprehensive description is given of the detailing of reinforced concrete columns, frames and walls in Section IV. The reader is also referred for more information to the later section on integrated structures.

Section V covers prestressed concrete systems with some basic structural detailing of beams and anchorages. Again the reader is referred to other sections, in particular Section VIII regarding the use of prestressed tendon elements in integrated structures. Section VI presents structural detailing in composite construction, precast concrete elements, joints and connections.

Section VII includes basic structural detailing of reinforced concrete foundations and earth-retaining structures. An effort is made to include a number of foundation drawings so that the reader can appreciate the quality and design required for a specific job.

Students of civil and structural engineering who have worked through to this part of the book will have acquired the background necessary to draw the majority of reinforced, prestressed, precast and composite concrete structures commonly encountered in professional practice. To assist the reader in his/her completion of drawings, an unusually large number of drawings have been incorporated into the text since they are generally the principal communication between the structural engineer/designer, architect, builder and client.

Case studies in Section VIII which include the structural detailing of the following special structures in concrete:

- reinforced concrete beam/slab bridge deck,
- culvert bridge super and substructures,

- continuous RC girder deck,
- reinforced concrete box bridge deck,
- open spandrel arch bridge – reinforced and prestressed,
- reinforced concrete rigid frame bridge details,
- composite/steel – concrete bridge deck,
- reinforced concrete rigid frame bridge,
- bridge bearings and substructural layouts,
- samples of reinforced concrete cylindrical shells, hyperbolic
  shells: groin type hyperbolic paraboloid shells and domes,
  water retaining structures and silos with elevated towers,
  nuclear shelter,
  pressure and containment vessels for nuclear power plants, gas and oil installations and cells for offshore platforms,
  hydroelectric and irrigation/hydraulics structures, spillways, piers, intakes, switch yard foundations, electric manholes, chutes, gates, tunnels and culverts.

An increasing emphasis has been placed on the role of the designer in planning reinforcement and structural details so that the detailer can do his/her work thoroughly without having to complete the design himself. Improved methods and standards presented in the text should result in better construction and reduced costs.

The book will serve as a useful text for teachers preparing a syllabus for technician and graduate courses. Each major section has been fully explained to permit the book to be used by practising engineers and postgraduate students, particularly those facing the formidable task of having to design/detail complicated structures for specific contracts and research assignments. Contractors will also find this book useful in the preparation of construction drawings.

M.Y.H. Bangash
April 1992

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The author wishes to express his appreciation to friends, colleagues and some students who have assisted in the early developments of this book by suggesting relevant changes. The author has received a great deal of assistance, encouragement and inspiration from practising engineers and contractors, particularly those for whom he has acted as consultant. The author is indebted to all those people and organizations who are referred to in this book and to the following, in particular, for making this book a reality:

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The Offshore Technology Conference Center, Houston, Texas, USA
The UK Atomic Energy, Winfrith, Dorset, UK

A number of original drawings have been modified to comply with the current drafting codes and requirements.

The undertaking could never have been achieved without the patience, encouragement and understanding of the author's family.

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V.13,14	Cabco
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VIII.2.6,7,8	Perkins and Will, Chicago
VIII.2.10	S.D. Castillo
VIII.6.3,4,5	Kaiser Engineers and Constructors Inc.

Conversion Factors

Length
1 inch = 25.4 mm
1 foot = 0.3048 m

Area
1 $foot^2$ = 0.0929 m^2
1 $inch^2$ = 645.2 mm^2

Mass
1 lb = 0.454 kg

Force
1 lbf = 4.448 N
1 kip = 4.448 kN
1 kip/ft = 14.594 kN/m

Density
1 lb/ft^3 = 16.018 kg/m^3

Pressure
1 lb/m^2 = 6.895 kPa (N/m^2)
1 lb/ft^2 = 47.880 Pa
1 kip/in^2 = 6.895 MPa (MN/m^2)
1 kip/ft^2 = 47.880 kPa

Prefixes in SI units
G = giga 10^9
M = Mega 10^6
k = kilo 10^3
m = milli 10^{-3}
Pa = Pascal

Section I

General Requirements for Structural Detailing in Concrete

I.1 Introduction

This section gives general requirements for structural detailing in concrete. A slight departure from these requirements can be expected because each project is different. Individual structural engineers and designer detailers also influence the style of working drawings and schedules. Moreover, structural detailing in concrete can vary since it can be considerably affected by external requirements including those of authorities such as gas, electricity, water, municipal, etc.

I.2 Drawings

Full drawings are prepared by structural engineers acting as consultants as part of the tender documentation. The architects are involved in the preparation of the site and other general arrangement plans. The main contractors are involved in preparation of temporary work drawings, including shoring and formwork. During the contract, drawings are sometimes modified by minor amendments and additional details. These drawings are generally updated as the projects progress. The drawings, which are distributed to other engineers including those providing services and to contractors, are prints taken from the original drawings made on tracing paper, called *negatives*. These negatives are provided with thick borders as a precaution against tearing. Plastic film on the other hand gives a smooth hard wearing surface. Almost all drawings are done in ink. A typical drawing sheet contains the following data in the panel on the right-hand side of the drawing.

Starting from the top	*Example*
NOTES	Specification etc.
REVISION . . .	751/10 Rev D (details of amendments)
NAME OF THE ENGINEER	Bangash Consultants
NAME OF THE CLIENT/ ARCHITECT	Bangash Family Estate
DRAWING TITLE . . .	BANGASH ESTATE CENTRE FOUNDATION LAYOUT
SCALES/DRAWN BY/DATE . . .	1:20, 1:50, 1:100/Y. Bangash/13 July 1992 Underneath the name of the person and the date
DRAWING NUMBER	The drawing numbers may run in sequence such as 751 or 1, 2, 3 or 100, 101, etc.

The International Standard Organisation (ISO) recommends A or B ranges for paper sizes and most common are A1 (594 × 841 mm) and B1 (707 × 1000 mm), for structural detailing in concrete A2 (420 × 594 mm) size is recommended. For small sketches and detailing and specifications, design teams and contractors use A4-sized (210 × 297 mm) sheets. All major drawings and site plans carry the north sign.

I.2.1 Drawing instruments

The most general instruments required for good drawings are: a drawing board, woodcase pencils, clutch pencils, automatic pencils, technical drawing pens, erasers, scales, set squares, templates and stencils. A description of these is excluded from this text as they are well known.

I.2.2 Linework and dimensioning

Drawings consist of *plan*, *elevation* and *section*. The structure is viewed 'square on' to give a series of plans, elevations and sections. The two basic types are: first-angle projection and third-angle projection. Dimensioning varies from country to country. Some examples are given later on in this section and in other sections of the book.

I.2.2.1 Line thickness

The following line thicknesses (based on ISO line thickness) are recommended for concrete drawings:

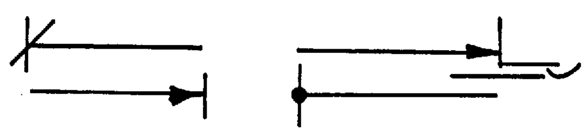
		Colour code
General arrangement drawings	0.35 mm	Yellow
Concrete outlines on reinforcement drawings	0.35 mm	Yellow
Main reinforcing bars	0.70 mm	Blue
Links/stirrups	0.35–0.70 mm	—
Dimension lines and centre lines	0.25 mm	White

The line thickness increases in the ratio $1:\sqrt{2}$, for example, $0.25\sqrt{2} = 0.35$ etc.

I.2.2.2 Dimensioning

As stated in Section I.2.2.1, dimension lines of 0.25 mm thickness are shown in several ways. Some are given below. A gap is necessary between the dimension line and the structural grid. Dimensions are given in different ways. In SI units, dimensions are given as follows in various countries:

Britain (BS 1192) Codes:	All major dimensions shown, say, 1700 for 1700 mm
Sweden	1700 mm rather than 1700
Switzerland	1.700 m
Italy	1700
Japan	1.7 m and 1700
Germany	1.7 m



USA	Major dimensions in ft (feet), smaller dimensions in inches
Pakistan/India	Same as USA on some projects in metres and millimetres.

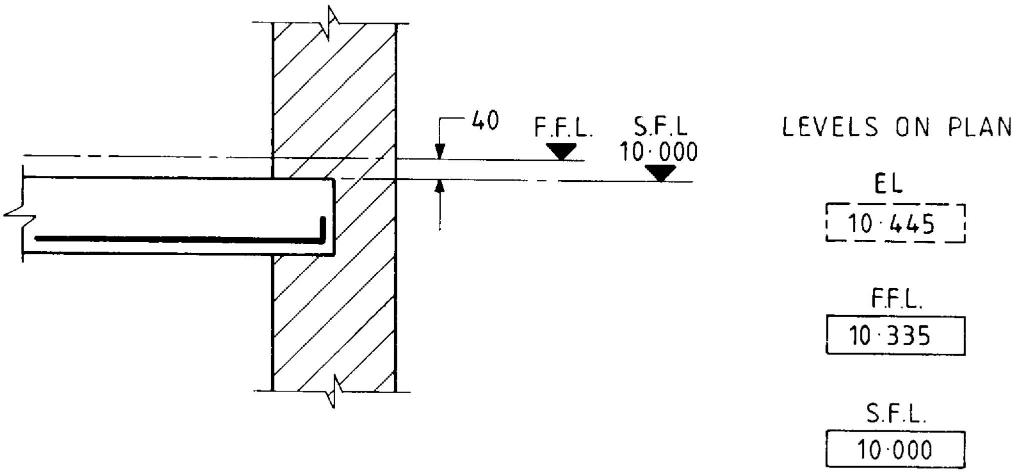
I.2.3 Grids and levels

A point on the drawing can be located by a grid reference. A grid is a series of vertical and horizontal lines on the plan of the structure. They are sometimes called *building grids*. They may not have identical spacings but it is preferable that the spacing is constant in the same row between the grid lines. The grid lines are identified by letters and numbers. On sections and elevations, various levels are marked. Typical examples are shown in Sheet No. I.1 for grids and levels and a proper notation is shown for reference beams and columns.

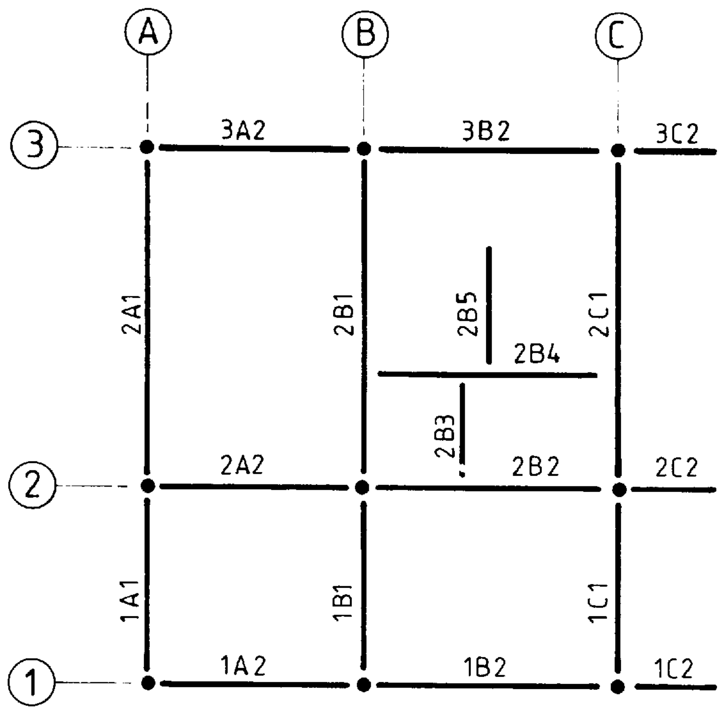
GRIDS AND LEVELS

SHEET NO. 1.1

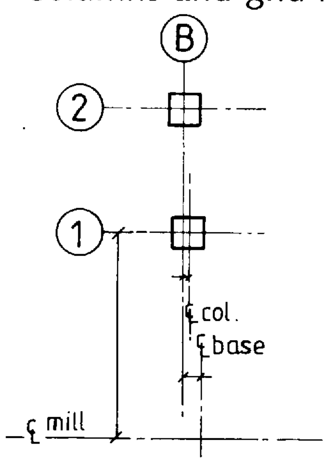
(a) Levels on section and elevation



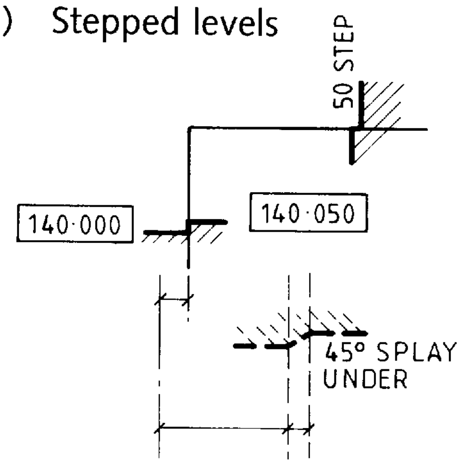
(b) Grid lines and reference system



(c) Columns and grid lines

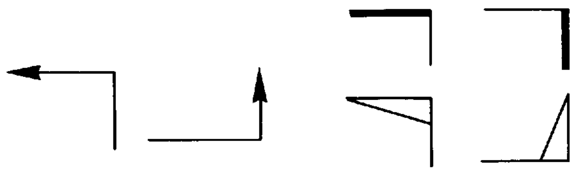


(d) Stepped levels



I.2.4 Sections and elevation marker

The exact style cannot easily be determined as it varies from country to country. In a way, it is not important what style is used, as long as it is simple and clear. The markers are located on the plane of the section or elevation with indicators pointing in the direction of the view. The section markers must be shown in the correct direction and the letters must read from the bottom of the drawing. Some of them are shown later on various drawings and details in this book either with horizontal and vertical thick lines



or arrow heads of the types shown. In some important cases two thick lines are shown. Where sections are indicated they are marked as shown below.

<u>X-X</u>   **<u>A-A</u>**

Similar markers can be seen on different drawings. The author has deliberately changed these markers on drawings to give the reader a choice of any marker that he or she wishes to adopt.

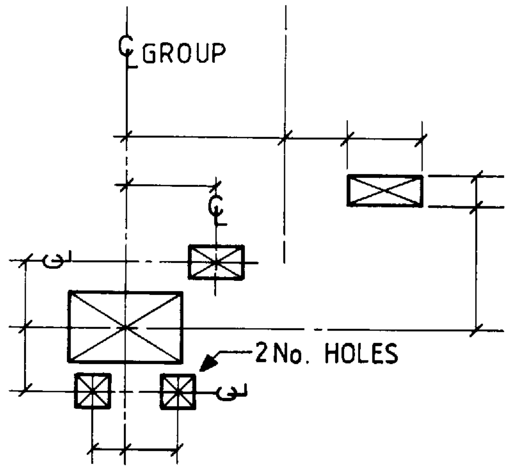
I.2.5 Symbols and abbreviations

aggregate	agg	centres	crs
bitumen	bit	centre to centre	c/c
blockwork	blk	centre line	℄
brickwork	bwk	finished floor level	FFL
building	bldg	structural floor level	SFL
column	col	average	av
concrete	conc	external	ext
damp proof course/	dpc/dpm	figure	FIG or fig
membrane		internal	int
diameter	dia, ∅	holes	hls or HOLES
drawing	drg	radius	rad
elevation	EL	inside/outside dia	id/od
foundation	fdn	sheet	sh
full size	FS	horizontal/vertical	hor/vert
setting out point	SOP	not to scale	NTS or nts
setting out line	SOL	bottom	B or b
near face	NF	top	T or t
far face	FF	existing level	
each face	EF	(plan) × 100 000	
each way	EW	section $\nabla^{10\,000}$	

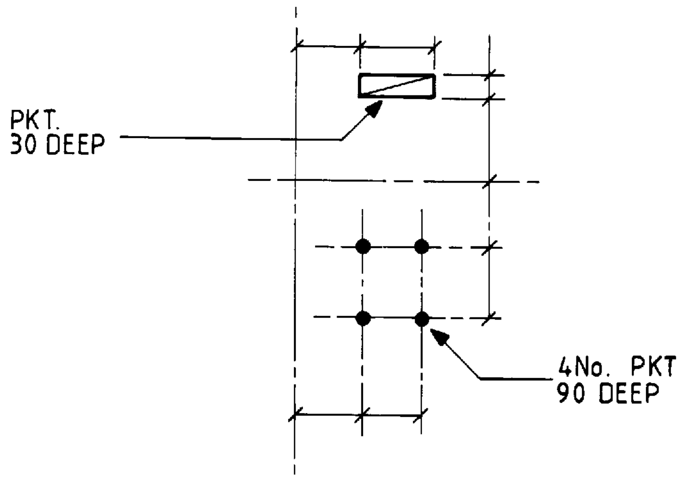
HOLES, RECESSES, NIBS AND KERBS

SHEET NO. 1.2

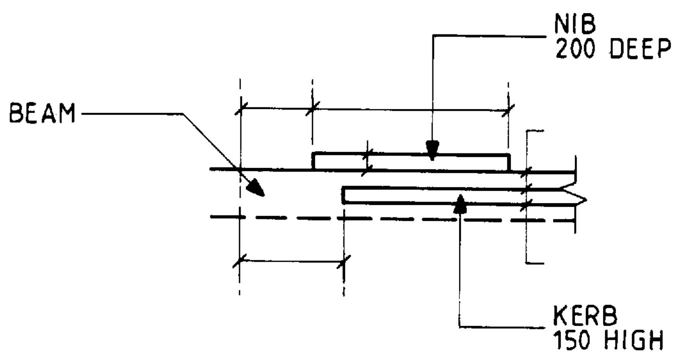
(a) Holes in concrete structures



(b) Pockets and recesses



(c) Nibs and kerbs on beams



square	sq	metre	m
right hand	rh	millimetre	mm
sketch	sk	minimum	min
number	no or NO		
approximately	approx		
specifications	spec		
pockets	PKT		
kerb	KERB		
nib	NIB		

With reference to reinforcement
far face outer layer F1
far face second layer F2
near face outer layer N1
near face second layer N2
bottom/top face outer layer B1/T1 or b1/t1
bottom/top face second layer B2/T2 or b2/t2

I.2.6 Holes, pockets, recesses, nibs and kerbs (curbs)

They are either shown as thin cross-lines or single diagonal lines with appropriate symbols. A typical example is shown on Sheet No. I.2.

I.2.7 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-sectional area. It is important to compare these bars with the American system bars. It is useful in case the drawings are done using American steels.

	Bars												
Britain, Europe, Japan, Russia: Bar types (mm)	8	10	12	16	20		25		32		40		
USA, Canada, S. America: Bar types (mm) denoted by # or no.		#3	#4	#5	#6	#7 (22 mm)	#8	#9 (29 mm)	#10	#11 (35 mm)		#14 (43 mm)	#18 (57 mm)
Area (mm^2)	50	78	113	201	314	387	491	645	804	1006	1257	1452	2581

I.2.7.1 *Spacing and arrangement of bars*

Bars are spaced on the basis of a number of factors which include beam sizes, aggregate sizes, spacers, concrete cover and many others including requirements imposed by other services. Sheet No. I.3 gives a summary of spacing and arrangement of bars. Both single and group bars are shown. A number of other combinations are possible. When bars of different diameters are used, they tend to be grouped in similar sizes. Some of them are:

10,12,16; 16,20; 20,25; 16,20,25; 20,25,32.

I.2.8 Fabric

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

(a) Square mesh fabric — regular bars of lightweight (A Type). They are used in walls and slabs.
(b) Structural fabric — main wires 100 mm crs (B Type), cross-wires 200 mm crs.
(c) Long mesh fabric — main wires 100 mm crs (C Type), cross-wires 400 mm crs.
(d) Wrapping fabric — lightweight square mesh (D Type) encased conditions for fire resistance mainwire cross-sectional area 252 mm^2; fy = 250 N/mm^2.

The following chart gives the parameters for fabric reinforcement:

Mesh type	Size of wires (mm) Main	Size of wires (mm) Cross	Area (mm^2) Main	Area (mm^2) Cross	Weight (kg/m^2)
1. *Square mesh* (200 × 200)					
A393	10	10	393		6.16
A252	8	8	252		3.95
A193	7	7	193		3.02
A142	6	6	147		2.22
A98	5	5	98		1.54
2. *Structural fabric* (100 × 200)					
B1131	12	8	1131	252	10.90
B785	10	8	785	252	8.14
B503	8	8	503	252	5.93
B386	7	7	385	193	4.53
B283	6	7	283	193	3.73
B196	5	7	196	193	3.05
3. *Long mesh fabric* (100 × 400)					
C785	10	6	785	70.8	6.72
C636	9	6	636	70.8	5.55
C503	8	5	503	49.0	4.34
C385	7	5	385	49.0	3.41
C283	6	5	283	49.0	2.61
4. *Wrapping fabric*					
D49 (100 × 100)	2.5	2.5	49	49	0.76
D98 (200 × 200)	5.0	5.0	98	98	1.54

I.2.9 Cover to reinforcement

The distance between the outermost bars and the concrete face is termed the cover. The cover provides protection against corrosion, fire and other accidental loads. For the bond to be effective an effective cover is needed. Various concrete codes allow grouping or bundling of bars and in such a case the perimeter around a bundle determines the equivalent area of a 'single bar'. The cover also depends on the grade of concrete and the full range of exposure conditions.

The table overleaf gives the nominal cover for such conditions. For concrete against water and earth faces, the cover shall be at least 75 mm.

I.2.10 Dimensional tolerance and spacers

Dimensional tolerance should be allowed at several stages in reinforced concrete detailing, e.g. bar bending, provision of shutter and fixing of reinforcement.

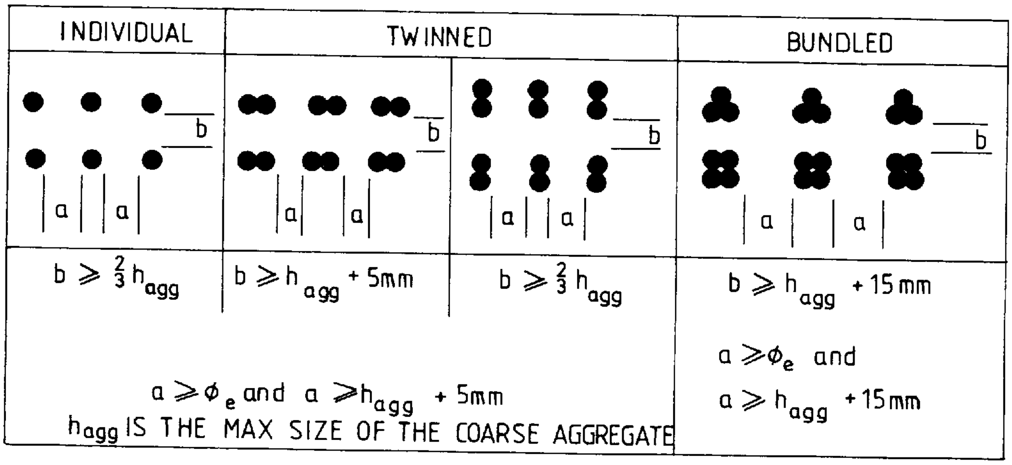
On-site minimum cover = Nominal cover − Tolerance of 5 mm.

Spacers as shown in Sheet No. I.3 are needed to achieve the required cover between bars and the shutter. They are cast into the concrete. There are different types of

SPACING AND ARRANGEMENT OF BARS

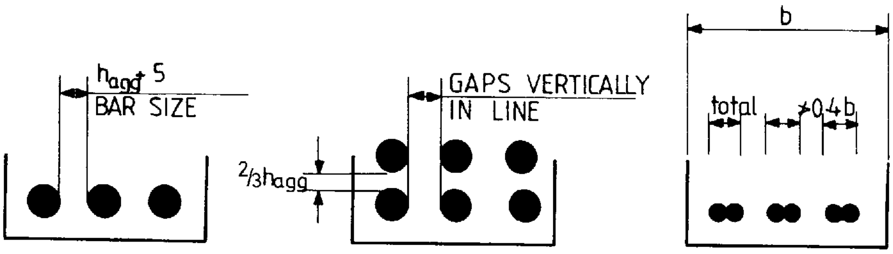
SHEET NO. 1.3

(a) Spacing of bars

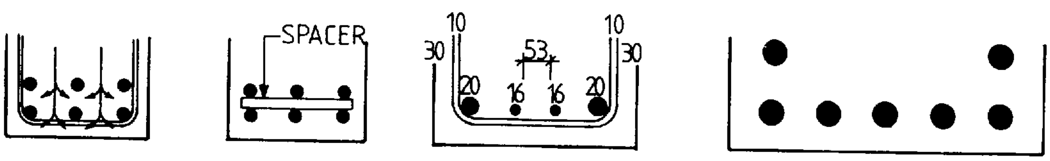


(b) Bar arrangements

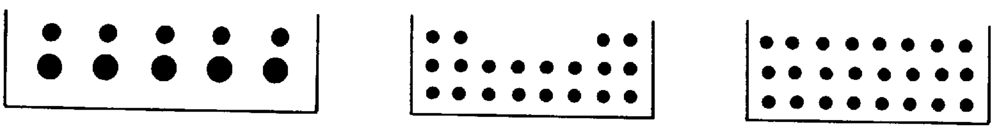
(i)



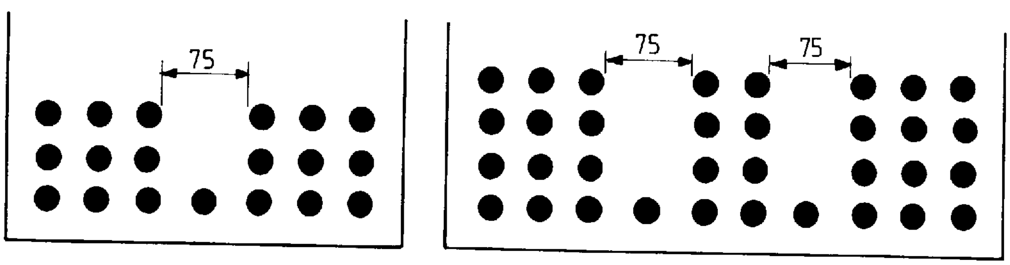
(ii)



(iii)



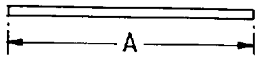
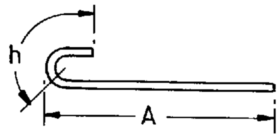
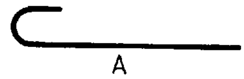
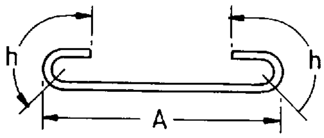
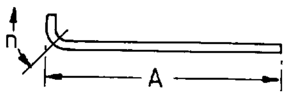
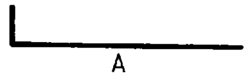
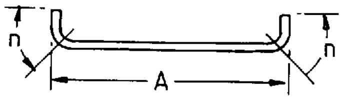
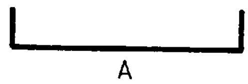
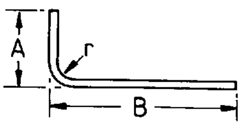
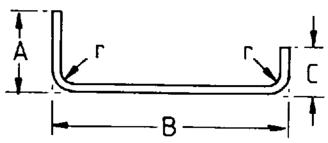
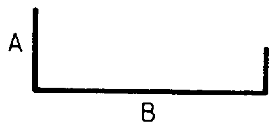
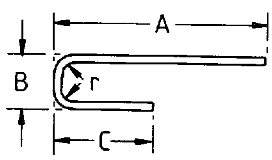
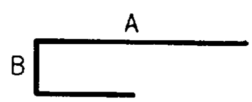
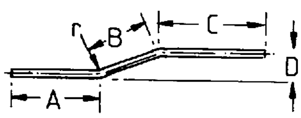
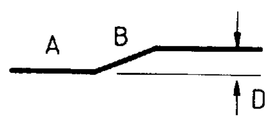
(iv)



Conditions of exposure	Nominal cover* (mm)				
Mild	25	20	20**	20**	20**
Moderate	—	35	30	25	20
Severe	—	—	40	30	25
Very severe	—	—	50+	40***	30
Extreme	—	—	—	60***	50
Water/cement ratio	0.65	0.60	0.55	0.50	0.45
Concrete grade	c30	c35	c40	c45	c50

* All values in the table are for h_{agg} maximum aggregate size of 20 mm.
** To be reduced to 15 mm provided $h_{agg} > 15$ mm.
***Air-entrainment should be used when concrete is subject to freezing.

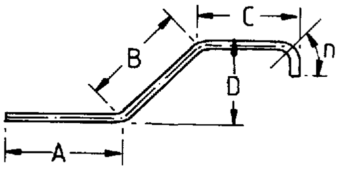
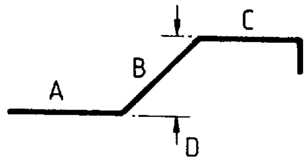
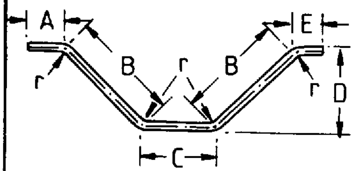
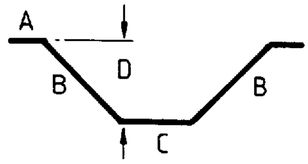
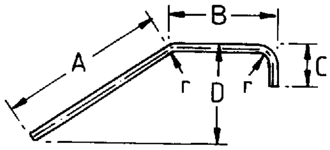
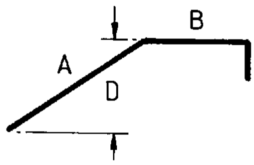
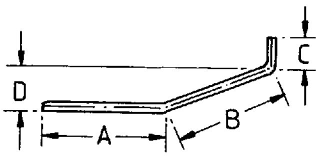
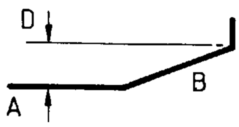
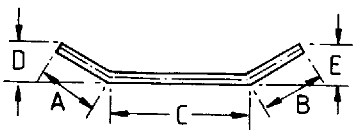
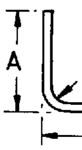
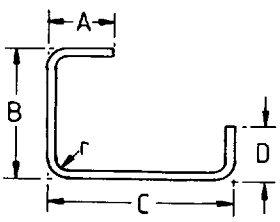
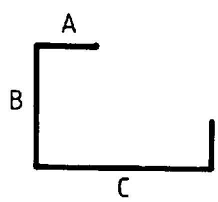
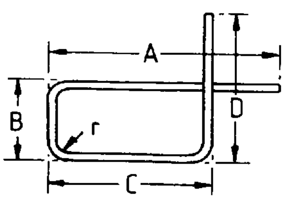
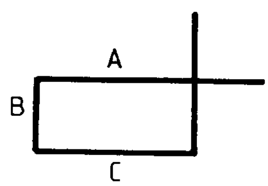
spacers. They are normally plastic or concrete, but spacers in the form of steel chairs are also used. They serve to support the steel. All spacers must prevent the dislodgement of the reinforcement cage. They can be used for vertical bars in walls and columns and are clipped into the bars.

SHAPE CODE			SHEET NO. 1.4
SHAPE CODE	METHOD OF MEASUREMENT OF BENDING DIMENSIONS	TOTAL LENGTH OF BAR (L) MEASURED ALONG CENTRE LINE	SKETCH & DIMENSIONS TO BE GIVEN IN SCHEDULE
20		A	STRAIGHT
32		A+h	
33		A+2h	
34		A+n	
35		A+2n	
37		A+B −1/2R − ϕ	
38		A+B+C−R−2ϕ	
OR		A+B+C−R−2ϕ	
41		WHERE D IS AT LEAST 2ϕ A+B+C A+B+C−r−2ϕ IF THE ANGLE TO THE HORIZONTAL > 45°	

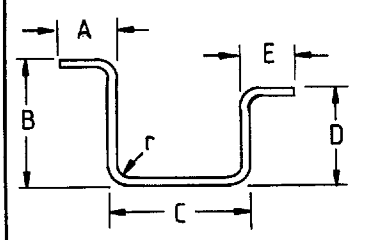
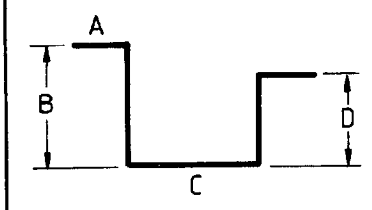
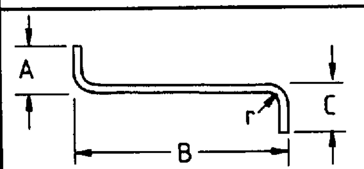
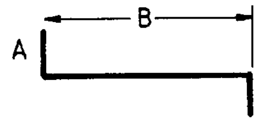
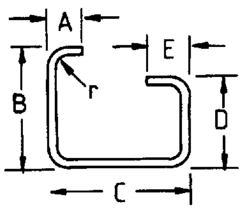
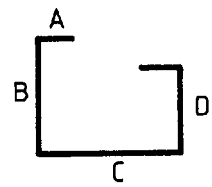
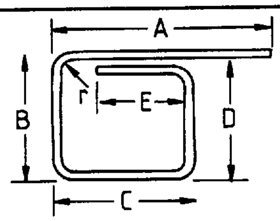
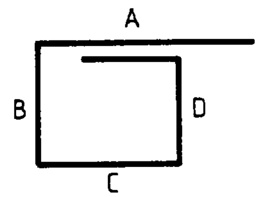
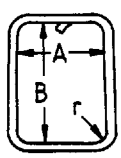
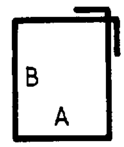
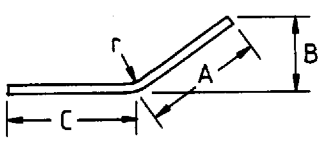
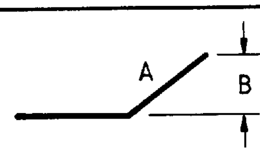
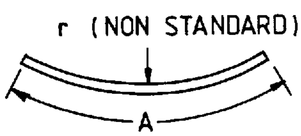
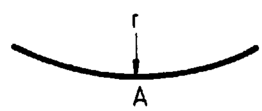
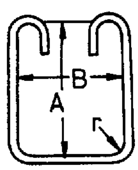
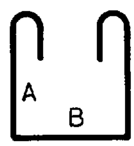
I.2.11 Bar shape codes

The standard shapes for the bending of reinforcing bars are generally given specific numbers called *shape codes*. They are listed on Sheet Nos. I.4 to I.8. Where construction demands a special shape not available in these sheets, a special shape code 99 of any form should be used.

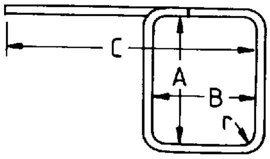
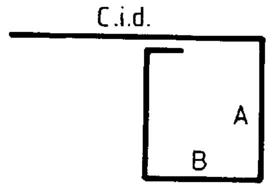
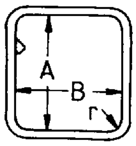
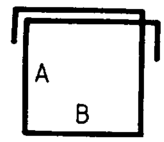
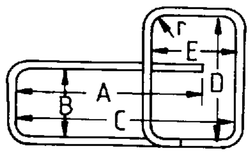
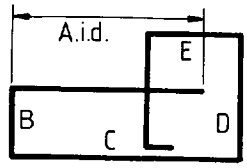
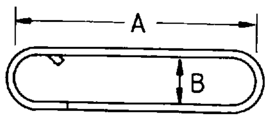
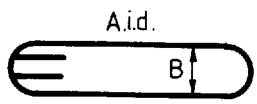
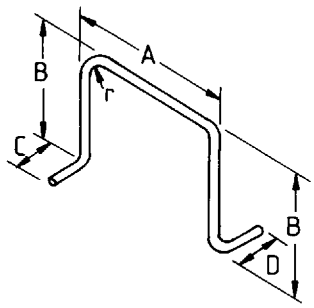
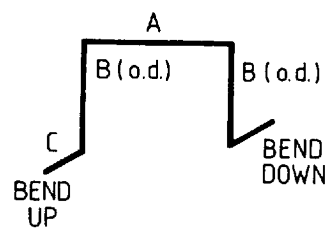
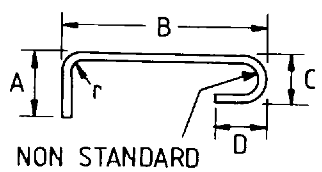
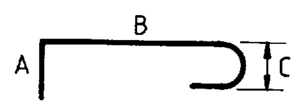
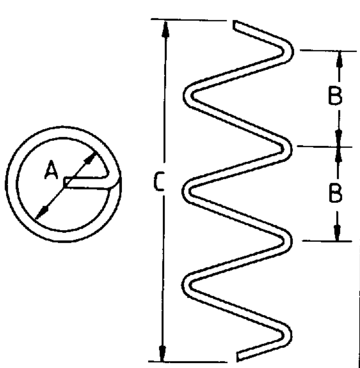
SHAPE CODE (CONTINUED) — SHEET NO. 1.5

SHAPE CODE	METHOD OF MEASUREMENT OF BENDING DIMENSIONS	TOTAL LENGTH OF BAR (L) MEASURED ALONG CENTRE LINE	SKETCH & DIMENSIONS TO BE GIVEN IN SCHEDULE
42		IF ANGLE WITH HORIZONTAL IS 45° OR LESS $A+B+C+n$ IF THE ANGLE > 45° $A+2B+C+E-2r-4\phi$	
43		IF ANGLE WITH HORIZONTAL IS 45° OR LESS $A+2B+C+E$	
45		$A+B+C-\frac{1}{2}r-\phi$	
48		$A+B+C$	
49		IF ANGLE WITH HORIZONTAL IS 45° OR LESS $A+B+C$	
51*		$A+B-\frac{1}{2}r-\phi$ (SEE SHAPE 37)	
52		$A+B+C+D-1\frac{1}{2}r-3\phi$	
		$A+B+C+D-1\frac{1}{2}r-3\phi$	

SHAPE CODE (CONTINUED) SHEET NO. 1.6

SHAPE CODE	METHOD OF MEASUREMENT OF BENDING DIMENSIONS	TOTAL LENGTH OF BAR (L) MEASURED ALONG CENTRE LINE	SKETCH & DIMENSIONS TO BE GIVEN IN SCHEDULE
53		A + B + C + D + E - 2r - 4ϕ	
54		A + B + C - r - 2ϕ	
55		A + B + C + D + E - 2r - 4ϕ	
OR		A + B + C + D + E - 2r - 4ϕ	
60*		2 (A + B) + 20ϕ	
62*		IF ANGLE WITH HORIZONTAL IS 45° OR LESS A + C	
65		A	
72		2A + B + 25ϕ	

SHAPE CODE (CONTINUED) SHEET NO. 1.7

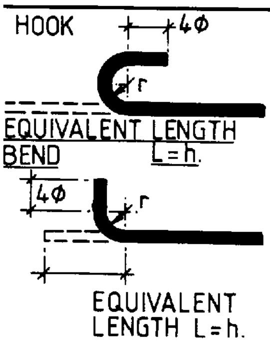
SHAPE CODE.	METHOD OF MEASUREMENT OF BENDING DIMENSIONS	TOTAL LENGTH OF BAR (L) MEASURED ALONG CENTRE LINE	SKETCH & DIMEMSIONS TO BE GIVEN IN SCHEDULE
73		2A + B + C + 10 Φ	
74		2A + 3B + 20Φ	
75		A + B + C + 2D + E + 10 Φ	
81		2A + 3B + 22Φ	
83*		A + 2B + C + D −2r − 4Φ	
85	 NON STANDARD	A + B + 0.57C + D −1/2 r − 2.57Φ	
86		WHERE B IS NOT GREATER THAN A/5 $\frac{C}{B}$ π (A + d) + 8Φ l (MAX) 12 m	HELIX A = INTERNAL Φ (mm) B = PITCH OF HELIX (mm) C = OVERALL HEIGHT (mm)

REINFORCEMENT, ANCHORAGE, LAP LENGTHS AND LINKS

SHEET NO. 1.9

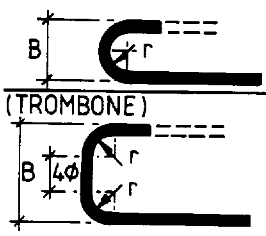
ANCHORAGE (BS8110 CLAUSE 3·12·8)

(a) Equivalent straight anchorage lengths of standard hooks and bends (mm)



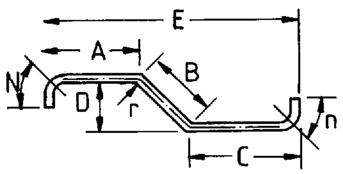
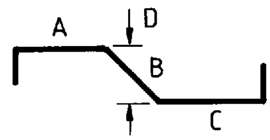
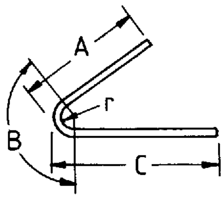
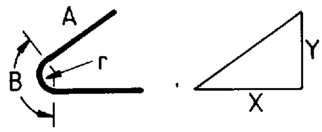
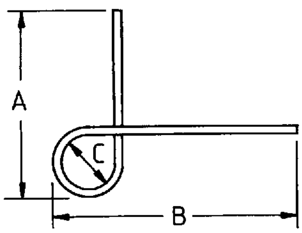
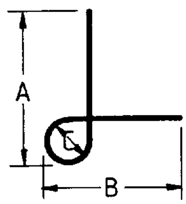
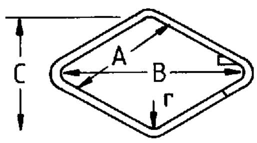
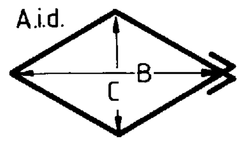
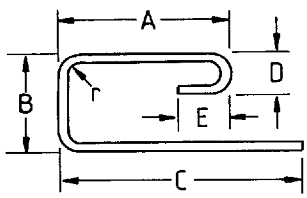
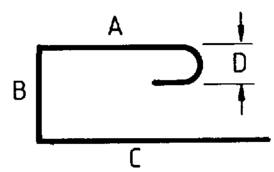
ANCHORAGE TYPE	VALUE	fy N/mm2	BAR SIZE, mm 8	10	12	16	20	25	32	40
HOOK	16ϕ	250	128	160	192	256	320	400	512	640
	24ϕ	460	192	240	288	384	480	600	768	960
BEND	8ϕ	250	64	80	96	128	160	200	256	320
	12ϕ	460	96	120	144	192	240	300	384	480

(b) Minimum overall depth of various U-bars (mm)



SHAPE CODE	B	r	fy N/mm2	8	10	12	16	20	25	32	40
(HOOK) (HAIRPIN)	6ϕ	2ϕ	250	50	60	75	100	120	150	195	240
	8ϕ	3ϕ	460	65	80	100	130	160	-	-	-
	10ϕ	4ϕ	460	-	-	-	-	-	250	320	400
(TROMBONE)	10ϕ	2ϕ	250	80	100	120	160	200	250	320	400
	12ϕ	3ϕ	460	100	120	145	195	240	-	-	-
	14ϕ	4ϕ	460	-	-	-	-	-	350	450	560

SHAPE CODE (CONTINUED) SHEET NO. 1.8

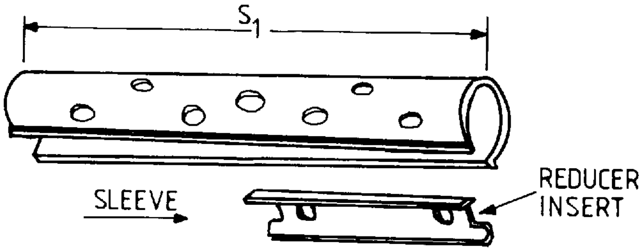
99	ALL OTHER SHAPES - TYPICAL DETAILS SHOWN BELOW.		
99		IF ANGLE WITH HORIZONTAL IS 45° OR LESS & r IS 12 ϕ OR LESS. $A+B+C+2n$ OR $E+2n+B-\sqrt{B^2-D^2}$	
99		IF ANGLE WITH HORIZONTAL IS 45° OR LESS $A+B+C-2(r+\phi)$ IF ANGLE IS GREATER THAN 45° & r EXCEEDS 12 ϕ LENGTH TO BE CALCULATED.	 (SEE NOTE 3)
99		$A+B+1\frac{1}{3}C$	
99		$4A+20\phi$	
99		CALCULATE	

Sheet No. I.9 gives data for the reinforcement anchorages, lap lengths and links for various bar sizes and for various yield strengths of steel.

BARS, COUPLERS AND CONSTRUCTION JOINTS

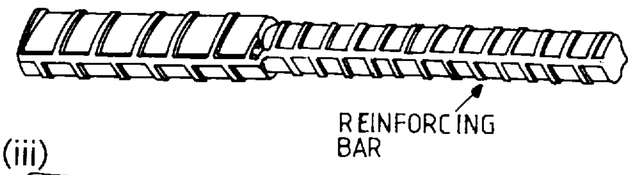
SHEET NO. I.10

(i)

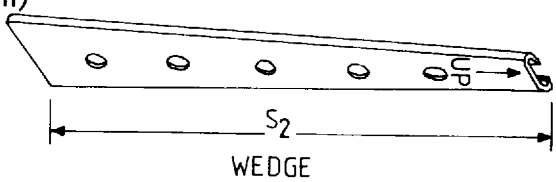


φ BAR DIAMETER
φo OUTSIDE DIAMETER
L LENGTH
P PITCH
Lt THREADED LENGTH OF EACH BAR

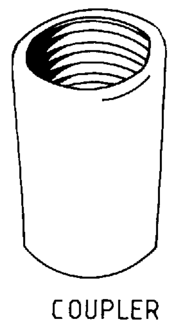
(ii)



(iii)



(iv)

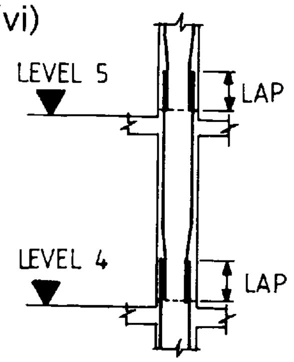


(v)

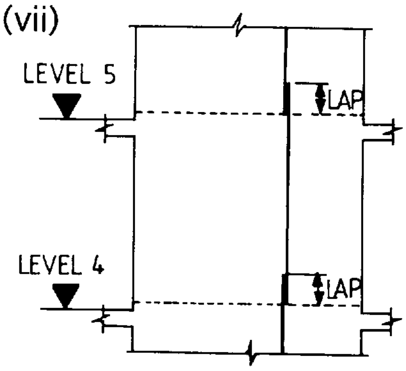
φ (mm)	φ (mm)	L (mm)	P (mm)	Lt (mm)	SLEEVE S_1 (mm)	WEDGE S_2 (mm)
20	35	55	1·581	40	140	200
25	43	75	1·814	45	150	210
32	50	100	2·117		192	292
40	60	125	2·540	65	240	340

Construction joints

(vi)



(vii)



I.2.12 Anchorage length and reinforcement joints

Both cases and mats of reinforcement are assembled from individual bars of manageable lengths and weights. In order to maintain continuity of the reinforcement for large components, reinforcing bars are coupled by using bar couplers. The joints can be in tension or compression. A simple tension joint is formed with a single sleeve which is compressed onto the bar using a hydraulic press. Couplers can be developed using a combination of a threaded sleeve and a stud. The object is that the tensile strength of such an arrangement must at least be equal to the strength of the bar. Sheet No. I.10 gives couplers with specifications and construction joints where they can be used.

The minimum lap length for bars T12 and T25 can generally be taken as 300 mm and 350 mm respectively.

The American Concrete Institute (ACI Clause 11.5.5.3) Code 318–77 gives useful comparison. The tensile lap length (l_d) in SI units is given by:

$$l_d = 0.019\, A_b f_y / \sqrt{f'_c}, \qquad l_d \nless 0.058\, d_b f_y,$$

where d_b = ∅ is the bar diameter; f'_c = cylindrical strength of concrete; f_y = yield strength of steel; A_b = area of the bar.

The lap length of the compression steel is specified as:

$$l_d = 0.24\, f_y d_b / \sqrt{f'_c} \text{ for SI units}; \qquad l_d \nless 0.044\, f_y d_b.$$

On Sheet No. I.9, Tables (a) (b), the hook details are given. They are mostly in agreement with ACI code 318-77 except for the following:

$4d_b$ or 4∅ or 4d are relevant for bars #3 to 8,
$5d_b$ or 5∅ or 5d are relevant for bars #9 to 11,
$6d_b$ or 6∅ or 6d are relevant for bars #14 to 18.

Hence while following the American practice they must be included. The value of B in Table I.9.2 is taken to be $12d_b$. For minimum laps of compression bars in unwelded splices for bars less than 32 mm, the Russian recommendation is 20 to 30 times the diameter of the bar.

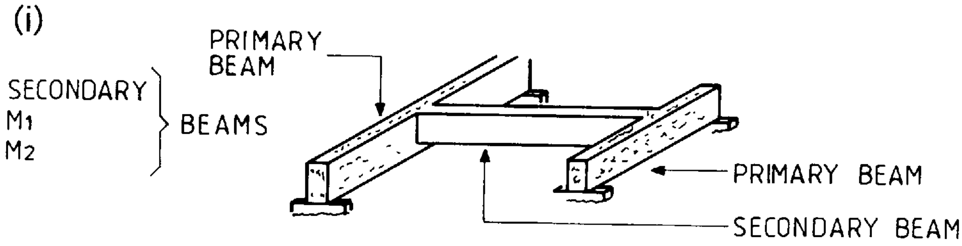
Local Bond. Sometimes the reinforcement details may be influenced by the effects of local bond stress. For minimum lap of compression a suitable length of 20 times the bar size is provided.

INTERCONNECTED BEAMS

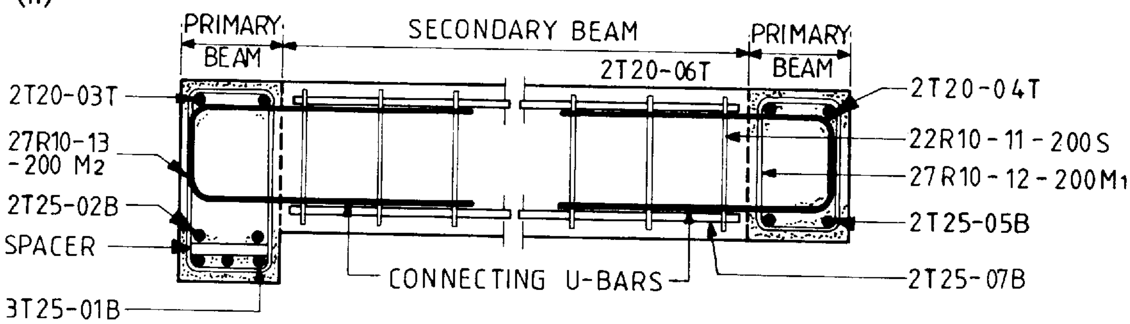
SHEET NO. I.11

(a) Beam grid

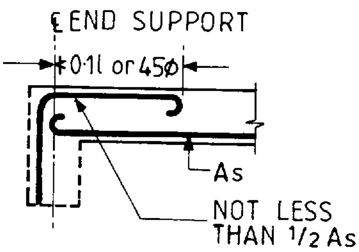
(i)



(ii)

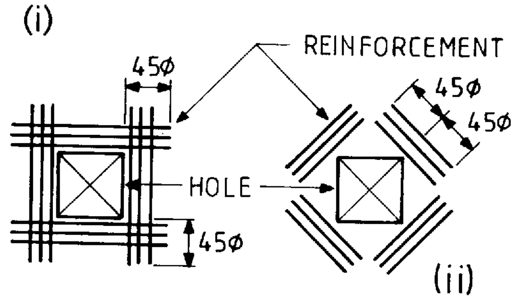


(b) Beam monolithic with walls

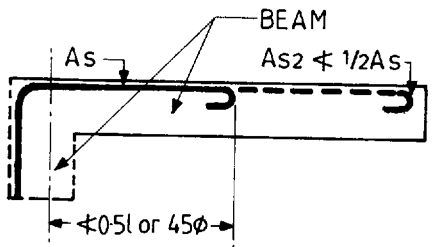


(d) Holes in a beam

(i)

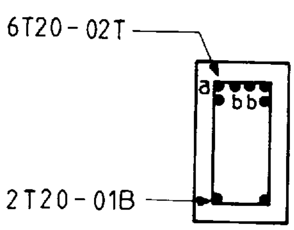


(c) Cantilever beams

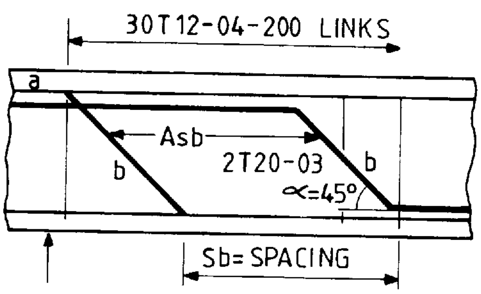


(e) Shear resistance of bent-up bars

(i)



(ii)



Asb = AREA OF BENT-UP BARS

Sheet No. I.11 shows some details of interconnected beams with and without holes and shear bars.

(a) *Beam grid* (Sheet No. I.11)
Cases (i) and (ii) show the layout and a typical detailing of primary and secondary beams. Main reinforcement, shear links or stirrups and connecting U-bars are clearly indicated.

(b) *Beam monolithic with a wall*
When a beam is monolithic with a wall, the minimum lap or bond length of a hook shall be 0.1 × beam length or 45 times the diameter of the bar. The total steel area of the top bars with hooks shall not be less than half of the total area of main steel. This is shown in case (b) on Sheet No. I.11.

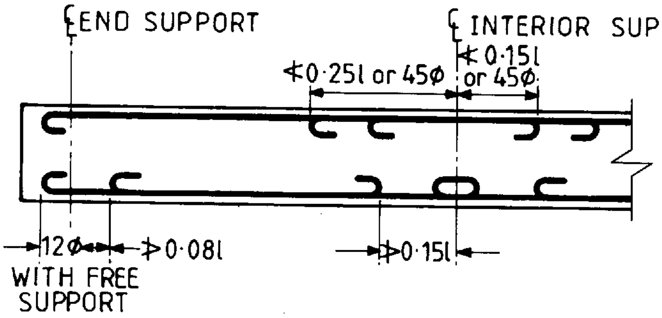
(c) *Cantilever beams*
A cantilever beam shall be reinforced in a manner shown in case (c), on Sheet No. I.11. Again, the top hooked bars of total steel area A_s shall have a bond length not less than half of the effective span length. Where bars are extended beyond 0.5 × length or 45 times diameter, the area of steel shall not be less than half the steel area A_s.

(d) *Holes in a beam*
There are several ways of reinforcing holes in a beam. The most well known are the square and the orthogonal layouts which are shown in case (d) on Sheet No. I.11. In all cases the bond length beyond the hole shall not be less than 45 times the diameter of the bar.

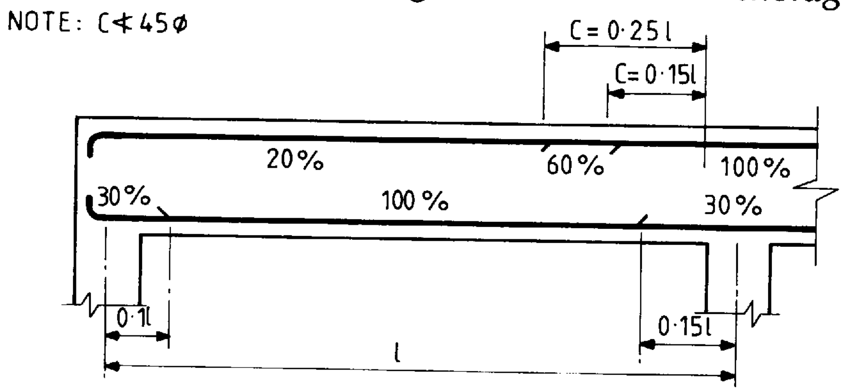
(e) *Bent-up bars*
Sometimes shear links and their shear amount cannot resist enormous shear faces. The bent-up bars are introduced to resist these shear forces. A typical layout is shown in case (e) on Sheet No. I.11.

CURTAILMENT OF BARS IN BEAMS SHEET NO. I.12

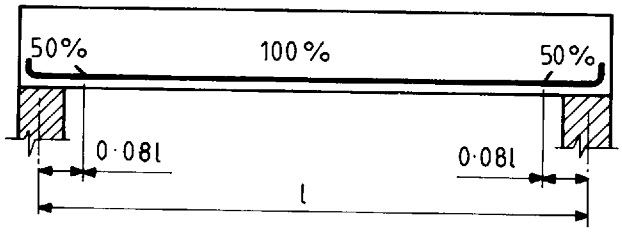
(a) Continuous beams without bent bars with hooks



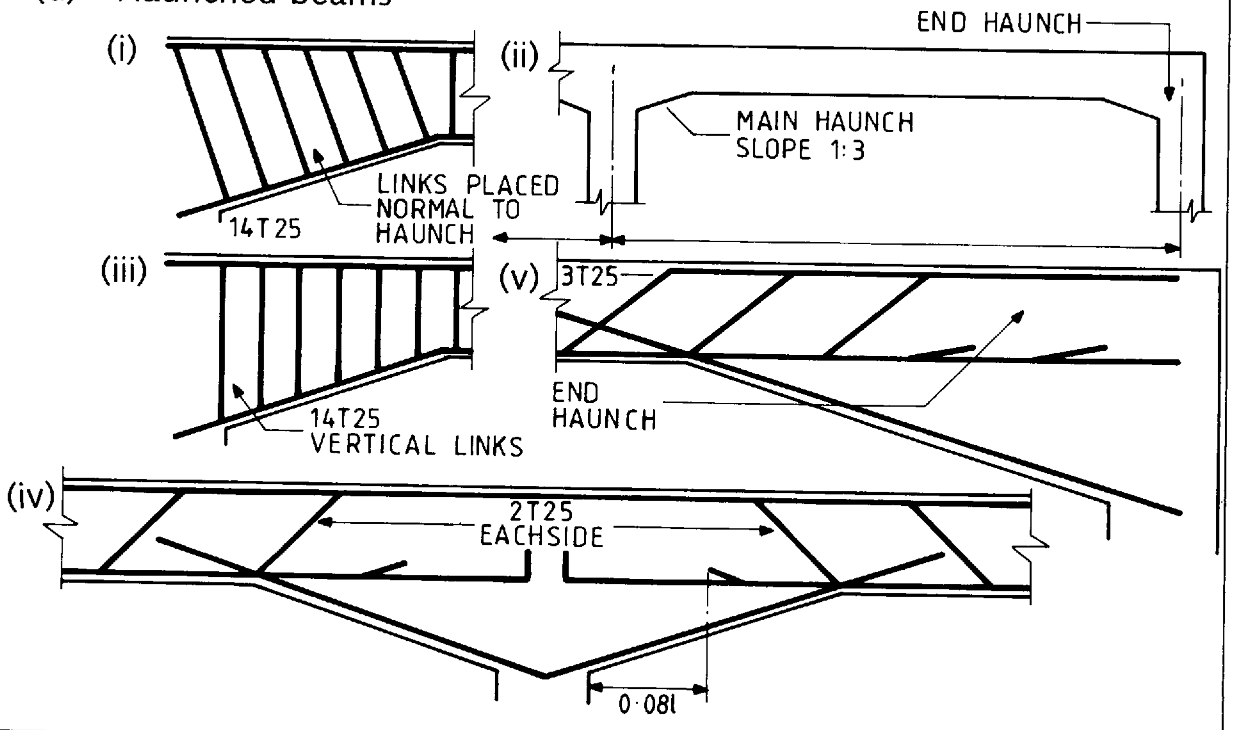
(b) Continuous beams with straight bars and end anchorage



(c) Simply supported beams



(d) Haunched beams



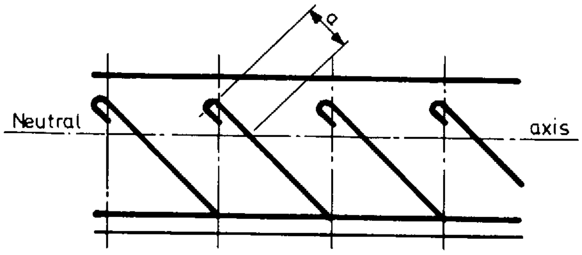
I.2.13 Curtailment of bars in beams

Bending moments and other loading effects vary from one section of the span to the other. Where maximum effects are achieved, a correct amount of reinforcement is provided. As the maximum effects are reduced, economy of reinforcement is achieved by stopping-off or *curtailing* bars (BS 8110 or any others). The codes generally give clear-cut rules for curtailment in different elements of structures. Cases given on Sheet No. I.12 are based on BS 8110. Where other codes are involved, the bibliography should be consulted and the drawings modified and prepared accordingly.

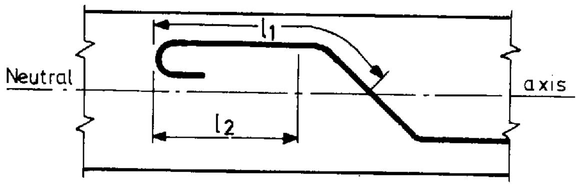
BENT BARS AND COLUMN LINKS SHEET NO. I.13

(a) Bent bars in deep beams

(i)

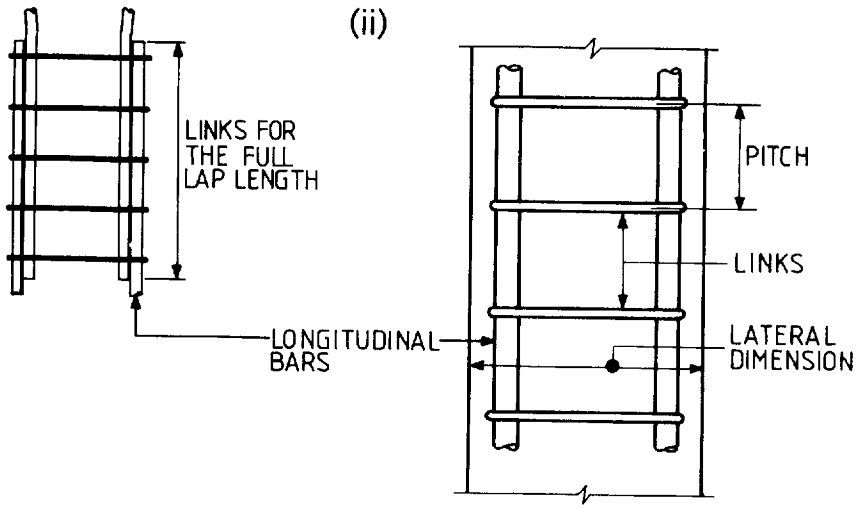


(ii)

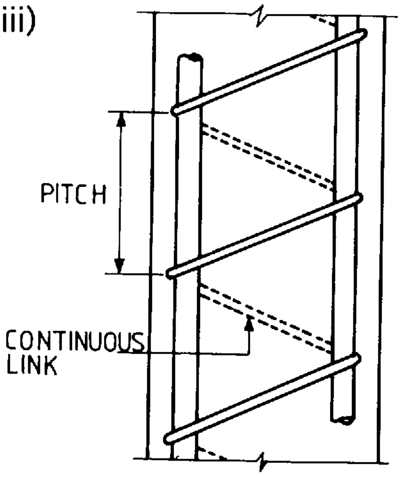


(b) Transverse reinforcement and vertical spacing of links

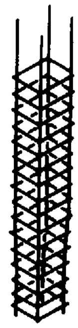
(i) (ii)



(iii)



(iv) Isometric



I.2.14 Bent bars and column links

Case (a) on Sheet No. I.13 gives bent bars as recommended by the European Code on Concrete (UC3). This case is similar to the structural detailing of bent-up bars adopted for many years in France and Germany.

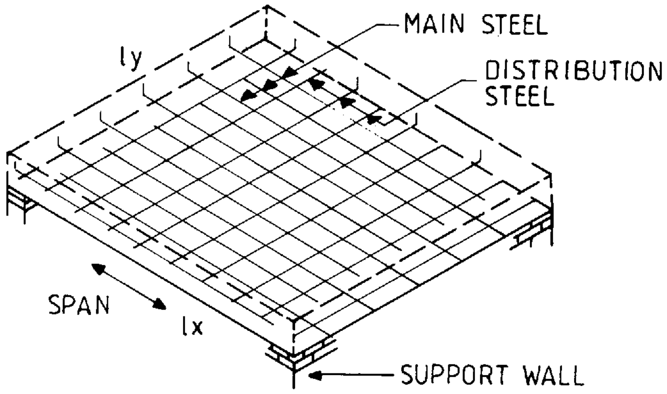
Case (b) on Sheet No. I.13 refers to column links. Longitudinal bars are the main steel, and links which contain the main steel are provided to prevent the main steel from bursting through the sides of the column. Where column lengths are such that bar splices are required they should have adequate lap lengths. The links can be of a square or a continuous helix type. A square cage is shown in the isometric view. In order to achieve continuity in the column–foundation system, starter bars of adequate length from the foundations are produced and are lapped with the main longitudinal reinforcement of the column. Details of these are fully described later on in this book.

SLAB REINFORCEMENT

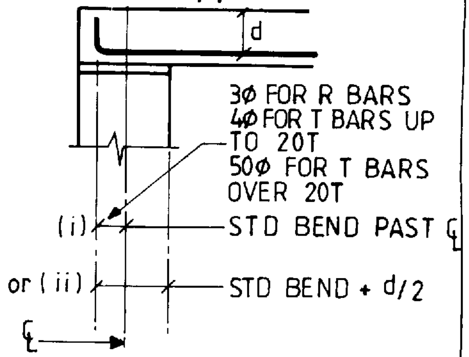
SHEET NO. 1.14

(a) Isometric view

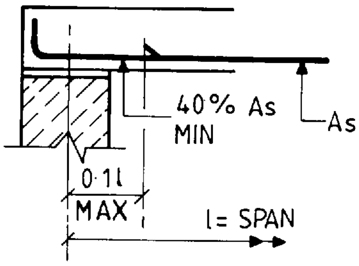
(i)



(ii) Wall support

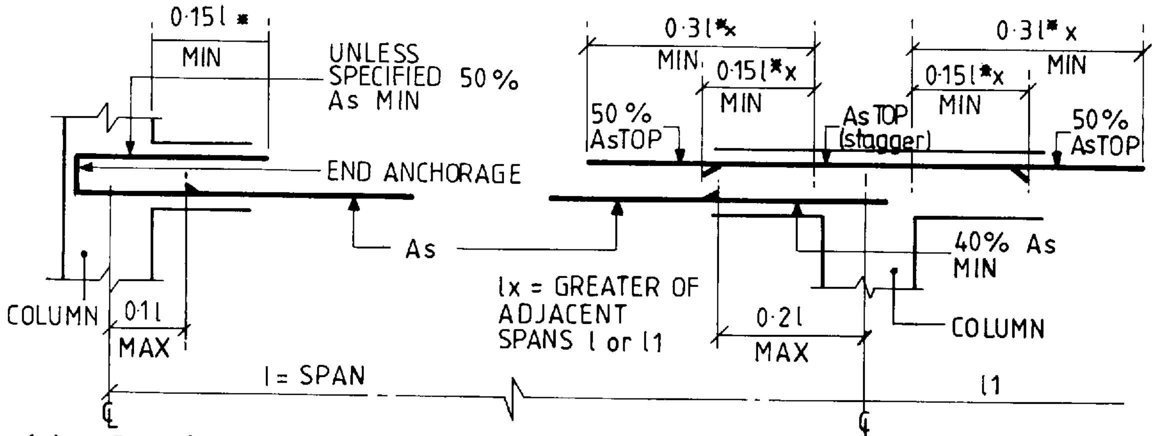


(b) Simple end

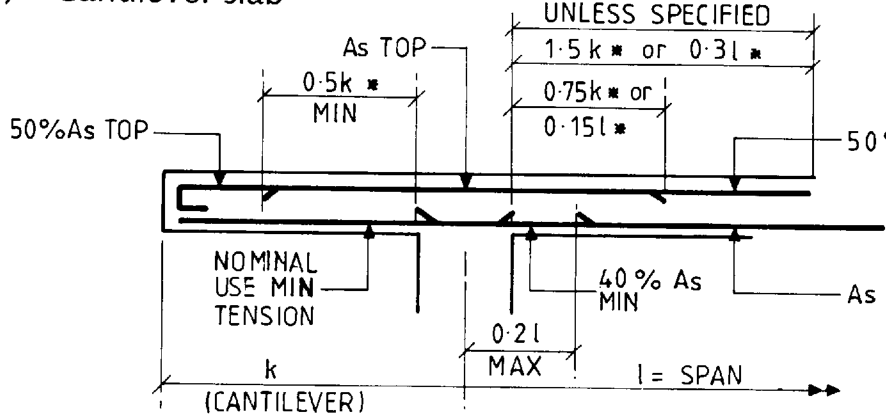


(c) Restrained end support

(d) Continuous internal support



(e) Cantilever slab



* or 45Ø WHICHEVER IS THE GREATER

I.2.15 Slab reinforcement and method of detailing

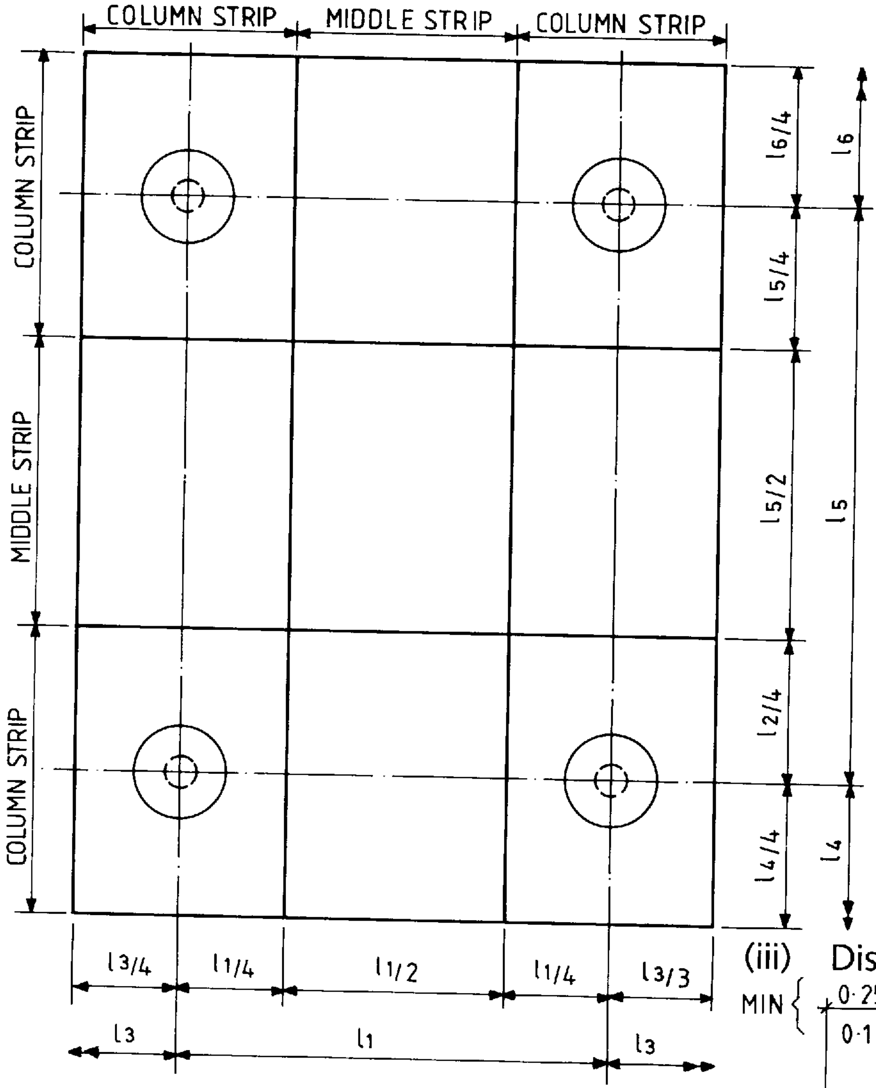
Sheet No. I.14, case (a), item (i) gives an isometric view of the main steel and distribution steel in a simply-supported concrete slab. A specification based on BS 8110 is given when the wall support is given to this slab. For different end restraints cases (b) to (d) on Sheet No. I.14 show the reinforcement arrangement and anchorages. The specifications indicated are based on the requirements of BS 8110. This sheet can be modified for other codes.

Sheet No. I.14, case (a) shows various types of restrained ends which can be adopted for slabs. Case (b) on Sheet No. I.14 indicates the procedure for bar curtailment in a slab recommended by BS 8110. A typical bar arrangement is shown in cases (c) and (e) on Sheet No. I.14.

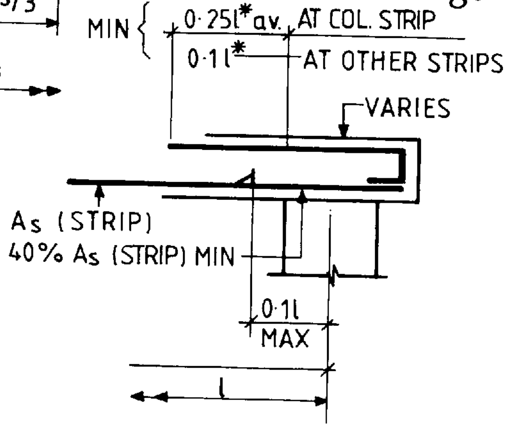
FLAT SLABS WITH DROP PANELS

SHEET NO. I.15

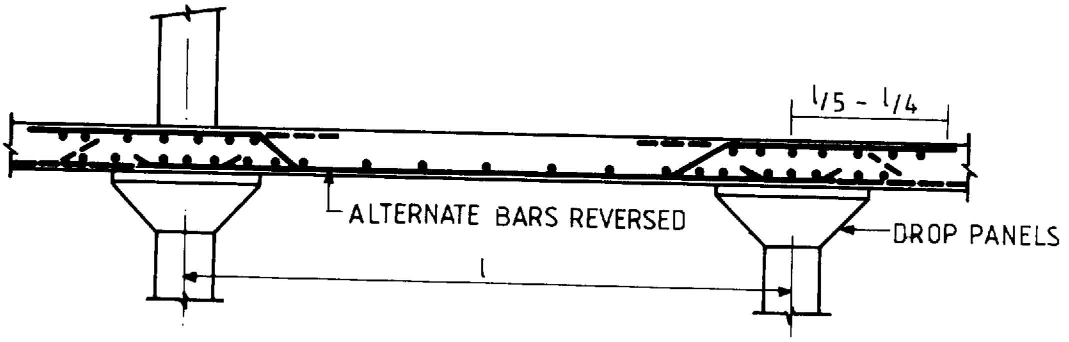
(i) Slab division



(iii) Discontinuous edge



(ii) Section through flat floor slab



I.2.16 Flat slab

A flat slab is a reinforced concrete slab supported directly on and built monolithically with the columns. As shown on Sheet No. I.15, the flat slab is divided into middle strips and column strips. The size of each strip is defined using specific rules. The slab may be of uniform thickness supported on simple columns. It is more economical to thicken the slab around the columns and to provide columns with flared heads. They are called *drops* and stiffen the slab over the columns and, in turn, reduce the shear stress and reinforcement. Flat slabs become economical where a number of panels of equal or nearly equal dimensions are required or where, for a limited headroom, large clear floor spaces are required. These flat slabs may be designed as continuous frames. However, they are normally designed using an empirical method governed by specified coefficients for bending moments and other requirements which include the following:

(a) There should be not less than three rectangular bays in both longitudinal and transverse directions.

(b) The length of the bay $\frac{\ell 5}{4}$ etc. shall not be greater than $\frac{\ell 1}{3} \times$ width $\frac{\ell 3}{3}$.

(c) The length of the adjacent bays should not vary by more than 10%.

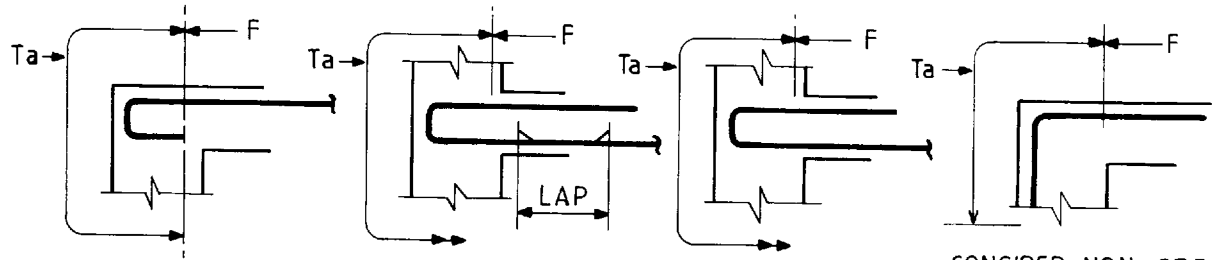
Cases (i) and (ii) on Sheet No. I.15 give a full picture of the panel division system and the reinforcement layout.

The drop panel is 1.25 to 1.50 times thicker than the slab beyond the drop. The minimum slab thickness is 125 mm or $\ell/36$ for interior continuous panels without drops and end panels with drops or $\ell/32$ for end panels without drops or $\ell/40$ for interior continuous panels with drops. The length ℓ is the average length and width of the panel. For some unknown reason, when the last edge of the slab sits on a column, the details of such an edge shall be carried out as shown in case (iii) on Sheet No. I.15.

LAPS AND BAR CURTAILMENT — SHEET NO. I.16

(a) Restrained ends

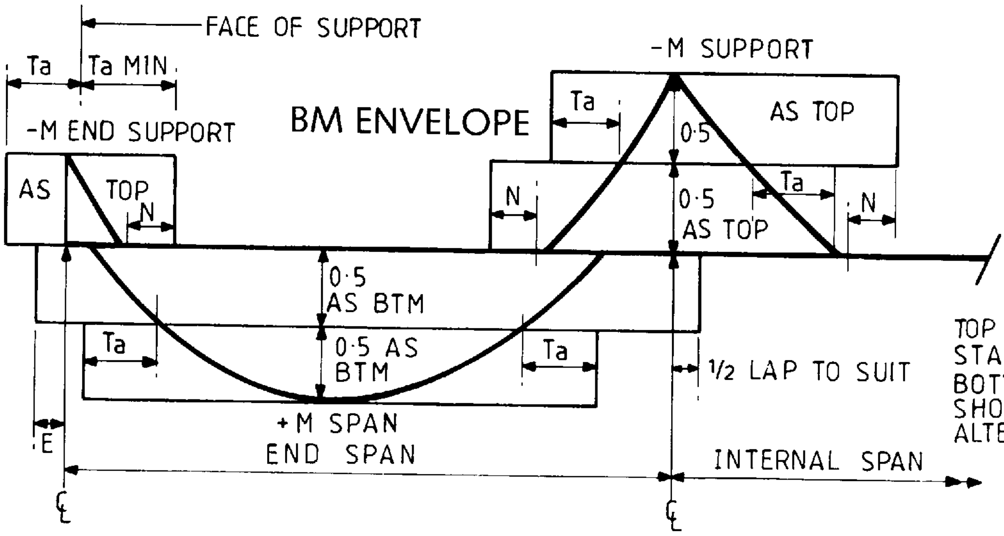
(i) U-Bars in top (ii) U-Bars extended (iii) 'Trombone' bars (iv) L-Bars in top



CONSIDER NON-STD RADIUS VERTICAL LEG > 8ø

KEY F = FACE OF VERTICAL BAR IN RESTRAINING MEMBER
Ta = TENSION ANCHORAGE LENGTH

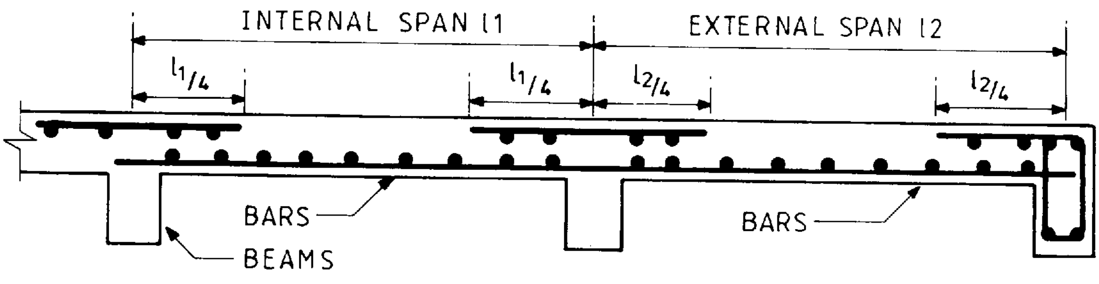
(b) General recommendations for bar curtailment in slabs



TOP BARS SHOWN STAGGERED
BOTTOM BARS SHOWN ALTERNATE

Ta = TENSION ANCHORAGE LENGTH
N = NORMINAL 12ø or d (EFFECTIVE DEPTH) WHICHEVER IS GREATER
BTM = BOTTOM
E = EFFECTIVE END ANCHORAGE REQUIRED IF SIMPLE SUPPORT
ø = BAR NOMINAL SIZE
BM, M = BENDING MOMENT

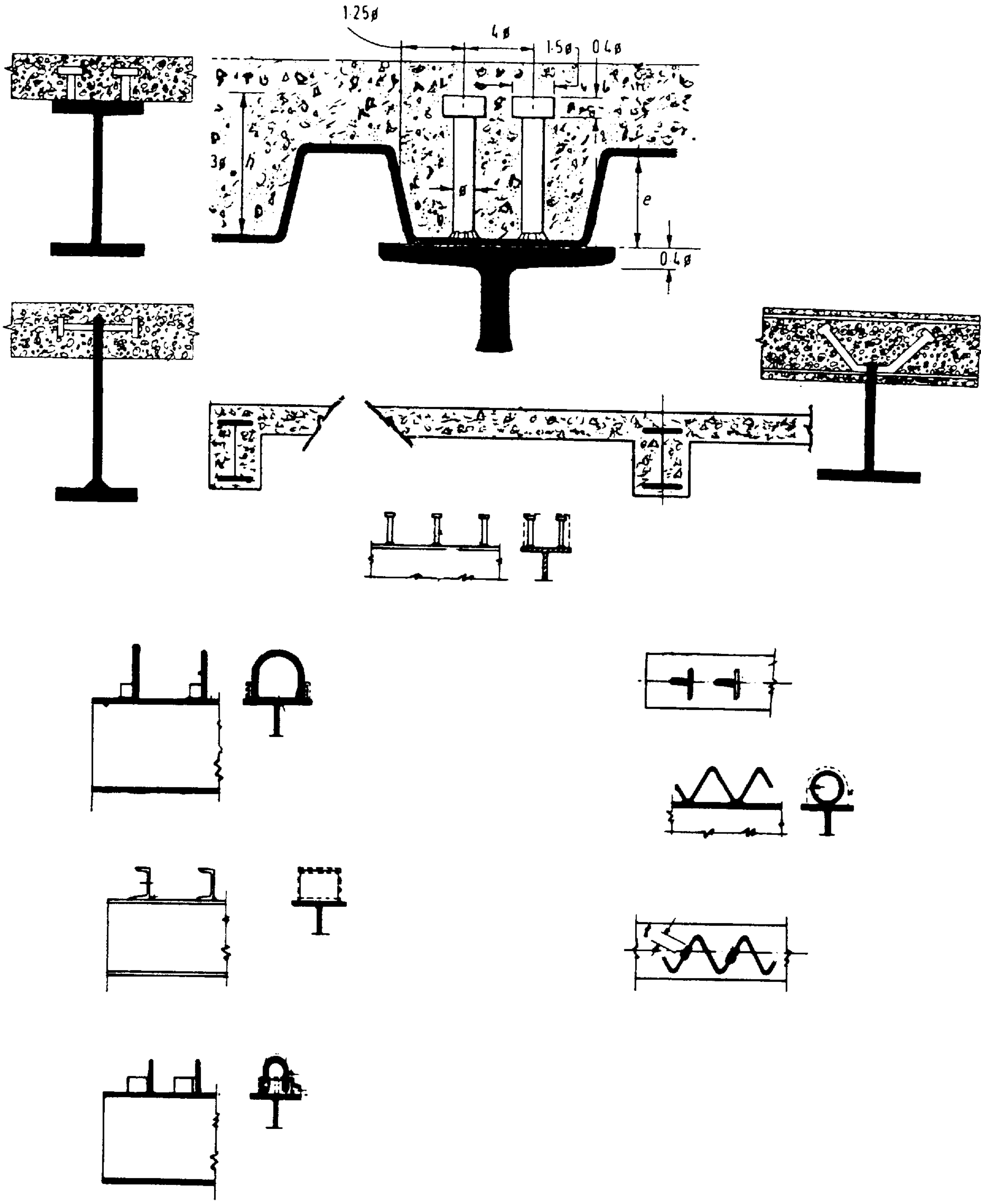
(c) Continuous beam/slab with straight bars



The general layout of the reinforcement is based on both bending moments (in spans) and bending moments in addition to direct loads (on columns). Typical examples are shown in Sheet No. I.16.

COMPOSITE SECTIONS AND CONNECTOR TYPES

SHEET NO. I.17



I.2.17 Composite sections

This book gives a number of cases for detailing composite sections later. The following are the main types:

(a) steel sections encased in concrete;
(b) steel beam flanges embedded in concrete;
(c) steel studs in concrete welded to flanges of steel beams or any other sections.

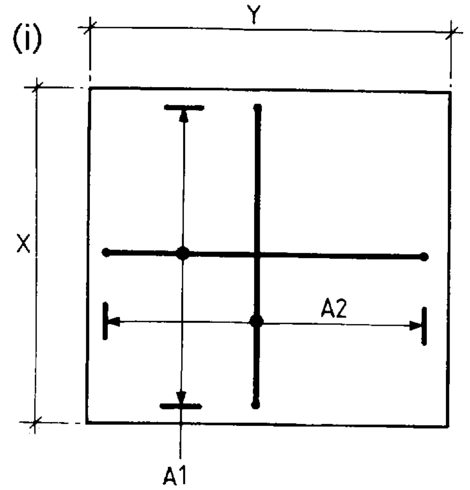
Sheet No. I.17 gives some composite sections.

EXAMPLES OF TABULAR METHOD OF DETAILING

SHEET NO. I.18

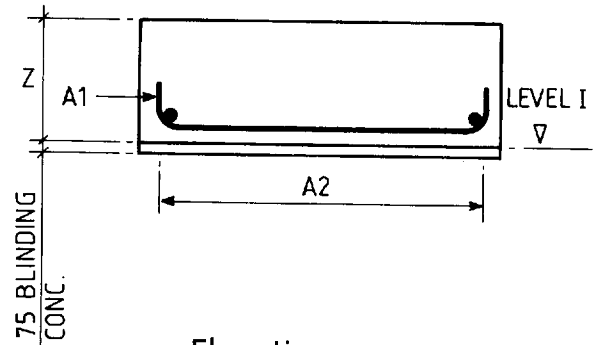
NOTATION
COL – COLUMN
SECT – SECTIONAL
ELEV – ELEVATION
DIMS – DIMENSION

(i)



Plan

(ii)



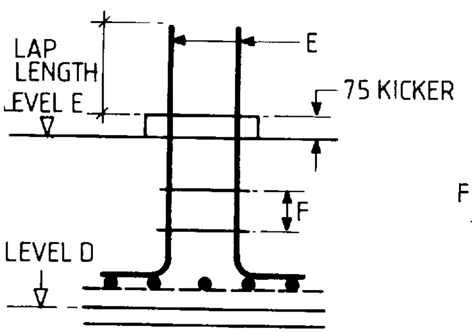
Elevation

(iii)

COLUMN BASES

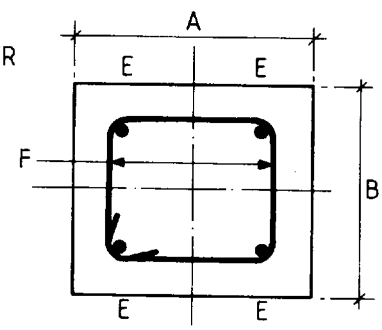
BASE	No. OFF	X	Y	Z	REINFORCEMENT		LEVEL D
					B1	B2	

(iv)

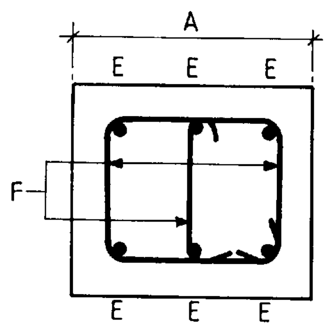


A – A

(v)



(vi)



(vii)

COL	No.OFF	LEVEL		REINFORCEMENT		SECT	ELEV	COLUMN DIMS	
		C	D	E	F			A	B

I.2.18 Reinforcement designation and tabular method of detailing

In this section a comparative study is given for reinforcement designation. Drawings are modified to replace British Reinforcement Designation and others are noted below.

Country	Reinforcement designation
Britain	4T25-05-250t or T, B (4 number of 25 mm diameter high tensile bar of No; 5 at 250 mm centres top (t, T) or bottom B) 4R8-06-300 Links
Sweden	4∅25 C 250 4∅8 C 300 stirrups
Pakistan/India	4No. 25 mm ∅ 250 mm C/C 4No. 8 mm ∅ 300 mm stirrup spacings
Germany	4Bügel (bars) ∅ 25 S_{bu} = 25 cm
Soviet Union (now CIS)	25 ∅ (5) 4 NL 25 L . . . (L = length of the bar)
France	4∅25 C 250 4∅8 C 300 stirrups
USA	4#8 250 crs # 4 stirrups No. legs 300 mm crs (written in Imperial units)

All bars in slabs and other structures are designated using examples based on the Tabular Method of Detailing which is shown on Sheet No. I.18.

I.2.19 Structural details and concrete behaviour

The choice of a structural detail can significantly influence the performance of a structure. Bond, anchorage, bearing, fire, corrosion and other properties of concrete have to be taken into consideration individually or in combination in the design and detailing of concrete structures. Where coating, grouts, binders, sealants and patching are needed, epoxy compounds are used or specified with concrete details. Since concrete is weak in tension, it is important that where bond is most important, structural details must ensure the force transfer between steel and concrete. In the case of bearings, structural details must be adequate to transfer forces from one member to another with a limited area of high local stresses. Structural details must cater for thermal expansion and creep where they are expected. The fire endurance of concrete structures is an essential part of a good design. The endurance period is generally taken as one hour plus. For high seismic risk, a certain minimum number of bars must be provided as continuous longitudinal steel for beams. For beams framing into both sides of a column, these bars must extend through the column for at least twice the beam depth without splices. The structural engineer must indicate quantities of reinforcement, cut-off points and length and location of splices to satisfy code requirements. Where concrete structures are subject to impact, reinforcement details must take into account potential zones of spalling, scabbing and cracking. The bars must span these areas.

Section II

Reinforced Concrete Beams and Slabs

II.1 Reinforced Concrete Beams

Beams are structural elements carrying external loads that cause bending moments, shear forces and torsional moments along their length. The beams can be singly or doubly reinforced and can be simply supported, fixed or continuous. The structural details of such beams must resist bending, diagonal tension, shear and torsion and must be such as to transmit forces through a bond without causing internal cracking. The detailer must be able to optimize the behaviour of the beams under load. He must liaise with the structural engineer on the choice of structural details needed for particular conditions.

The shapes of the beam can be square, rectangular, flanged or tee (T). Although it is more economical to use concrete in compression, it is not always possible to obtain an adequate sectional area of concrete owing to restrictions imposed on the size of the beam (such as restrictive head room). The flexural capacity of the beam is increased by providing compression reinforcement in the compression zone of the beam which acts with tensile reinforcement. It is then called a doubly reinforced concrete beam. As beams usually support slabs, it is possible to make use of the slab as part of a T-beam. In this case the slab is generally not doubly reinforced.

Where beams are carried over a series of supports, they are called continuous beams. A simple beam bends under a load and a maximum positive bending moment exists at the centre of the beam. The bottom of the beam which is in tension is reinforced. The bars are cut off where bending moments and shear forces allow it. This aspect was discussed in Section I.2.19. In a continuous beam the sag at the centre of the beam is coupled with the hog at the support. A negative bending moment exists at the support. Where a positive moment changes to a negative moment, a point of contraflexure or inflection occurs at which the bending moment is zero. An adequate structural detailing is required to cater for these changes. Again this aspect is discussed in Section I. The reinforcement bars and their cut-off must follow the final shape of the final bending moment diagram.

Where beams, either straight or curved, are subjected to in-plane loading, they are subjected to torsional moments in addition to flexural bending and shear. The shape of such a moment must be carefully studied prior to detailing of reinforcement. The codes including BS 8110 give a comprehensive treatment on the provision of shear reinforcement, namely links and bent bars. Again, whether the beams are simply supported, rigid or continuous the shear force diagram will give a proper assessment of the number and spacing of such bars.

In circumstances where the bars are given lap lengths, they must be in line with the provisions of a code. As discussed in Section I, all bars are checked for bond using standard formulae, so that it should be possible to transfer stresses from one material to the other. The structural detailing of reinforcing bars must prevent relative movement or slip between them and the concrete.

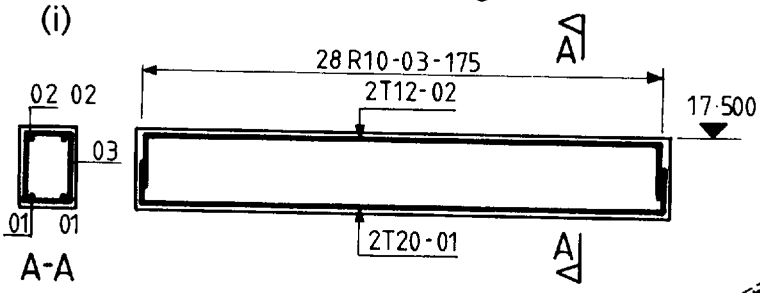
As discussed earlier, the increased compressive area of concrete obtained by using a T-beam is not available at the support. Over the support, the compression zone lies below the neutral axis. In order to strengthen the beam at the support a greater depth with a haunch is provided. The beam will have a different section at the support from that at the centre. Special care is needed to design and detail such a beam.

BEAMS

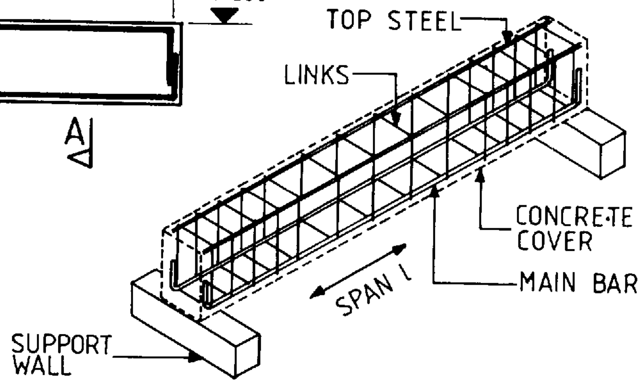
SHEET NO. II.1

(a) Simply supported rectangular beams

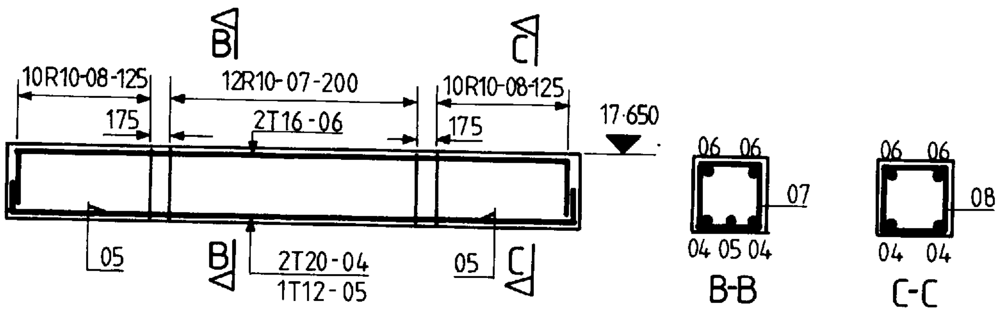
(i)



(ii) Isometric view

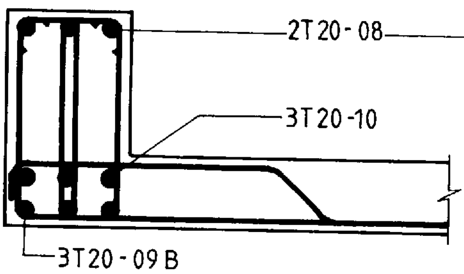


(iii)

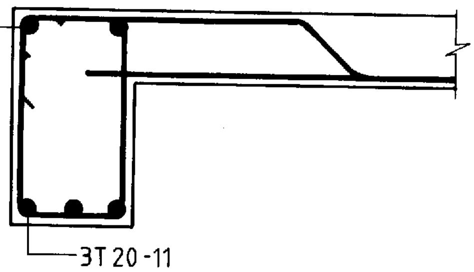


(b) Simply supported L-Beams

(i) Downstand

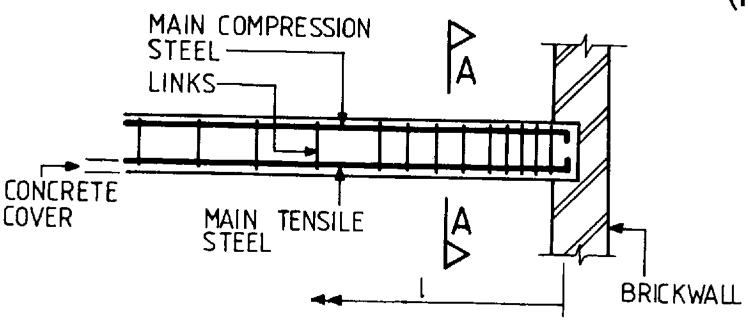


(ii) Upstand

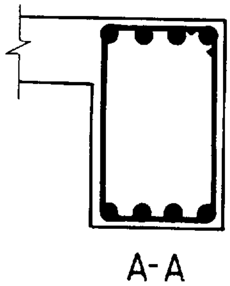


(c) Simply supported doubly reinforced beams

(i)



(ii)



Since beams are reinforced in the longitudinal direction against bending, Sheet No. II.1.a shows structural detailing of simply supported reinforced concrete beams for light loading (II.1.a(i)) and for heavy loading (II.1.a(iii)) together with an isometric view (II.1.a(ii)) indicating how main bars and links are placed. The reinforcement layouts are self-explanatory, for example under II.1.a(i), 28R10-03-175 means twenty eight numbers of round ten millimetre diameter mild steel bars of identification number 3 are placed at 175 mm centre to centre. All such bar sizes and spacings are determined from the loading and secondary conditions such as fire and corrosion. Where down-stand and upstand beams in construction become necessary, an optimum reinforcement layout should be devised. One such layout is shown in Sheet No. II.1.b. A typical doubly reinforced concrete beam layout is given in II.1.c(i) and II.1.c(ii).

Sheet No. II.2 demonstrates how links and bent bars are placed in relation to main reinforcement. The examples chosen are for rectangular, L and T-beams with a single system of links. A double system of links is specifically included in II.2.b(iv). Straight and inclined bars for resisting shear are detailed under II.2.c.

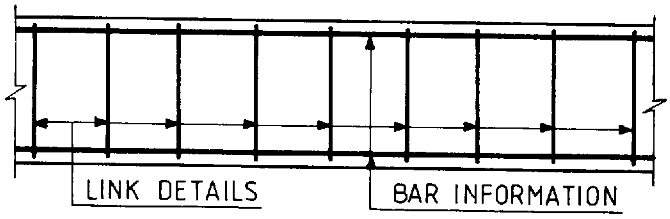
Sheet No. II.3.a gives reinforcement layouts for both inverted and upright T-beams. A composite bending moment diagram is given in II.3.b(i) with cut-off positions along with two types of reinforcement layouts. A single continuous beam is shown in II.3.b(ii). A continuous beam with bent bars in a frame is detailed with several cross-sections in II.3.c. Continuous beams with slabs and columns are detailed separately in Section IV.

LINKS AND BENT BARS

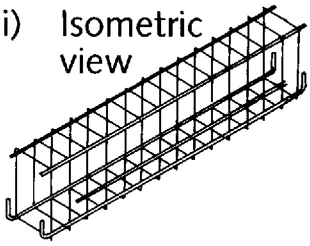
SHEET NO. II.2

(a) Links in beams

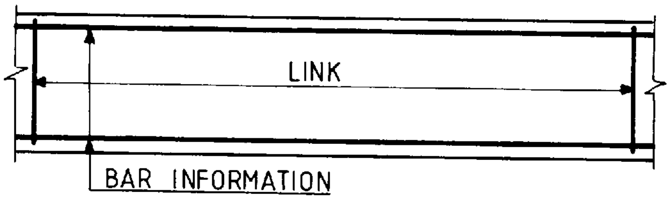
(i)



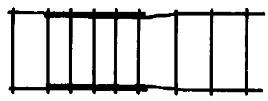
(iii) Isometric view



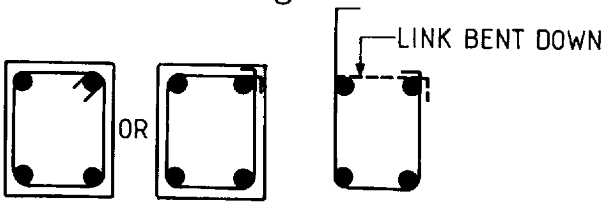
(ii)



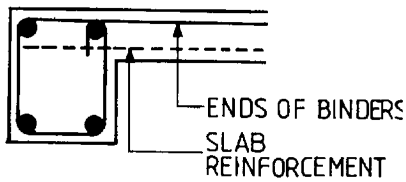
(iv) Beam lap



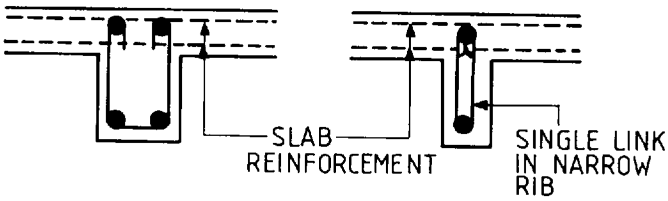
(b) (i) Links in rectangular beams



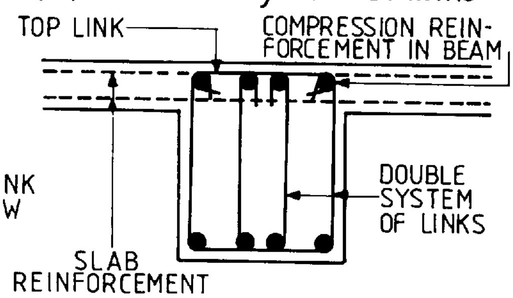
(ii) Links in L-Beams



(iii) Links in T-Beams

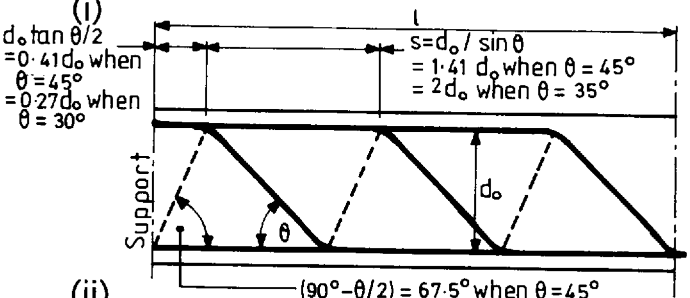


(iv) Double system of links

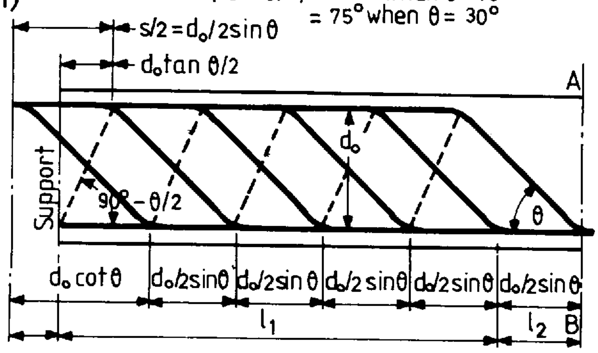


(c) Straight and inclined bars

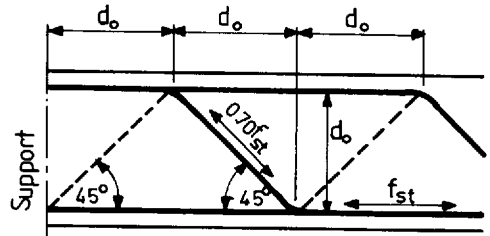
(i)



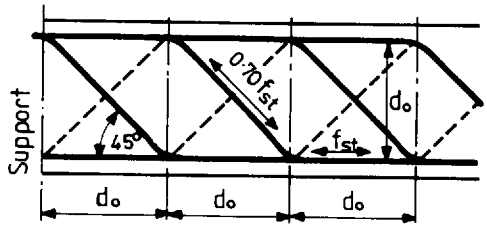
(ii)



(iii)



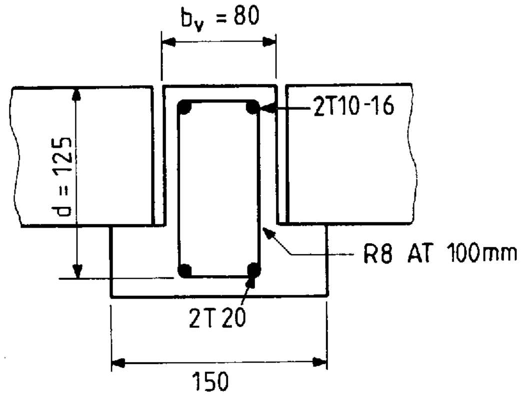
(iv)



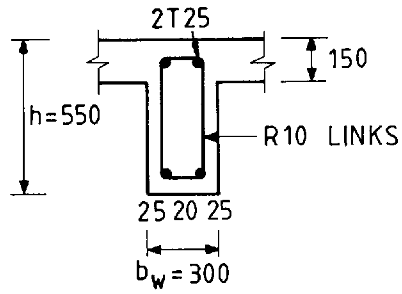
REINFORCEMENT LAYOUTS SHEET NO. II.3

(a) Simply supported T-beam

(i)

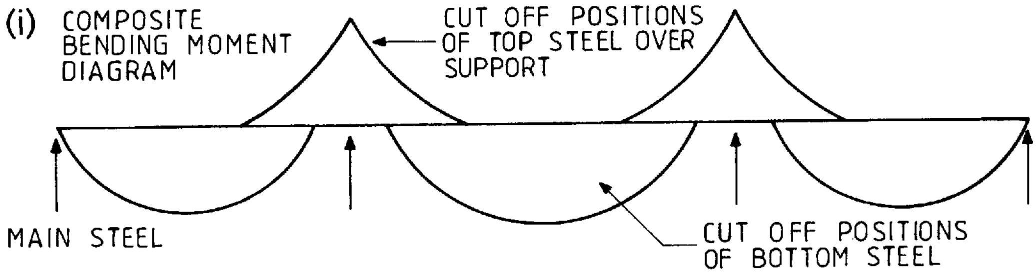


(ii)

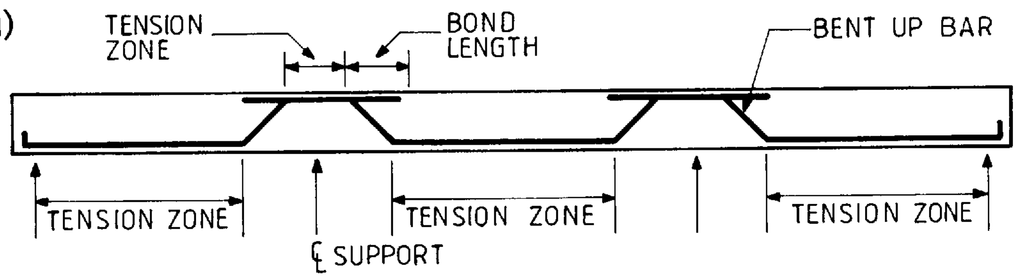


(b) Continuous beams

(i)

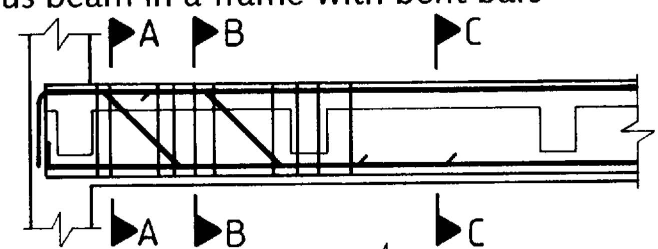


(ii)

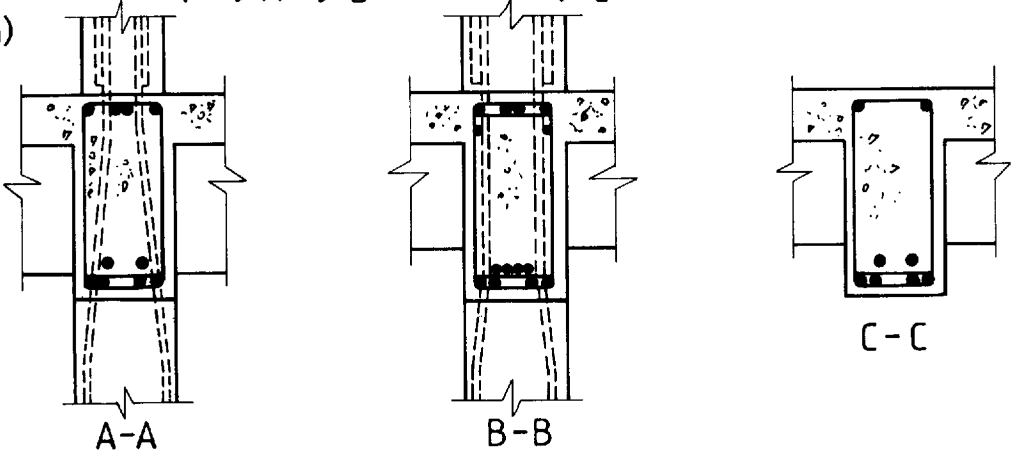


(c) Continuous beam in a frame with bent bars

(i)



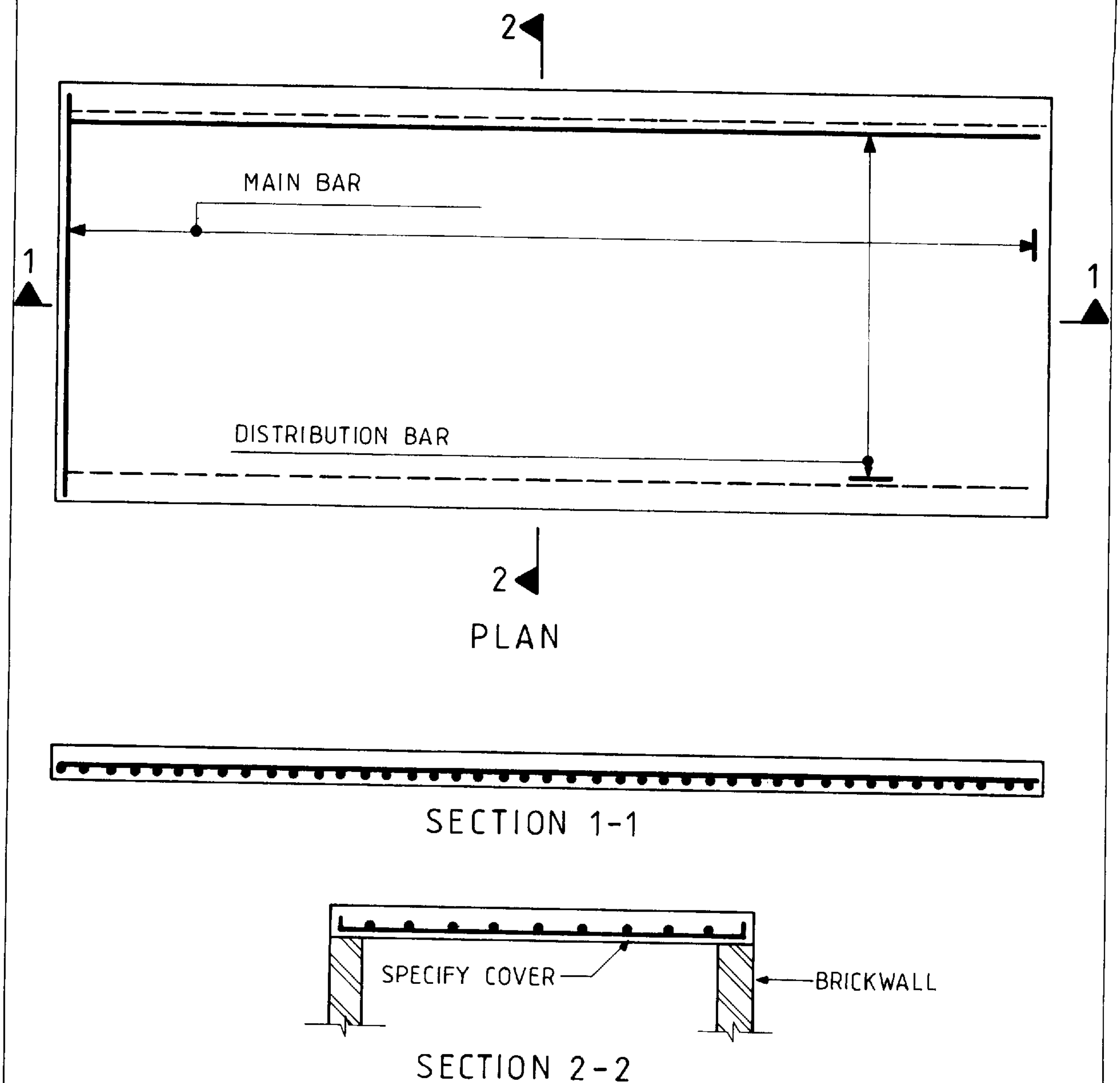
(ii)



ONE-WAY SLABS ON WALLS AND BEAMS

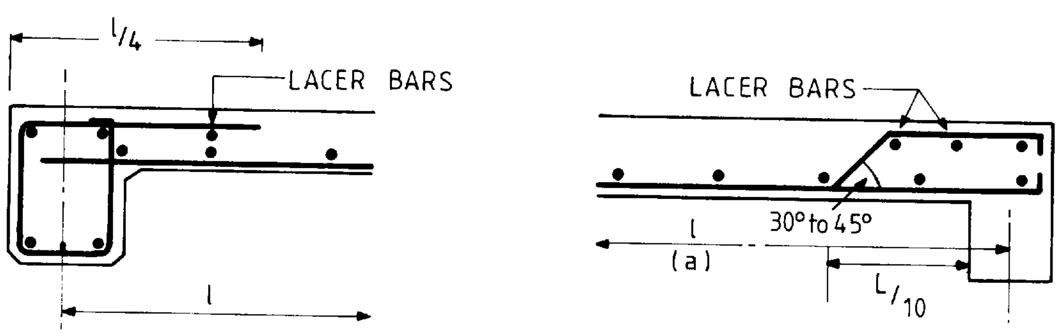
SHEET NO. II.4

(a) One-way simple slab



(b) Simple slabs supported on concrete beams

(i) (ii)



II.2 Reinforced Concrete Slabs

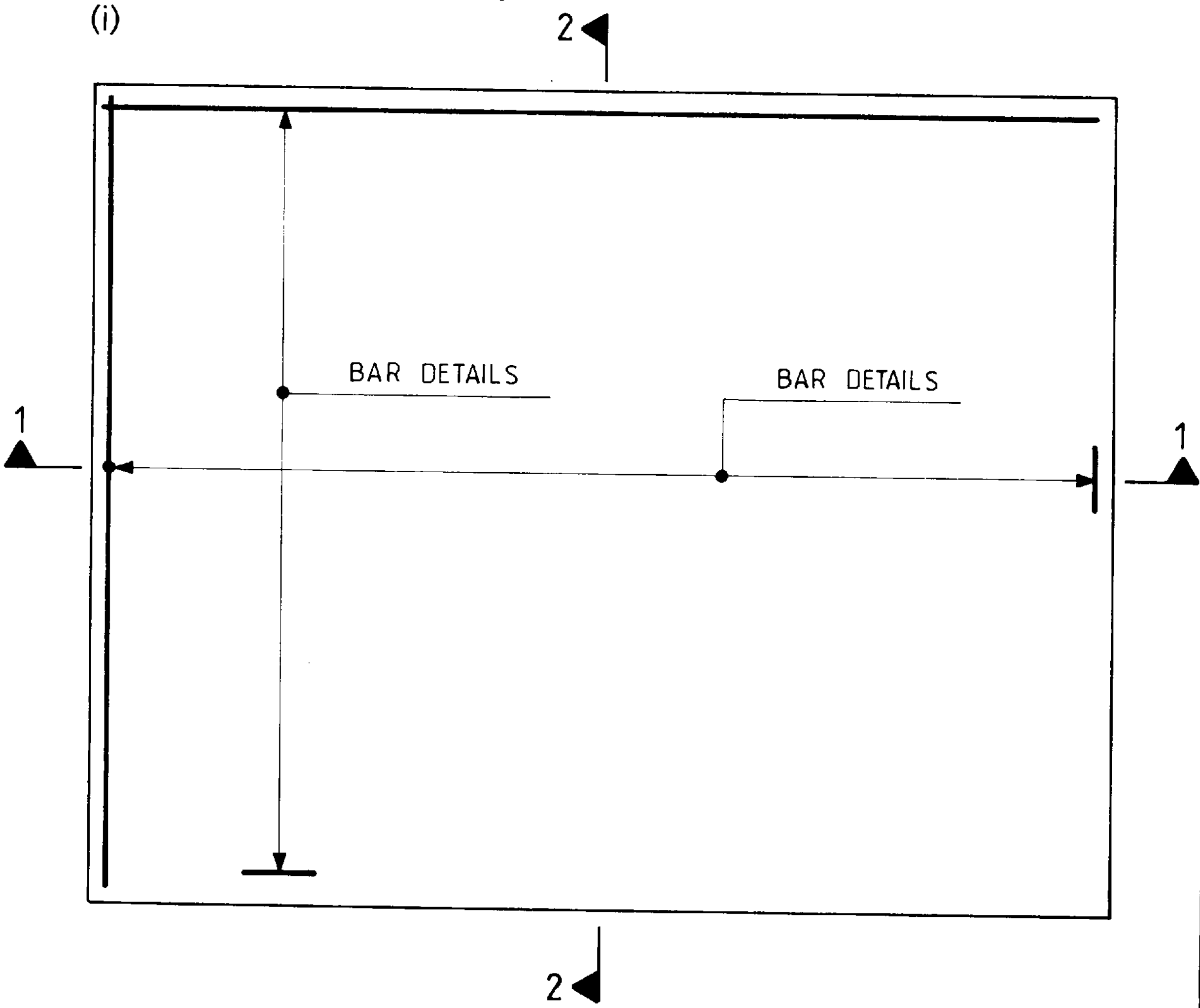
Slabs are divided into suspended slabs and supported slabs. Suspended slabs may be divided into two groups: (1) slabs supported on edges of beams and walls and (2) slabs supported directly on columns without beams and known as *flat slabs*. Supported slabs may be *one-way slabs* (slabs supported on two sides and with main reinforcement in one direction only) and *two-way slabs* (slabs supported on four sides and reinforced in two directions). In one-way slabs, as shown on Sheet No. II.4.a, the main reinforcement is provided along the shorter span. In order to distribute the load, a distribution steel is necessary and it is placed on the longer side. One-way slabs generally consist of a series of shallow beams of unit width and depth equal to the slab thickness, placed side by side. Such simple slabs can be supported on brick walls and can be supported on reinforced concrete beams in which case lacer bars are used to connect slabs to beams, a typical detailing of this is shown in II.4.b. Bond and anchorage details will be the same as for simple beams. This has been discussed in Section I.

TWO WAY SLAB

SHEET NO. II.5

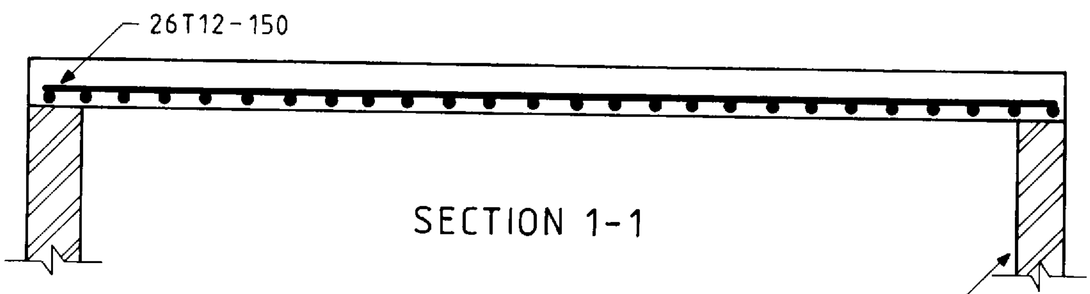
(a) Simply supported two-way slab

(i)

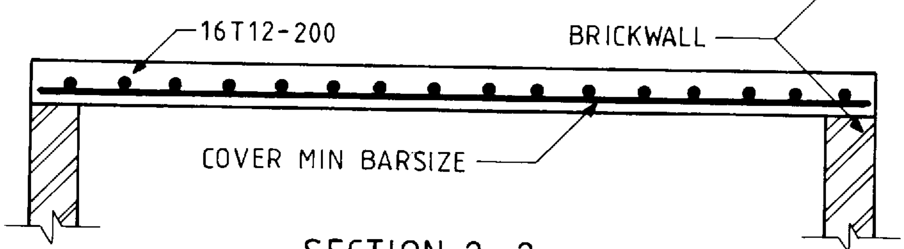


PLAN

(ii)

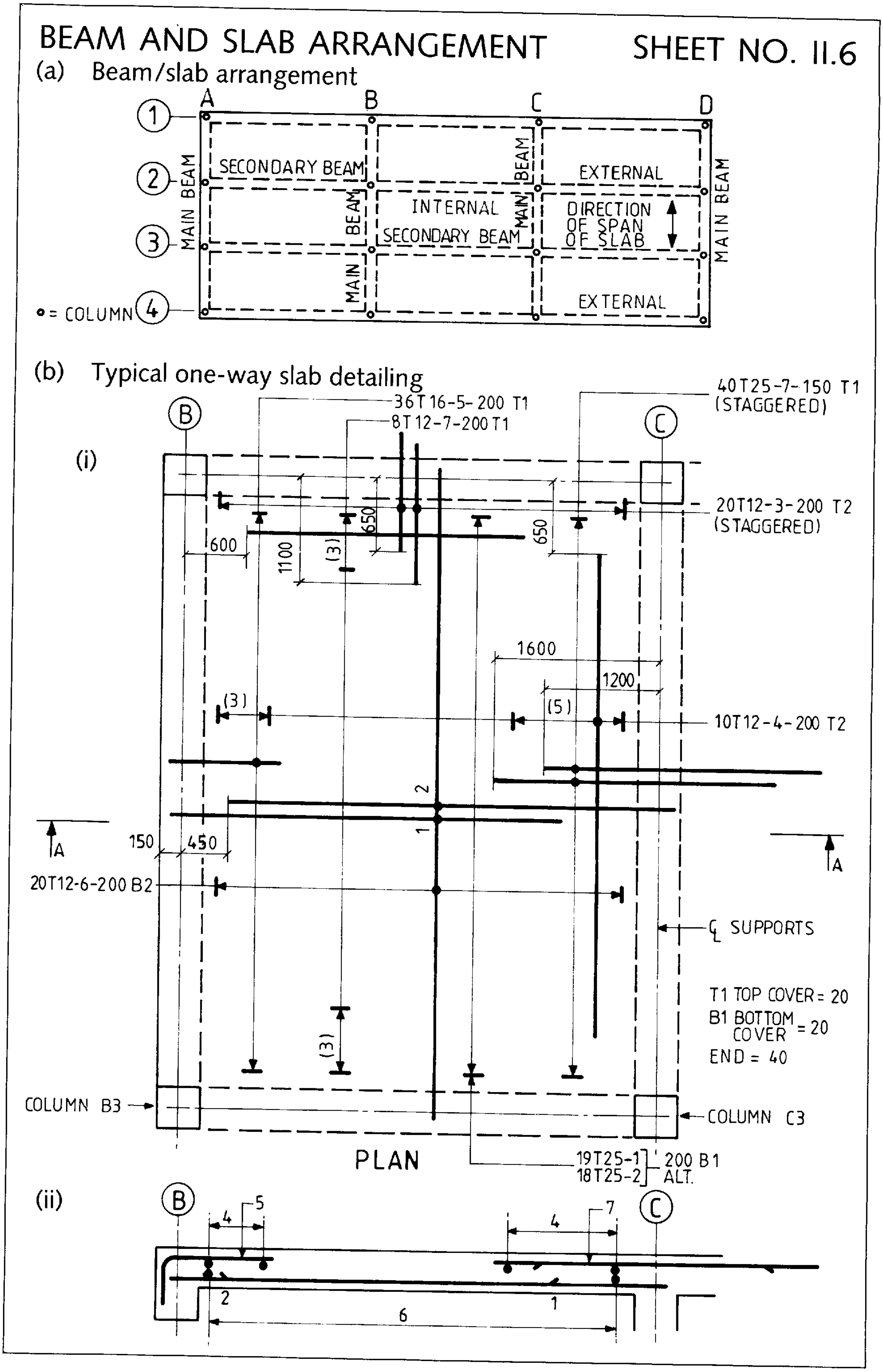


(iii)



SECTION 2-2

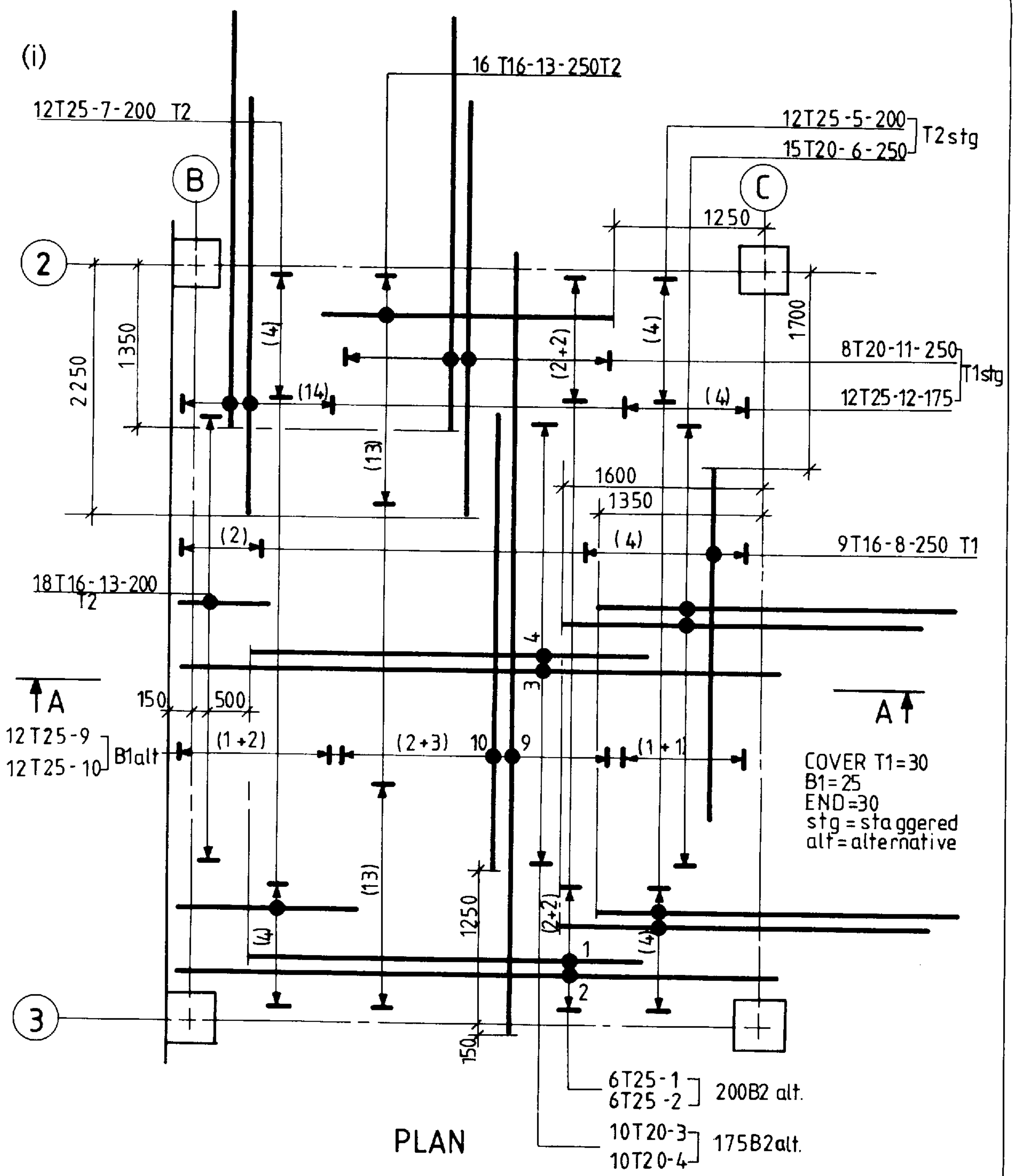
Slabs with reinforcement in two directions or two-way slabs bend in two directions. The principal values of bending moments determine the size and number of reinforcement bars in each direction. Most codes give formulae and tables of coefficients for computing bending moments in both directions. A typical layout for a two-way simply supported slab is shown on Sheet No. II.5.


BEAM AND SLAB ARRANGEMENT
SHEET NO. II.6
(a) Beam/slab arrangement
A
B
C
D
1
2
3
4
SECONDARY BEAM
MAIN BEAM
BEAM
INTERNAL
SECONDARY BEAM
MAIN
EXTERNAL
DIRECTION OF SPAN OF SLAB
EXTERNAL
MAIN BEAM
° = COLUMN
(b) Typical one-way slab detailing
(i)
36T16-5-200 T1
8T12-7-200T1
40T25-7-150 T1 (STAGGERED)
20T12-3-200 T2 (STAGGERED)
600
1100
650
(3)
650
1600
1200
(3)
(5)
10T12-4-200 T2
2
1
A
150
450
20T12-6-200 B2
A
℄ SUPPORTS
T1 TOP COVER = 20
B1 BOTTOM COVER = 20
END = 40
(3)
COLUMN B3
COLUMN C3
PLAN
19T25-1
18T25-2
200 B1 ALT.
(ii)
B
C
4
5
4
7
2
1
6

In R.C. building construction, every floor generally has a beam/slab arrangement and consists of fixed or continuous one-way or two-way slabs supported by main and secondary beams. Sheet No. II.6.a shows such an arrangement. The usual arrangement of a slab and beam floor consists of slabs supported on cross-beams or secondary beams parallel to the longer side and with main reinforcement parallel to the shorter side. The secondary beams in turn are supported on main beams or girders extending from column to column. Part of the reinforcement in the continuous slabs is bent up over the support, or straight bars with bond lengths are placed over the support to give negative bending moments. In large slabs separate reinforcement over the support may be necessary. This is also demonstrated in Section I. A typical one-way continuous slab/beam arrangement is given in Sheet No. II.6.b for the general arrangement given in II.6.a.

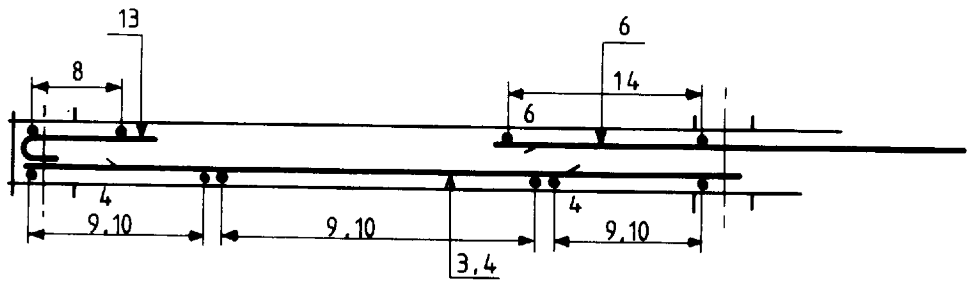
FLAT SLAB WITHOUT DROP PANELS SHEET NO. II.7

(i)



PLAN

(ii)



A-A

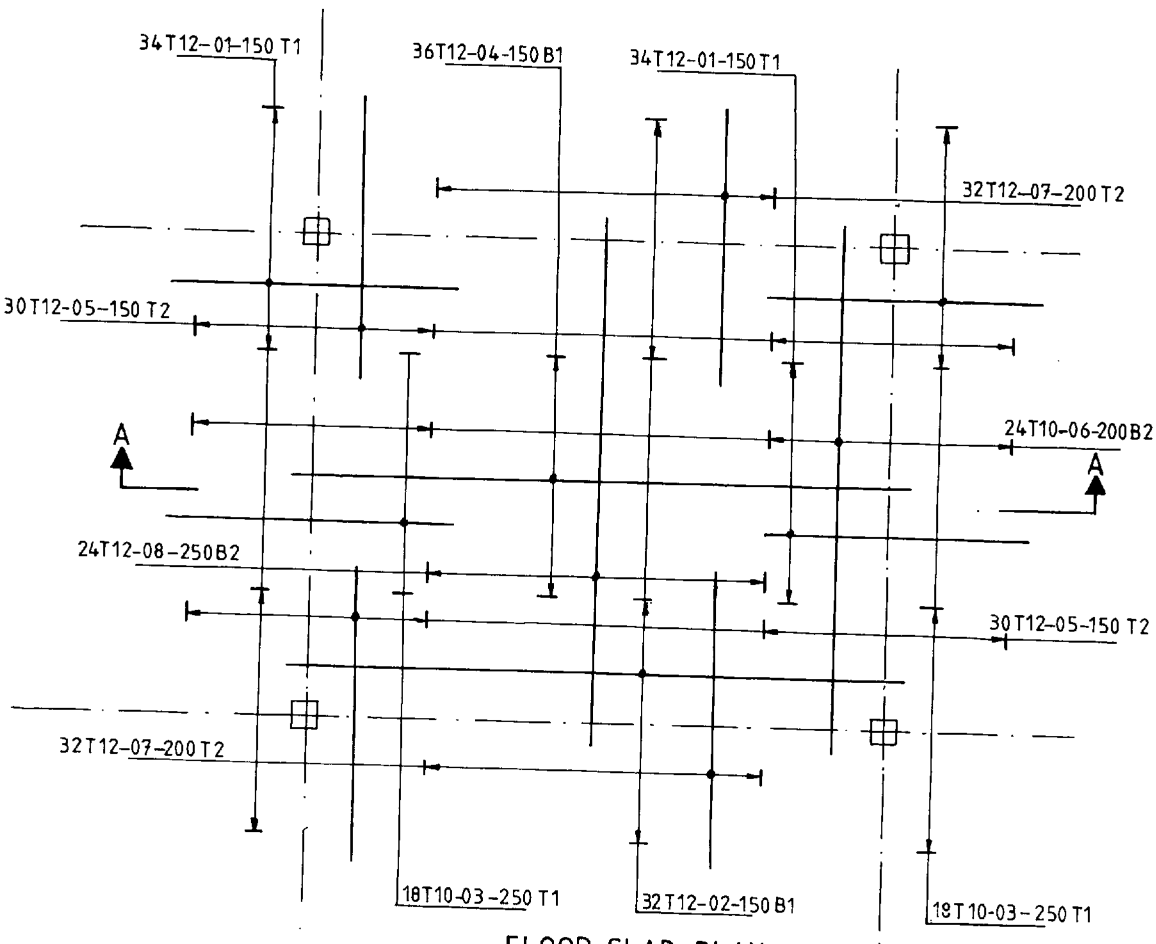
A *flat slab*, as discussed earlier, if supported directly on and built monolithically with columns, may differ from a two-way slab in that it is not supported on beams. The slab may be of uniform thickness supported on simple columns. Generally the slab around the columns is thickened in order to provide columns with *flared heads*, known as *drops*. The drop stiffens the slab over the column and reduces the shear stress and the reinforcement. Codes also recommend the distribution of bending moments between column strips and middle strips as shown in Section I. A great deal of research has been carried out on flat slabs without drops. Flat slabs without drop panels and with drop panels are respectively detailed on Sheet Nos. II.7 and II.8.

Continuous slabs with mesh fabric are given on Sheet No. II.9. Ribbed slab panel with reinforcement details are given in II.9(iii).

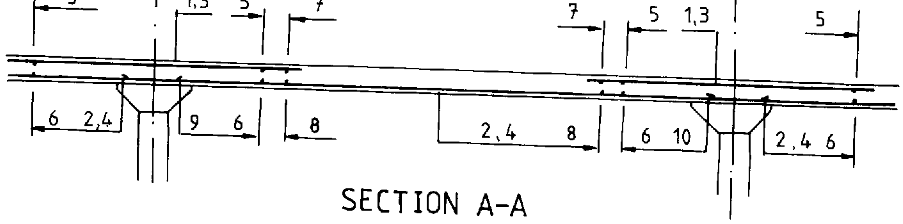
Sheet No. II.10 gives a reinforcement layout for a simple panel under missile impact. In Section IV, additional structural detailing is demonstrated for beam/slab column arrangements.

FLOOR SLAB

SHEET NO. II.8



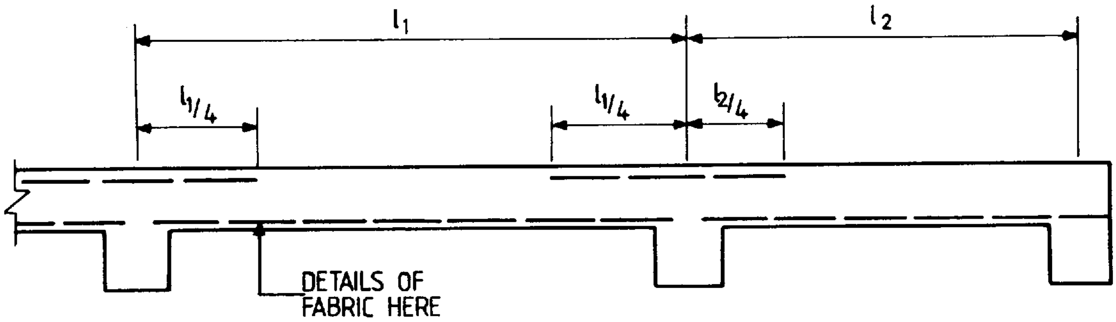
FLOOR SLAB PLAN
SCALE: 1:50



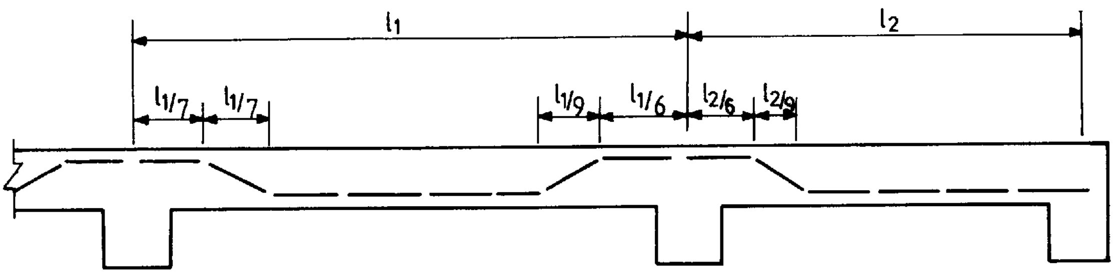
SECTION A-A
SCALE: 1:50

CONTINUOUS SLAB REINFORCED WITH MESH FABRIC AND RIBBED SLAB PANEL

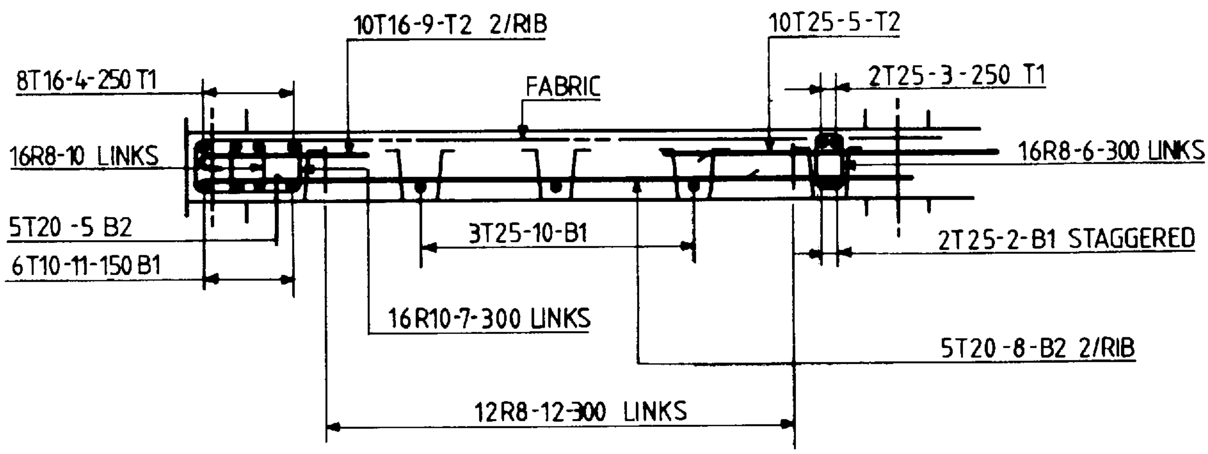
SHEET NO. II.9



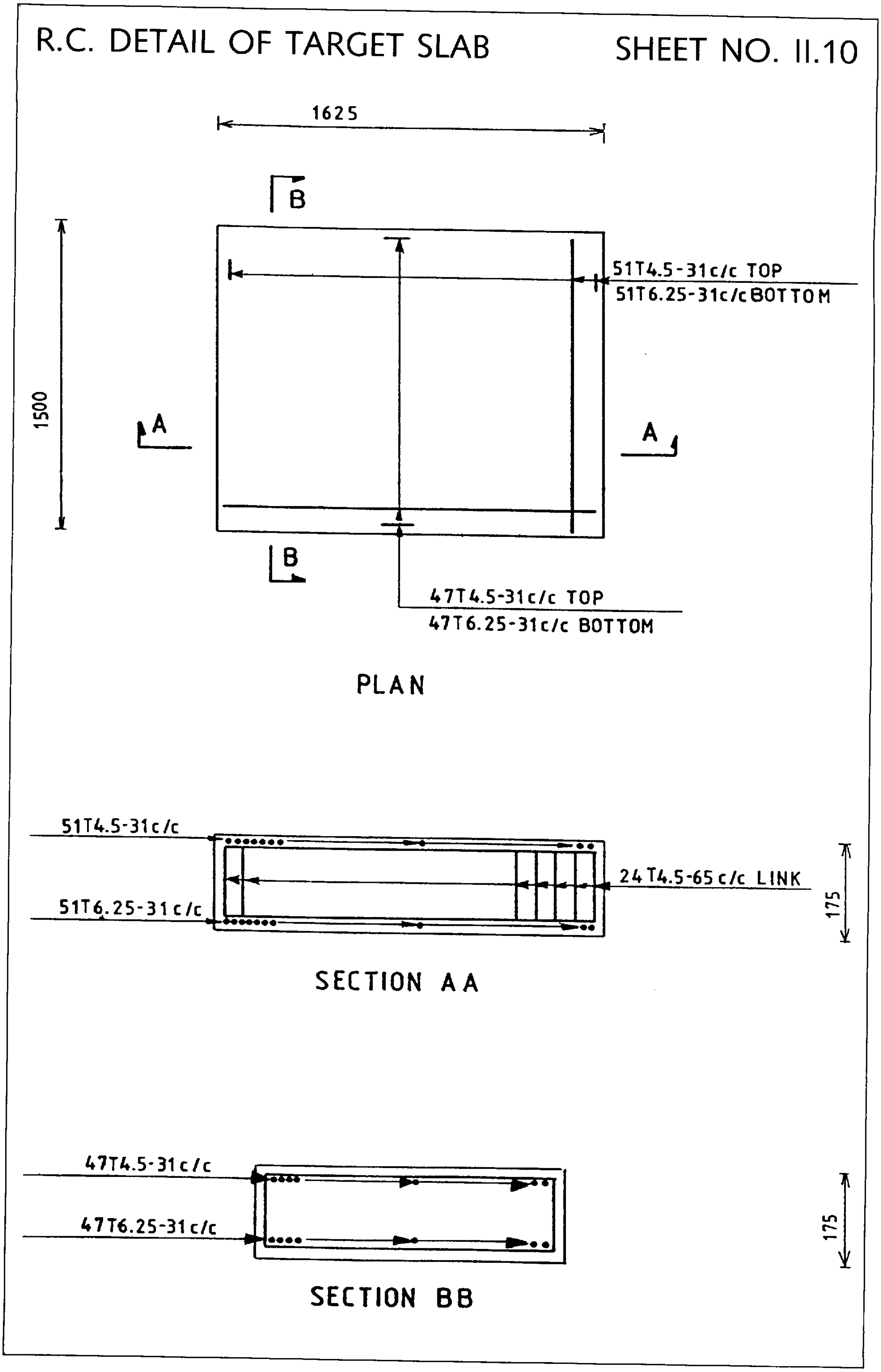
(i) Flat slab



(ii) Waved fabric



(iii) Ribbed slab panel

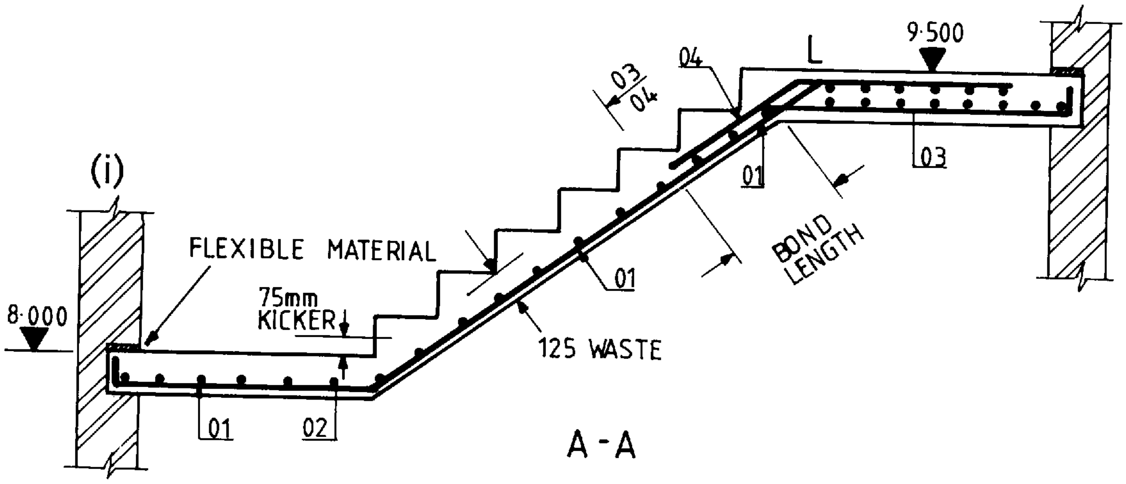

R.C. DETAIL OF TARGET SLAB
SHEET NO. II.10
1625
1500
B
A
51T4.5-31c/c TOP
51T6.25-31c/cBOTTOM
47T4.5-31c/c TOP
47T6.25-31c/c BOTTOM
PLAN
51T4.5-31c/c
51T6.25-31c/c
24T4.5-65c/c LINK
175
SECTION AA
47T4.5-31c/c
47T6.25-31c/c
175
SECTION BB

Section III

Stairs and Staircases

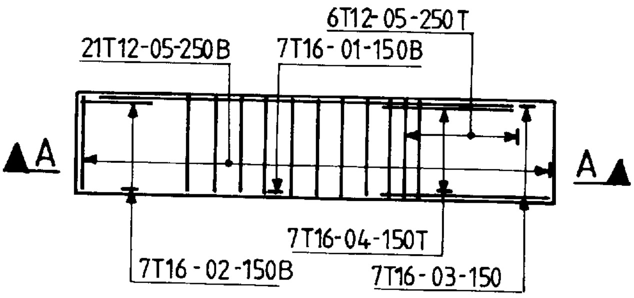
STAIRCASE REINFORCEMENT SHEET NO. III.1

(a) Straight stairflight supported on brickwork



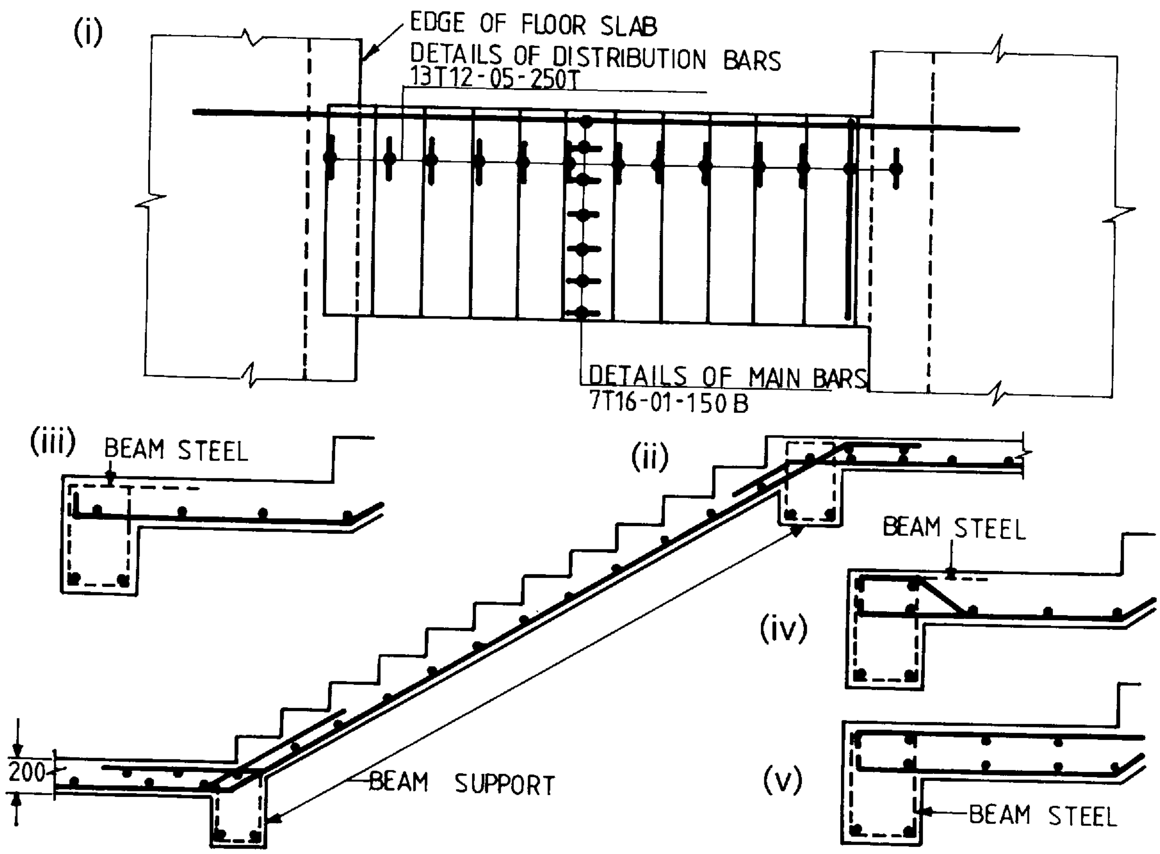
A - A

(ii)



PLAN (Small scale)

(b) Straight stairflight on beam supports



III.1 Stairs and their Types

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

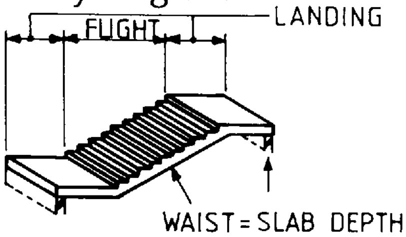
(a) a sloping slab spanning from one floor to a landing or another floor;
(b) a sloping slab carried on sloping beams from one floor to another or to a landing.

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.a and III.3.b. 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.

STAIRCASE WITH SLAB CONSTRUCTION

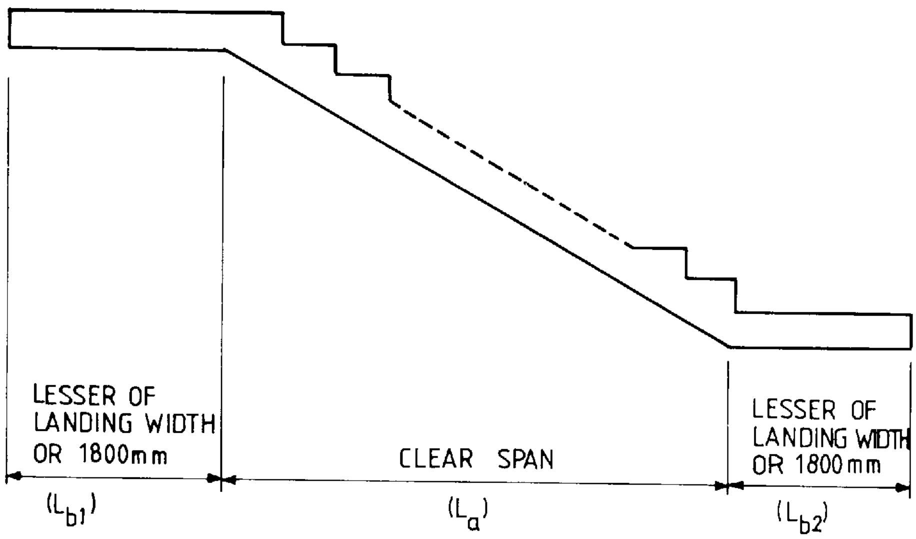
SHEET NO. III.2

(i) Key diagram



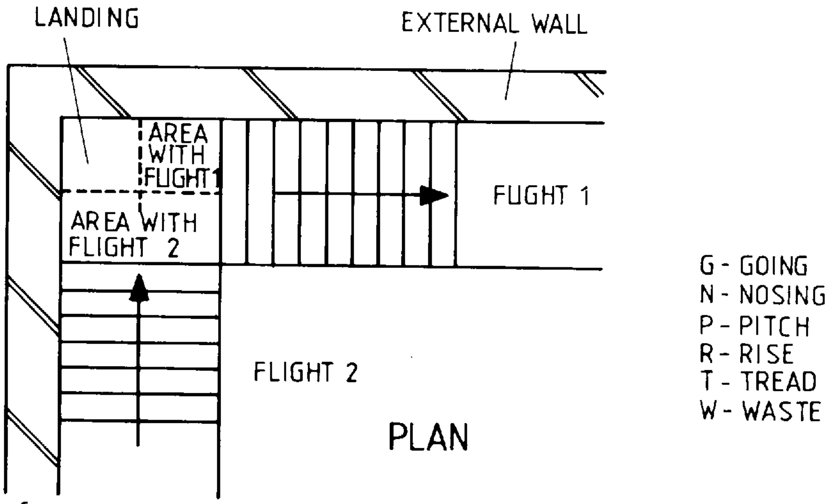
(a) Slab construction

(i)

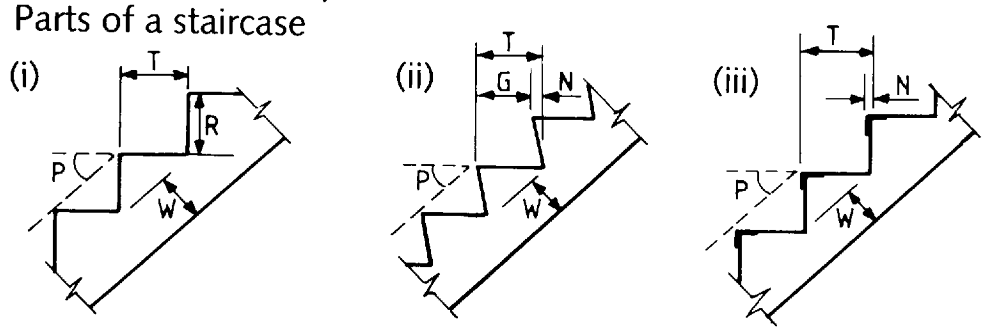


ELEVATION

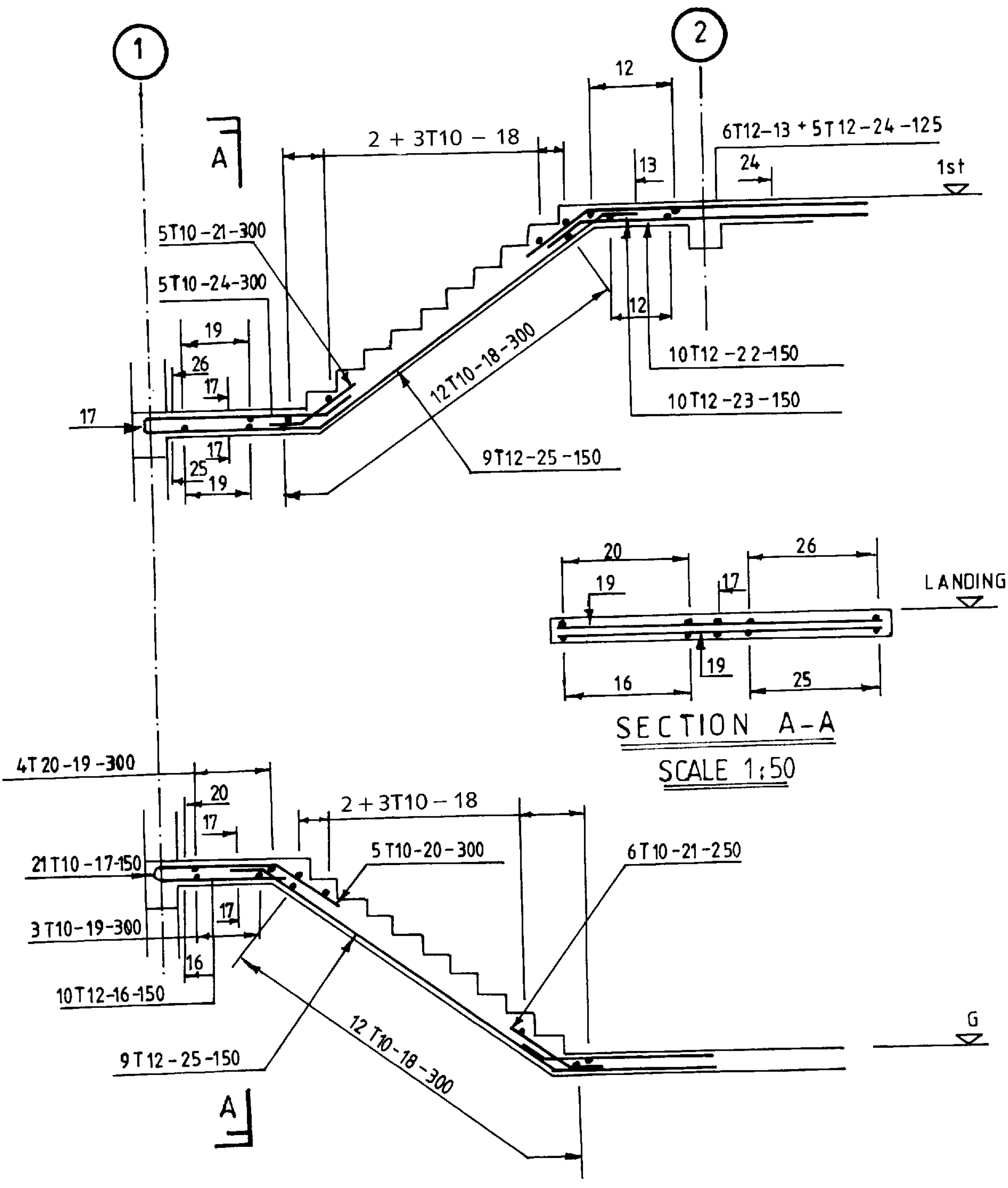
(ii)



(b) Parts of a staircase



STAIRCASE ELEVATION SHEET NO. III.3

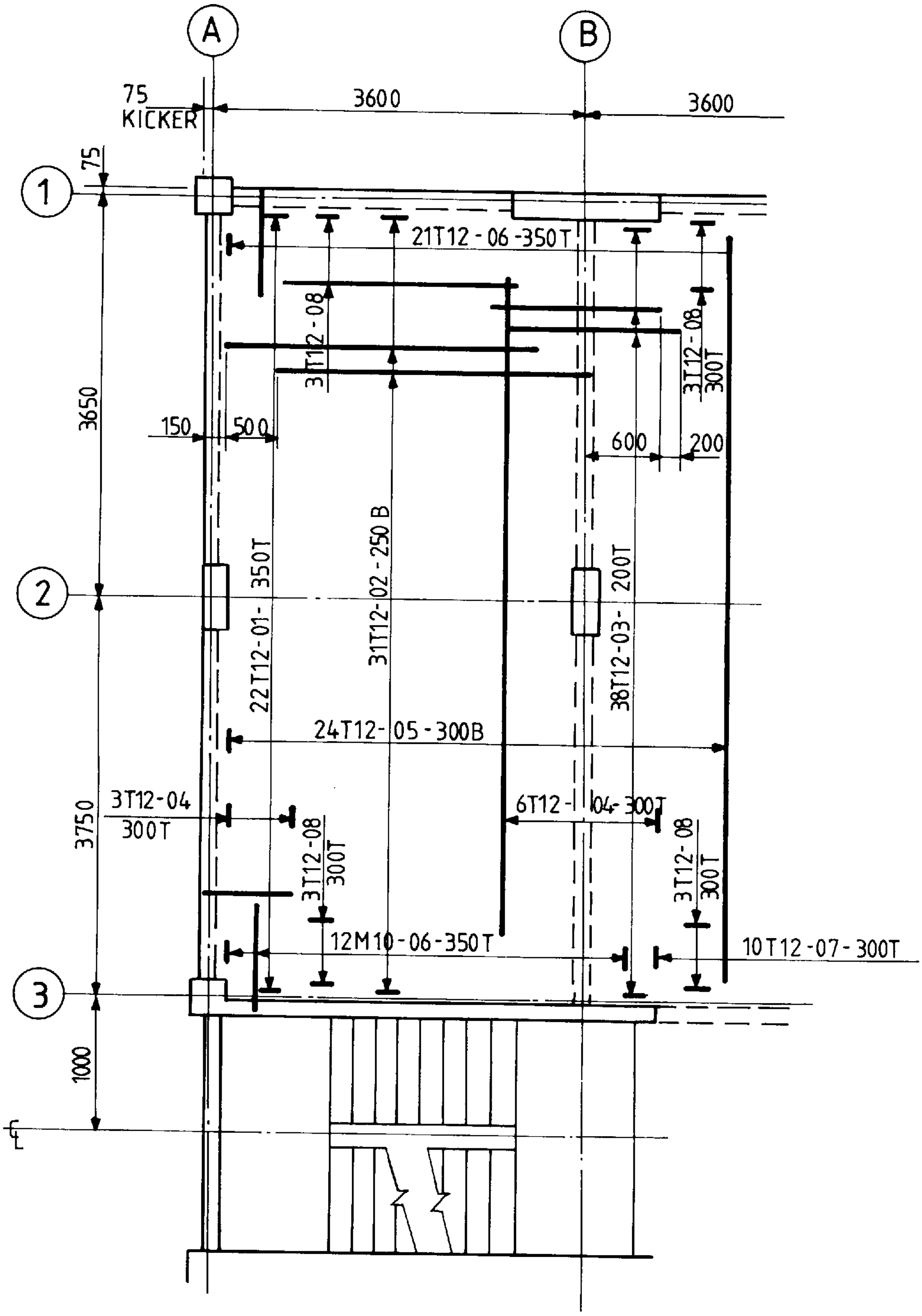


STAIRCASE ELEVATION

SCALE 1:50

STAIRCASE WITH THE BEAM SLAB ARRANGEMENT

SHEET NO. III.4



PLAN

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

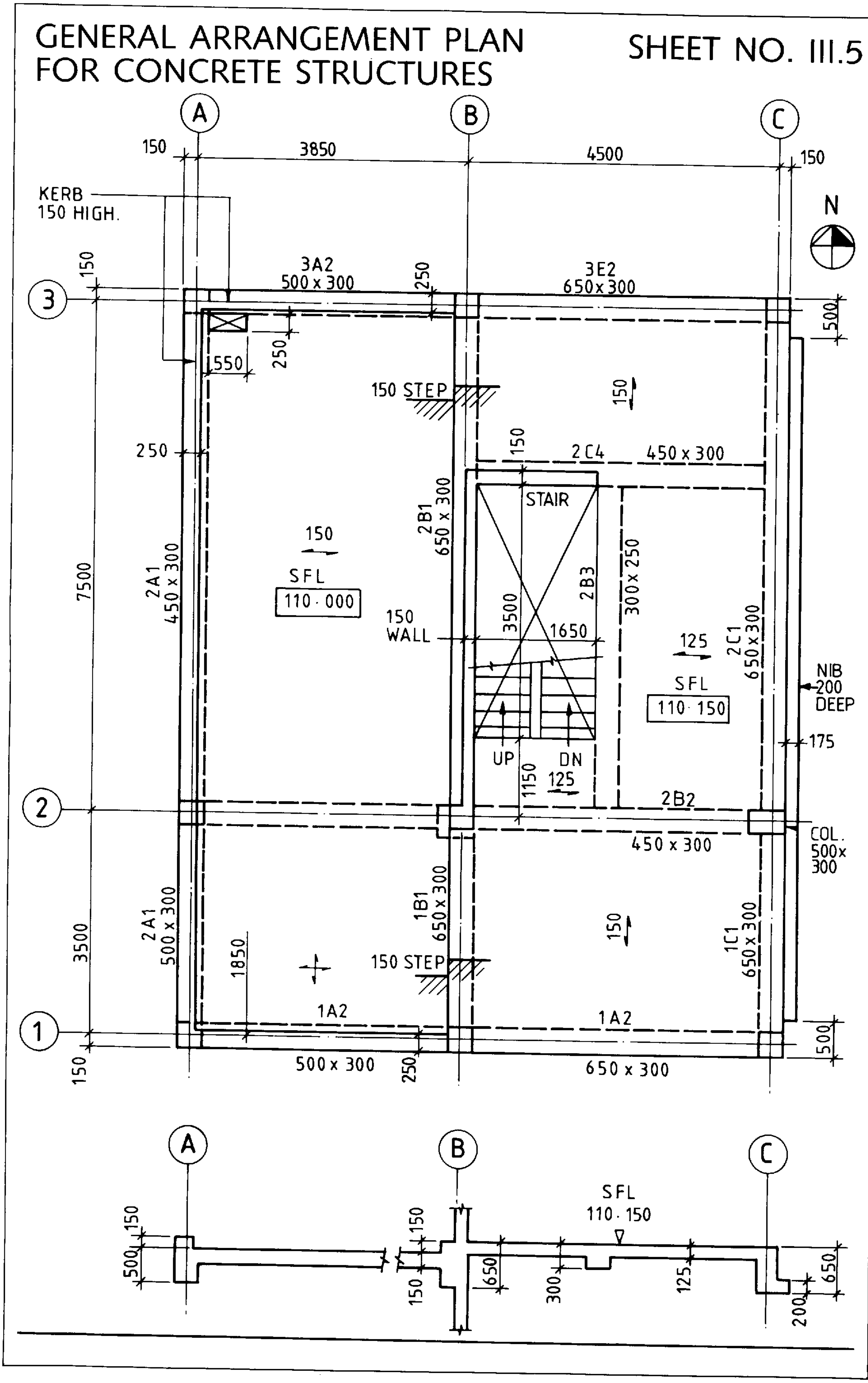
The dimensions and other specifications are derived from the general layout of the building or structure where the stairs are to be used. Two typical layouts given on Sheet Nos. III.4 and III.5 show the exact positioning of these staircases with respect to gridwork and floor levels. Sheet No. III.4 gives 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. They are not included as their use is very limited.

Precast concrete staircases have recently become very popular and a number of companies are involved in producing them. In this book Birchwood prestressed concrete staircases are shown on Sheet Nos. III.6 to III.9. Sheet Nos. III.6 and III.7 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.8 and III.9 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:

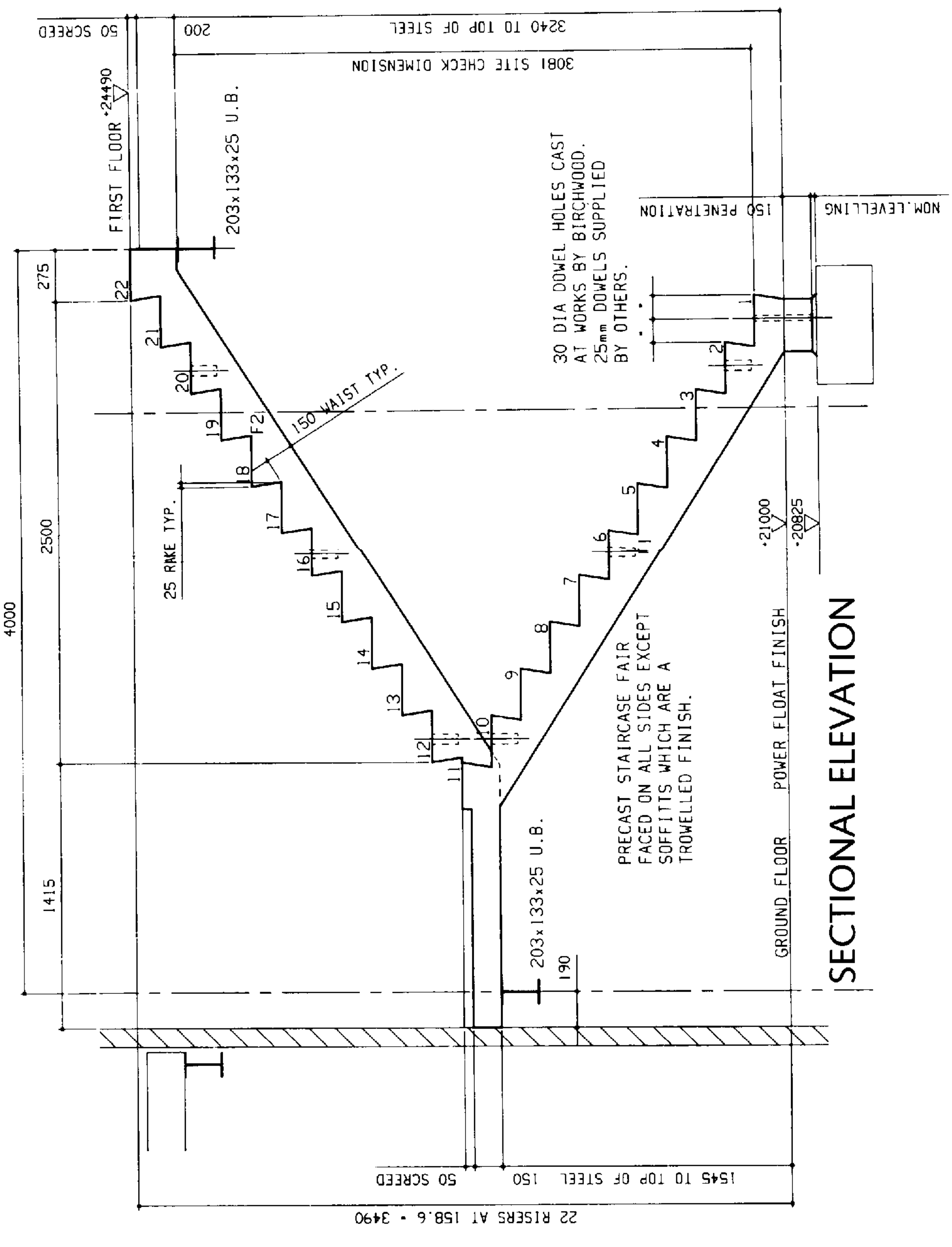
Staircase type	Rise (max.)	Going (min.)
Private – giving single access	220	220
Common – giving joint or multi-access	190	240
Disabled	170	250
Institutional and assembly buildings	180	250
Any type not described	190	250

The above information has been abstracted from Building Regulations Documents K:1985, M:1987 and amendment 1:1988


GENERAL ARRANGEMENT PLAN
FOR CONCRETE STRUCTURES
SHEET NO. III.5
A
B
C
1
2
3
N
150
3850
4500
150
KERB
150 HIGH.
3A2
500 x 300
3E2
650x300
250
500
550
250
150 STEP
250
2C4
450 x 300
STAIR
2B1
650 x 300
150
SFL
110 · 000
150
WALL
3500
1650
2B3
300x 250
125
SFL
110 · 150
2C1
650x300
NIB
200
DEEP
175
UP
DN
1150
125
2B2
450 x 300
COL.
500x
300
7500
2A1
450 x 300
2A1
500 x 300
3500
1B1
650x300
1850
150 STEP
1A2
1A2
1C1
650x300
150
500 x 300
250
650 x 300
500
SFL
110 · 150
150
500
150
150
650
300
125
200
650

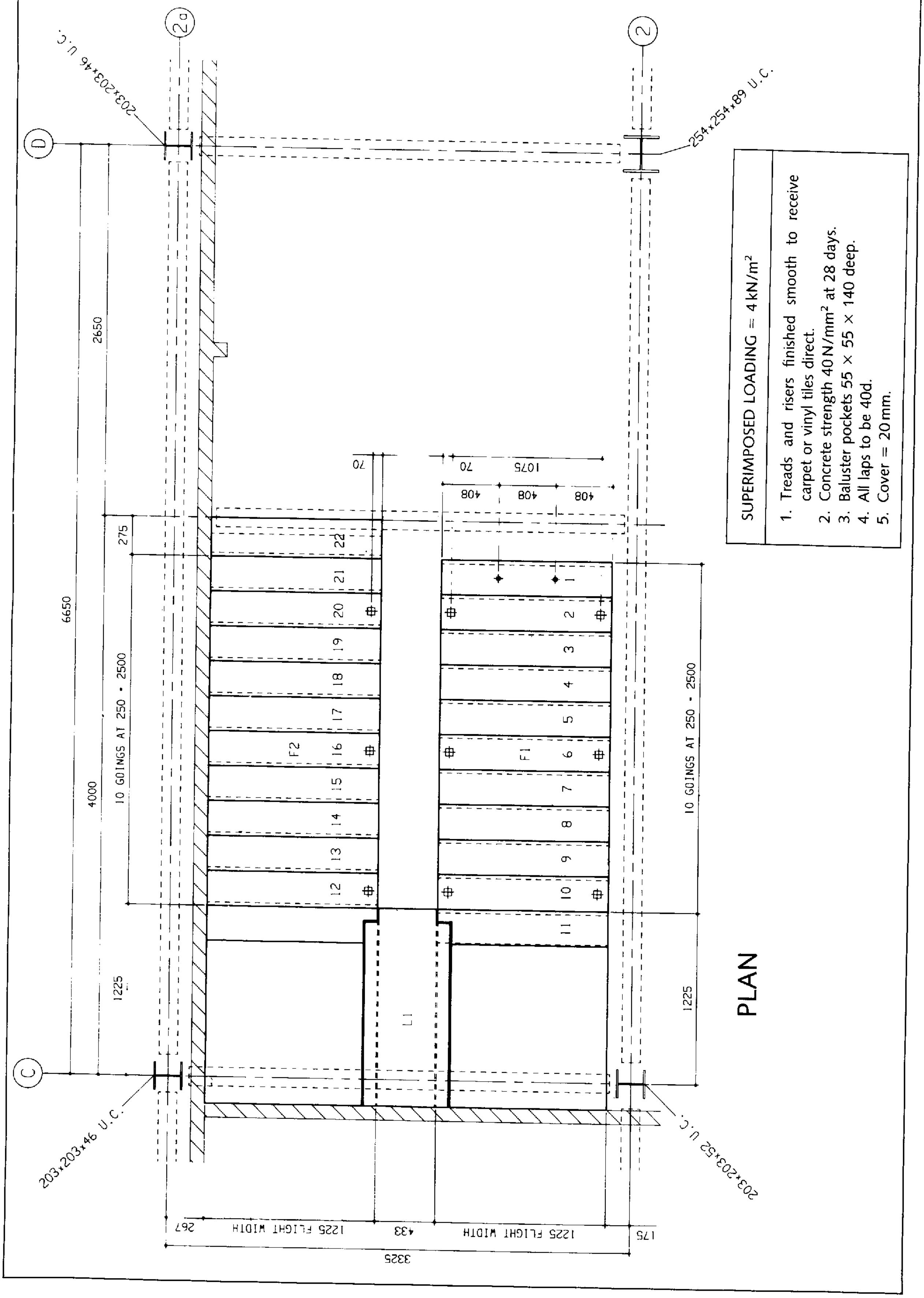
BIRCHWOOD PRECAST CONCRETE STAIRCASE

SHEET NO. III.6



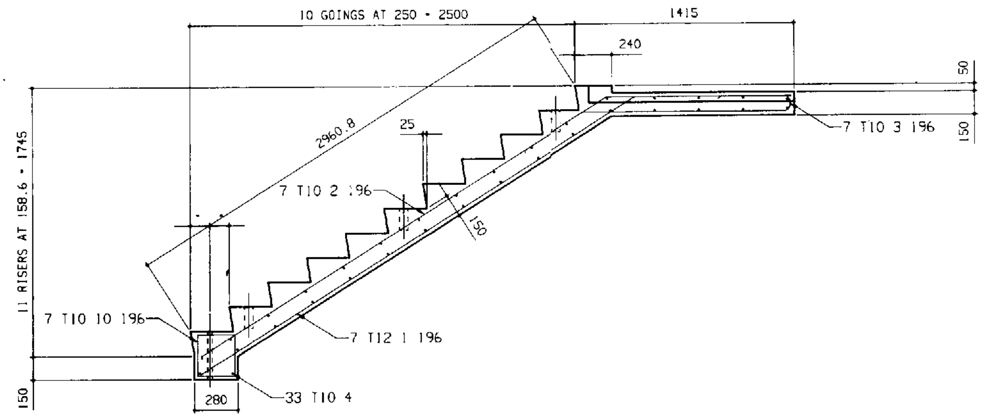
BIRCHWOOD PRECAST CONCRETE STAIRCASE

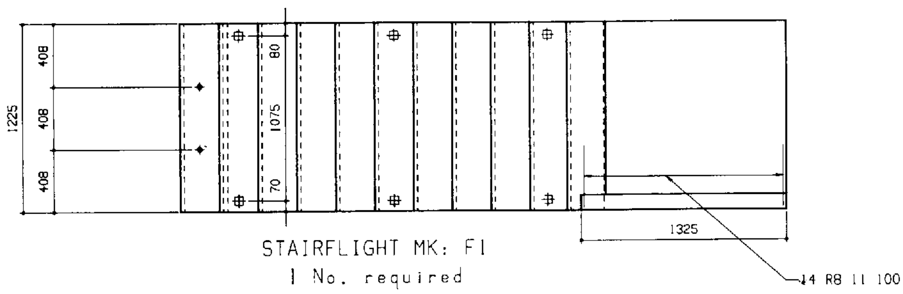
SHEET NO. III.7

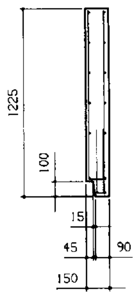


BIRCHWOOD PRECAST CONCRETE STAIRCASE SHEET NO. III.8

Reinforcement Details–1

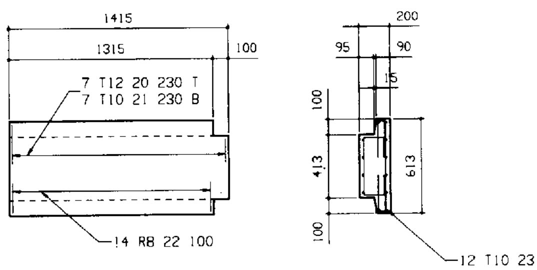






STAIRFLIGHT MK: F1
1 No. required
Volume of Concrete = 1.12 cubic metres
Total Weight of Flight = 2.771 tonnes

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.

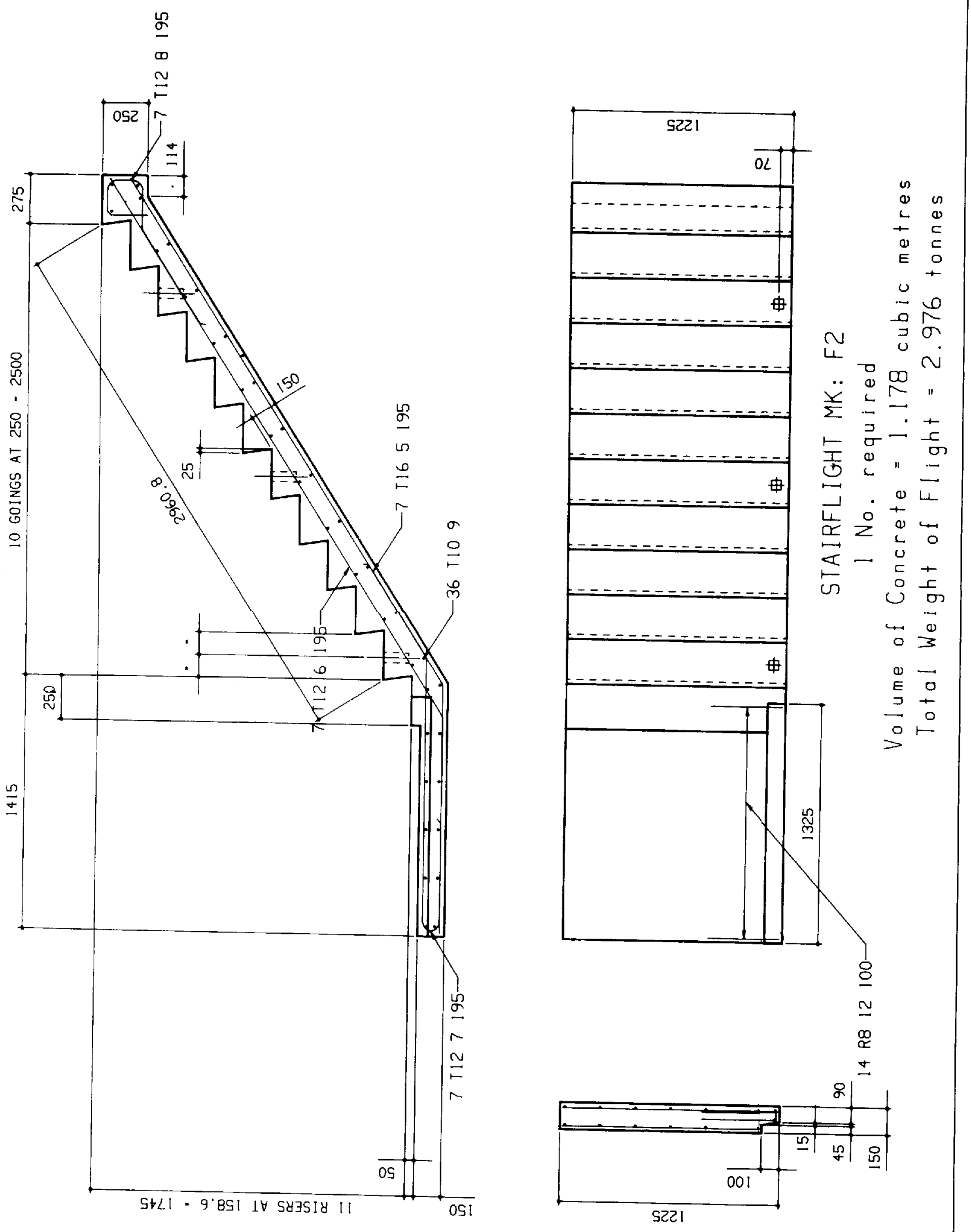


LANDING MK: L1
1 No. required
Volume of Concrete = 0.169 cubic metres
Total Weight of Landing = 0.406 tonnes

BIRCHWOOD PRECAST CONCRETE STAIRCASE

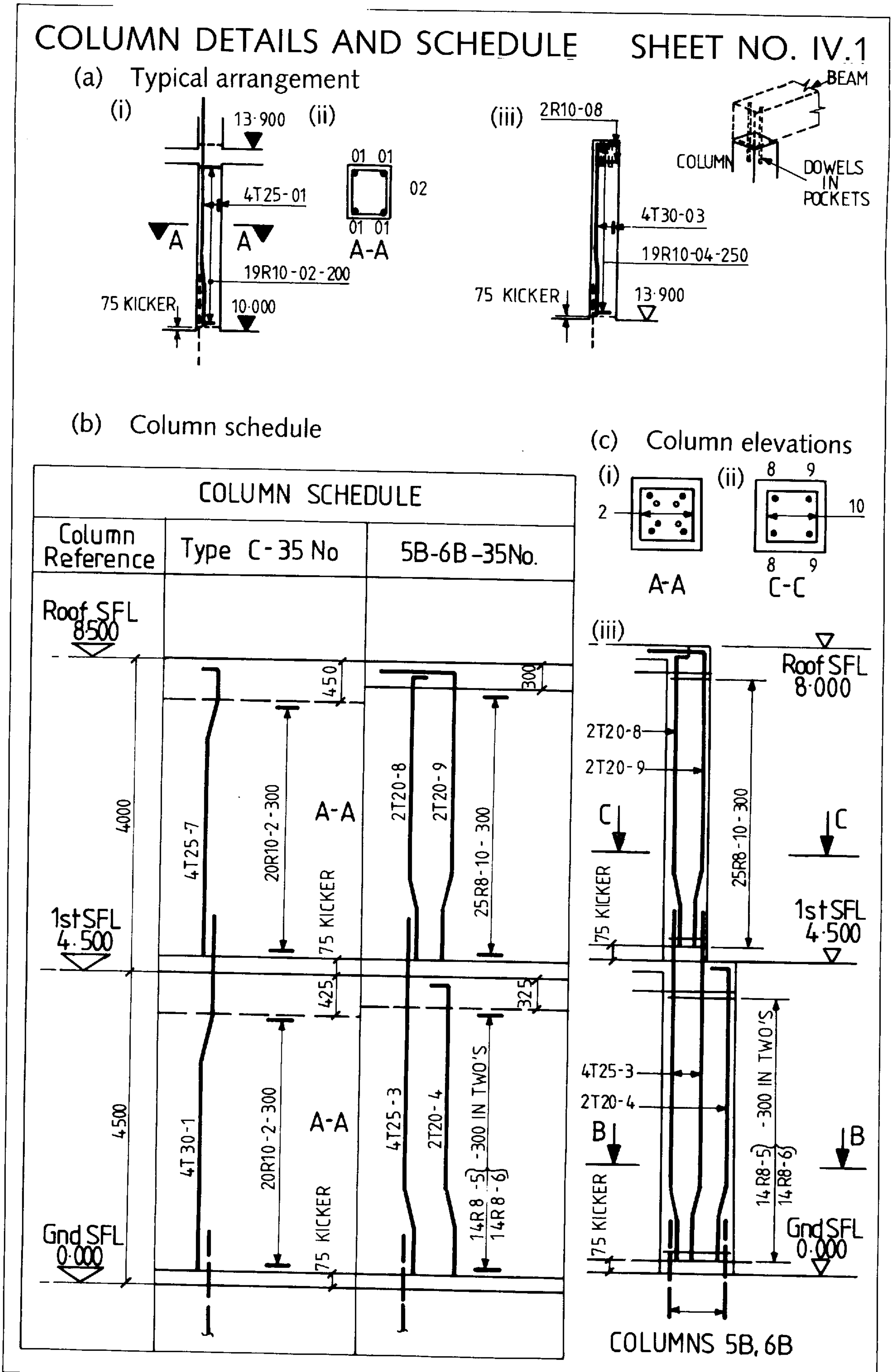
SHEET NO. III.9

Reinforcement Details–2



Section IV

Columns, Frames and Walls



COLUMN DETAILS AND SCHEDULE
SHEET NO. IV.1
(a) Typical arrangement
(i)
13·900
4T25-01
A
A
19R10-02-200
75 KICKER
10·000
(ii)
01 01
02
01 01
A-A
(iii)
2R10-08
4T30-03
19R10-04-250
75 KICKER
13·900
BEAM
COLUMN
DOWELS IN POCKETS
(b) Column schedule
COLUMN SCHEDULE
Column Reference
Type C-35 No
5B-6B-35No.
Roof SFL 8500
1st SFL 4·500
Gnd SFL 0·000
4000
4500
450
300
4T25-7
20R10-2-300
A-A
75 KICKER
2T20-8
2T20-9
25R8-10-300
425
325
4T30-1
20R10-2-300
A-A
75 KICKER
4T25-3
2T20-4
14R8-5
14R8-6
-300 IN TWO'S
(c) Column elevations
(i)
2
A-A
(ii)
8 9
10
8 9
C-C
(iii)
Roof SFL 8·000
2T20-8
2T20-9
C
C
25R8-10-300
75 KICKER
1st SFL 4·500
4T25-3
2T20-4
B
B
14R8-5
14R8-6
-300 IN TWO'S
75 KICKER
Gnd SFL 0·000
COLUMNS 5B, 6B

IV.1 Columns

Columns are usually under compression and they are classified as short columns or long and slender columns. Long columns are liable to buckle under axial loads. The length of the column is the distance between supports at its end or between any two floors. The effective length of a column is governed by the condition of fixity at its ends in position and in direction. Codes give the values of the effective length for a number of cases by multiplying the actual length by a factor. Columns may also be loaded eccentrically or there may be a bending moment imposed on them in addition to concentric (axial) and eccentric loads.

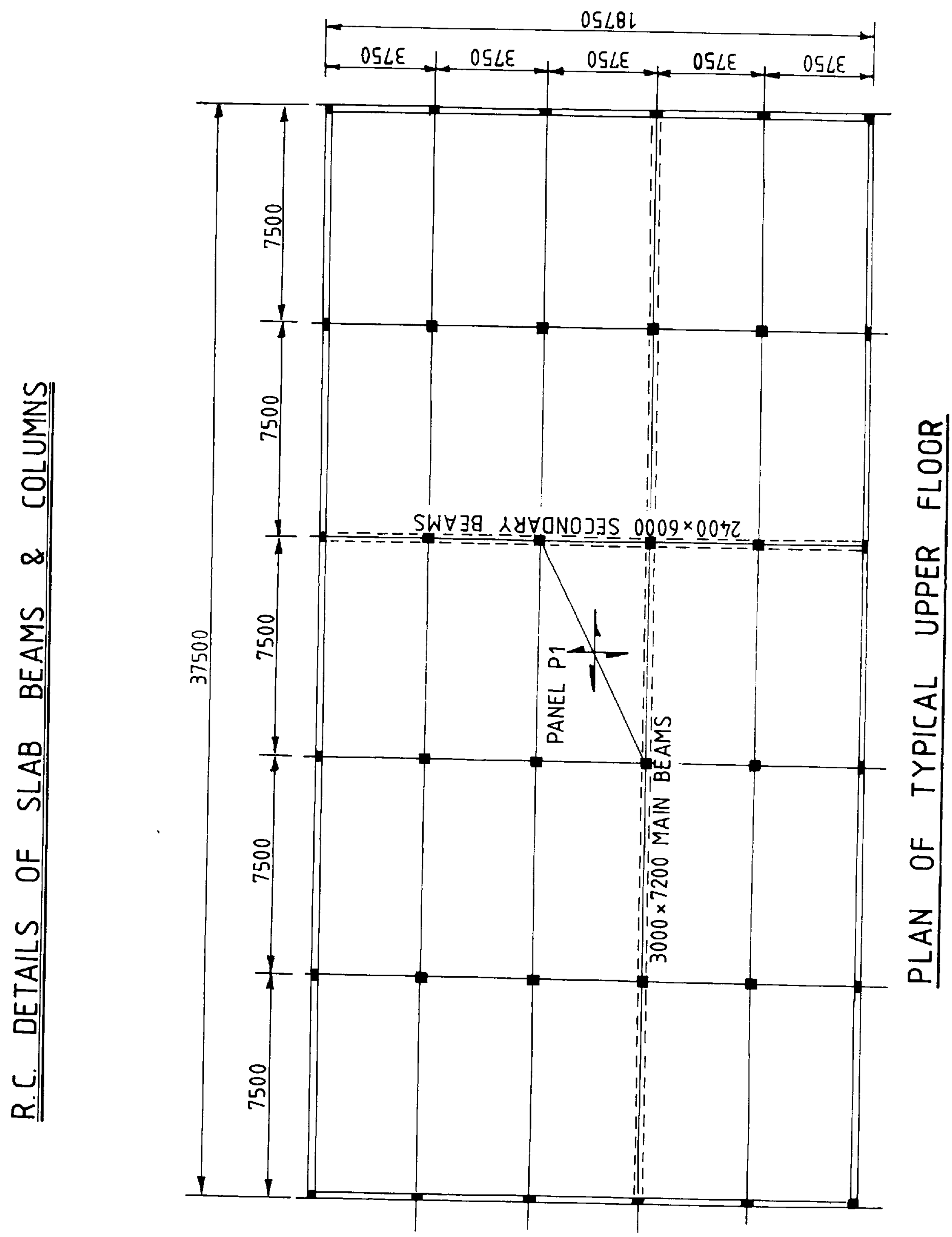
Reinforcement in the form of longitudinal bars is provided both in short and long columns. These reinforcements are necessary to withstand both tension and compression loads. The most efficient location of the longitudinal reinforcement is near the faces of the columns. Such locations reduce the possibility of the reinforcement buckling with the resulting inability to take the load for which the column is supposed to be designed. Such buckling is prevented by lateral reinforcement in the form of ties or closely-spaced spirals. Again, codes give detail specifications for their design including sizes, spacings and the strength of concrete. The minimum number of longitudinal bars in a tied column should be four and the minimum diameter of bar is 12 mm. Typical details of columns and ties are given in Section I. They give locations of longitudinal reinforcement in specifically shaped columns and the method of providing ties to stop them buckling in any direction.

In any large job, it is necessary to give elevations to columns with their respective cross-sections and a column bar schedule must be provided to give column reference, column type and elevation and reinforcement details at various elevations. Sheet No. IV.1 gives, in brief, all these requirements for a specific construction. As column design is based on requirements already discussed above, sizes and reinforcement may change but the layout will be identical to the one given on Sheet No. IV.1.

The reinforcement bars, depending upon a specific construction, may require couplers, provided on the lines suggested in Section I. Care is taken to provide adequate laps where construction joint detailing is needed. Again a reference is made to specific codes and to Section I.

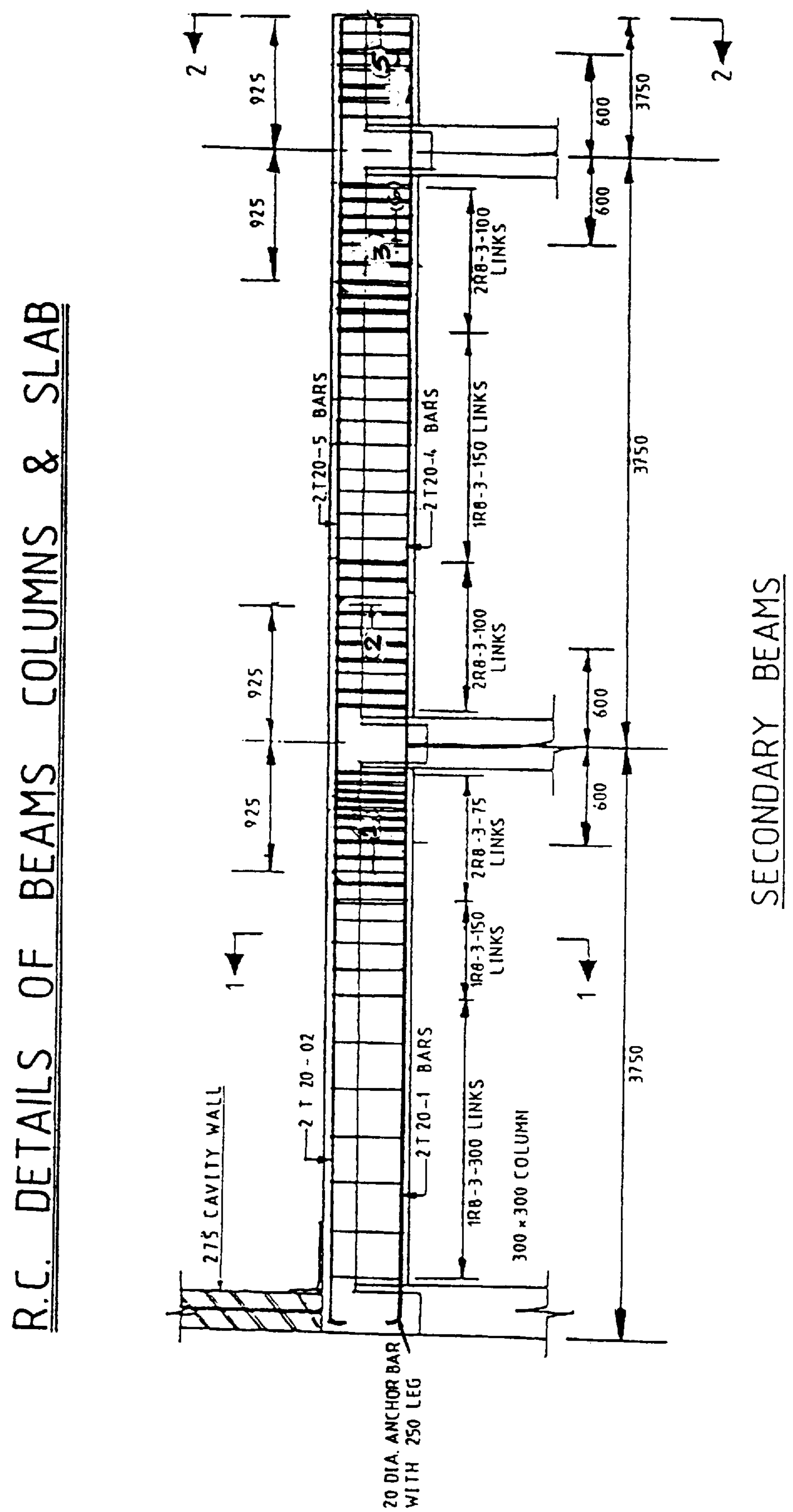
R.C. DETAILS OF SLAB BEAMS AND COLUMNS

SHEET NO. IV.2



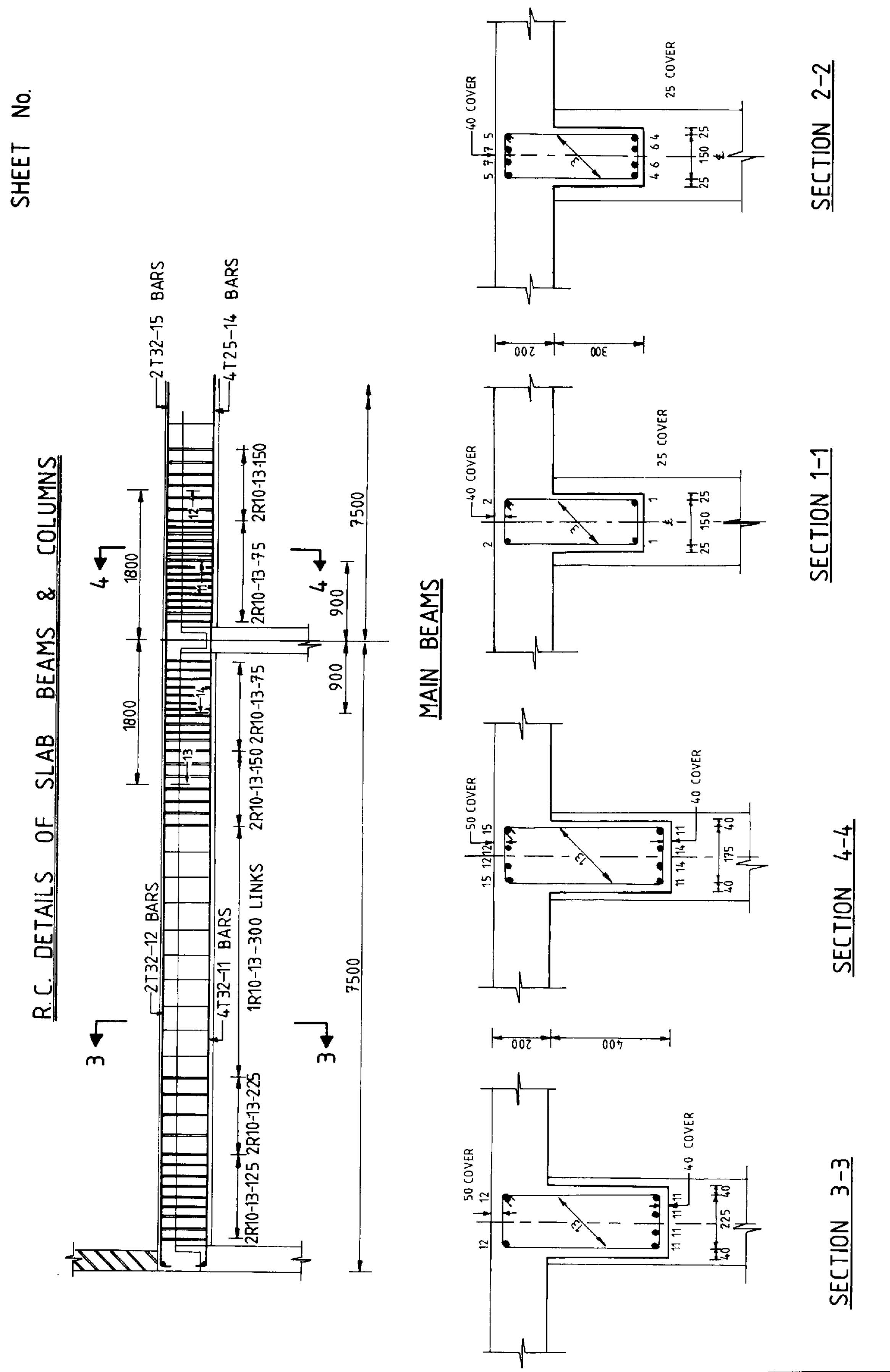
In most constructions, carrying out integrated structural detailing in concrete is unavoidable. Generally in framed constructions, slabs, beams and columns are involved. Sheet No. IV.2 gives a general plan for a typical floor showing main and secondary beams, slabs and columns. Sheet Nos. IV.3 to IV.6 give examples of detailing. Various R.C. components needed for the floor are shown on Sheet No. IV.2. All structural details are self-evident and indicate how an integrated structure can be designed and detailed.

R.C. DETAILS OF BEAMS, COLUMNS AND SLAB — SHEET NO. IV.3



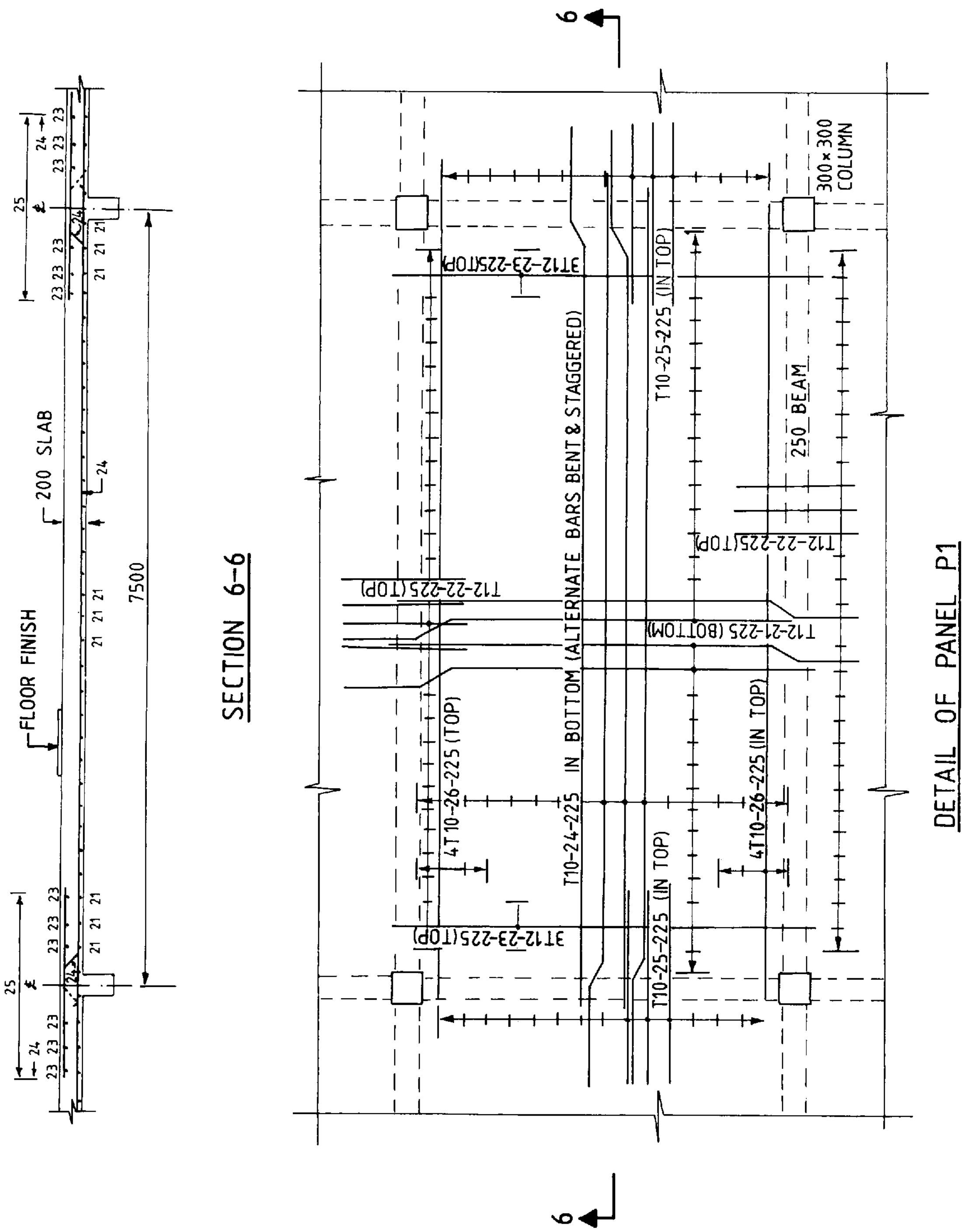
R.C. DETAILS OF SLAB BEAMS AND COLUMNS

SHEET NO. IV.4

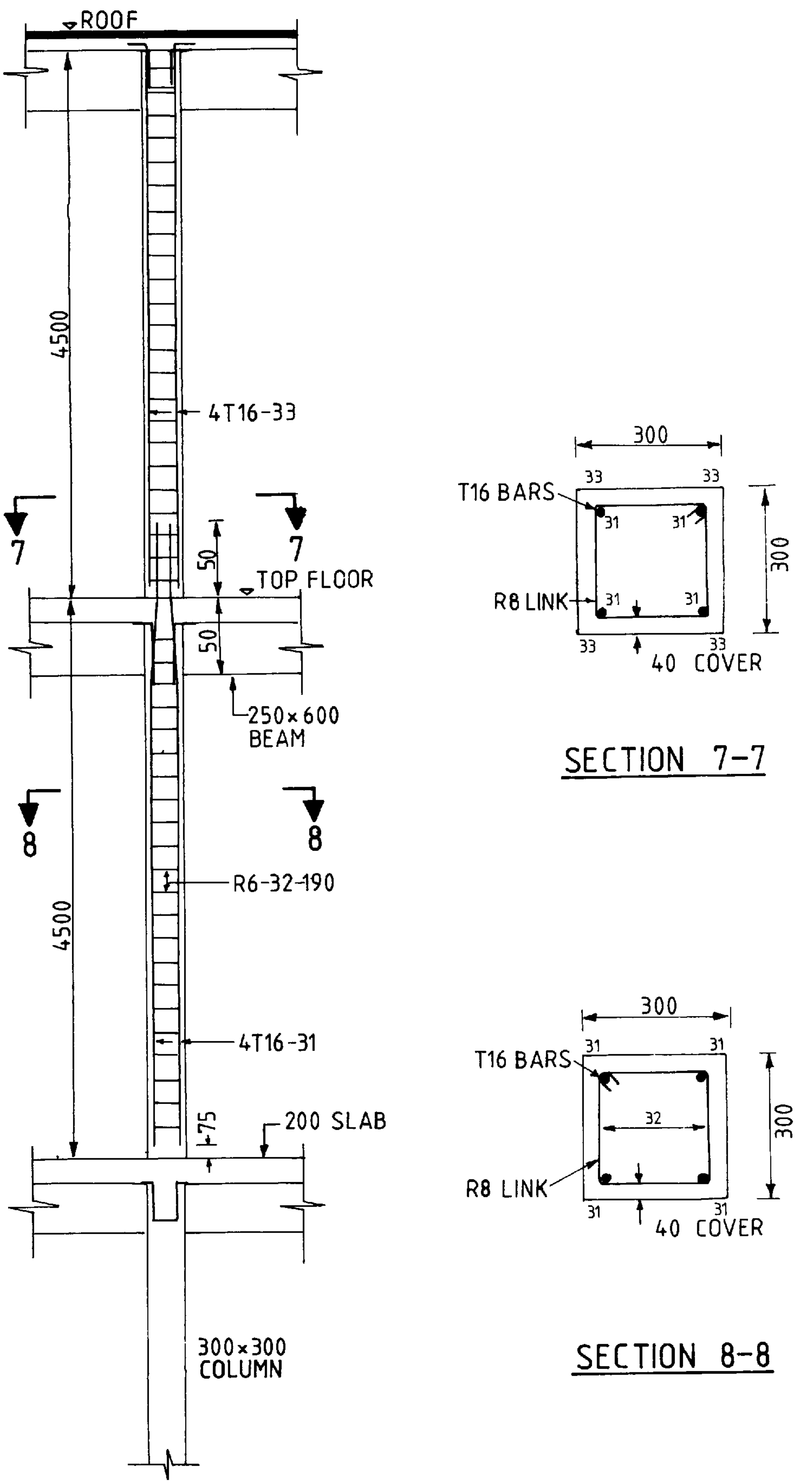


R.C. DETAILS OF SLAB BEAMS AND COLUMNS

SHEET NO. IV.5



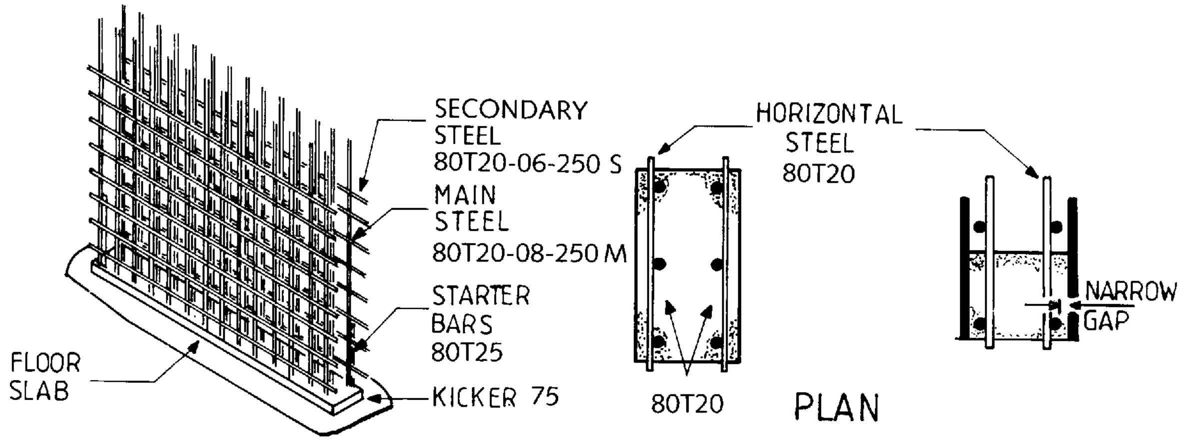
R.C. DETAIL OF INTERIOR COLUMN SHEET NO. IV.6



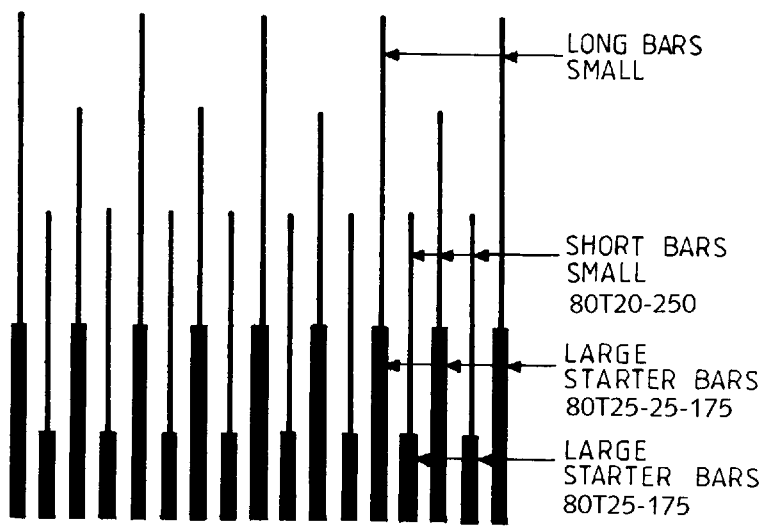
STRUCTURAL WALLS

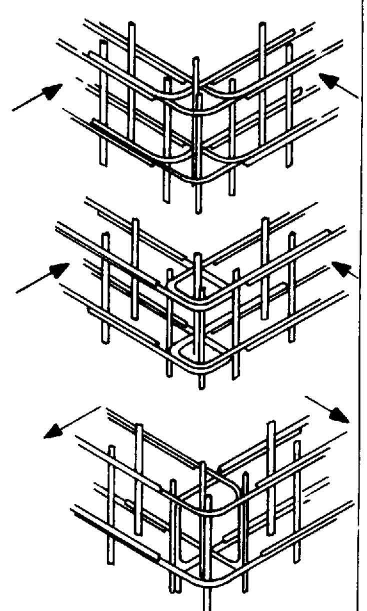
SHEET NO. IV.7

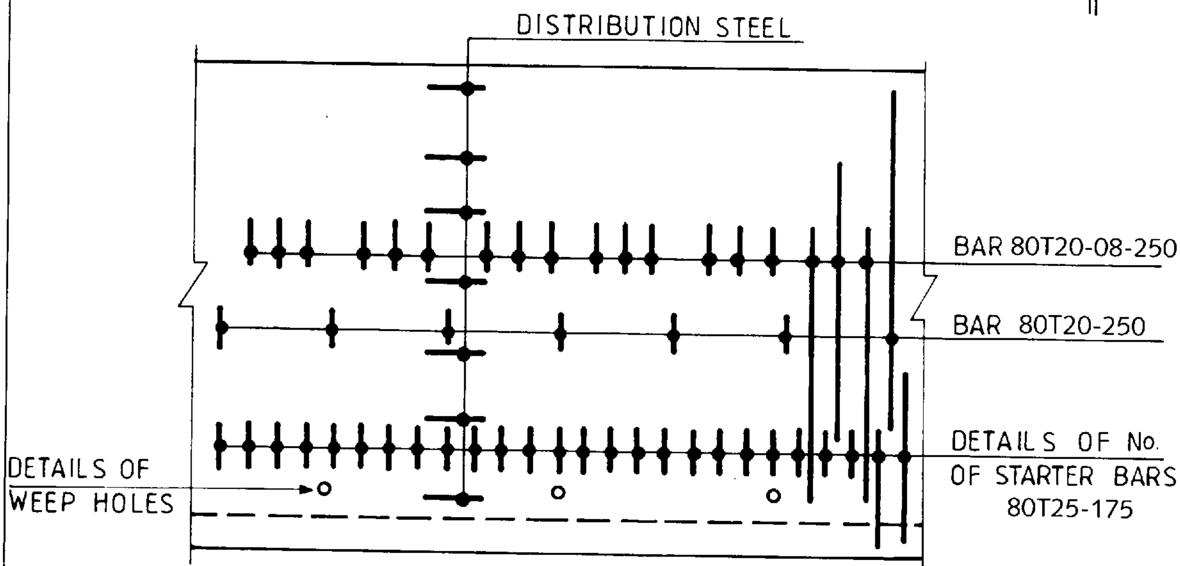
(a) Wall reinforcement isometric view



(b) Opening and closing corners







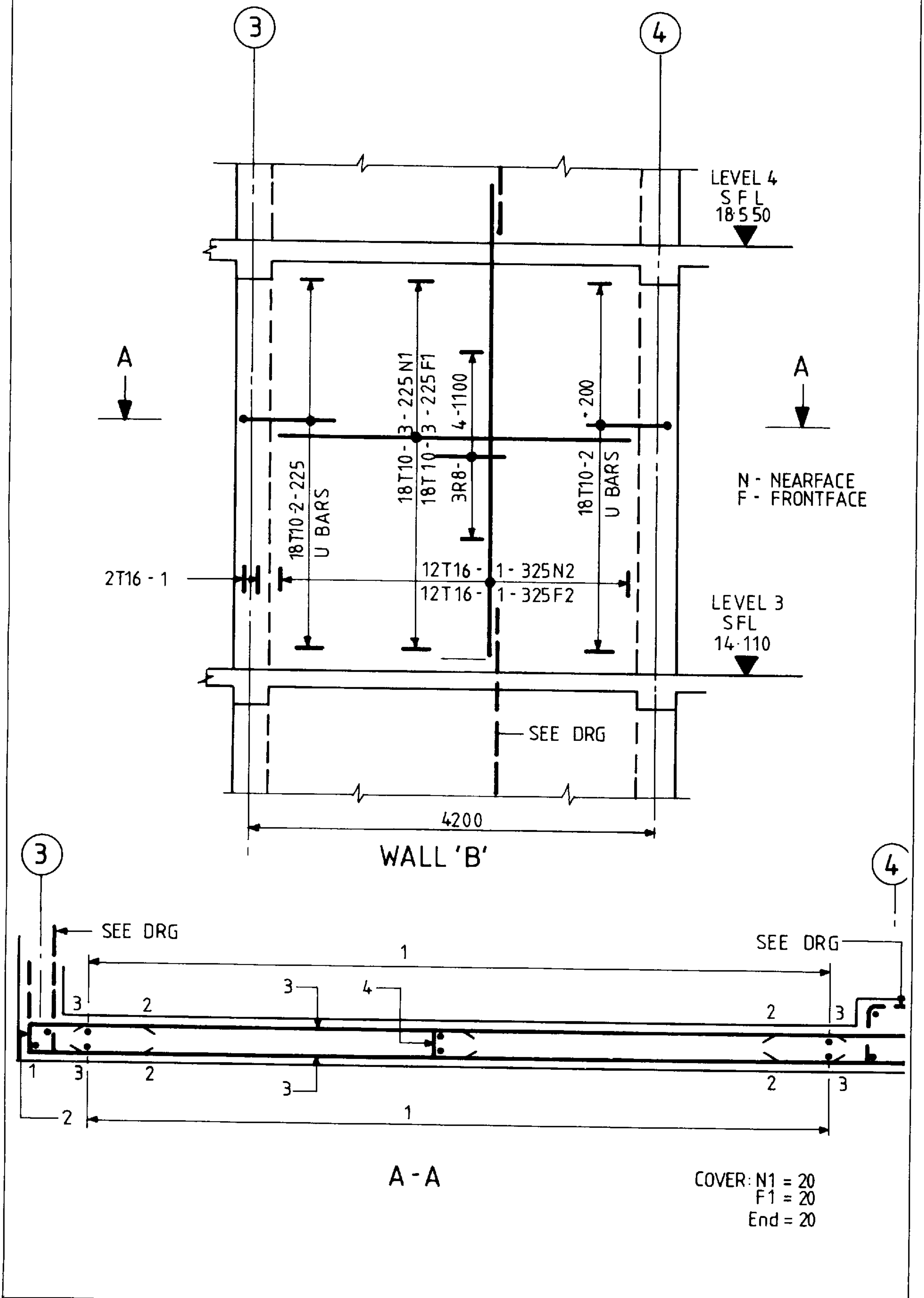
IV.2 Reinforced Concrete Walls

Reinforced concrete walls are generally subjected to axial loads. A typical isometric view of the reinforcement mesh is given on Sheet No. IV.7.a. A schedule is prepared for long, short and starter bars and their cut-off lengths together with opening and closing corners. The sizes of these bars depend on a specific construction and loads carried by a wall. Sheet No. IV.8 gives reinforcement details for an integrated structure, beams, slabs and walls (including shear walls and laterally loaded walls). Again codes are consulted for wall specifications and minimum bar diameters and wall thicknesses.

IV.3 Portal and Frames

Sheet No. IV.9 gives reinforcement details for three different types of portals and frames. Again the thicknesses of frames and bar sizes depend on types of load. The general layout will still assume the same shape as indicated on Sheet No. IV.10. The frame corner reinforced with loops is shown on Sheet No. IV.10. It is practised in Germany and is widely recommended by the Eurocode on Concrete and by the American Concrete Institute.

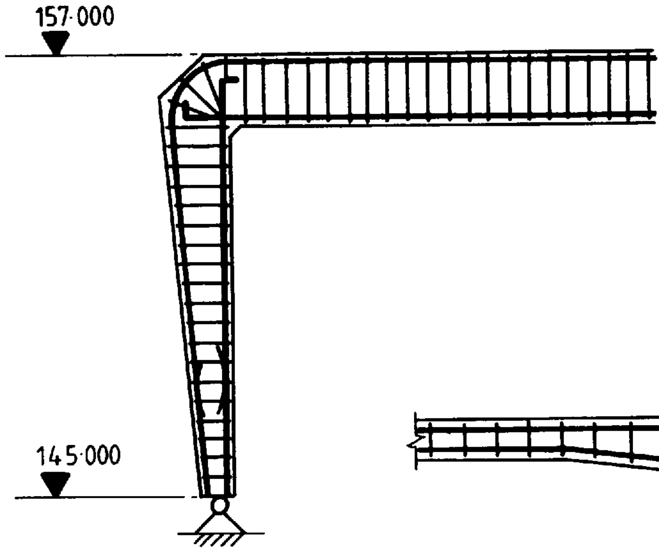
STRUCTURAL WALL SHEET NO. IV.8

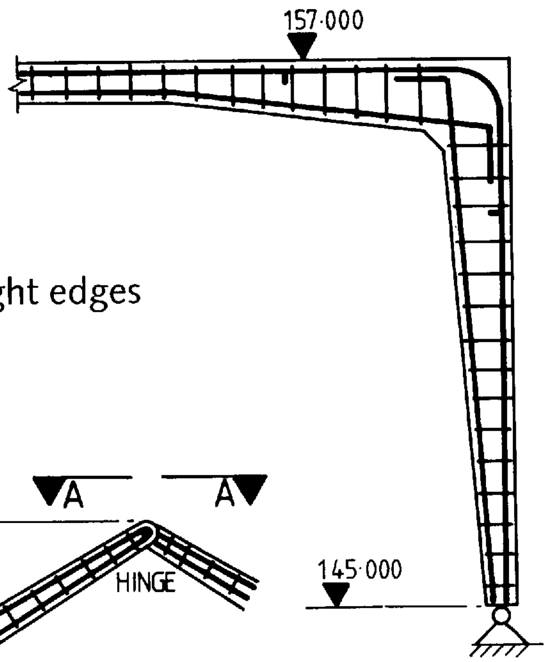


PORTALS AND FRAMES

SHEET NO. IV.9

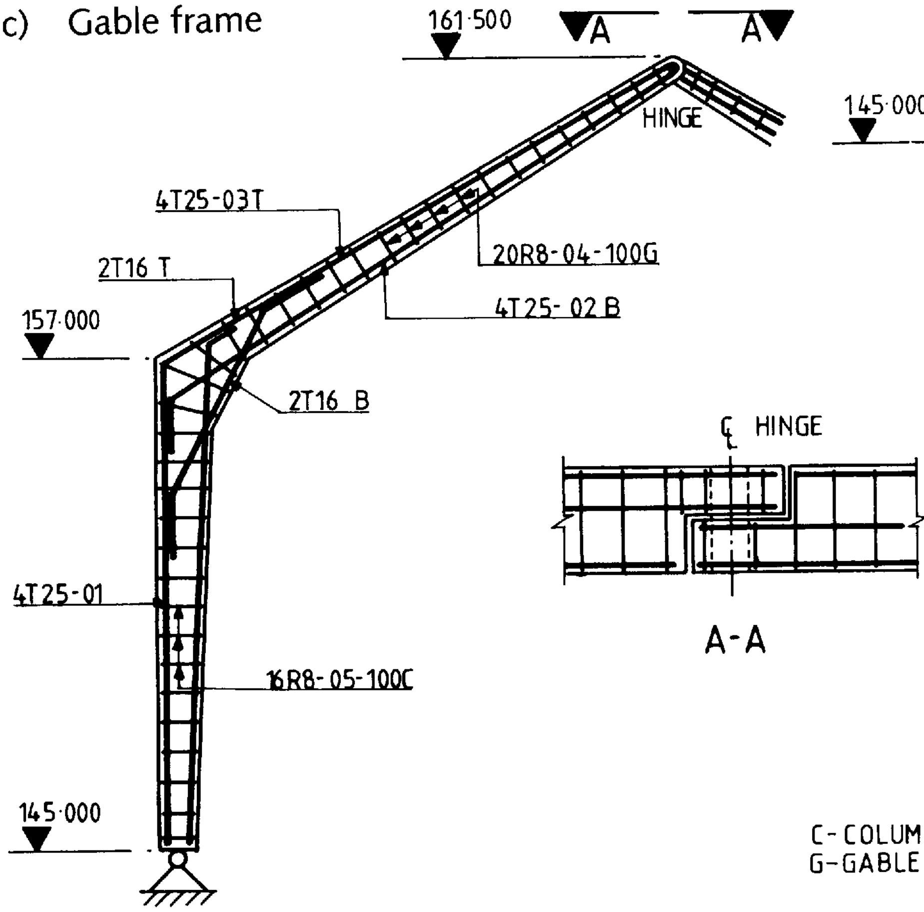
(a) Rectangular portal with chamfered edges





(b) Rectangular portal with straight edges

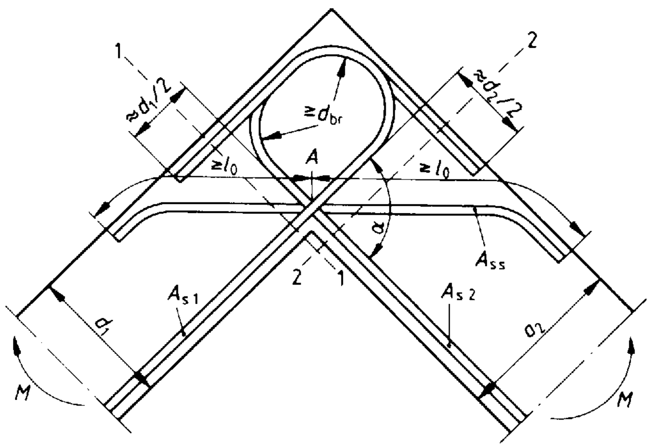
(c) Gable frame



A-A

C-COLUMN
G-GABLE

FRAME CORNERS WITH LOOP REINFORCEMENT (GERMAN PRACTICE) SHEET NO. IV.10



(With Permission of DIN Deutsches Institut Für Normung E.V. Berlin, p. 63 DIN 1045)

Bar diameter $d_{br} > 5$ cm and $> 3\ d_s$ ≤ 5 cm and $\leq 3\ d_s$

Hooks, bends, loops, links in cm $15\ d_s^{28}$ $20\ d_s$ d_1 and $d_2 \not> 100$ cm $d_s = \varnothing$ bar diameter

Sections 1–1 and 2–2 are required for the design.
Transverse reinforcement or links shall be the same as on Sheet Nos. IV.8 and 9.

Section V

Prestressed Concrete

V.1 General Introduction

Prestressed concrete has attained worldwide recognition in the development of industrialized construction and design. Prestressing consists of introducing imposed deformations by tensioning prestressing wires, cables or strands and tendons to a high stress which decreases with time due to various losses such as shrinkage, creep, steel relaxation, friction and wobbling effects. The word *prestress* is associated with the following:

(a) pretensioned concrete;
(b) post-tensioned concrete.

In the case of pretensioned concrete structures, the tensioning of the tendon is carried out before concreting. The prestressing force is held temporarily either by a specially-constructed prestressing bed or by a mould or form. When the concrete strength reaches the specified transfer strength, detensioning and stress transfer to such structures can be performed. In practice these structures are prefabricated.

In the case of post-tensioned concrete structures, the tensioning of the tendon is carried out after casting and hardening of the concrete. This method is more effective in the design and construction of high-rise and long-span concrete structures. The design and detailing of such structures are influenced by the serviceability classification, which includes the amount of flexural tensile stresses allowed while carrying out the design/detailing of such structures. They are then classified into individual classes which are given below:

Class 1: no flexural tensile stresses.
Class 2: flexural tensile stresses but no visible cracking.
Class 3: flexural tensile stresses but surface width of cracks not exceeding 0.1 mm for members in very severe environments and not exceeding 0.2 mm for all other members.

The structural detailing of prestressed concrete members must take into consideration durability, fire resistance and stability. The relevant codes include BS 8110 which should strictly be followed for the correct evaluation of design ultimate loads and the characteristic strength of concrete and steel.

Generally high strength concrete is used for prestressed concrete work. The steel used in prestressed concrete is generally of a much higher strength than mild steel. This aspect is discussed later on in the choice and evaluation of prestressing systems.

Material data and prestressing systems are given on Sheet Nos. V.1 to V.14. In such the prestressing tendons can be bonded and unbonded. The structural detailing is affected when the prestressed concrete structure is designed with bonded and unbonded tendons. Before the prestressing load is transmitted into various zones of concrete with bonded or unbonded tendons, it is necessary to protect the areas immediately under the anchorages against bursting effects caused by large loads generated by prestressing tendons.

A conventional steel in the form of reinforcing cages or helicals is provided below the anchorages in concrete to take much of the bursting effects. Codes give assistance in the design of such reinforcement, known as the *anchorage reinforcement*. The end areas where the anchorages rest are known as *anchorage* or *end blocks*. The purpose of such reinforcement is to transfer forces from anchorages smoothly into the concrete without causing internal cracks. The prestressing loads are affected by losses, elastic shortening of concrete, shrinkage and creep of concrete, relaxation of steel, anchorage slip and friction and wobbling effects. Again codes are consulted on these losses due to short and long term loads.

In order to sustain effectively the bending moments, deflections and shear, particularly in post-tensional systems, the tendon should be given a profile over its length where parasitic or secondary moments are to be avoided in a continuous structure. The tendon or cable shall then have a *concordant profile*.

V.2 Prestressing Systems, Tendon Loads and Material Properties

V.2.1 Available systems

(a) Wire/strand directly tensioned.
(b) Macalloy System using high tensile bars.
(c) Freyssinet System (France).
(d) BBRV System (Switzerland).
(e) CCL System (Britain).
(f) KA System (Germany).
(g) VSL System (Switzerland).

The details of the above systems are given below.

Sheet No. V.1 gives data for strand characteristics for standard, super and Dyform strands. Sheet No. V.2 is a table giving basic data for Macalloy bars listing tendon sizes, characteristic loads, bearing plates and duct sizes.

Sheet No. V.3 gives further data on cold worked high tensile bars and cold drawn and pre-straightened wire used generally in pretensioned concrete structures. Sheet No. V.4 is a monogroup for a well-known 15/15 mm normal strand system used in the Freyssinet System. A similar monogroup exists for other strand sizes. Sheet No. V.5 gives the BBRV System where a single tendon formed from individual wires is used. Sheet Nos. V.6 to V.9 give comprehensive data on BBRV tendon systems. Data for the small capacity BBRV systems are given on Sheet No. V.10. Sheet No. V.11 shows the large tendon developed by BBRV to initially take up a 1000-tonne prestressing load. This type of tendon is used in the Dungeness B prestressed concrete pressure vessels. The stress–strain curve of this tendon and its basic data are given on Sheet Nos. V.12, Sheet Nos. V.13 and V.14 give structural detailing and data for Cabco prestressing tendons manufactured by Cable Cover Ltd.

STRAND CHARACTERISTICS

SHEET NO. V.1

Nominal size	Nominal area	Characteristic strength	Characteristic load	Initial load	
mm	mm^2	f_{pu} N/mm^2	P_k kN	$0.8 P_k$ kN	$0.7 P_k$ kN
Standard 7 – wire (normal and low relaxation) to BS 3617					
12.5	94.2	1750	165	132	115
15.2	138.7	1640	227	182	159
Standard 19 – wire (normal and low relaxation) to BS 4757					
18.0	210	1760	370	296	259
Super 7 – wire (normal and low relaxation)					
12.9	100.6	1830	184	147	129
15.4	143.2	1750	250	200	175
Dyform 7 – wire (low relaxation)					
12.7	112	1870	209	167	146
15.2	165	1820	300	240	210
18.0	223	1700	380	304	266
Maximum relaxation for initial load				$0.8 P_k$	$0.7 P_k$
Normal relaxation strand				12%	7%
Low relaxation strand				3.5%	2.5%

DATA FOR MACALLOY SINGLE BAR STRESSING SYSTEM

SHEET NO. V.2

Size of tendon Bar No./mm	Minimum centre of anchorage	Initial load 0.7 P_k kN	Initial load 0.8 P_k kN	Size of bearing plate mm × mm	Size of duct (int. dia.) mm
1/20	100 single	228	260	100 × 100	40 for each bar
2/20		455	520	200 × 100	
3/20		683	780	300 × 100	
1/22		263	300	125 × 125	
2/22		526	600	250 × 125	
3/22		788	900	375 × 125	
1/25	120 single	350	400	125 × 125	
2/25		700	800	250 × 125	
3/25		1050	1200	375 × 125	
1/28	120 single	438	500	140 × 140	
2/28		876	1000	280 × 140	
3/28		1314	1500	420 × 140	
1/32	150 single	560	640	150 × 150	42.5 for each bar
2/32		1120	1280	300 × 150	
3/32		1680	1920	450 × 150	
4/32		2240	2560	300 × 300	110
1/35		665	760	175 × 150	45 for each bar
2/35		1330	1520	350 × 175	
3/35		1995	2250	525 × 150	
1/40	175	875	1000	200 × 175	50 for each bar
2/40		1750	2000	400 × 175	
3/40		2625	3000	600 × 175	
4/40	350	3500	4000	400 × 350	140

COLD WORKED HIGH TENSILE BARS SHEET NO. V.3

Nominal size	Nominal area	Characteristic strength	Characteristic load	Initial load	
mm	mm^2	f_{pu} N/mm^2	P_k kN	$0.8\,P_k$ kN	$0.7\,P_k$ kN
20	314	1035	325	260	228
25	491	1020	500	400	350
32	804	995	800	640	560
40	1257	995	1250	1000	875

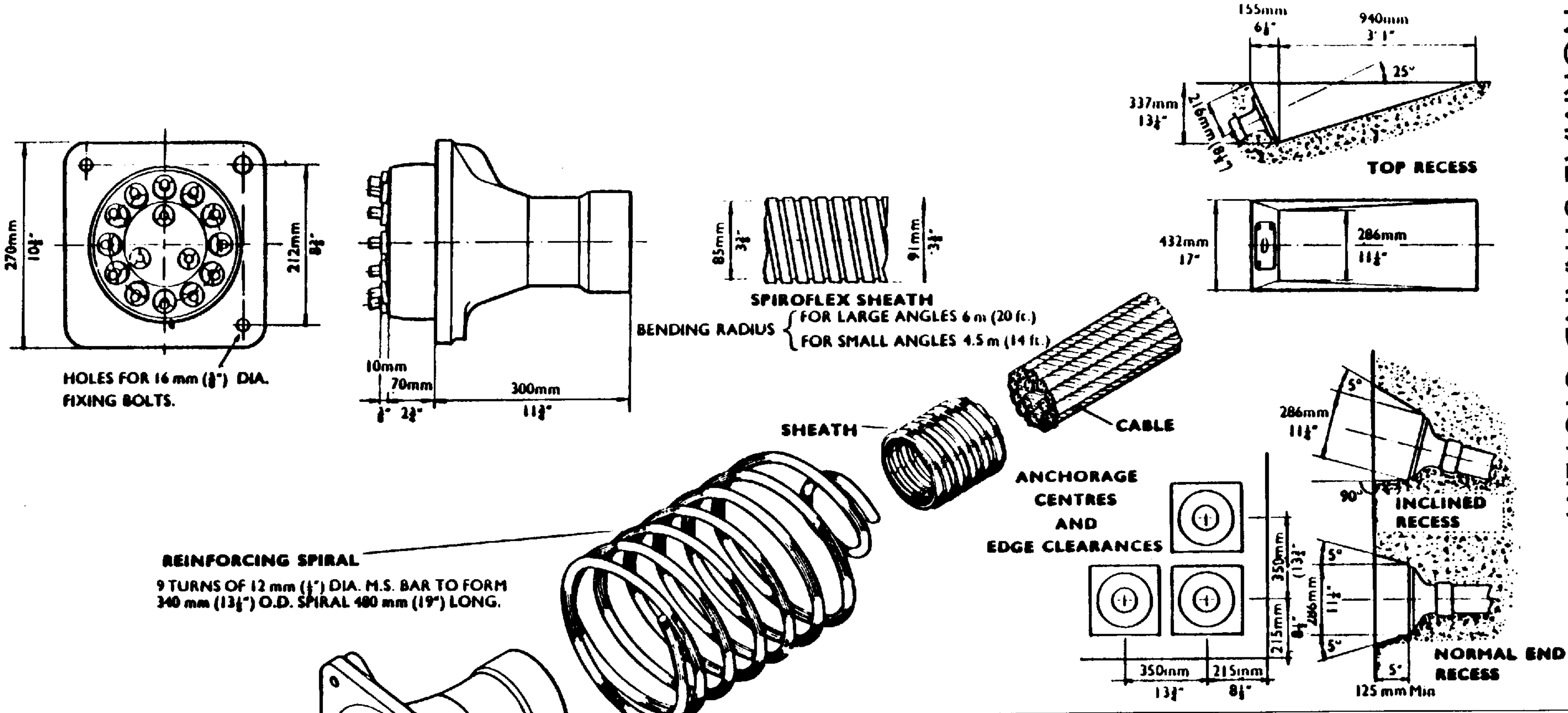
COLD DRAWN AND PRE-STRAIGHTENED WIRE (NORMAL AND LOW RELAXATION)

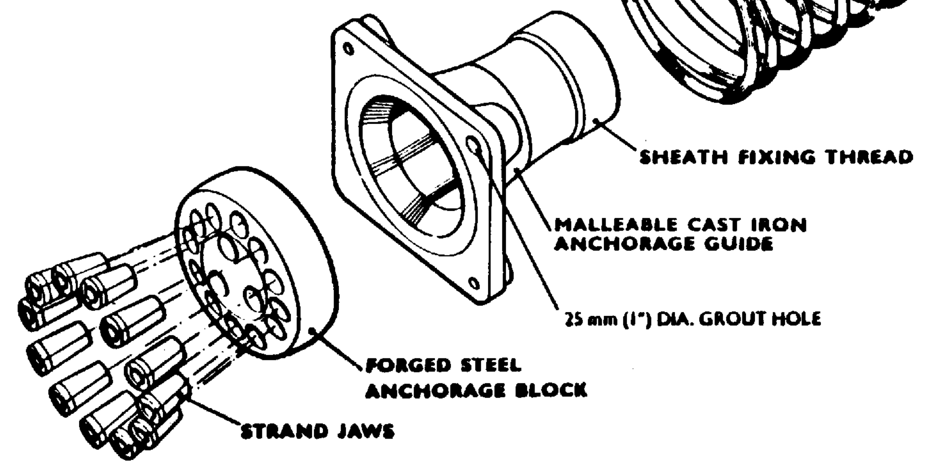
Nominal size	Nominal area	Characteristic strength	Characteristic load	Initial load	
mm	mm^2	f_{pu} N/mm^2	P_k kN	$0.8\,P_k$ kN	$0.7\,P_k$ kN
4	12.6	1720	21.7	17.3	15.2
5	19.6	1570	30.8	24.6	21.6
7	38.5	1570	60.4	48.3	42.3

Maximum relaxation for initial load	$0.8\,P_k$	$0.7\,P_k$
Normal relaxation wire	8.5%	5%
Low relaxation wire	3%	2%

'FREYSSI' MONOGROUP–15/15 mm NORMAL STRAND SYSTEM

SHEET NO. V.4





DESIGN DATA

15 mm 'N' NORMAL STRAND

15 mm strand is available from manufacturers to many specifications. This system should only be used for strand not exceeding 250 kN (56,000 lb), guaranteed ultimate tensile strength which is the limit of jack capacity. For higher strength strands, this anchorage should be used, but with the total number of strands reduced to a maximum of 13.

STRAND AND CABLE PROPERTIES
(based on 227 kN (51,000 lb.) strand to B.S.3617)

	Initial Tension (70% U.T.S.)		U.T.S.		Sectional Area		Mass	
	kN	Kips	kN	Kips	mm^2	in^2	kg/m	lb/ft
15 mm 'N' STRAND	159	35.7	227	51.0	138.7	0.215	1.10	0.74
5/15 mm 'N' CABLE	2384	535.5	3405	765	2080	3.23	16.5	11.1

JACKING LENGTH
For attachment of stressing jack, cable length must be increased as follows:–
For single-end stressing:
1.3 m (4'3") for centre strands; 1.0 m (3'3") for outside strands.
For double-end stressing:
2.3 m (7'6") for centre strands; 1.8 m (6'0") for outside strands.

DUCT FRICTION
Friction in the duct due to curvature:–

μ -- 0.26.

Friction in the duct due to unintentional variation from the specified profile:–

k -- 0.003/m (0.001/k.)

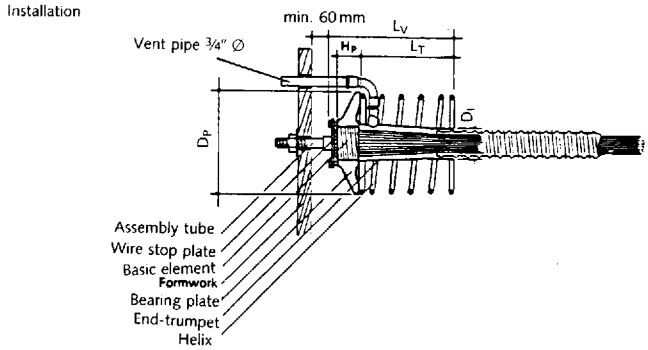
STRESSING
Stress cables with MonoGroup S-306 Jack.
For space required for jack access see
P.S.G. Technical Data Sheet No. 90

THE BBRV SYSTEM FOR PRESTRESSED CONCRETE

SHEET NO. V.5A

A fixed anchorage for use in conjunction with the Type 'C' stressing anchorage. The arrangement of the wires in the basic element and capacity are the same as in the Type 'C' anchorage.

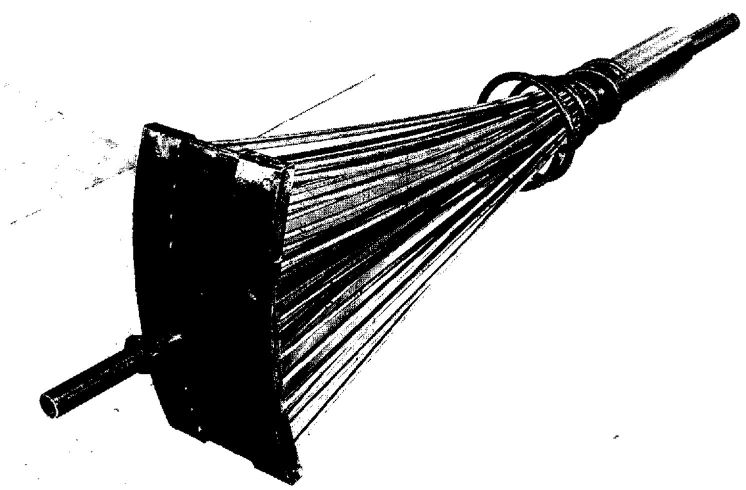
This type of fixed anchorage enables the full tendon force to be transmitted to the concrete immediately behind the bearing plate.



Type E anchorage		Type designation	E130		E170		E220	
Steel wire per anchorage, maximum number 7 mm (0.276") dia.			31		42		55	
			mm	in	mm	in	mm	in
Bearing plate	outside diameter	D_P	235	9.25	270	10.63	300	11.81
	thickness	H_P	52	2.05	60	2.36	68	2.68
End-trumpet	length	L_T	215	8.47	245	9.65	265	10.43
	connection, outer dia.	D_I	60	2.36	70	2.76	80	3.15
Assembly tube	minimum length		130	5.12	130	5.12	130	5.12
Length of anchorage		L_V	288	11.34	326	12.84	354	13.94

BBRV SINGLE FIXED ANCHORAGE SYSTEM TYPE SS, SR AND SL

SHEET NO. V.5B



BBRV TENDON SIZES AND THEIR PROPERTIES

SHEET NO. V.6

Tendon reference		B16	B24	B34	C42	C55	L73	L85	L97	L109	L121
No. of wires (7 mm dia.)		16	24	34	42	55	73	85	97	109	121
Characteristic strength using 1570 N/mm^2 wire		967	1450	2054	2538	3323	4411	5136	5861	6586	7311
Jacking force (kN) at 80% of C.S.		773	1160	1643	2030	2659	3529	4109	4689	5269	5849
Jacking force (kN) at 75% of C.S.		725	1088	1540	1903	2492	3308	3852	4396	4939	5483
Jacking force (kN) at 70% of C.S.		677	1015	1438	1776	2326	3087	3595	4103	4610	5118
Bearing Plate Side length (sq.)	A	178	220	250	280	300	335	360	385	405	425
Thickness	B	15	20	25	35	35	45	50	50	60	60
Trumpet Outside diameter	C	120	133	154	154	165	194	219	229	229	245
Anchor Head Thread diameter	D	100	115	130	90	98	125	130	145	150	155
Standard length	E	60	80	90	53	63	110	120	126	134	146
Overall diameter	F	—	—	—	—	—	160	165	185	190	200
Pull Sleeve Diameter	G	—	—	—	130	144	—	—	—	—	—
Standard length	H	—	—	—	118	138	—	—	—	—	—
Lock Nut Diameter	J	135	155	180	178	198	—	—	—	—	—
Thickness	K	30	40	50	45	53	—	—	—	—	—
Chocks Diameter	L	—	—	—	—	—	228	250	262	270	288
Min. thickness	M	—	—	—	—	—	48	52	55	59	62
Max. anchorage projection (Stnd. comps.)	N	67	87	97	118	138	205	219	228	240	255
Sheathing Internal diameter	O	40	50	60	65	75	85	95	100	105	110
External diameter		48	58	68	73	83	93	103	108	113	118

Length of trumpet 'P' ≃ Extension + 105 mm (B type anchors)
" + 120 mm (C type anchors)
" (L type anchors)

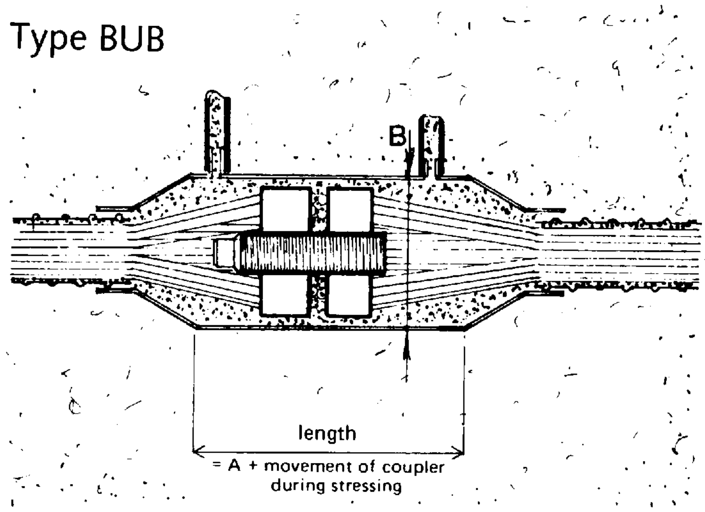
All dimensions are in millimetres.

BBRV COUPLING ANCHORS

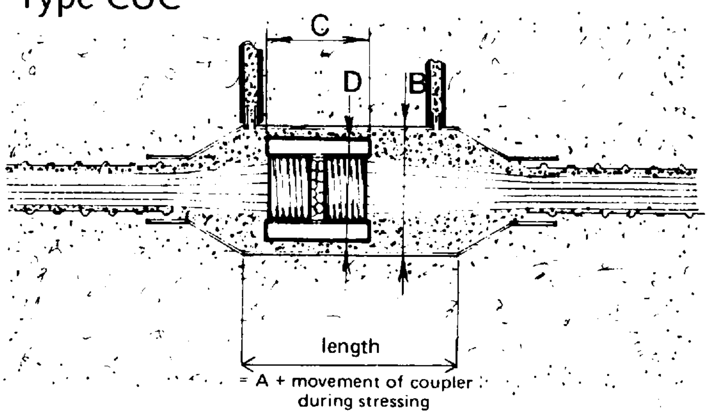
SHEET NO. V.7

Movable (unstressed)

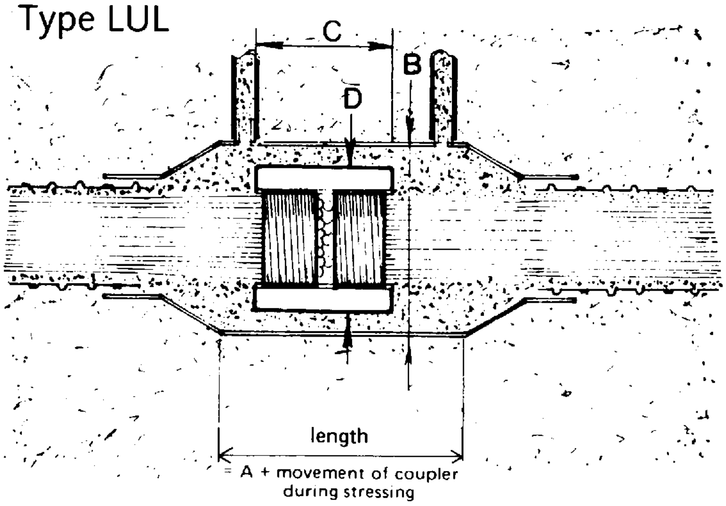
Type BUB



Type CUC



Type LUL



	A	B	C	D
B16	335	120	–	–
B24	405	133	–	–
B34	455	154	–	–
C42	160	154	140	130
C55	180	165	160	144
L73	210	180	195	161
L85	220	195	210	174
L97	235	205	215	186
L109	245	215	235	197
L121	255	230	250	208

BBRV COUPLING ANCHORS

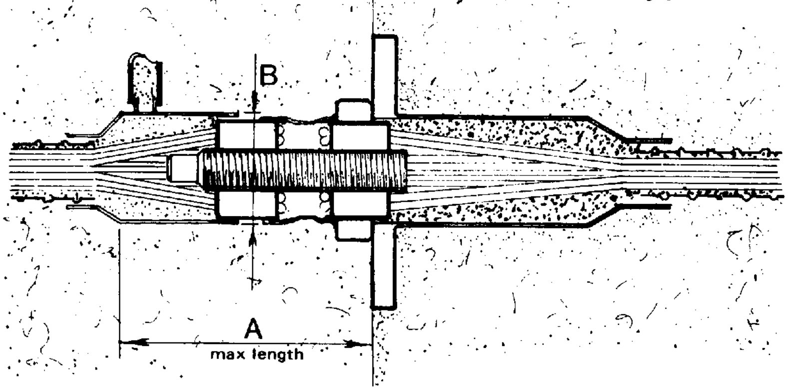
SHEET NO. V.8

Fixed (stressed)

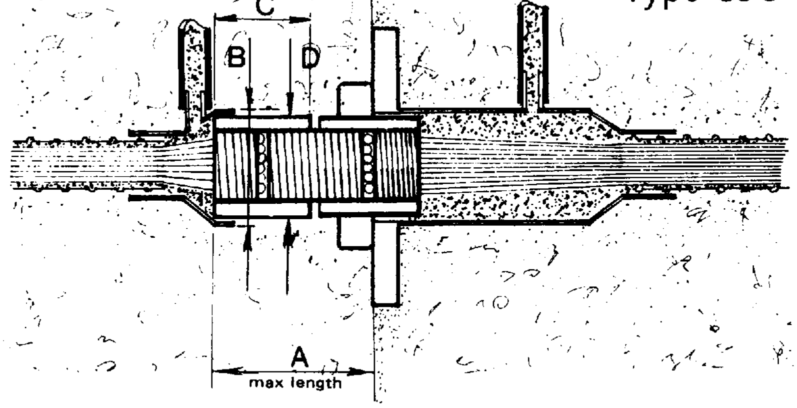
A	B	C	D
260	120	–	–
315	133	–	–
350	154	–	–
290	135	160	130
330	150	180	144
315	170	190	165
340	180	210	175
351	195	215	190
368	205	230	200
388	215	245	210

All dimensions are in mm.

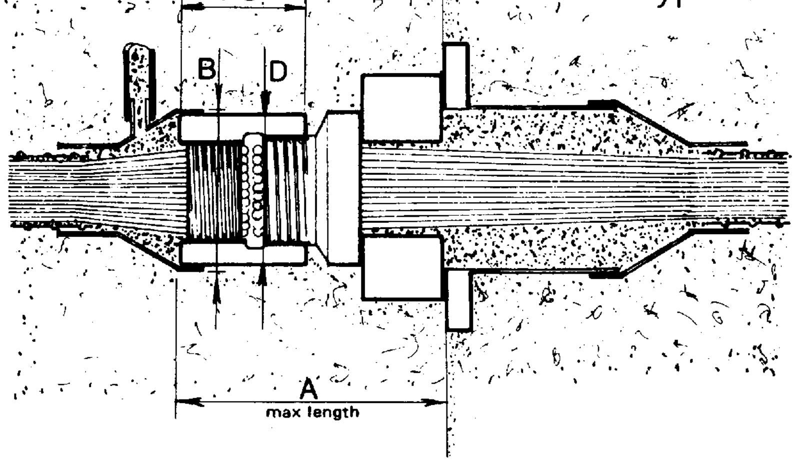
Type BSB



Type CSC



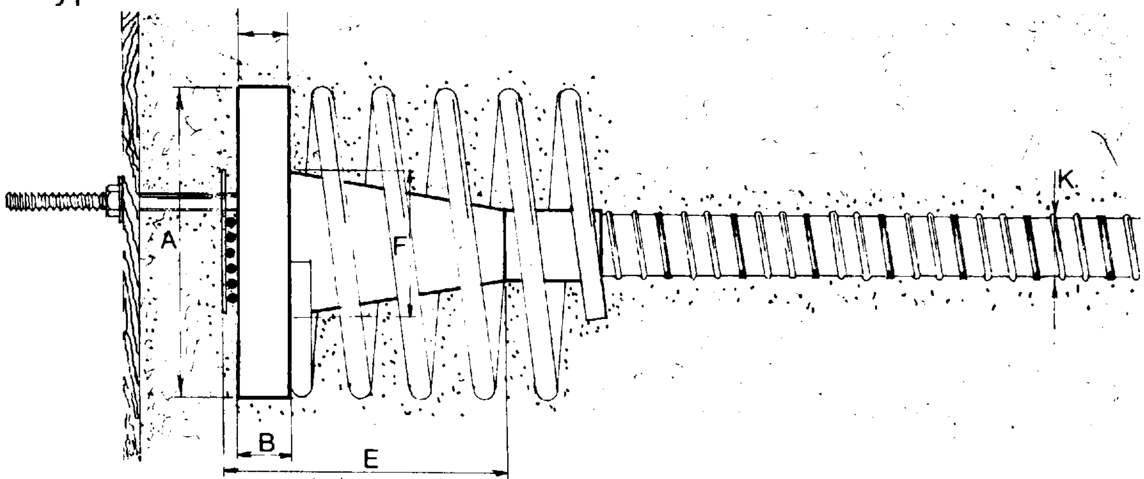
Type LSL

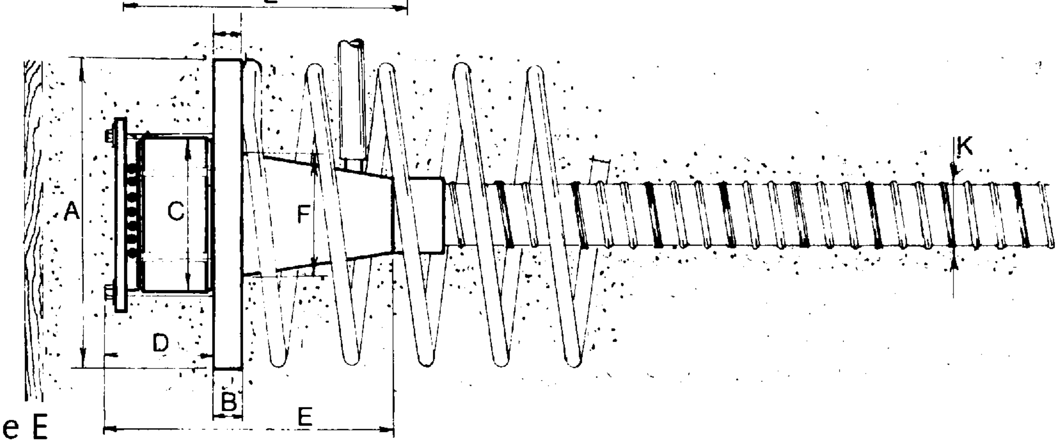


BBRV FIXED ANCHORS

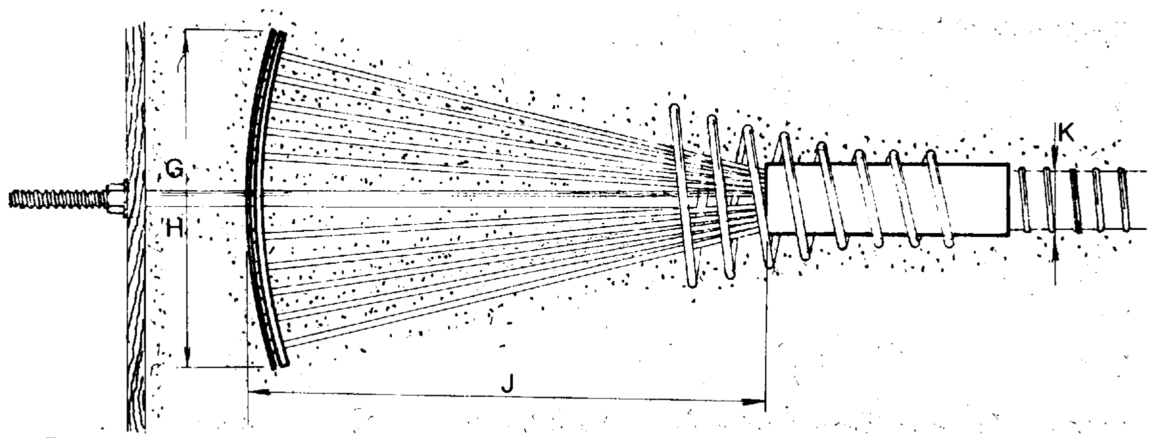
SHEET NO. V.9

Type F





Type E

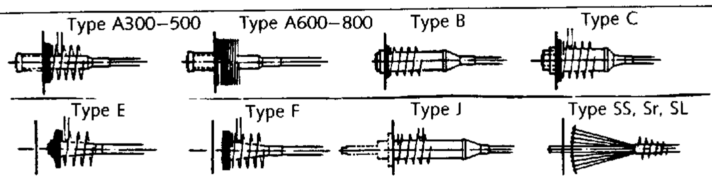


Type S

SMALL CAPACITY TENDONS UP TO 2658 kN

SHEET NO. V.10

Characteristic tensile strength f_u	Maximum working load (80% f_u)	Number of 7 mm dia. wires	Anchorages: Stressing	Anchorages: Fixed	Nominal reference	Standard single bearing plate	Combined bearing plate: Minimum centres of anchorages	Minimum concrete edge distance	SIM-TUBE sheathing internal diameter	Stressing equipment clearance dimensions with dynamometer	Stressing equipment clearance dimensions without dynamometer
kN	kN	No.	Type	Type	Ref. No.	mm	mm	mm	mm	mm	mm
						a × b	c × d	e		f × g dia.	h × g dia.
			B			150 × 150	138 × 138	76			
			J			150 × 150					
483	387	8		F	32	120 × 120			30	1524 × 310	1344 × 310
				SR		120 × 150					
				SL		60 × 300					
			B			175 × 175	171 × 171	89			
			J			175 × 175					
966	773	16		F	64	160 × 160			40	1524 × 310	1344 × 310
				SR		150 × 220					
				SL		80 × 400					
			B			200 × 200	197 × 197	108			
			J			200 × 200					
				F		220 × 220					
1450	1160	24		SS	100	220 × 220			50	1524 × 310	1344 × 310
				SR		160 × 300					
				SL		80 × 560					
			C			250 × 250	235 × 235	127			
				E		235 dia.					
1872	1498	31		SS	130	260 × 260			55	1524 × 340	1324 × 340
				SR		180 × 360					
				SL		120 × 560					
			B			250 × 250	235 × 235	127			
			J			250 × 250					
				F		260 × 260					
2054	1643	34		SS	138	260 × 260			55	1524 × 340	1324 × 340
				SR		180 × 360					
				SL		120 × 560					
			C			280 × 280	241 × 267	152			
				E		270 dia.					
2537	2029	42		SS	170	300 × 300			65	1880 × 440	1580 × 440
				SR		200 × 450					
				SL		140 × 650					
			C			300 × 300	267 × 305	152			
				E		300 dia.					
3322	2658	55		SS	220	340 × 340			75	1880 × 440	1580 × 440
				SR		220 × 500					
				SL		160 × 700					



TYPE 'F' FIXED ANCHORAGE

SHEET NO. V.11

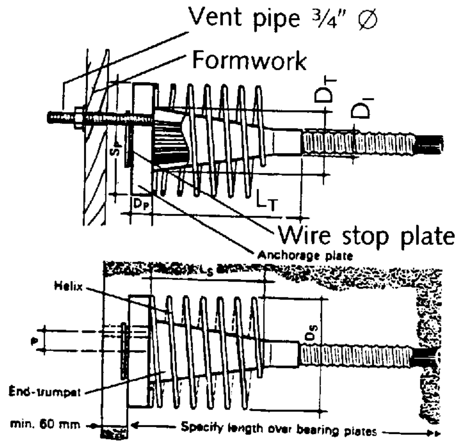
A fixed anchorage consisting of a rectangular steel plate drilled to receive the individual button-headed wires seated directly on this plate. A thin cover plate retains the button-heads during fixing.

With this anchorage, the prestressing force is transferred to the concrete through the plate.

Type 'F' anchorages are normally used in connection with movable anchorages of the Type 'B' series. If there are several tendons in one part of a structure, it is advisable to put half the Type 'F' anchorages at one end and half at the other.

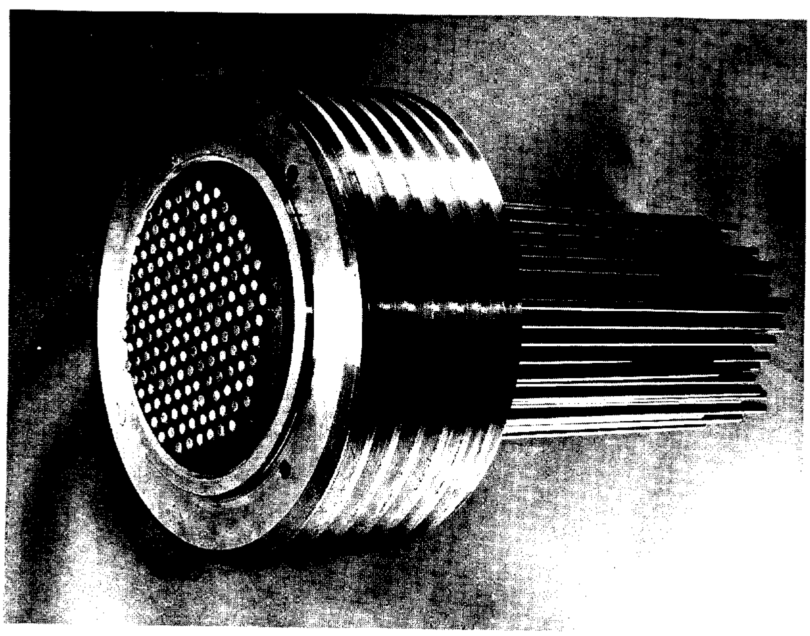
The anchorage is fastened to the formwork with a pipe which serves at the same time as a vent or as a grout connection.

This pipe passes through the plate and should be well-greased prior to fixing to facilitate removal after grouting.



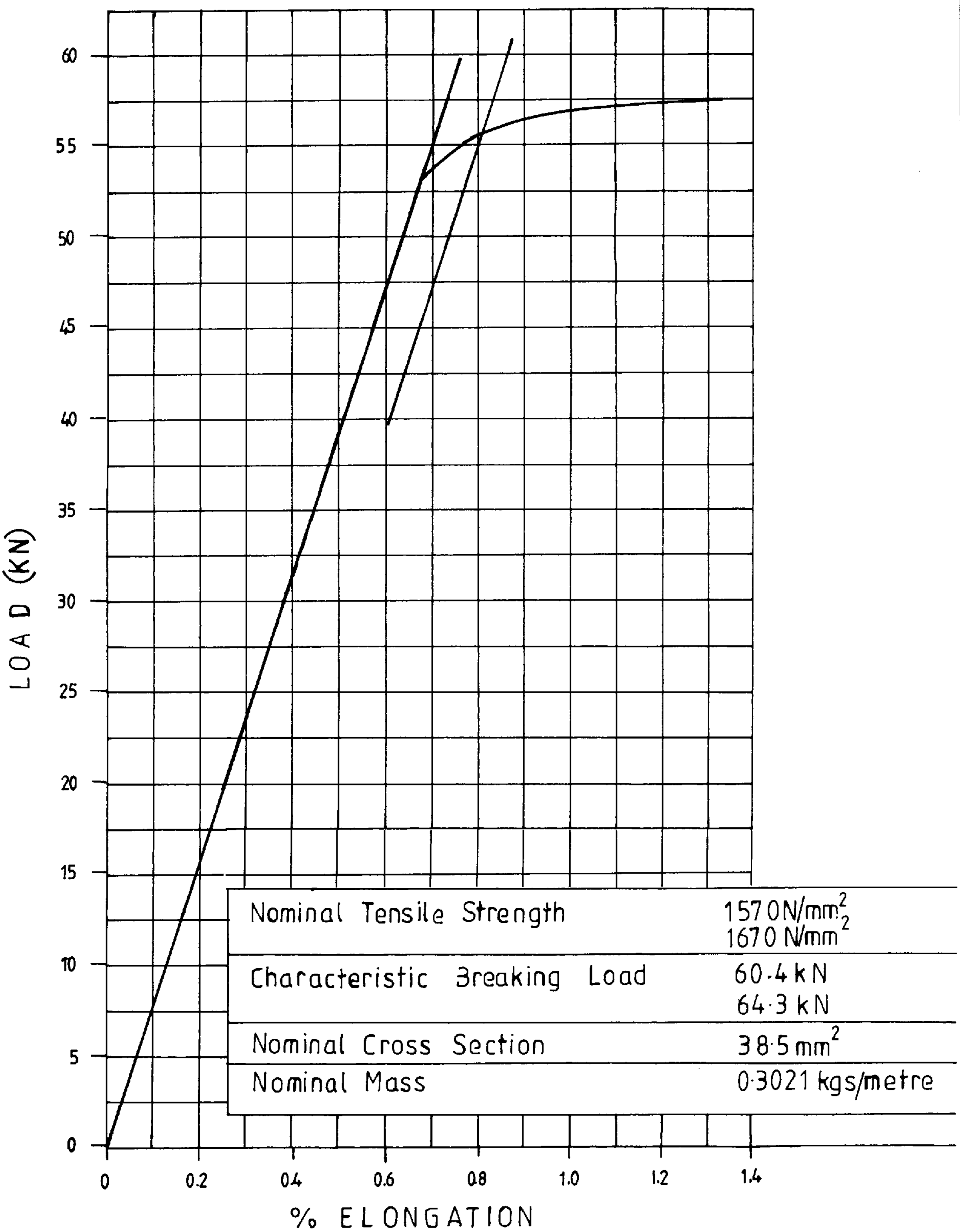
Type F anchorage		Type designation	F32		F64		F100		F138	
Steel wires per anchorage, maximum number 7 mm (0.276") dia.			8		16		24		34	
			mm	in	mm	in	mm	in	mm	in
Anchorage	side length	S_P	120	4.72	160	6.30	220	8.66	260	10.24
	thickness	D_P	15	0.59	25	0.98	40	1.58	50	1.97
End trumpet	outer diameter	D_T	87	3.43	112	4.41	128	5.04	148	5.83
	connection, outer dia.	D_I	35	1.38	45	1.77	55	2.17	60	2.36
	length	L_T	200	7.87	250	9.84	300	11.81	350	13.78
Helix	outer diameter	D_S	120	4.72	160	6.30	220	8.66	260	10.24
	length (approx.)	L_S	250	9.84	250	9.84	250	9.84	250	9.84
Distance of centre vent pipe to tendon axis		e	0	0	0	0	35	1.38	45	1.77

BBRV 163 No/7 mm Tendon



TYPICAL TENSILE LOAD EXTENSION GRAPH FOR 7 mm DIA. PLAN HIGH TENSILE WIRE

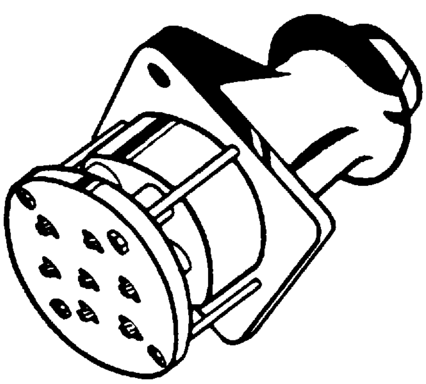
SHEET NO. V.12



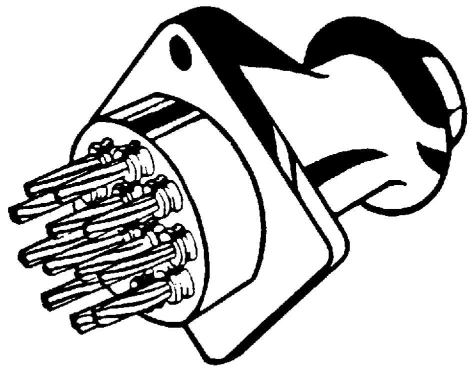
Nominal Tensile Strength	1570 N/mm^2 1670 N/mm^2
Characteristic Breaking Load	60·4 kN 64·3 kN
Nominal Cross Section	38·5 mm^2
Nominal Mass	0·3021 kgs/metre

CCL SYSTEM

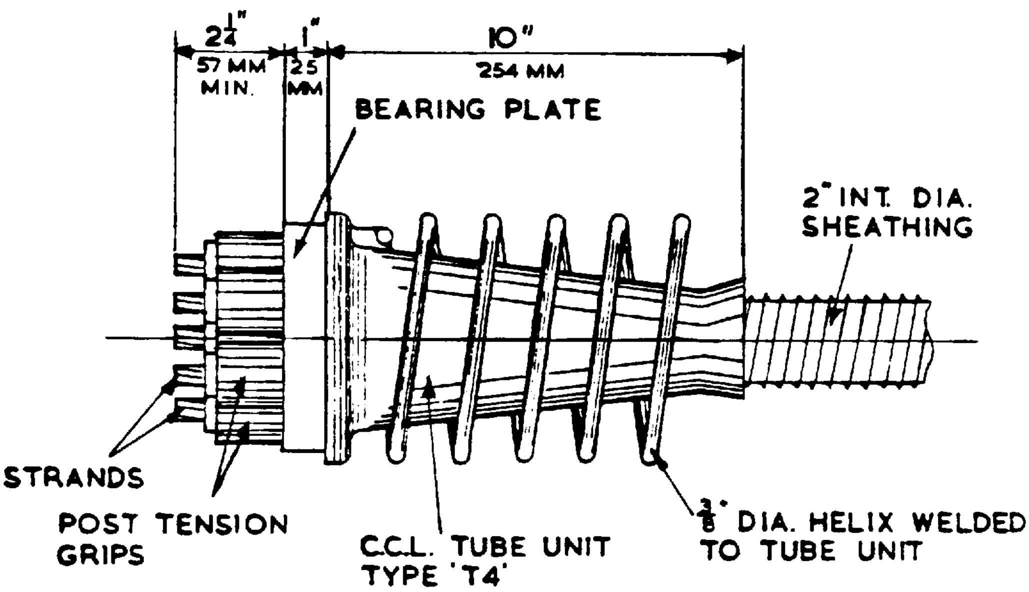
SHEET NO. V.13



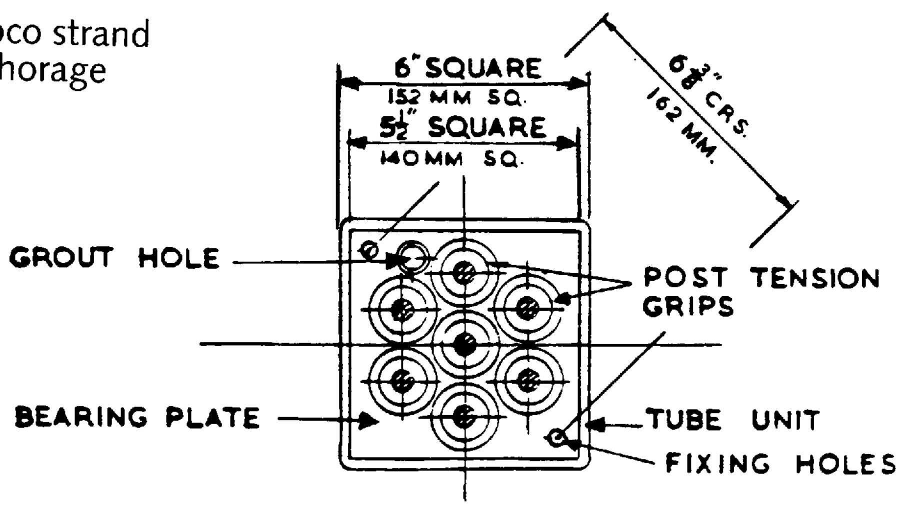
CABCO/MULTIFORCE
DEAD END (BURIED) ANCHORAGE



CABCO/MULTIFORCE
STRESSING ANCHORAGE



Cabco strand anchorage



CABCO PRESTRESSING TENDON MAIN DATA

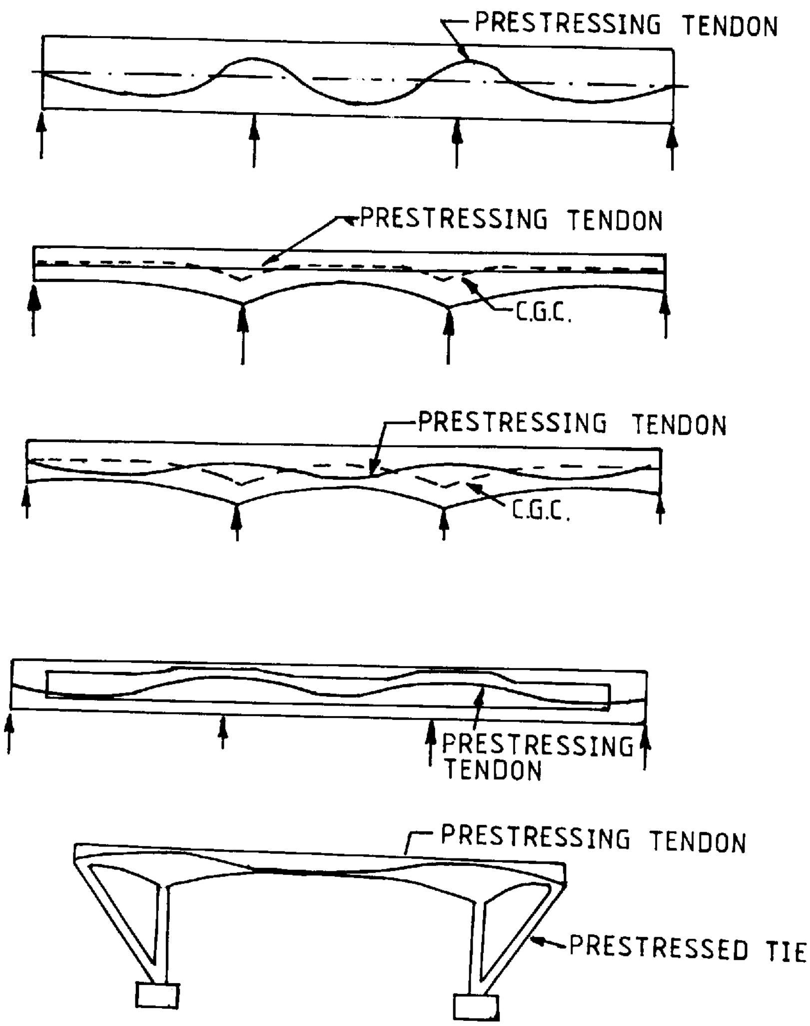
SHEET NO. V.14

Anchorage	System	Tendon*	Tendon Forces (kN) P_k	$0.8\,P_k$	$0.7\,P_k$	Anchorage size mm	Sheath internal dia. mm
U1	Cabco	4/13 STD.	660.0	528.0	462.0	130	42
		4/13 SUP.	736.0	588.8	515.2	"	"
		4/13 DYF.	836.0	668.8	585.2	"	"
U2	Cabco	4/15 STD.	908.0	726.4	635.6	175	51
		4/15 SUP.	1000.0	800.0	700.0	"	"
		4/15 DYF.	1200.0	960.0	840.0	"	"
		7/13 STD.	1155.0	924.0	808.5	"	"
		7/13 SUP.	1288.0	1030.4	901.6	"	"
		7/13 DYF.	1453.0	1170.4	1024.1	"	"
		4/18 STD.	1480.0	1184.0	1036.0	175	51
		4/18 DYF.	1520.0	1216.0	1064.0	"	"
U3	Cabco	7/15 STD.	1589.0	1271.2	1112.3	215	75
		7/15 SUP.	1750.0	1400.0	1225.0	"	"
		7/15 DYF.	2100.0	1680.0	1470.0	"	63
		12/13 STD.	1980.0	1584.0	1386.0	215	81
		12/13 SUP.	2208.0	1766.4	1545.6	215	"
	Multiforce	12/13 STD.	1980.0	1584.0	1386.0	215	"
		12/13 SUP.	2208.0	1766.4	1545.6	215	"
U4	Cabco	7/18 STD.	2590.0	2072.0	1813.0	245	81
		7/18 DYF.	2660.0	2128.0	1862.0	"	75
		12/13 DYF.	2508.0	2006.4	1755.6	"	75
		12/15 STD.	2724.0	2179.2	1906.8	"	81
		12/15 SUP.	3000.0	2400.0	2100.0	"	81
U5	Cabco	12/15 DYF.	3600.0	2880.0	2520.0	265	81
	Multiforce	19/13 STD.	3135.0	2508.0	2194.5	"	"
		19/13 SUP.	3496.0	2796.8	2447.2	"	"
		12/15 STD.	2724.0	2179.2	1906.8	245	"
		12/15 SUP.	3000.0	2400.0	2100.0	245	"
		12/15 DYF.	3600.0	2880.0	2520.0	265	"
U6	Multiforce	25/13 STD.	4125.0	3300.0	2887.5	300	90
		25/13 SUP.	4600.0	3680.0	3220.0	"	"
		13/15 DYF.	3900.0	3120.0	2730.0	"	84
U7	Multiforce	31/13 STD.	5115.0	4092.0	3580.5	335	100
		31/13 SUP.	5704.0	4563.2	3992.8	"	"
		19/15 STD.	4313.0	3450.0	3019.1	"	"
		19/15 SUP.	4750.0	3800.0	3325.0	"	"
		19/15 DYF.	5700.0	4560.0	3990.0	"	"
U8	Multiforce	19/18 DYF.	7220.0	5776.0	5054.0	"	"
	Strand-force	5/18 STD.	1776.0	1480.0	1295.0	362 × 89	114 × 25
		5/18 DYF.	1824.0	1520.0	1330.0	"	"
		10/18 STD.	3530.0	2960.0	2590.0	362 × 171	" twin
		10/18 DYF.	3648.0	3040.0	2660.0	"	" twin

* STD. Standard
SUP. Super Strand
DYF. Dyform Strand

TYPICAL CONTINUOUS PRESTRESSED BEAMS

SHEET NO. V.15



TYPICAL CONTINUOUS PRESTRESSED BEAMS

V.3 Structural Detailing of Prestressed Concrete Structures

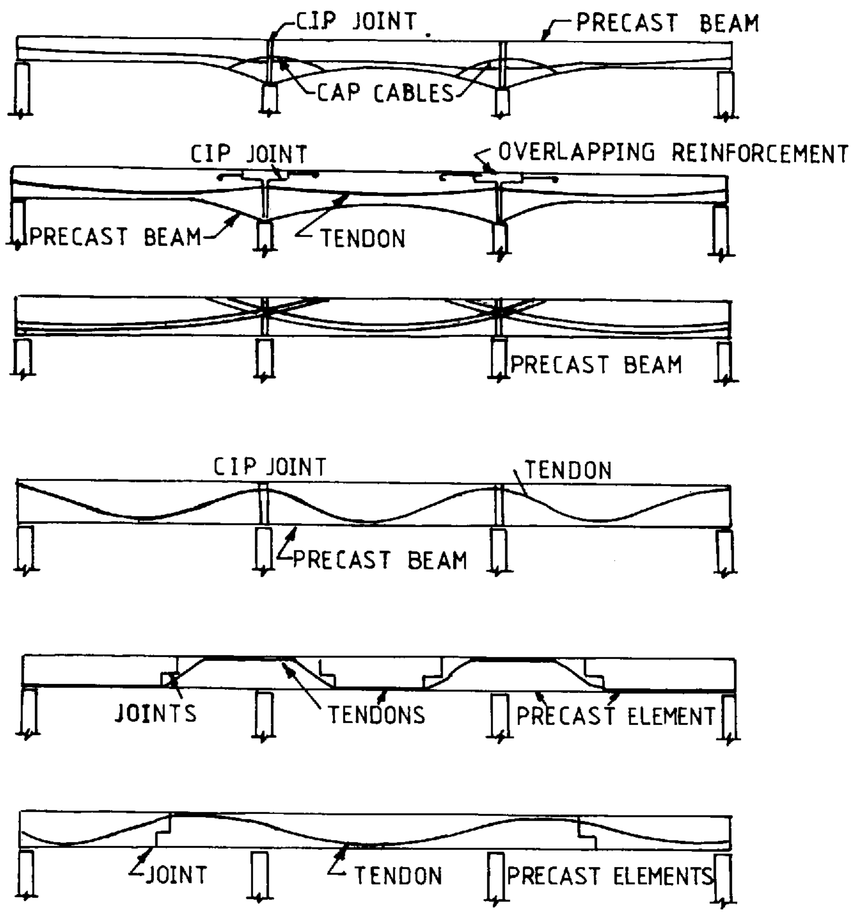
Prestressed concrete structural detailing of major structures is given later. In this section, the reader is familiarized with basic problems. The first object is to lay out cables. Here many variations exist. Sheet Nos. V.15 and V.16 show the tendon layouts for continuous beams, precast prestressed elements and cast-in-place (CIP) slabs on precast prestressed beams with continuous post-tensioned tendons.

Many variations exist in the design and detailing of prestressed beams. Sheet No. V.17 gives a detailed cross-section of a partially prestressed concrete beam. Sheet No. V.18 gives a typical example of anchorage reinforcement and tendon details of a beam using Freyssinet cone type anchorages.

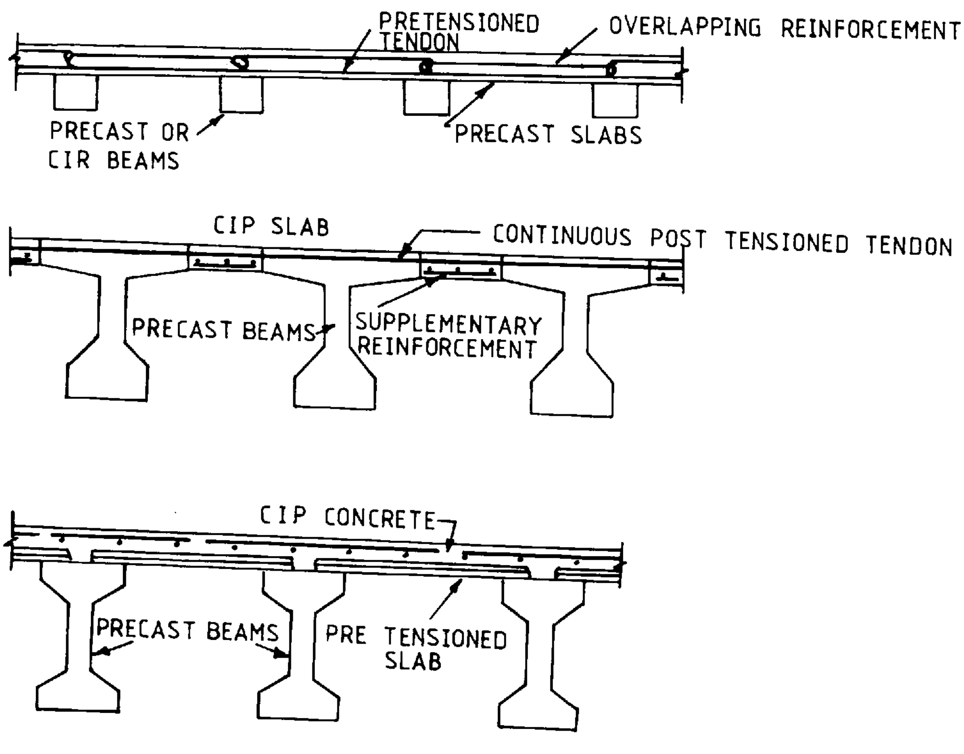
A number of available texts are mentioned in the references which can be referred to for the design and detailing of pre- and post-tensioned structures.

CONTINUOUS BEAMS OF PRECAST ELEMENTS

SHEET NO. V.16

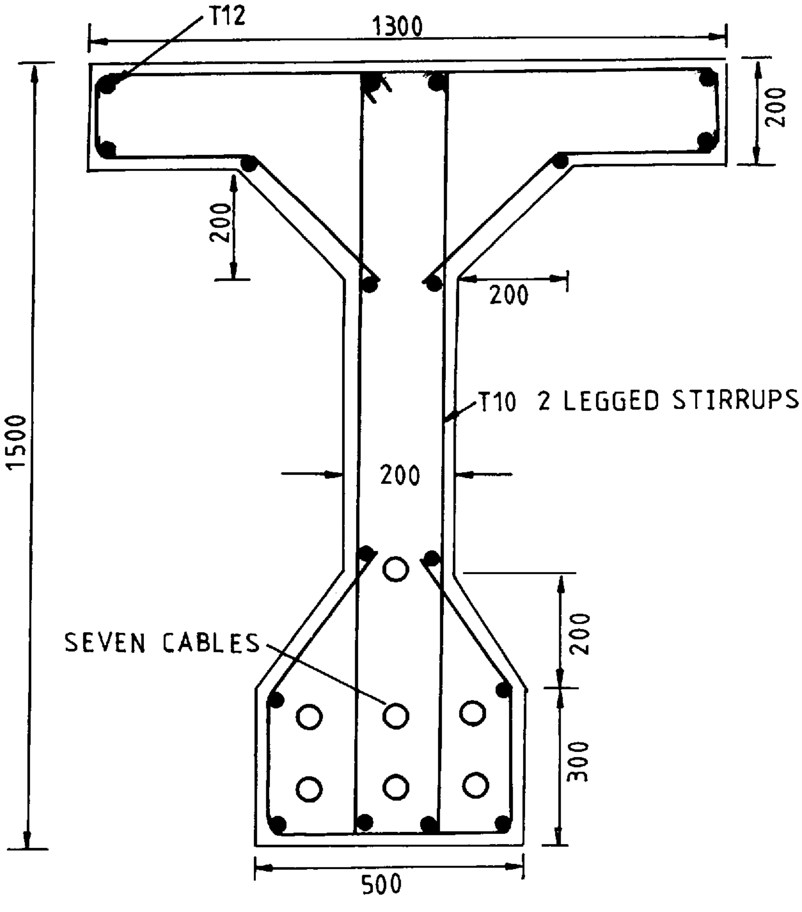


CONTINUOUS PRESTRESSED SLABS



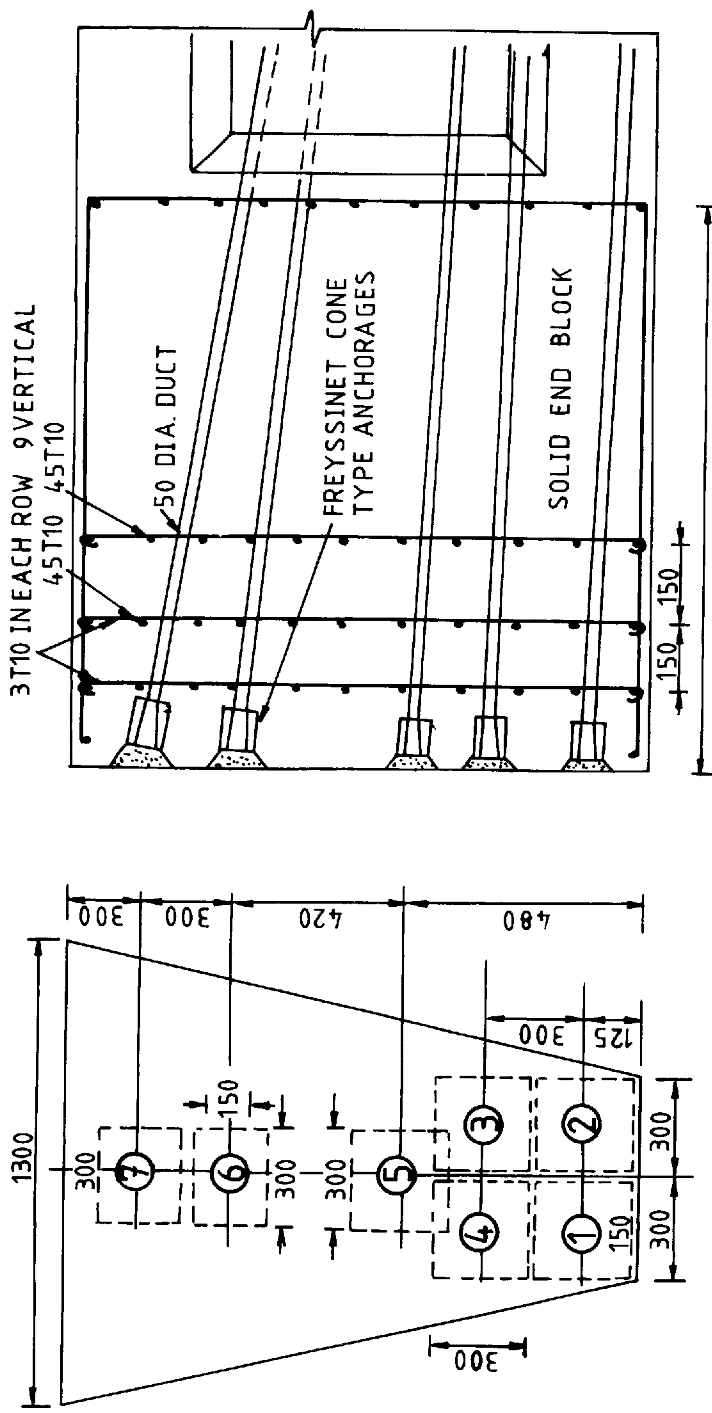
PARTIALLY PRESTRESSED CONCRETE BEAM

SHEET NO. V.17



ANCHORAGE ZONE REINFORCEMENT

SHEET NO. V.18



(b) Sectional elevation

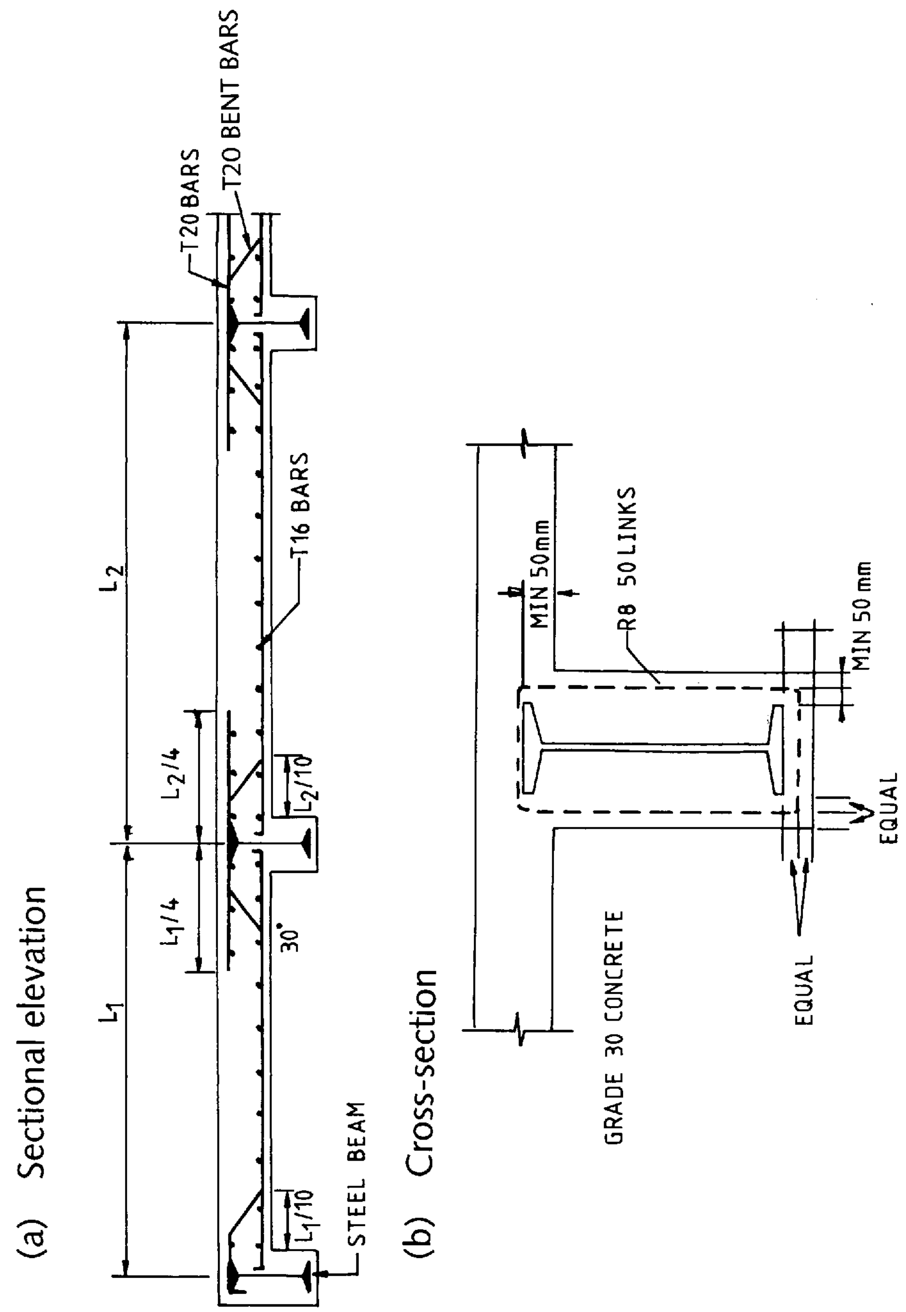
(a) Cross-section

Section VI

Composite Construction, Precast Concrete Elements, Joints and Connections

COMPOSITE STEEL–CONCRETE BEAM SLAB

SHEET NO. VI.1



(a) Sectional elevation

(b) Cross-section

VI.1 Composite Construction and Precast Elements

Composite construction consists of a combination of prefabricated unit and cast-*in-situ* concrete in a structure. The prefabricated unit may be in reinforced concrete, pre-stressed concrete or structural steel. To obtain composite action, shear connectors are placed in the form of studs, channels, spirals etc., projecting from steel units such as steel beams or precast units. Their function is to transfer horizontal shear entirely from one element to another. The shear connectors are welded on to steel beams and concrete is cast *in situ* around them. In the case of precast concrete elements such as beams and cast-*in-situ* slabs, a full horizontal shear is effected at the interface between these two elements when the deformation at the upper surface of the beam and the lower surface of the slab are the same.

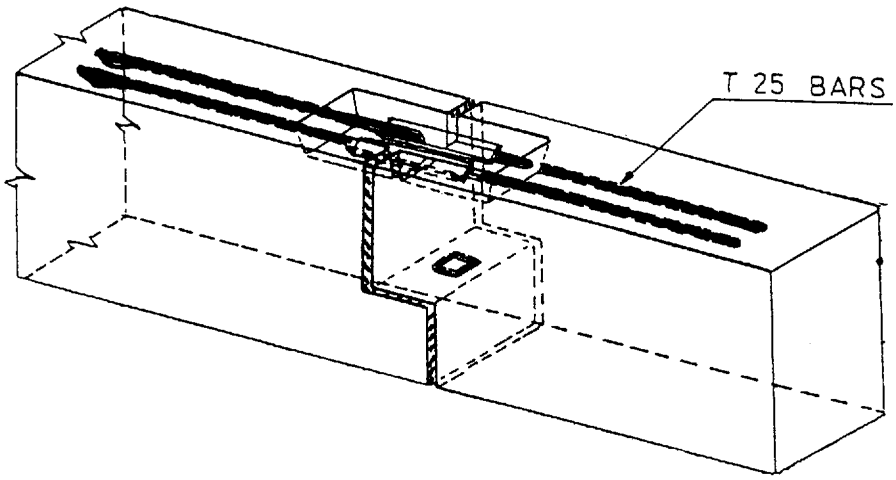
Precast construction consists of fabrication of various elements of a structure in a factory. Such a construction is commonly used in buildings and bridges. It results in an economy of formwork and scaffolding, economy in concrete, economy resulting from standardization and mass production of various elements and speedier construction. The disadvantages and shortcomings of such a construction are (a) transport costs, (b) the need for highly skilled labour, and (c) a reduction in the monolithic strength of the structure.

Sheet No. VI.1 shows a sectional elevation and a cross-section of a composite steel–concrete beam slab. The steel beam is encased in concrete. Codes give equations and specifications for designing and detailing such constructions.

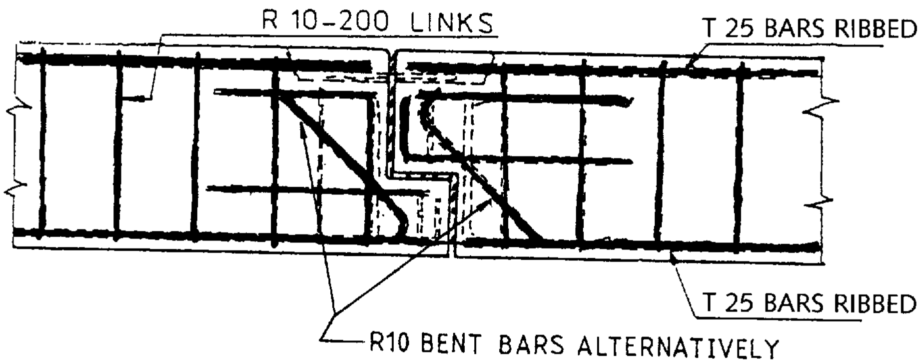
BEAM TO BEAM COMPOSITE CONNECTION (BARS WELDED)

SHEET NO. VI.2

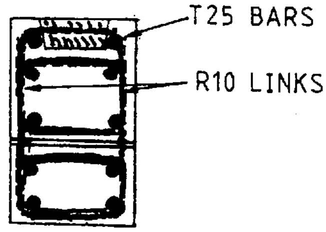
(a) Isometric view



(b) Sectional elevation



(c) Cross-section

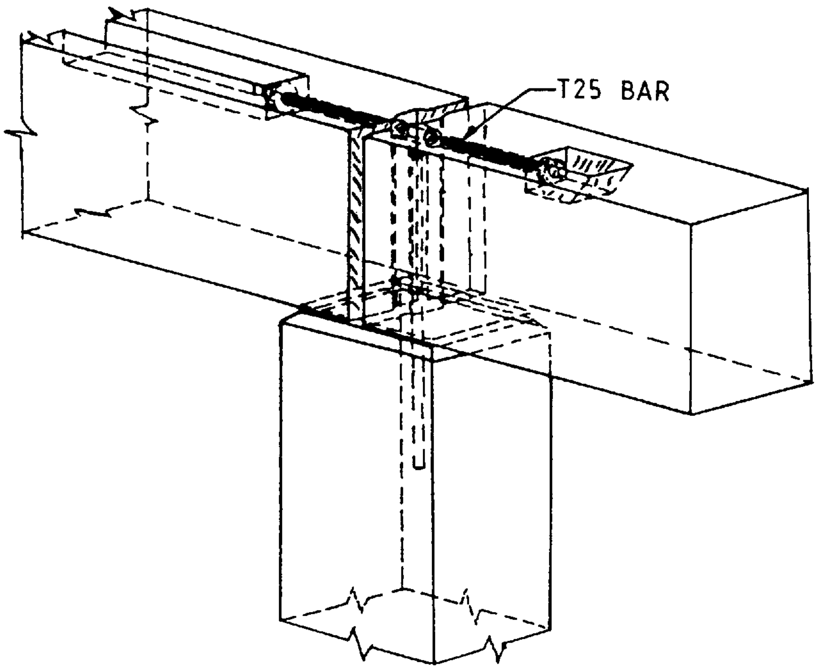


Sheet No. VI.2 refers to composite connections between two identical precast beam elements. Both the isometric view and the sectional elevation show the two beams with opposite notches or nibs connected by mechanical fastenings or bolts. Shear stresses at the nib are reduced by the introduction of the bent bars. In addition, a bar cast in one end is projected outside to be inserted into the hole left in the other element. The two elements will achieve a monolothic structure of higher efficiency. A similar method is adopted by connecting two precast concrete beam elements by means of high tensile bars as tie rods leaving grooves at the top of the concrete and filling them with a specified filler. At the bottom a steel bar as shown on Sheet No. VI.3 is welded to a steel plate which is then welded to a bearing plate on top of the precast column bonded by a steel bar. Sheet No. VI.4 shows a composite beam connected to the rib floor units using bars either with sleeve joints and links or bent bars welded to each other or a bar loop between the elements. In the later case in Sheet No. VI.4.a the common plates are welded. An isometric detailing in 3D is given for main beams connected to secondary beams using inserted bars in Sheet No. I.3.b Typical cross-sections for VI.4.b are given in VI.4.c.

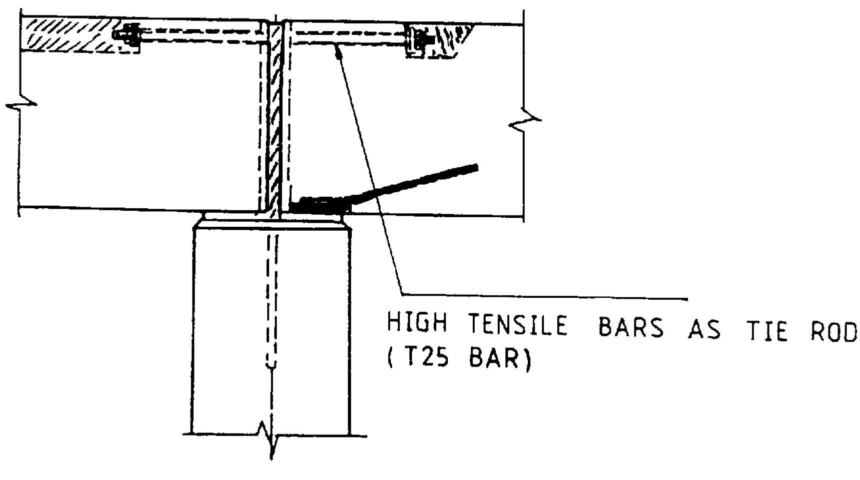
BEAM TO COLUMN CONNECTION USING HIGH TENSILE BARS AS TIE RODS

SHEET NO. VI.3

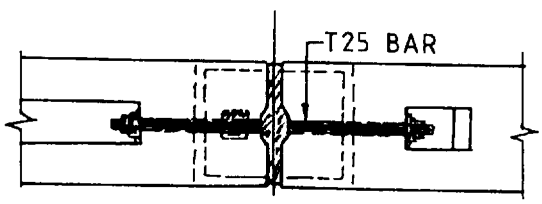
(a) Isometric view



(b) Sectional elevation

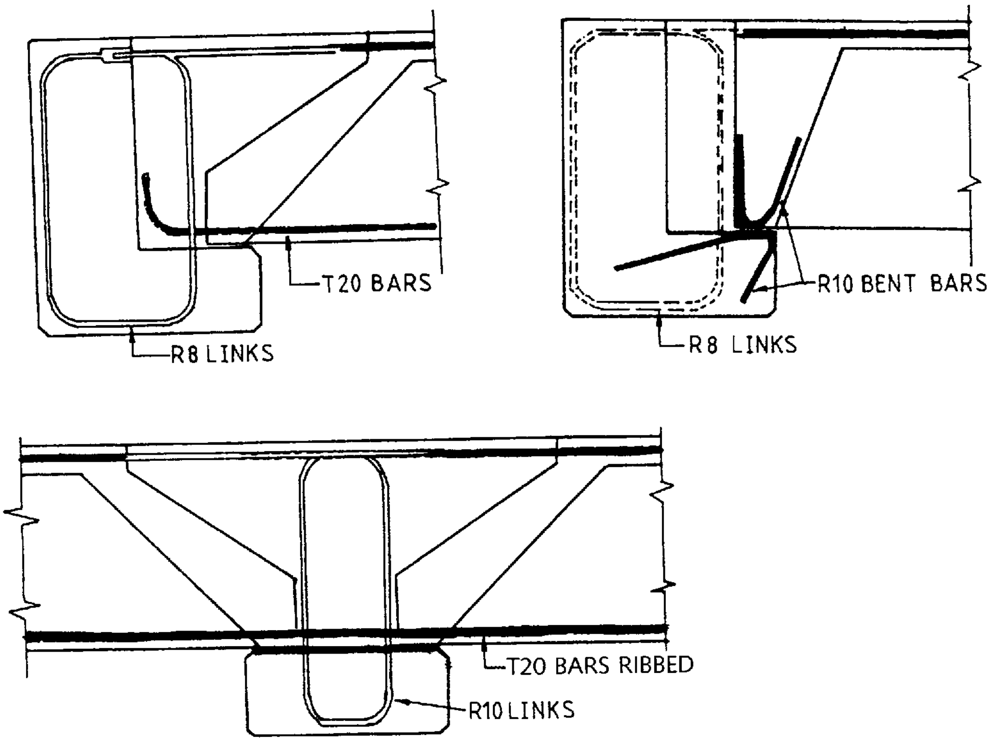


(c) Top plan

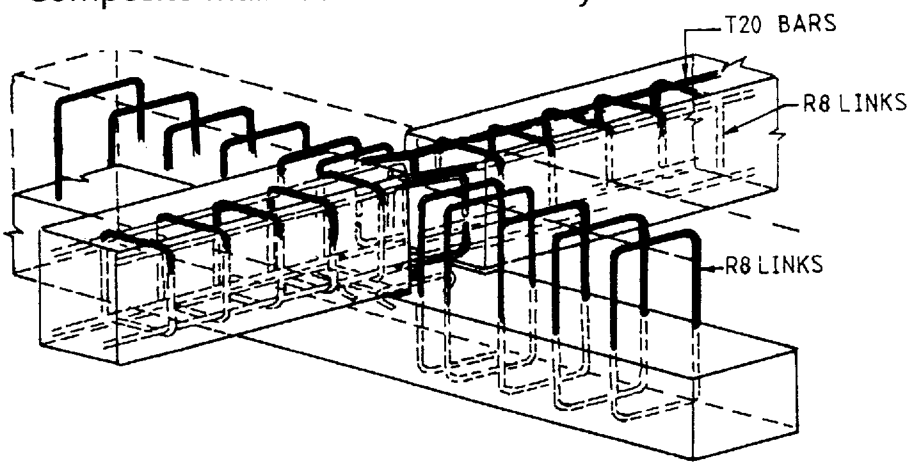


SHEET NO. VI.4

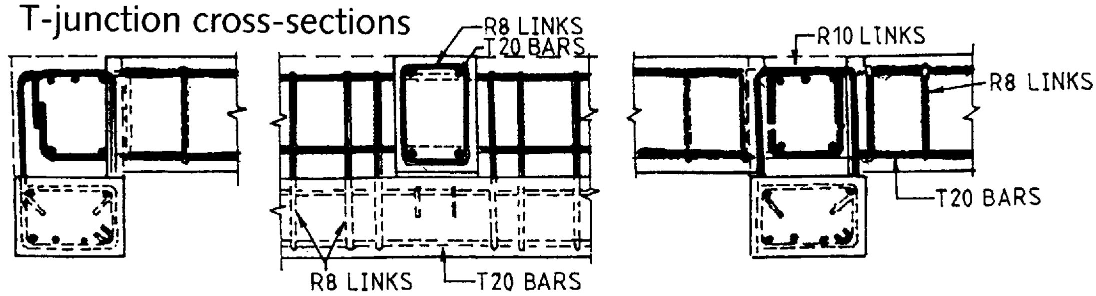
(a) Composite beam connected to ribbed floor units with skirted ends



(b) Composite main beam to secondary beams

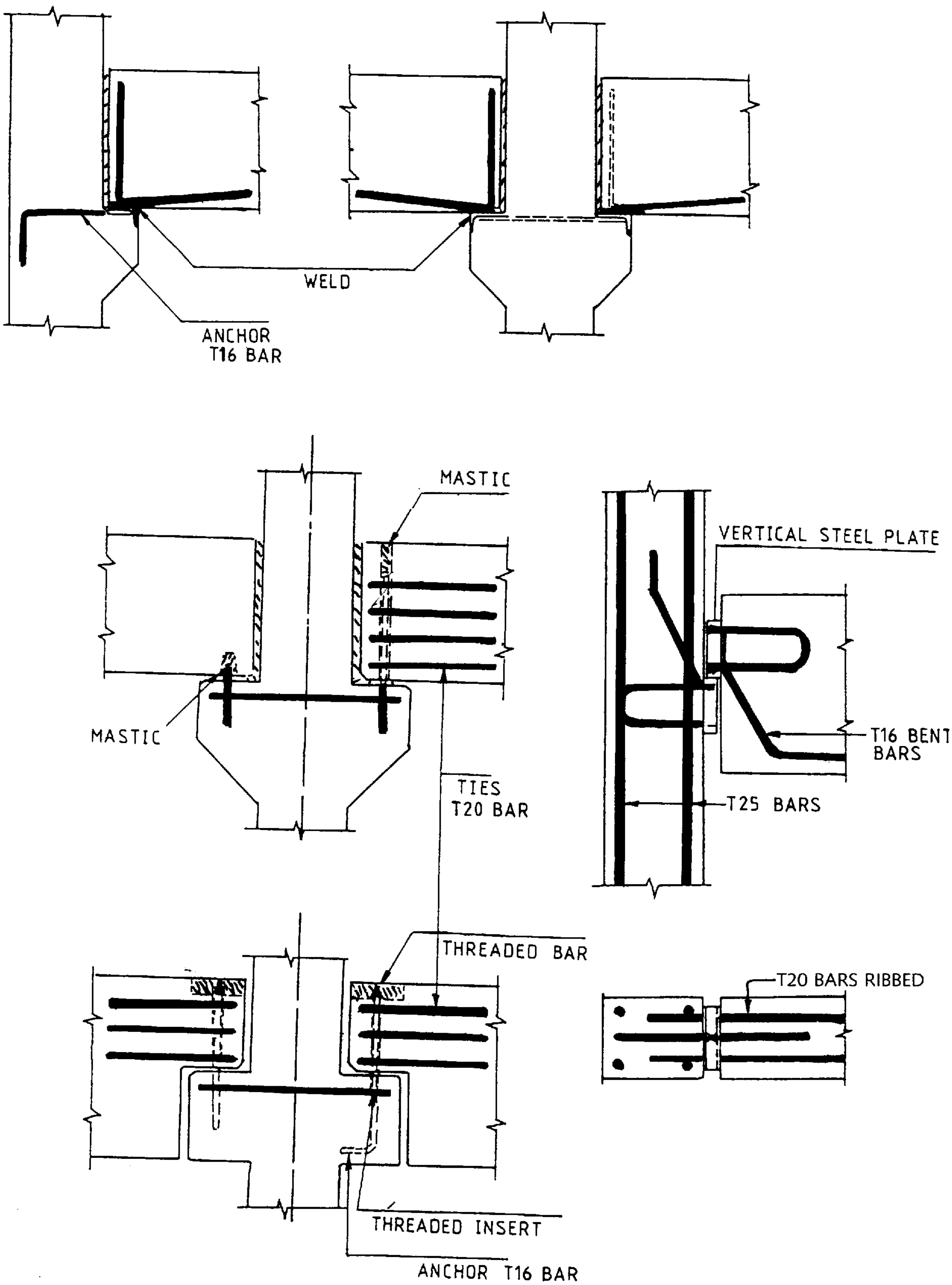


(c) T-junction cross-sections



BEAM TO COLUMN: USING STEEL BEARING PLATES, VERTICAL PLATES AND DOWELS

SHEET NO. VI.5



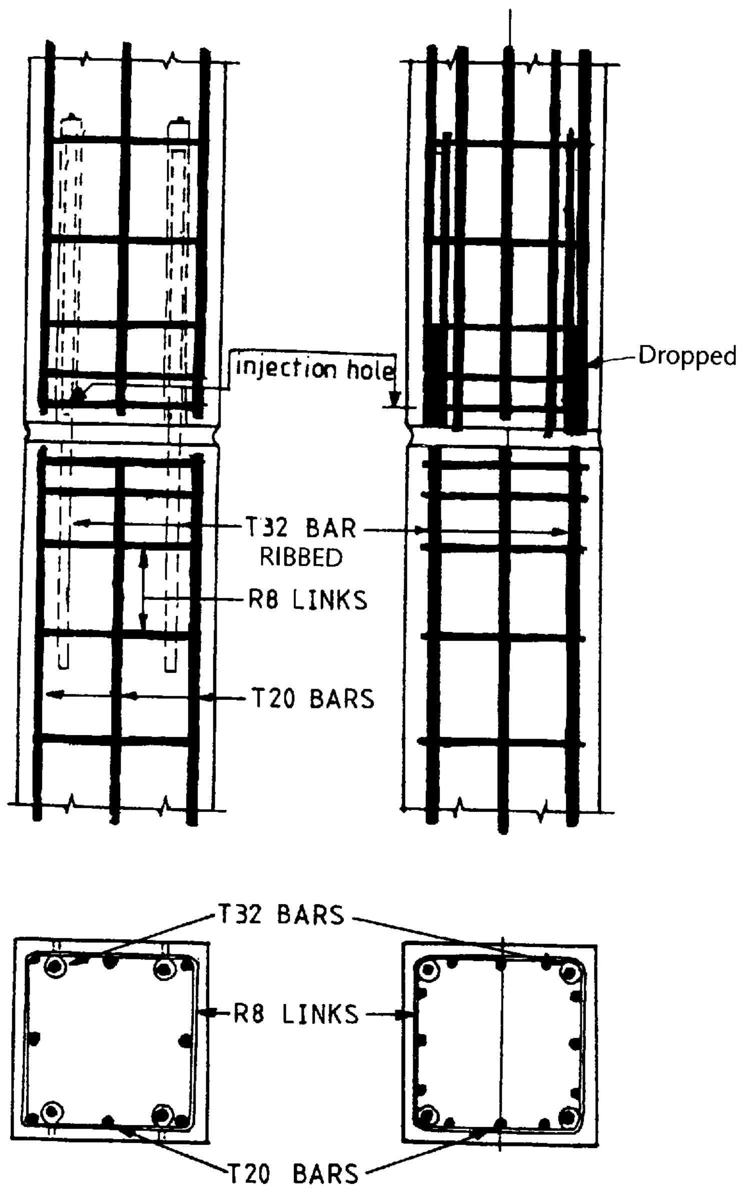
Precast concrete beams resting on column brackets or corbels are detailed using plates and dowel bars as threaded inserts as shown on Sheet No. VI.5. Where holes are left because of threaded bars, they are filled with an approved mastic. Details shown on Sheet No. VI.5 represent a few methods for connecting precast elements.

Sometimes factory-made column elements are to be connected to make larger columns of specified lengths. Dowel bars as shown on Sheet No. VI.6 are used to erect such columns. Injection holes are left to fill in hollow areas with grout.

Where prestressing is used to connect precast elements such as those shown on Sheet No. VI.5, instead of tie rods a post-tensioned cable or tendon is introduced. This is shown on Sheet No. VI.7. In such circumstances plastic or steel ducts are left with special holes in the top part of columns, and cables are finally pushed through and stressed. The steel plates at corbels are welded afterwards. A nominal weld of 6 mm would in most cases be enough.

COLUMN TO COLUMN CONNECTION USING DOWEL BARS

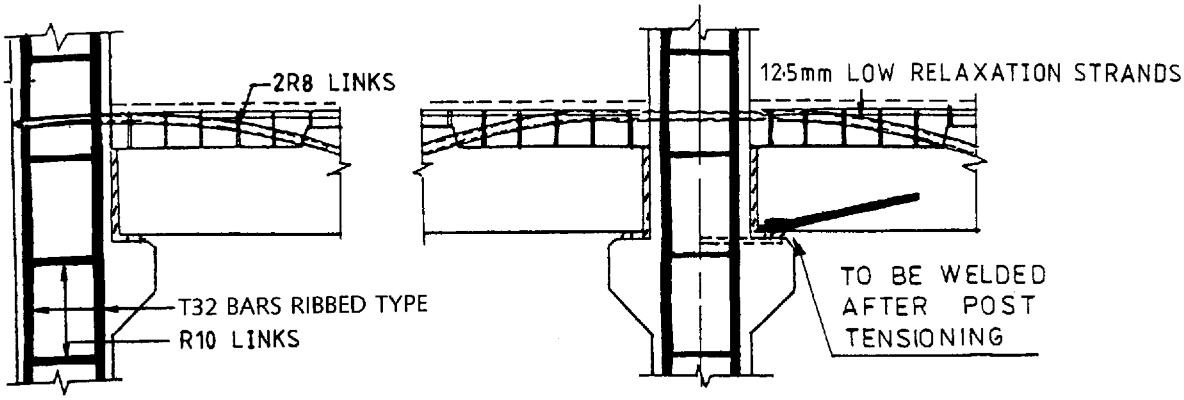
SHEET NO. VI.6



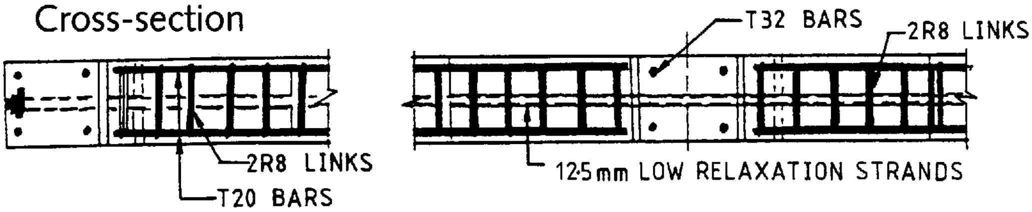
BEAM TO COLUMN: COMPOSITE BEAMS BY POST-TENSIONING SUPPORTED ON CONCRETE CORBELS

SHEET NO. VI.7

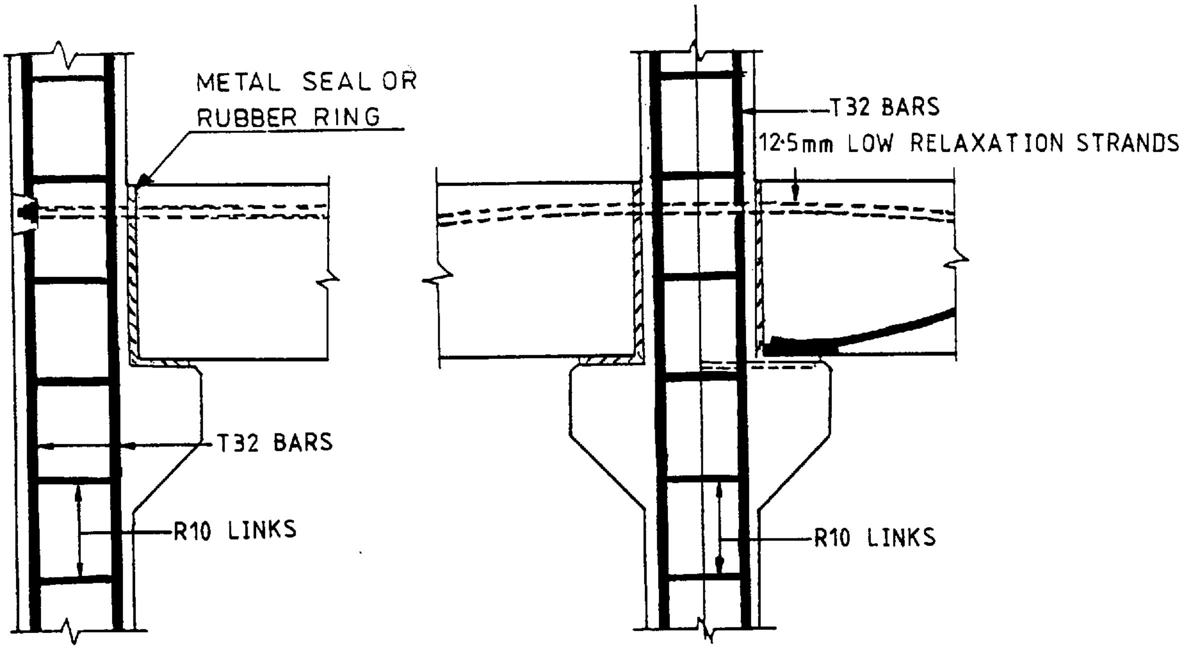
(a) Side view



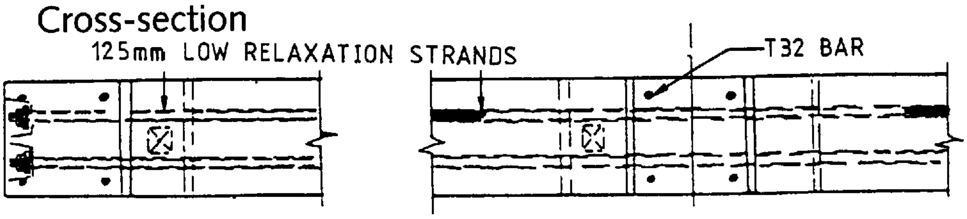
(b) Cross-section

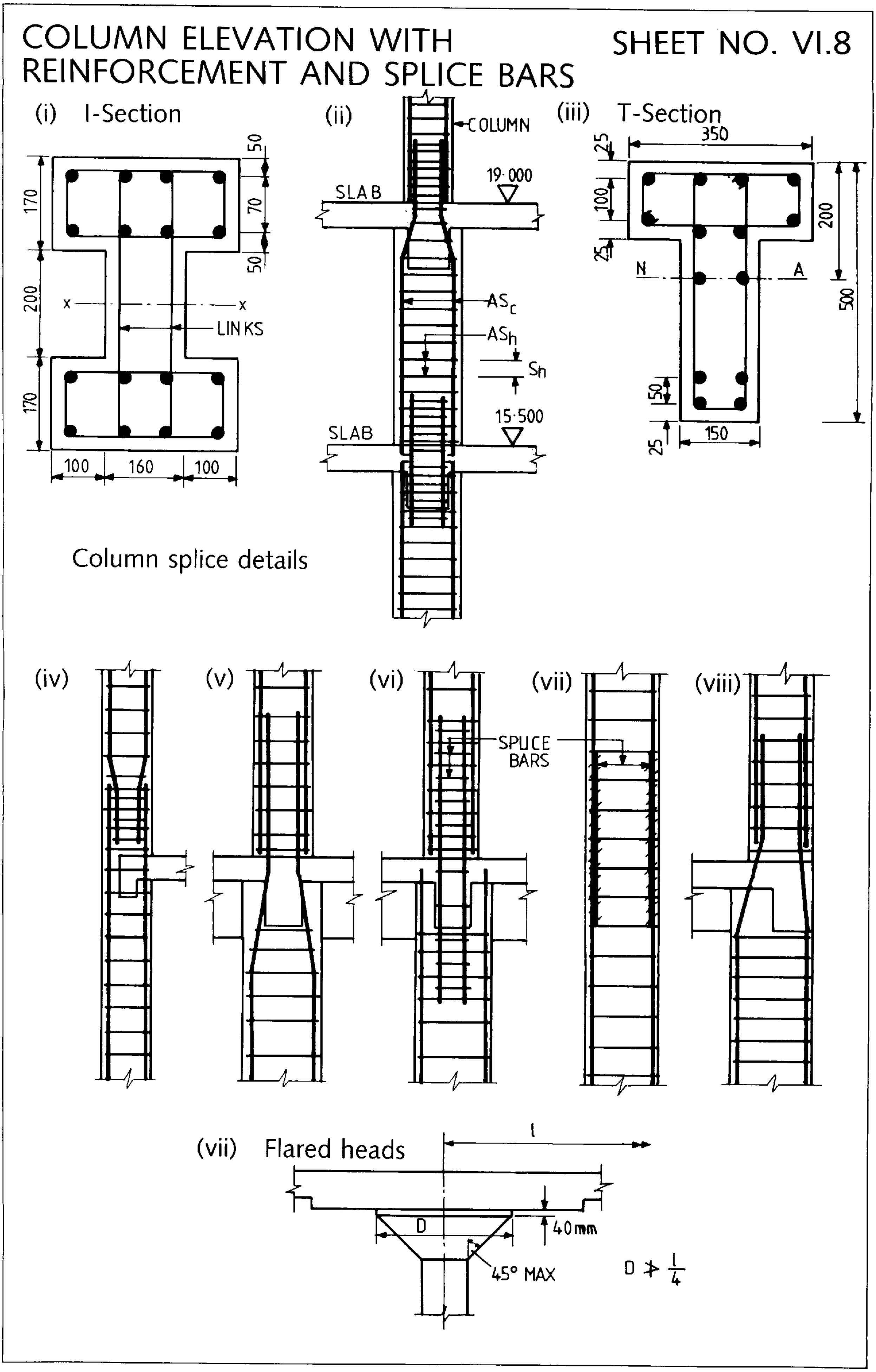


(c) Side view



(d) Cross-section




COLUMN ELEVATION WITH REINFORCEMENT AND SPLICE BARS
SHEET NO. VI.8
(i) I-Section
170
200
170
50
70
50
x
x
LINKS
100
160
100
(ii)
COLUMN
SLAB
19·000
ASc
ASh
Sh
15·500
SLAB
(iii) T-Section
350
25
100
25
200
500
N
A
50
25
150
Column splice details
(iv)
(v)
(vi)
(vii)
(viii)
SPLICE BARS
(vii) Flared heads
l
D
40mm
45° MAX
D ≯ l/4

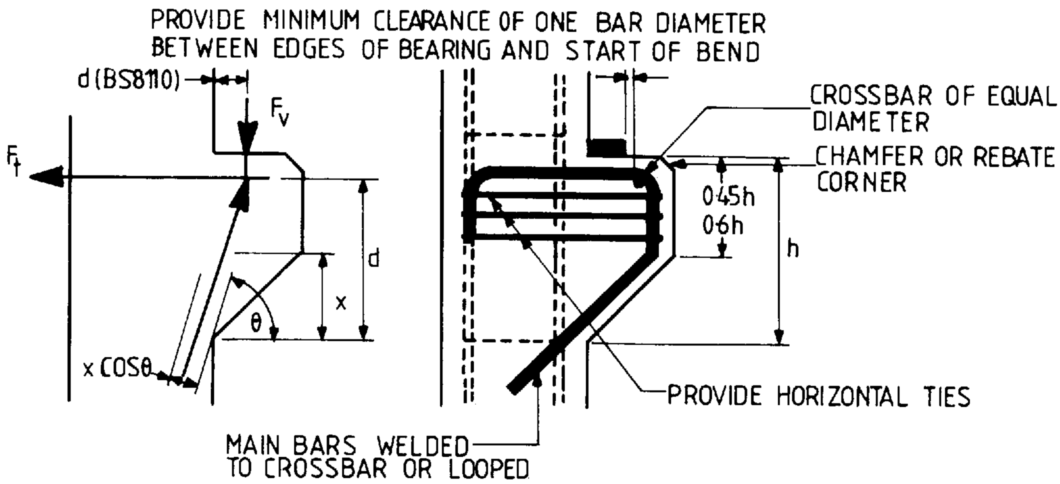
VI.2 Joints and Connections

A sequence of particular construction causes joints in a structure. Joints can be between old and fresh concrete and can be between two parts of a structure. Construction joints must be so positioned that the strength of a completed member is not affected. The most suitable place for a construction joint in a simple structure is where a bending moment is zero or a shear force is maximum. A construction joint may be at the junction of a rib and slab of a T-beam or a smaller beam at a short distance from the junction of intersecting beams. Joints can also be possible where columns at different floors are to be integrated with slab/beam construction. As shown in Sheet No. VI.8, a number of possibilities exist for lapping and splicing of bars at or around floor levels. They are detailed on column elevations on Sheet No. VI.8.

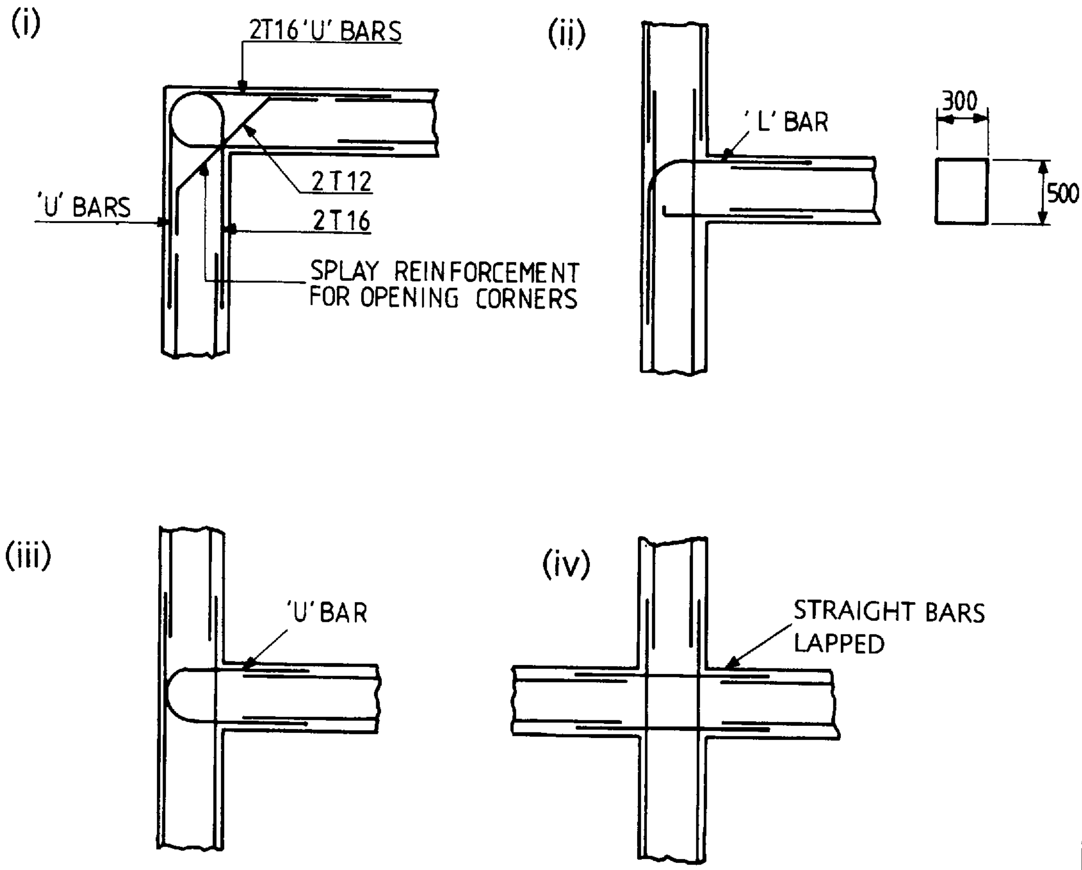
COLUMN BRACKETS AND CONNECTIONS

SHEET NO. VI.9

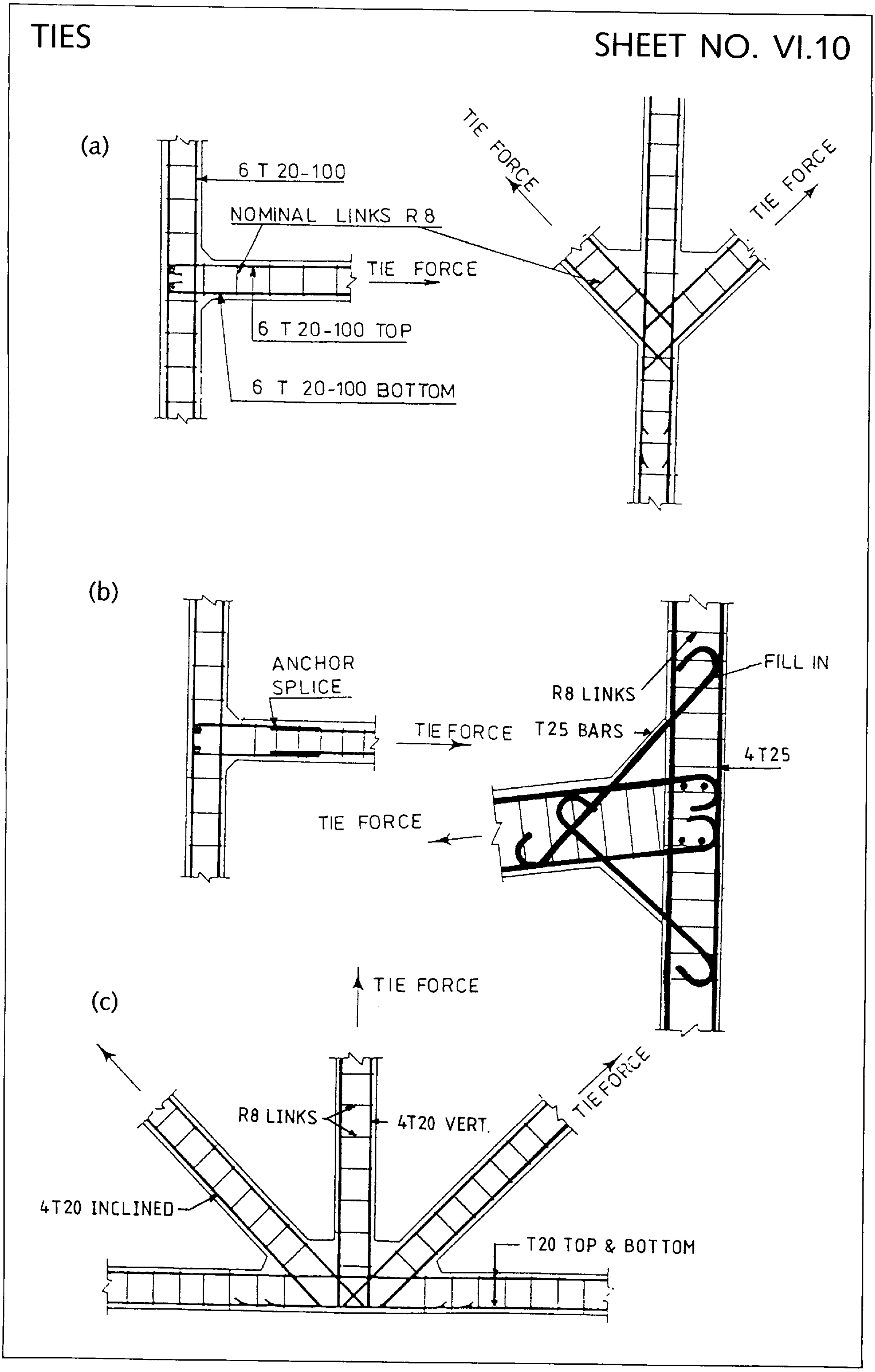
(a) Brackets



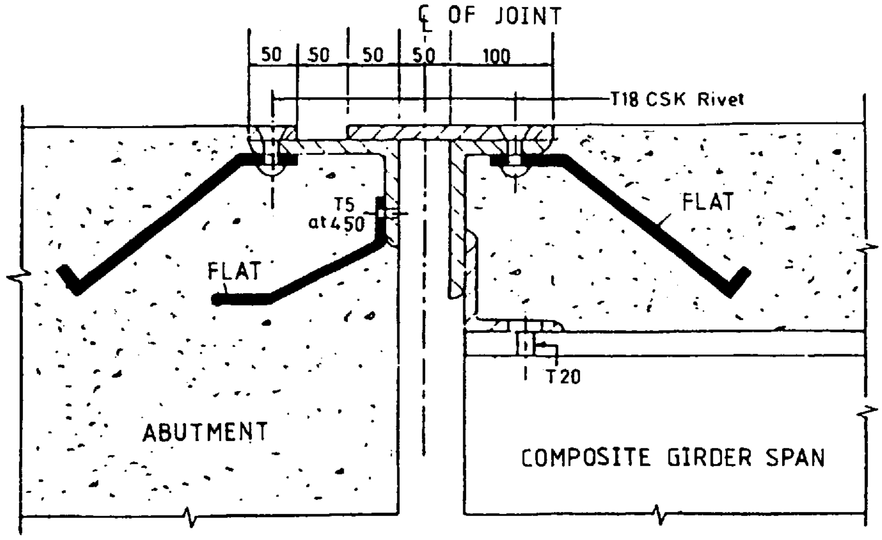
(b) Column connections



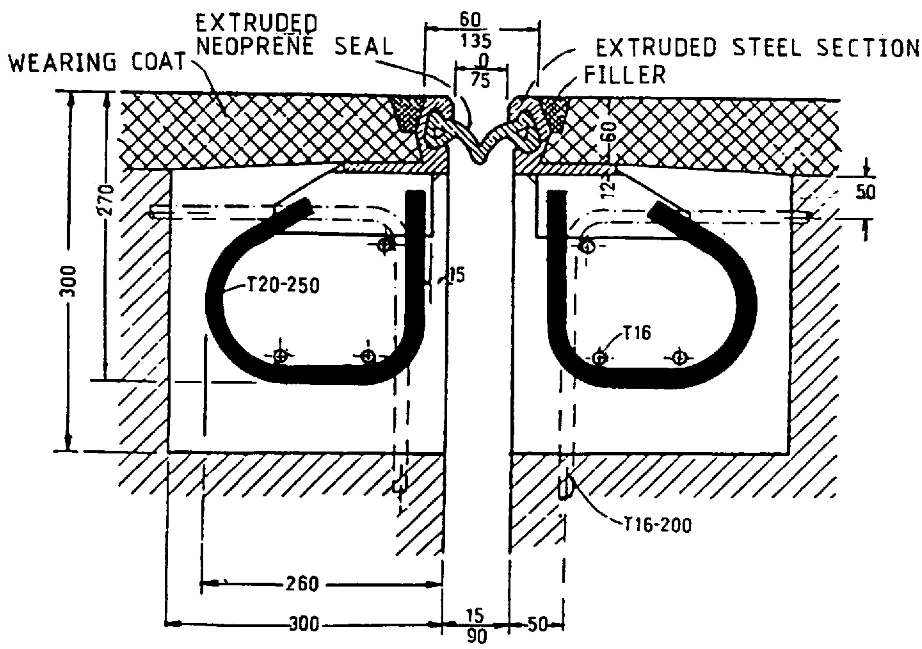
As explained in Section VI.1, beams are connected to columns using different methods. It depends where and at what level a beam (or beams) can be connected where corbels are involved. Their design and detailing as shown on Sheet No. VI.9 must depend upon induced loads and member sizes. Sheet VI.9.a gives a layout of a bracket or corbel showing the main reinforcement (thick bar) and links for shear. Columns can also be connected directly to beams or vice versa. Some of them are given in VI.9.b. Where reinforced concrete ties are required in frames and trusses some possible layouts and structural detailing of them are given on Sheet No. VI.10. Another important family of joints are the expansion joints in a bridge. Sheet No. VI.11 shows three different types of expansion joint used in bridges. They are classified on the basis of their movement but their function is common – to stop the creation of deformation in bridge decks or other structures subject to traffic loads and environmental loads. Other types of joint are those needed in walls, columns and floors. They need to be watertight. A family of such joints in concrete are detailed on Sheet No. VI.12. In such circumstances, it is important to give data on water bars made in rubber or plastics. Sheet No. VI.13 gives basic data on such water bars.


TIES
SHEET NO. VI.10
(a)
6 T 20-100
NOMINAL LINKS R 8
TIE FORCE
6 T 20-100 TOP
6 T 20-100 BOTTOM
TIE FORCE
TIE FORCE
(b)
ANCHOR SPLICE
TIE FORCE
R8 LINKS
FILL IN
T25 BARS
4T25
TIE FORCE
(c)
TIE FORCE
TIE FORCE
R8 LINKS
4T20 VERT.
4T20 INCLINED
T20 TOP & BOTTOM

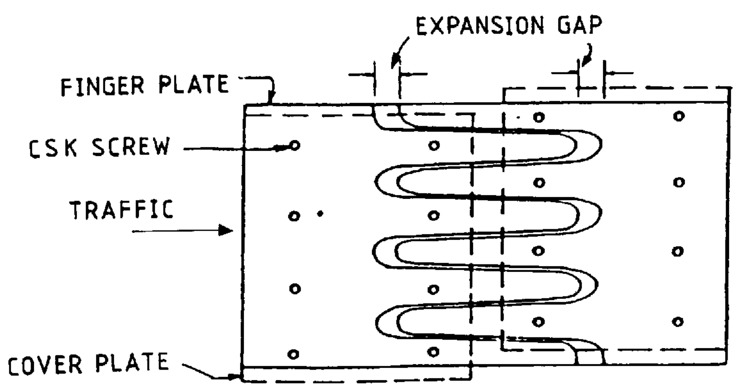
EXPANSION JOINTS FOR BRIDGES SHEET NO. VI.11



(a) Expansion joint for movement up to 60 mm

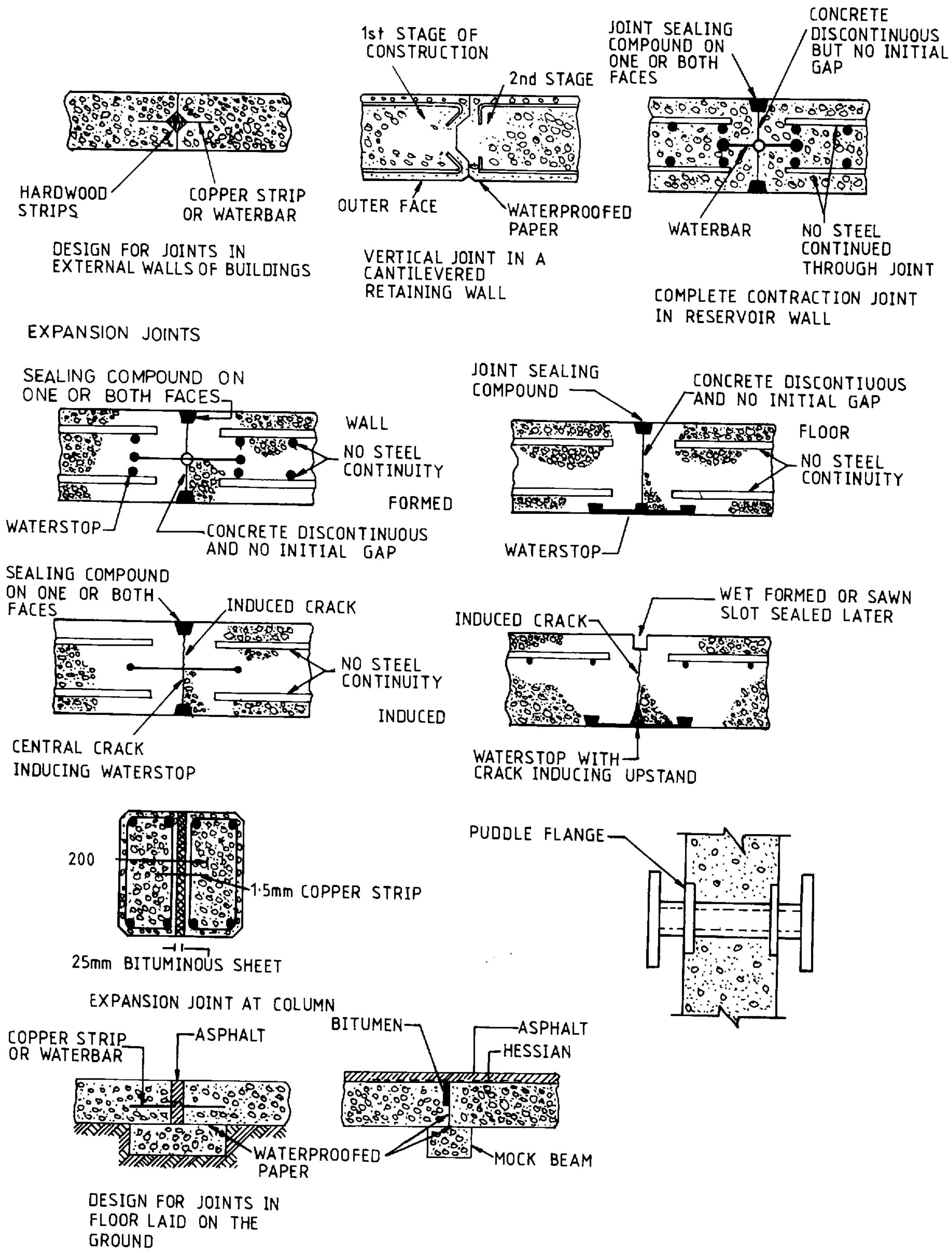


(b) Expansion joint for movement up to 75 mm



(c) Plan view of onset of finger plates for expansion joint for movement up to 150 mm

WATER JOINTS IN CONCRETE SHEET NO. VI.12



PLASTIC WATER BARS FOR EXPANSION JOINTS

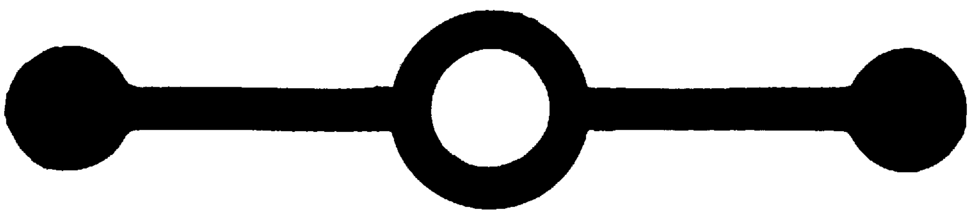
SHEET NO. VI.13

(a) Plain plastic water bar

Section	Sizes			
(i) Width	140 mm	190 mm	240 mm	305 mm
(ii) Web thickness	4.8 mm	4.8 mm	4.8 mm	4.8 mm
(iii) Size of edge bulbs	12.5 mm	19 mm	19 mm	19 mm
(iv) Width(int.) of centre bulb	12 mm	21 mm	21 mm	28 mm
Placing details				
(v) Minimum radius to which it can be bent on flat	8.25 m	14 m	16 m	29 m
(vi) Minimum radius to which it can be bent on edge	75 mm	150 mm	150 mm	230 mm

(b) Rubber central bulb water bar

Section	Sizes			
(i) Width	115 mm	150 mm	230 mm	305 mm
(ii) Web thickness	6.4 mm	9.5 mm	9.5 mm	9.5 mm
(iii) Edge bulb diameter	16 mm	19 mm	25 mm	25 mm
(iv) Centre bulb diameter	29 mm	29 mm	38 mm	50 mm
(v) Centre core diameter	19 mm	16 mm	19 mm	32 mm
Placing details				
(vi) Minimum radius to which it can be bent on flat	3.25 m	7 m	8 m	8.75 m
(vii) Minimum radius to which it can be bent on edge	75 mm	150 mm	150 mm	230 mm



Section VII

Concrete Foundations and Earth – Retaining Structures

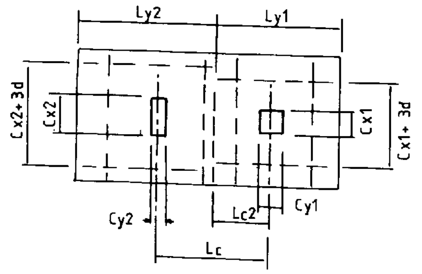
FOOTINGS

SHEET NO. VII.1

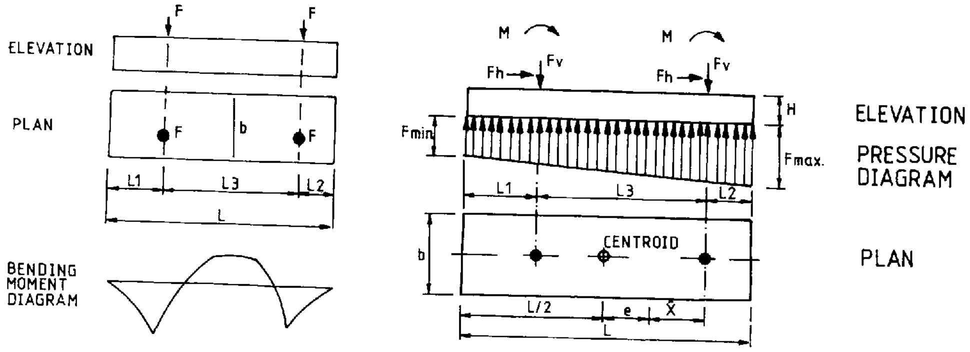
TABULAR METHOD FOR FOOTINGS

COLUMN REF	NO OFF	LEVEL	BASE REINFORCEMENT	SECTION	LINKS	STARTERS

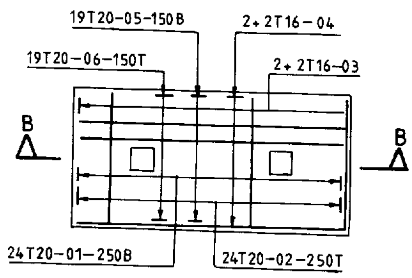
PAD TYPE COMBINED FOOTING



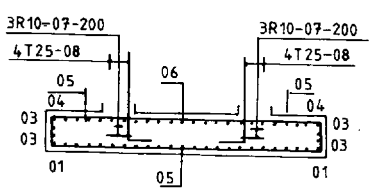
RECTANGULAR FOOTING



TYPICAL REINFORCEMENT DETAILS



PLAN



SECTIONAL ELEVATION

VII.1 General Introduction

An essential requirement in foundations is the evaluation of the load which a structure can safely bear. The type of foundation selected for a particular structure is influenced by the following factors:

(a) the strength and compressibility of the various soil strata;
(b) the magnitude of the external loads;
(c) the position of the water table;
(d) the need for a basement;
(e) the depth of foundations of adjacent structures.

The types of foundations generally adopted for buildings and structures are spread (pad), strip, balanced and cantilever or combined footings, raft and pile foundations. The foundations for bridges may consist of pad, piles, wells and caissons.

VII.2 Types of Foundations

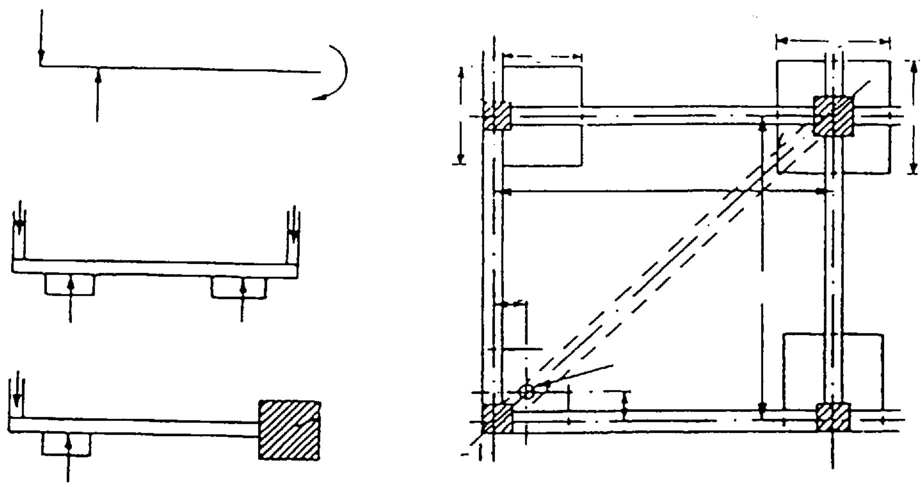
VII.2.1 Isolated spread foundation and pad footing and combined pad foundations

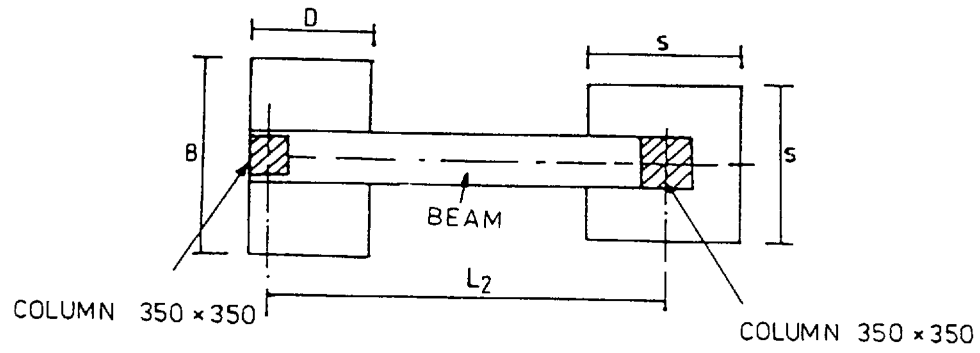
These are generally supporting columns and may be square or rectangular in plan and in section, they may be of the slab, stepped or sloping type. The stepped footing results in a better distribution of load than a slab footing. A sloped footing is more economical although constructional problems are associated with the sloping surface. The isolated spread footing in plain concrete has the advantage that the column load is transferred to the soil through dispersion in the footing. In reinforced concrete footings, i.e. pads, the slab is treated as an inverted cantilever bearing the soil pressure and supported by the column. Where a two-way footing is provided it must be reinforced in two directions of bending with bars of steel placed in the bottom of the pad parallel to its sides. If clearances permit, two-way square footings are used to reduce the bending moments. Where more than one column is placed on pads (combined footing), their shapes may be rectangular or trapezoidal; the latter produces a more economical design where large differences of magnitude of the column loads exist or where rectangular footings cannot be accommodated. Sheet No. I.18 gives section and plan together with a tabular method for reinforcement designation and scheduling. Sheet No. VII.1 gives pad-type combined footings and their behaviour under external loads and bearing pressures; typical reinforcement detailing for two different combined footings in plan and sectional

CANTILEVER, BALANCED AND STRIP FOUNDATIONS

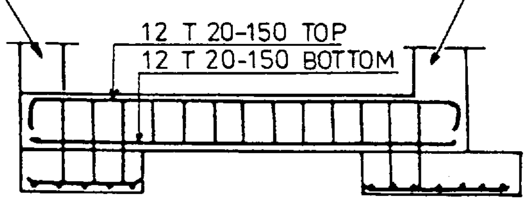
SHEET NO. VII.2

(a) Cantilever and balanced footings



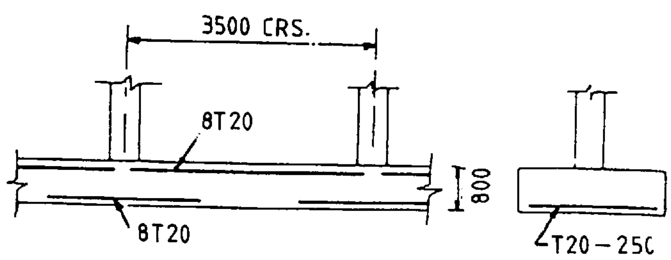


PLAN



REINFORCEMENT LAYOUT – SECTIONAL ELEVATION

(b) Strip footings



elevations. The specifications and quantities may change depending on the spread area and the column loads. In order to keep a record of the types of footings in particular areas and the bar schedule, a *tabular method* given on Sheet No. VII.1 is recommended using given headings.

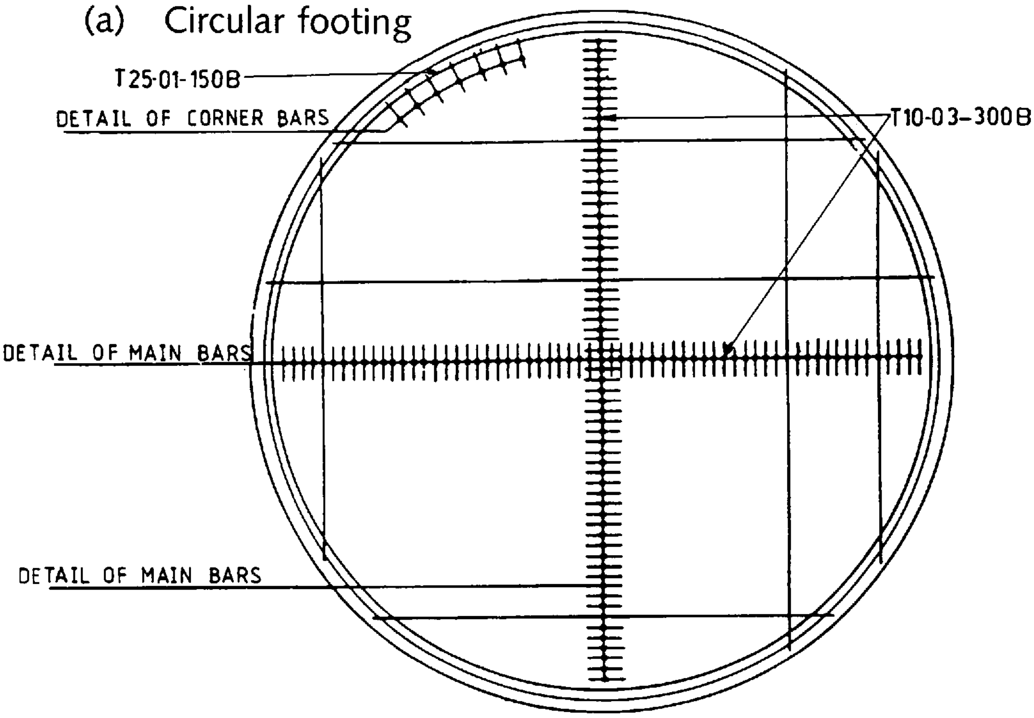
VII.2.2 Cantilever, balanced and strip foundations

Foundations under walls or under closely spaced rows of columns sometimes require (because of restrictions in one direction) a specific type of foundation, such as cantilever and balanced footings and strip footings. The principles and reinforcement details are given on Sheet No. VII.2.

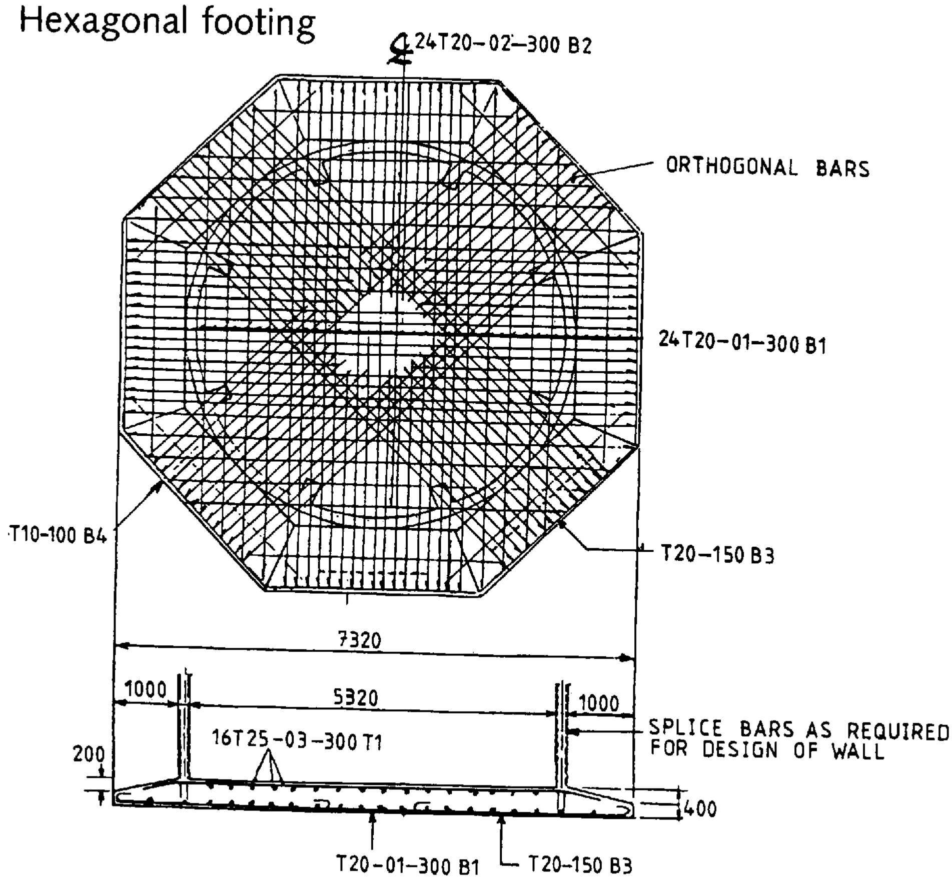
CIRCULAR AND HEXAGONAL FOOTINGS

SHEET NO. VII.3

(a) Circular footing



(b) Hexagonal footing



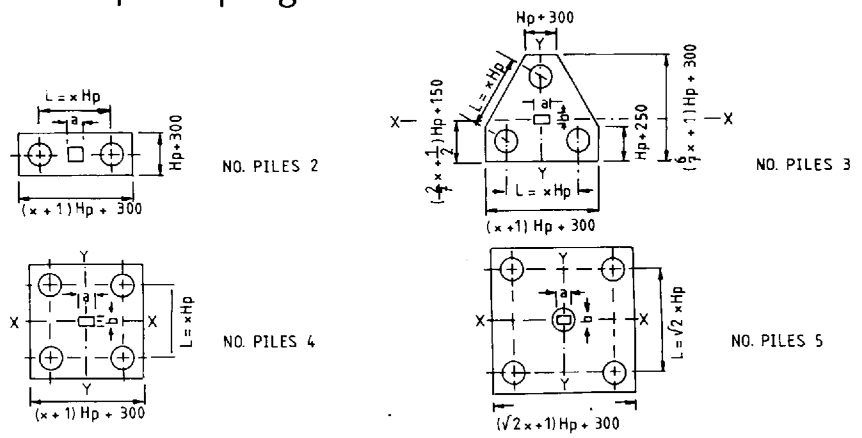
VII.2.3 Circular and hexagonal footings

For specific structures, it is sometimes economical to arrange the footings or foundations to suit their shapes. This applies to many cylindrical structures such as concrete pressure and containment vessels, hoppers/bunkers/silos and cells for offshore gravity platforms etc. Sheet No. VII.3 gives the structural detailing of such foundations.

PILE FOUNDATION

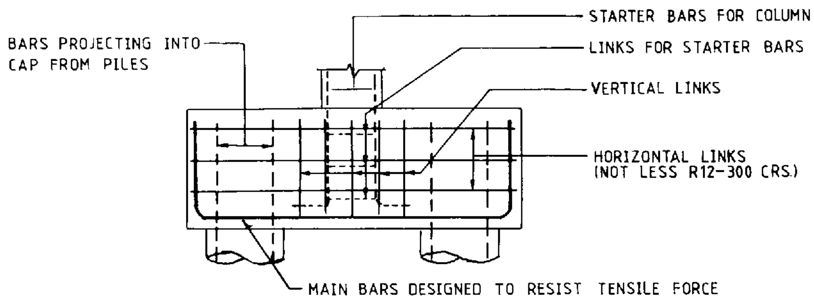
SHEET NO. VII.4

(a) Piles and pile caps: general recommendations

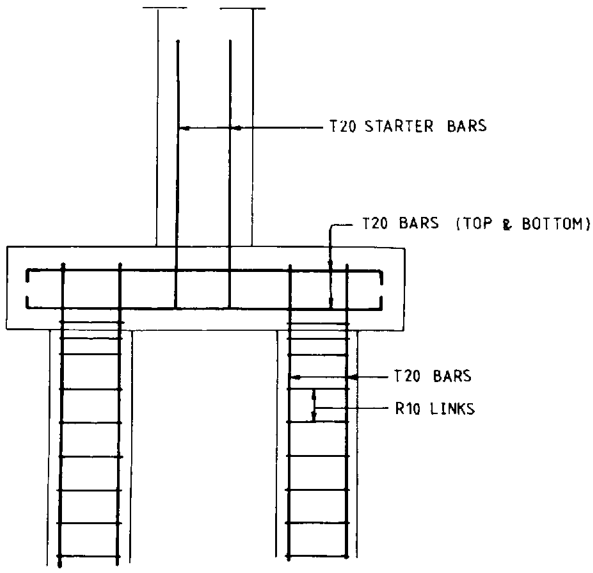


Hp DIA OF PILE: a,b DIMENSION OF COLUMN: x SPACING FACTOR OF PILES

(b) General reinforcement layout



(c) Two-pile cap reinforcement layout



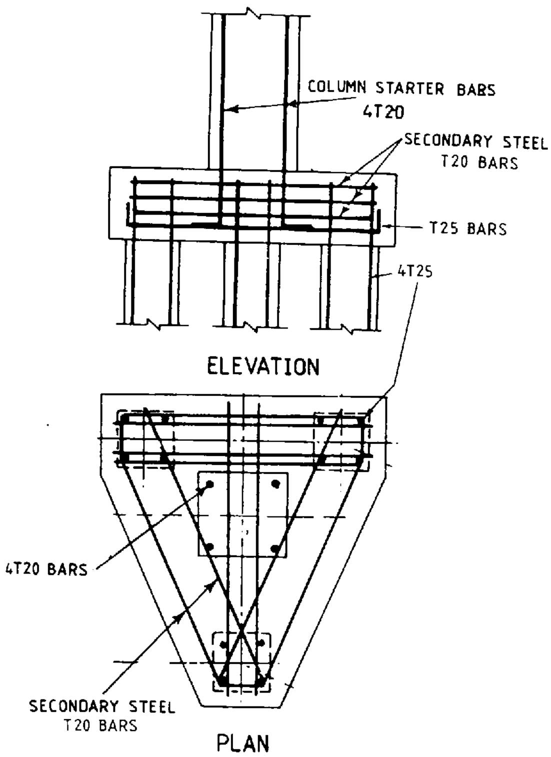
VII.2.4 Pile foundations

Where the bearing capacity of the soil is poor or the imposed loads are very heavy, piles, which may be square, circular or other shapes are used for foundations. If no soil layer is available, the pile is driven to a depth such that the load is supported through the surface friction of the pile. Sheet No. VII.4 gives the general layout of piles and pile caps and a typical generalized layout of pile and pile-cap reinforcement is shown in VII.4.a and b. Two-pile, three-pile, four-pile and six-pile foundation reinforcement details are given on Sheet Nos. VII.4 to VII.6. For all these pile foundations, the *tabular method* given on Sheet No. VII.5 is adopted under the recommended headings. These details form part of the drawings to be submitted for the superstructures.

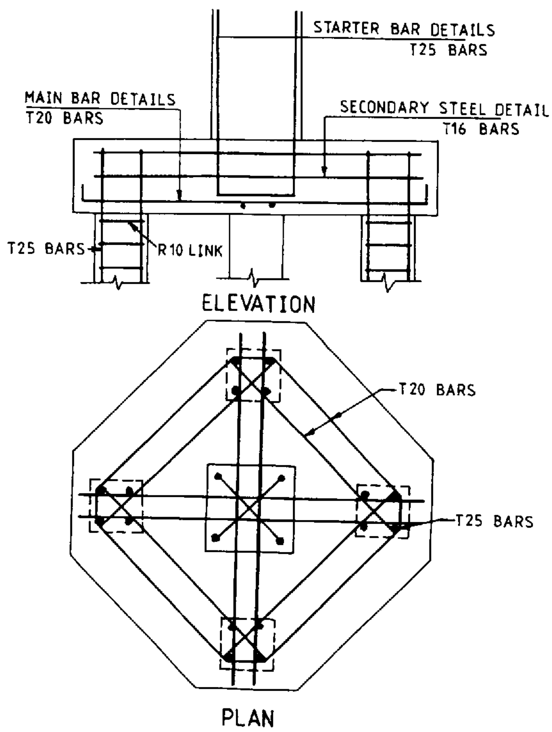
PILE FOUNDATION

SHEET NO. VII.5

Three-pile cap



Four-pile cap



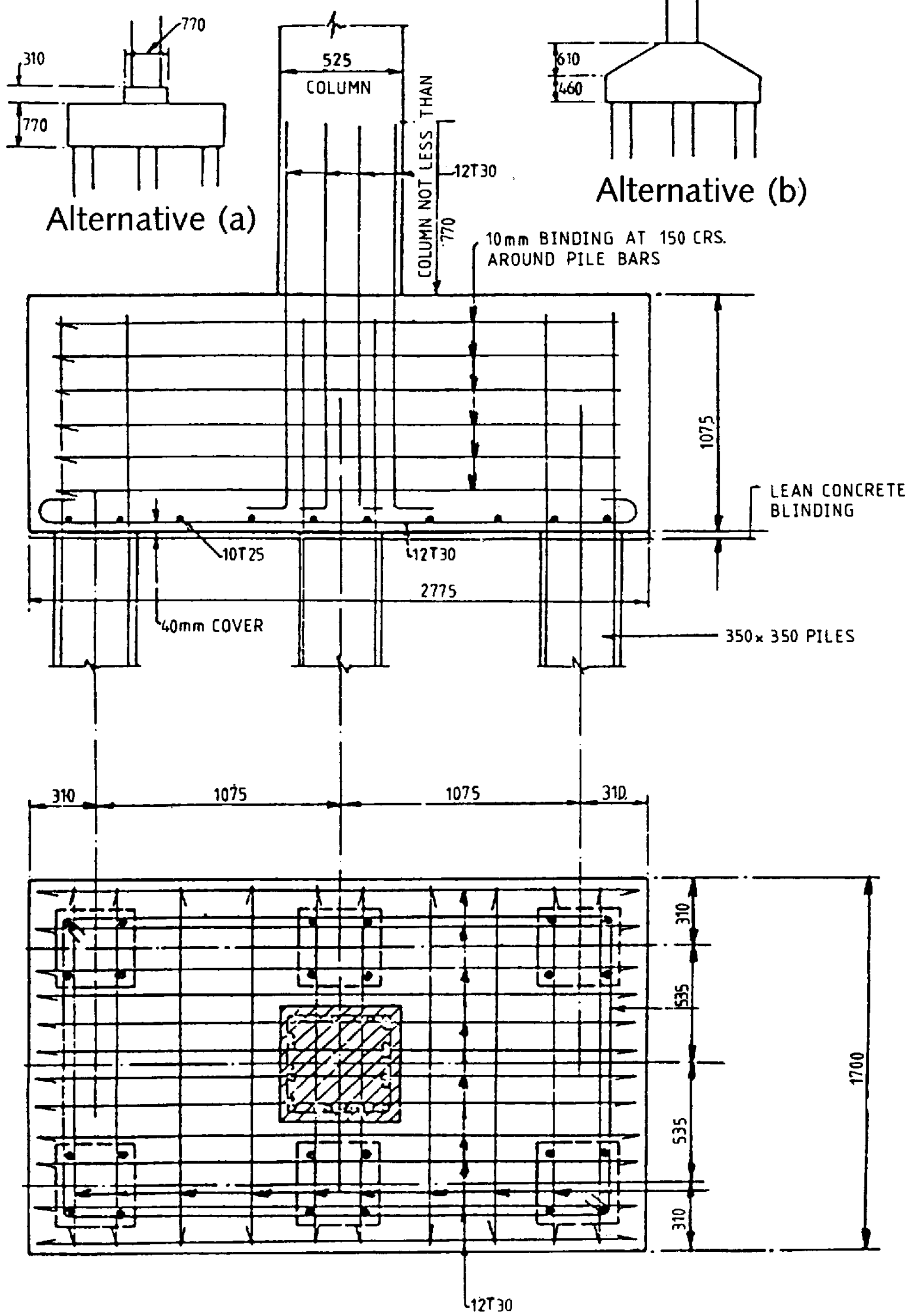
Tabular method

COLUMN REFERENCE	BASE TYPE	NO:OFF	BASE LEVEL CUT OFF LEVEL	BASE REINFORCEMENT			SECTION	LINKS	STARTER BARS.
				A	B	C		D	

PILE FOUNDATION

SHEET NO. VII.6

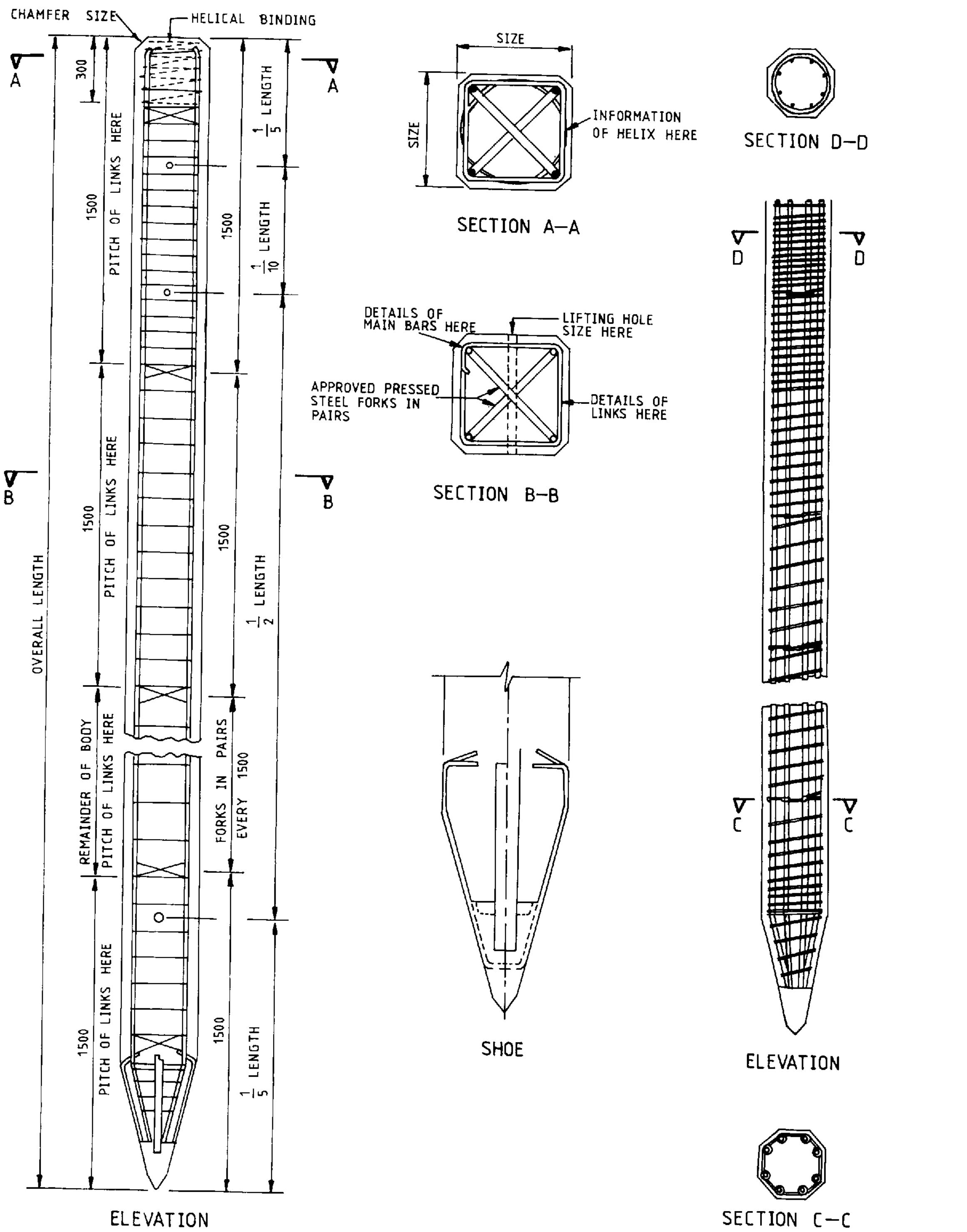
Six-pile cap



Details of pile cap

PRECAST CONCRETE PILES

SHEET NO. VII.7



(a) Square pile (b) Octagonal pile

The piles can be precast or cast *in situ*. One way of cast-*in-situ* construction is to drive into the soil a hollow tube with the lower end closed with a cast iron shoe or with a concrete plug. After the tube has reached the required depth, a steel reinforcement case is introduced in the pile and it is gradually filled with concrete. In the case of bored piles, a tube is driven into the ground and the soil inside the tube is removed with augers etc. The rest of the procedure for the steel case and concrete is the same as discussed earlier.

Where precast piles are used, they are designed and detailed to:

(a) bear the imposed load;
(b) withstand impact load during driving;
(c) withstand bending moments caused by self-load during handling.

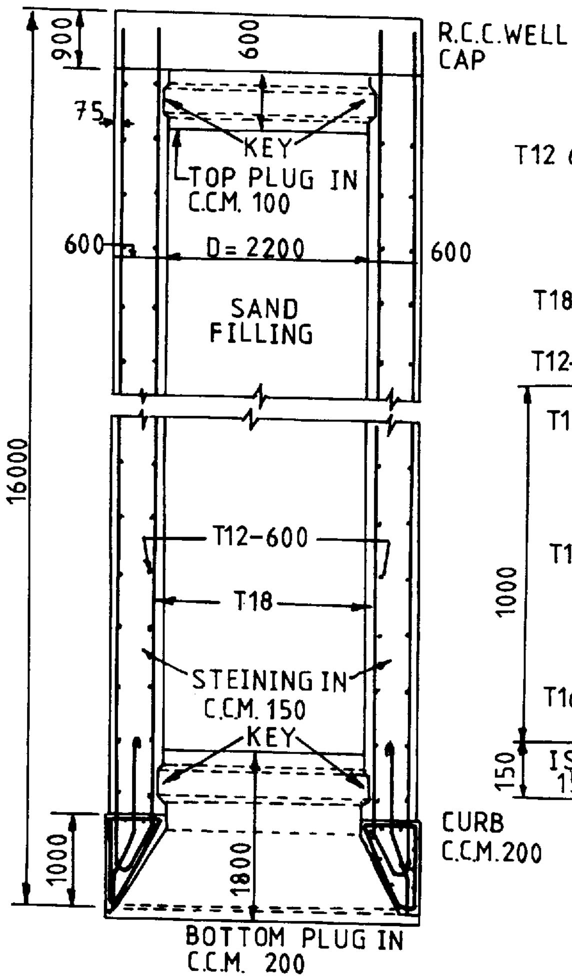
Numerous empirical formulae exist for the evaluation of the bearing capacity of a pile. Texts and codes relevant to this area can be consulted for a better design of piles and pile caps. Sheet No. VII.7 gives the reinforcement detailing of two types of piles, namely square and octagonal. The nominal pile sections in millimetres are: 300 × 300, 350 × 350, 400 × 400 and 450 × 450. For a 350 × 350 pile section the bar diameter varies from 20 to 32 mm for pile lengths of 9 to 15 m. Sections 400 × 400 and above are provided with bars of diameter 20 to 40 mm for pile lengths of 9 to 15 m. The link spacings are generally 150 mm unless otherwise specified. The loads on piles range from 400 kN to 1 000 kN.

At both the head and the foot of the precast concrete pile, the volume of lateral reinforcement shall not be less than 1% for lengths of at least three times the side of the pile. The pile must have at least a safety factory of two.

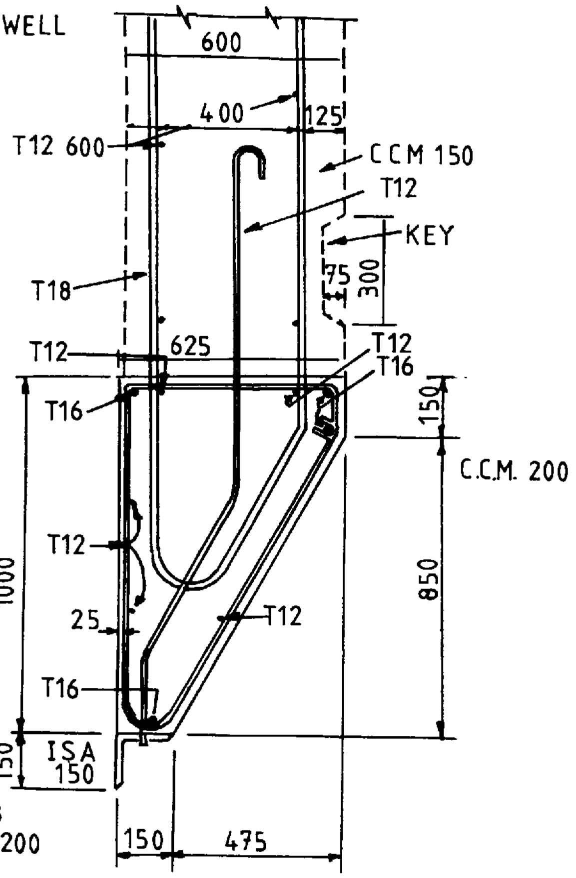
For minimum bending during handling, the points of suspension may be taken for one-point suspension, 0.29ℓ from one end and for two-point suspension 0.21ℓ from two ends where ℓ is the length of the pile.

WELL FOUNDATION

SHEET NO. VII.8



Well



Detail of curb

VII.2.5 Well foundations

These foundations are used for supporting bridge piers and abutments. The well foundation generally consists of steining, bottom plug, sand filling, top plug and well cap. The well cap is described in the next section on bridges.

The structural detailing of such a foundation is shown on Sheet No. VII.8. The well kerb carrying the cutting edge is made up of reinforced concrete. The cutting edge consists of a mild steel angle of 150 mm side. Where boulders are expected, the vertical leg is embedded in steining with the horizontal leg of the angle remaining flush with the bottom of the kerb. The steining consists of either brick masonry or reinforced concrete. The thickness of the steining should not be less than 450 mm nor less than given by the following equation:

$$t = k(0.01\,H + 0.1\,D),$$

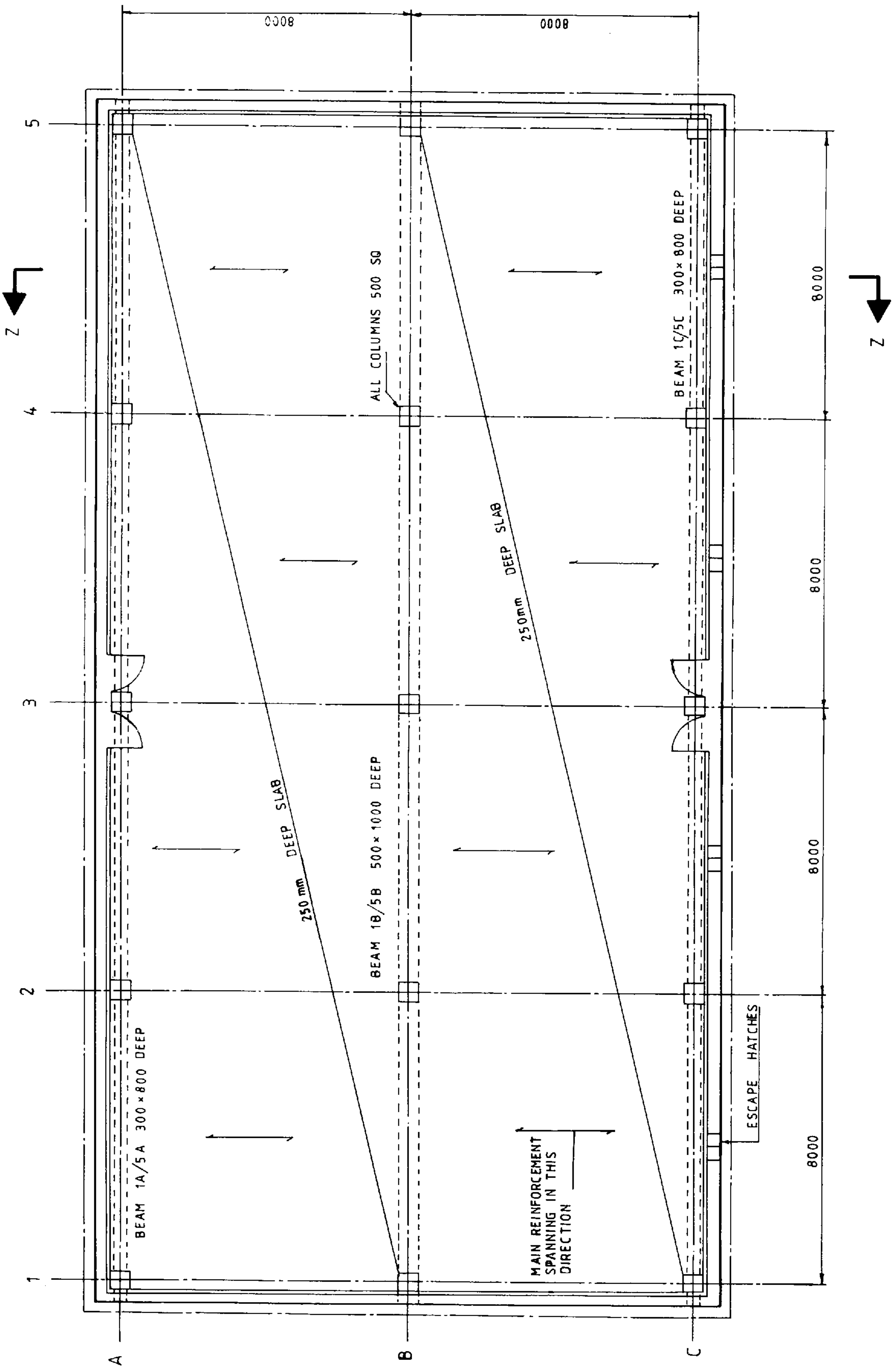
where:

t = minimum thickness of steining,
H = full depth to which the well is designed,
D = external diameter of the well,
K = subsoil constant,
= 1.0 sandy strata,
= 1.1 soft clay,
= 1.25 hard clay,
= 1.30 for hard soil with boulders.

The concrete steining shall be reinforced with longitudinal and hoop bars on both faces of the well. The bottom plug is provided up to a height of 0.3 m for small-diameter and 0.6 m for large-diameter wells. The concrete shall not be less than grade 30. A top plug is provided with a thickness of about 0.3 m beneath the well cap and on top of the compacted sand filling. The space inside the well between the bottom of the plug and top of the bottom plug is usually filled with clean sand. This is needed to provide stability and to prevent the well overturning.

PLAN OF GROUND FLOOR

SHEET NO. VII.9



VII.2.6 Raft foundations

When the spread footings occupy more than half the area covered by the structure and where differential settlement on poor soil is likely to occur a raft foundation is found to be more economical. This type of foundation is viewed as the inverse of a one-storey beam, slab and column system. The slab rests on soil carrying the load from the beam/column system which itself transmits the loads from the superstructure.

VII.2.7 Ground and basement floor foundations

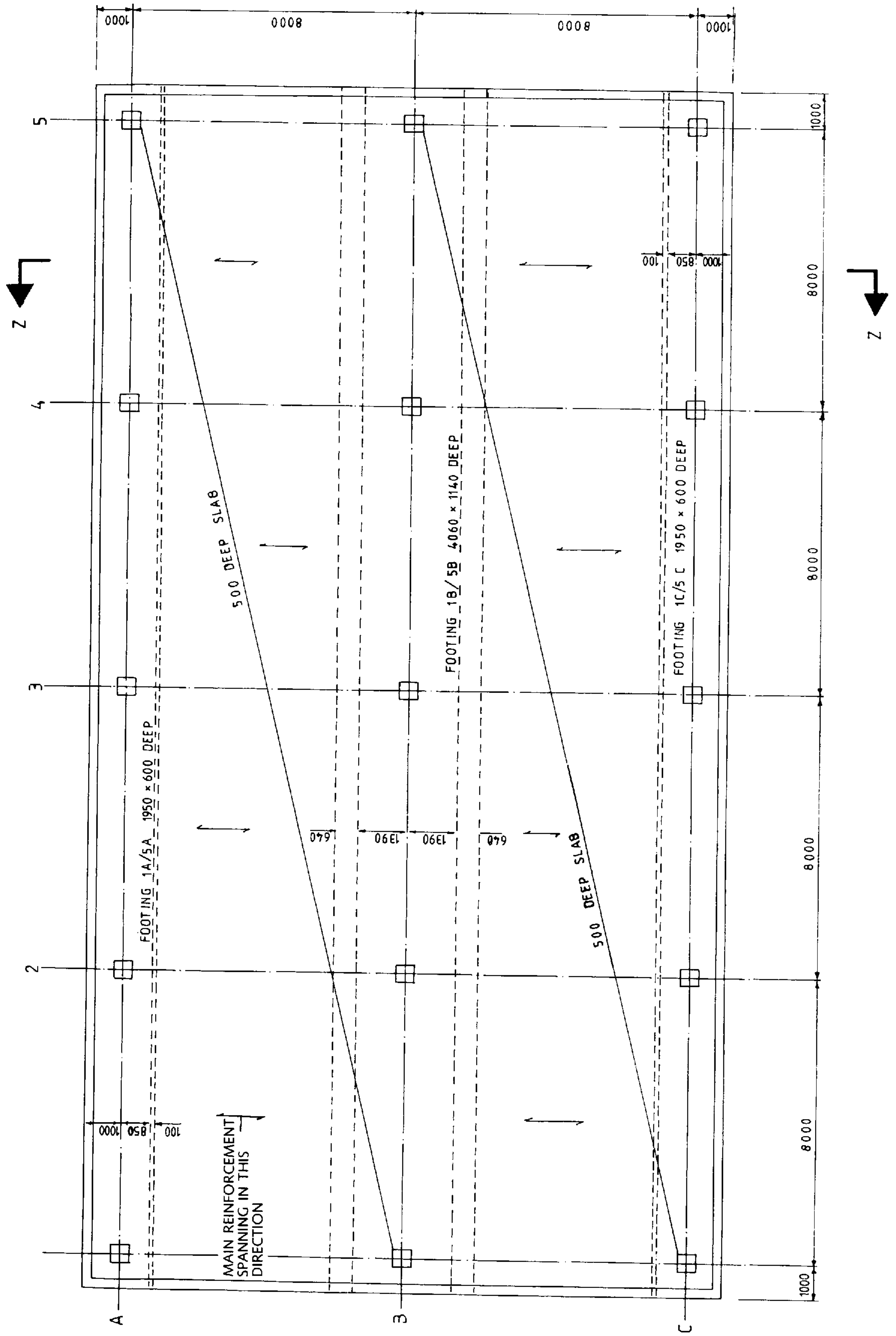
Most building constructions have basements. A scheme is presented through drawings on Sheet Nos. VII.9 to VII.13 giving the layout of the plans of the ground and basement floors, a typical sectional elevation of a scheme and reinforcement details of the basement floor slab and the adjacent retaining wall.

In such a scheme, building loads (imposed and dead), soil-bearing pressures, water table, buoyancy and equipment loads are included in the design.

In this scheme, wherever possible, special keys are introduced with pedestals to take the direct column load and to avoid punching failure occurring in adjacent parts of the slab. This may well also be treated as a raft foundation.

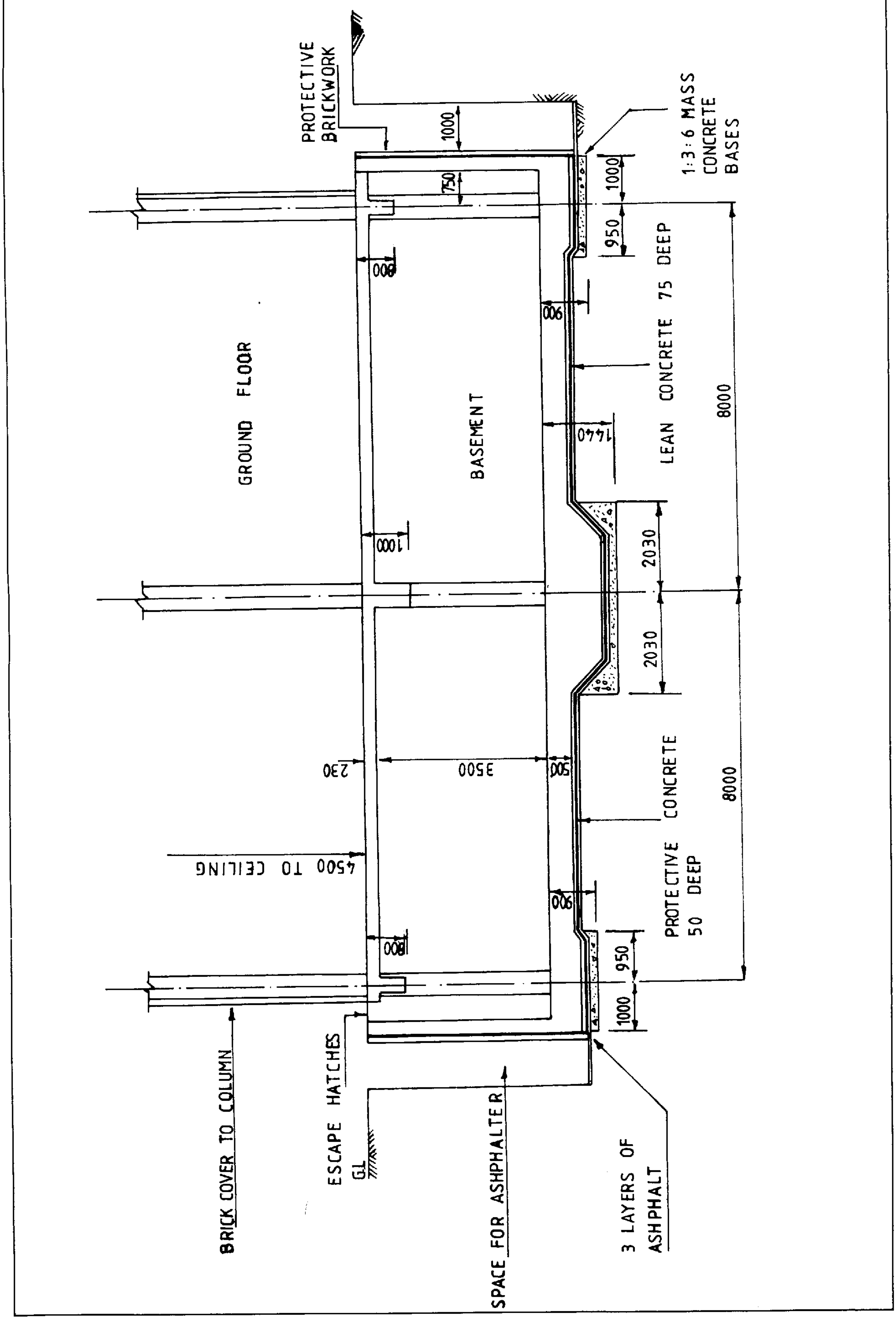
PLAN OF BASEMENT FLOOR

SHEET NO. VII.10



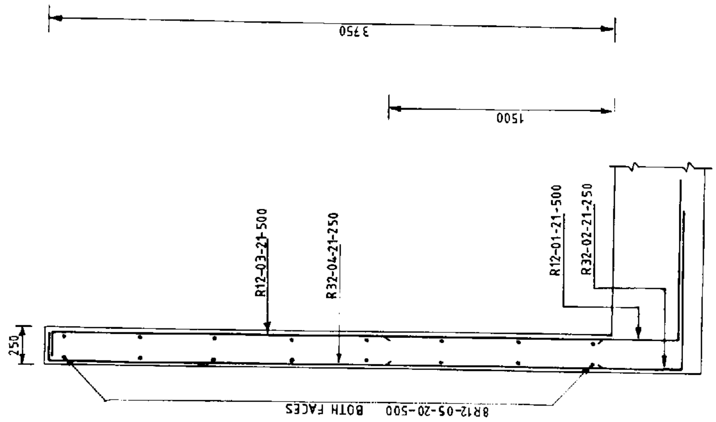
SECTION Z–Z

SHEET NO. VII.11



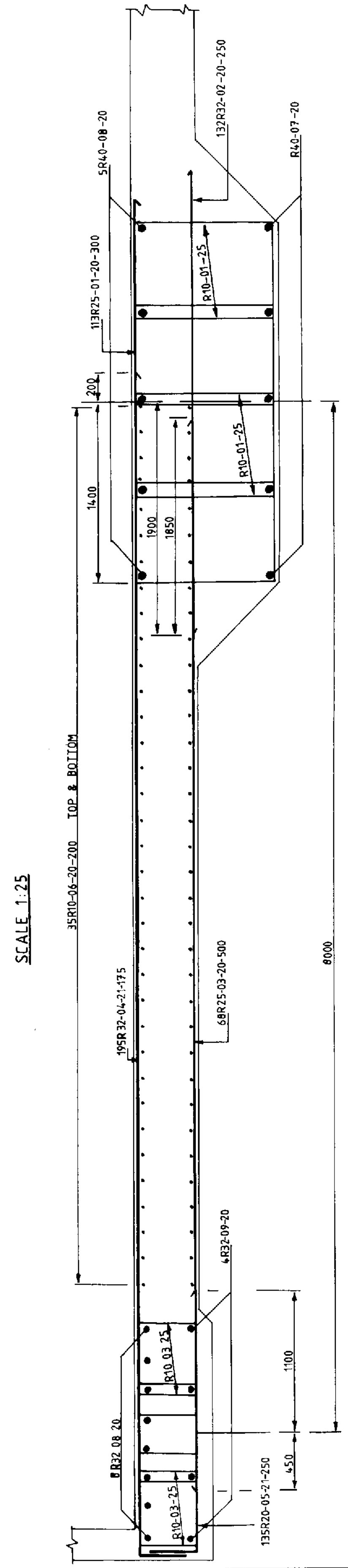
TYPICAL SECTION THROUGH RETAINING WALL

SHEET NO. VII.12

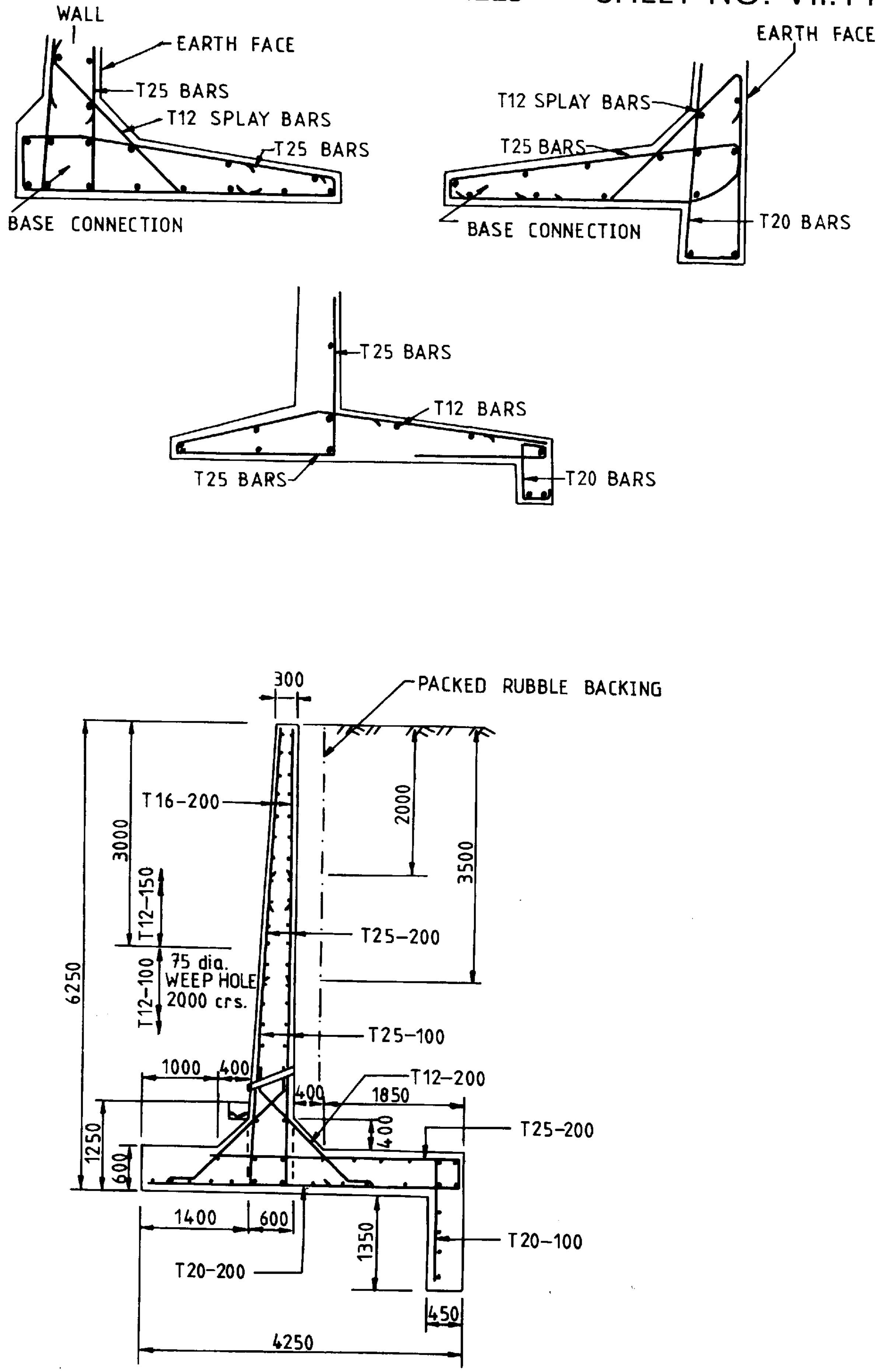


BASEMENT FLOOR SLAB

SHEET NO. VII.13



CANTILEVER RETAINING WALLS SHEET NO. VII.14



VII.2.8 Earth-retaining structures

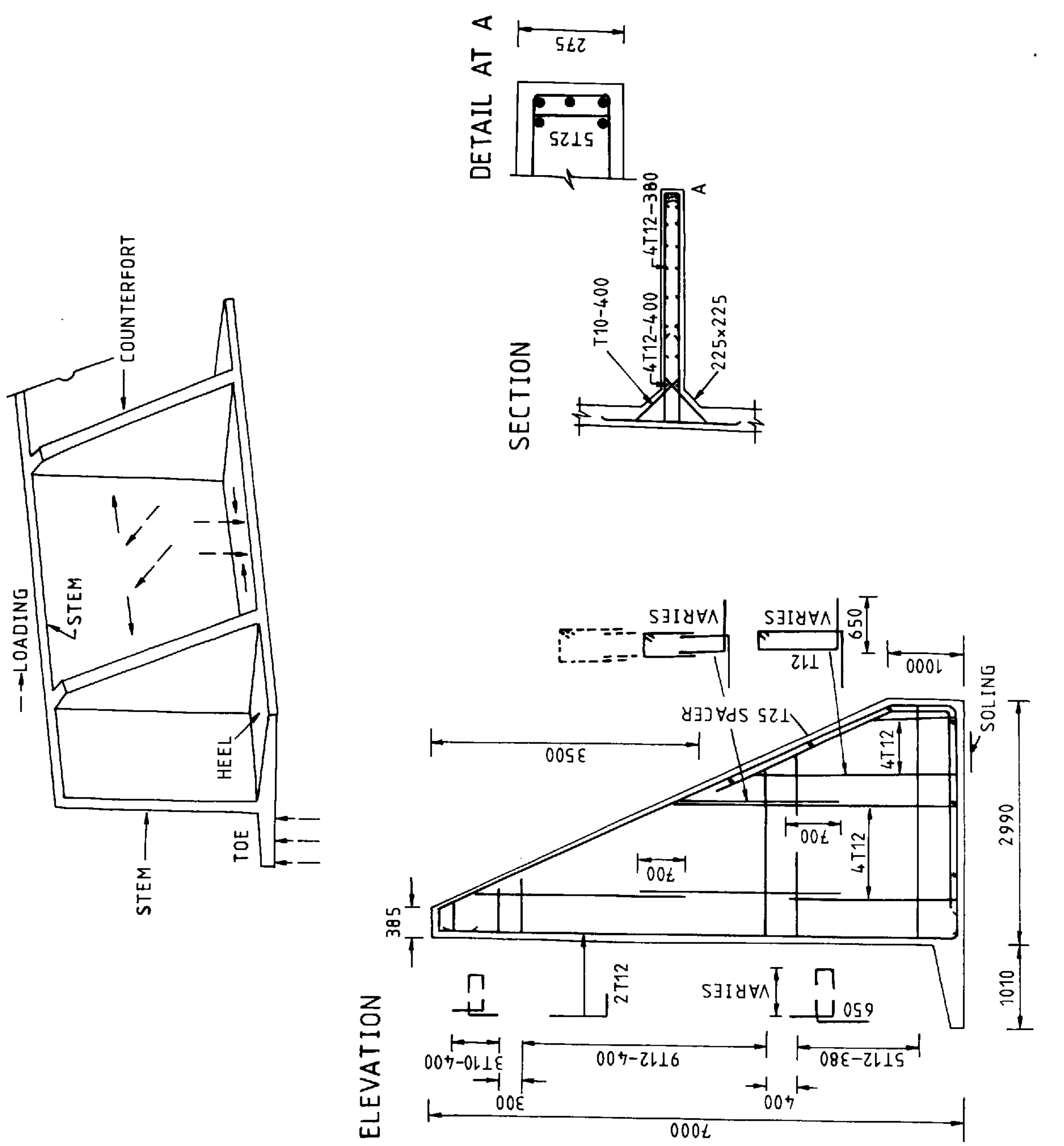
Walls for retaining earth sustain horizontal pressures exerted by the earth material. Retaining walls without supports may be broadly classified into two types, cantilever and counterfort. The *cantilever retaining wall* as shown on Sheet No. VII.14 may have its base in front of the wall or at the back. The back-base cantilever retaining wall is generally used to retain stored material. The soil under the front base has to sustain the vertical pressure induced in the base by the horizontal earth pressure on the vertical wall. In addition, the soil has to resist the horizontal sliding force due to the earth pressure on the vertical wall. Several codes exist to give recommendations for the design and detailing of such walls. The reinforcement layout and concrete thickness depend on the applied loads. The details given on Sheet No. VII.14 are modified while keeping the same optimum layout.

When the height exceeds 5 to 6 m, *counterfort retaining walls* are more economical. The counterforts extend beyond the vertical wall and the base at intervals of about 5 to 6 m. The vertical wall is designed as a continuous slab spanning between successive counterforts. Most of the time the counterforts act as tension members between the wall and the base. Sheet No. VII.15 gives the structural detailing of a counterfort retaining wall.

The retaining wall with shelves and sheet pile walls are outside the scope of this book. The former is seldom adopted, the latter is made in corrugated steel or wood.

COUNTERFORT WALLS

SHEET NO. VII.15



Section VIII

Special Structures

Section VIII.1
Bridges

VIII.1.1 General introduction to types of bridges

A bridge is subdivided into (a) the superstructure, (b) the substructure and (c) the foundation. The bridge deck system is the part of the superstructure directly carrying the vehicular loads. It is furnished with balustrades or parapets, crash barriers, highway surfacing, footpaths, traffic islands, railway tracks on ties, expansion joints and drainage systems. The substructure comprises piers, columns or abutments, capping beams and bearings. The foundations consist of reinforced concrete footings, spread foundations, rafts bearing directly on soil or rock and capping slabs supported on piles, wells and caissons. The superstructure of the bridge deck system can be any one or a combination of the following: slabs, coffered slabs, grids, beams, girders, cantilevers, frames, trusses and arches and cable-stayed.

Deck surface members may be classified into the three groups which may be of precast, cast-*in situ* and composite construction. They may be of conventional reinforcement, partially or fully prestressed or composite construction. The following classified system lists fully the types of bridges constructed in reinforced, prestressed and composite materials.

(a) *Slabs*
- (i) solid slabs }
- (ii) void slabs } Supported directly on piers, with or without haunches or drop heads;
- (iii) coffered slabs – they act like a grid;
- (iv) above with beams of reinforced concrete and prestressed concrete (precast or *in situ* beams).

(b) *Beams**
- (i) longitudinal stringed beams with webs spaced apart and integral with the deck slab;
- (ii) longitudinal and transverse beams forming a grid system integral with the deck slab;
- (iii) inverted longitudinal beams, trusses, and girders, fully or partially integral with the deck;
- (iv) a single central longitudinal spine beam, T-beam; truss and girder composite or monolithic with deck.

*Note:

T-beams (precast beam slab deck)
- (a) T-beam with *in situ* concrete topping;
- (b) 'tophat' beams with *in situ* concrete topping;
- (c) continuous beams.

Span range for:
(a) precast post-tensioned I-beam 20–35 m;
(b) precast post-tensioned T-beam ranges up to 45 m.

(c) *Boxes*
(i) A single longitudinal box beam or several box beams with and without cantilevered top flanges comprised of:
  (a) a double webbed single unicellular box;
  (b) twin or multiple unicellular boxes with or without cross-beams or diaphragms.

(d) *Frames* (with or without struts)

They may have members in one or more plane. They may be portal frames (single or multiple), vierendeel girders trestle piers, spill through abutments and towers for cable-stayed or suspension bridges.	Short-span bridges over highways or rivers or flyovers over freeways.

(e) *Arches*
They are classified as:
(i) solid arches;
(ii) open spandrel arches;
(iii) solid spandrel arches;
(iv) tied arches;
(v) funicular arches;
(vi) strut-frame with inclined legs.

(f) *Suspension and cable-stayed bridges*
Suspension bridges with draped cables and vertical or triangulated suspender hangers are adopted for spans exceeding 300 m. *Cable-stayed* bridges are economical over the span range of the order of 100 to 700 m with concrete deck, pylons and frames. For cable-stayed the elevational and transverse arrangements are given below.
(i) Elevational arrangement:
single, radiating, harp, fan, star and combination.
(ii) Transverse arrangement:

single plane (vertical – central or eccentric); double plane (vertical or sloping).	No cables single, double, triple, multiple or combined.

VIII.1.2 Types of loads acting on bridges

They are classified as follows.

(i) *Permanent and long term loads*:
dead; superimposed; earth pressure and water pressure of excluded or retained water.
(ii) *Transient and variable loads (primary type)*:
vehicular loading; railway loading; footway loading and cycle loading.
(iii) *Short term load*:
erection loads; dynamic and impact loads.
(iv) *Transient forces*:
braking and traction forces; forces due to accidental skidding and vehicle collision with parapet or with bridge supports.
(v) *Lurching and nosing by trains.*

(vi) *Transient forces* due to natural causes:
wind action; flood action and seismic forces.

(vii) *Environmental effects*:
loads generated due to creep, shrinkage of concrete; prestress parasitic moments or reactions and prestrain and temperature range or gradient.

Relevant codes are consulted for the application of these loads on bridge structures.

VIII.1.3 Substructures supporting deck structures

The deck structures are supported directly on:

(a) mass concrete or masonry gravity abutments;
(b) closed-end abutments with solid or void walls such as cantilevers, struts or diaphragms;
(c) counterforted or buttressed walls or combinations;
(d) open-end or spill-through abutments with trestle beams supported on columns.

The intermediate piers can be of the following type:

(a) solid or void walls with or without capping beams;
(b) single solid or void columns with or without caps;
(c) trestles and bents;
(d) specially shaped columns, e.g., V-shaped or fork shaped etc.

In most cases bridge bearings are needed to transmit deck loads to substructures and to allow the deck to respond to environmental and vehicle loads.

VIII.1.4 Structural details

Bridge engineering is a vast field and based on site and other requirements no two bridges can be totally the same. Here the reader is given examples of some reinforced, composite and prestressed concrete bridges with simplified structural details.

Sheet No.

VIII.1.1 shows a reinforced slab culvert layout with sectional elevation and plan.
VIII.1.1.a shows a reinforced concrete beam/slab bridge on skew.
VIII.1.2 shows a reinforced concrete T-beam bridge superstructure in cross-section, the longitudinal section of a central beam and a plan for a reinforced concrete deck slab integral with main beams.
VIII.1.3 and VIII.1.4 } show deck and girder details of a continuous reinforced concrete girder bridge.
VIII.1.5 shows a reinforced concrete twin-box bridge deck with parapets.
VIII.1.6 shows a composite steel beam concrete deck bridge with a typical longitudinal elevation and cross-section with shear connectors.
VIII.1.7 shows structural details of a reinforced concrete rigid frame with footings. The road surface rests on this frame.
VIII.1.8 shows a reinforced concrete bow-string bridge showing arches and suspenders with their reinforcement details. Cross-beams and cross-sections of the bow-string at various zones are fully detailed.
VIII.1.9 shows typical bridge decks with post-tensioned girders and pretensioned

beams. They are shown in relation to their respective reinforced concrete decks.

VIII.1.10 shows additional bridge decks with post-tensioned girders and also gives an articulated prestressed concrete balanced cantilever bridge. For the arrangement of prestressing and the tendon profile see Section V.

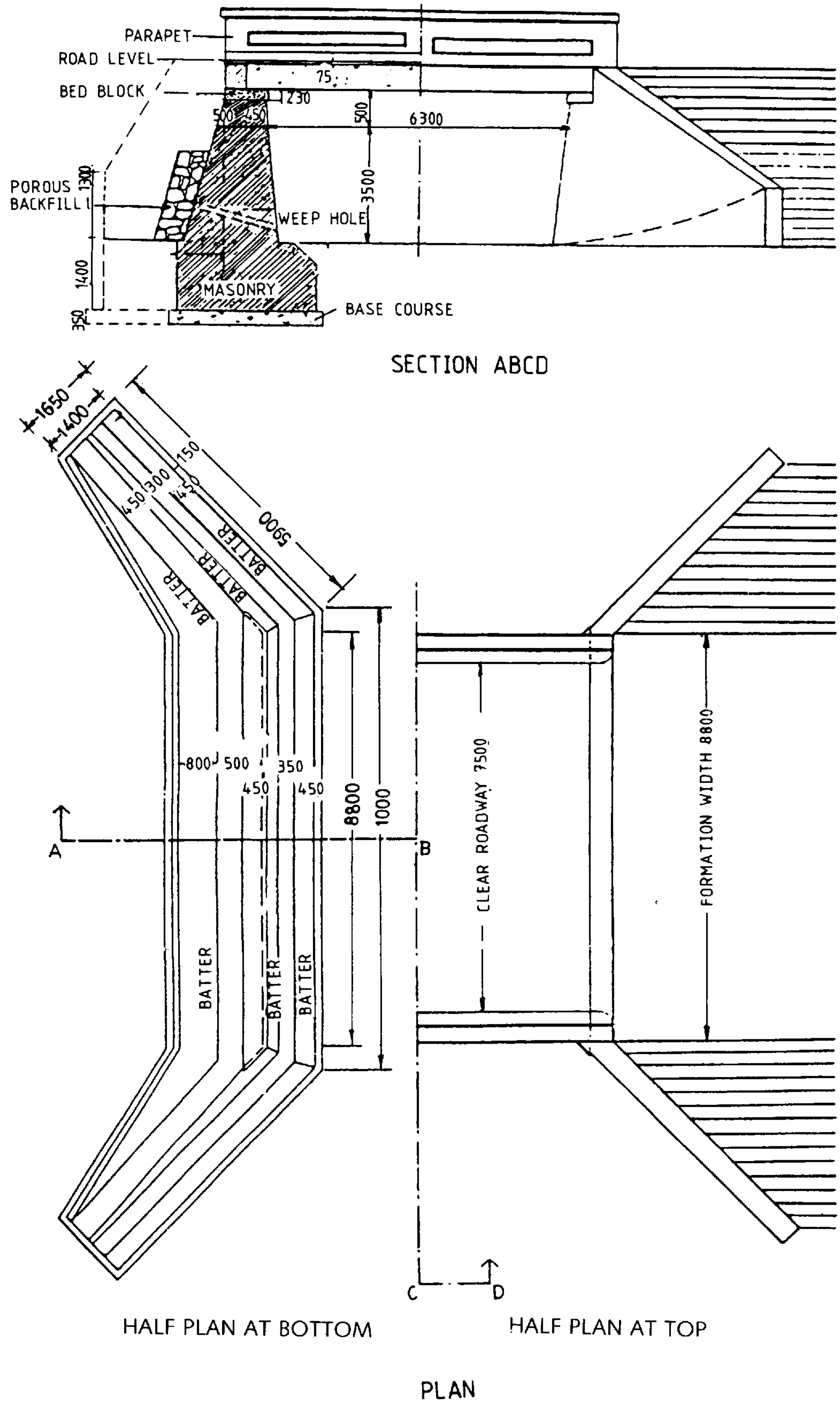
VIII.1.11 to VIII.1.15 show elevations and cross-sections of an open spandrel arch bridge scheme and relevant structural details of parts where prestressing and conventional steel are recommended.

VIII.1.16 shows a choice of bridge substructure comprising piers and bed blocks.

VIII.1.17 and VIII.1.18 show reinforcement details of a typical pier bent and well cap for a pier consisting of several wells.

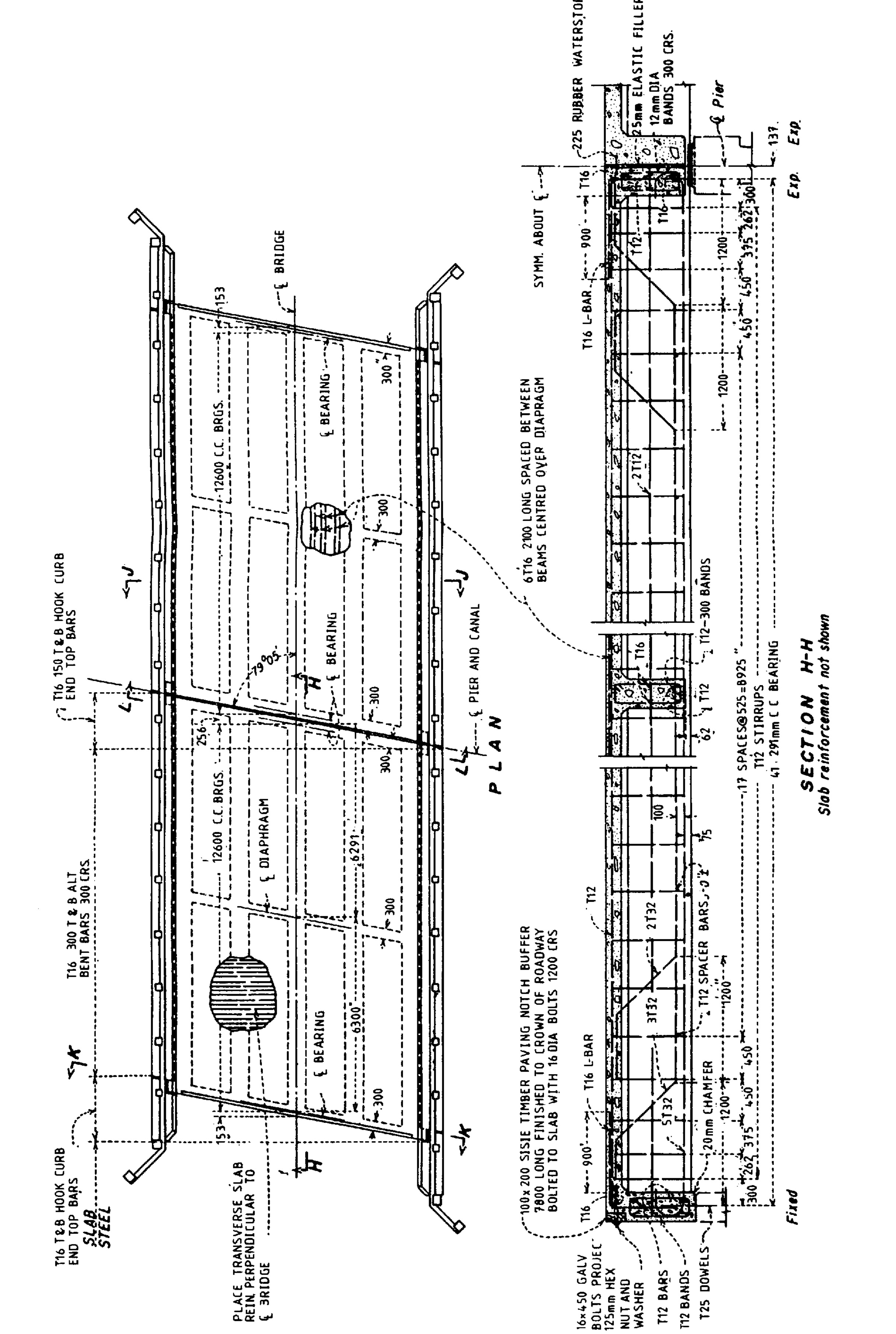
REINFORCED CONCRETE SLAB CULVERT LAYOUT

SHEET NO. VIII.1.1



REINFORCED CONCRETE BEAM/SLAB BRIDGE DECK

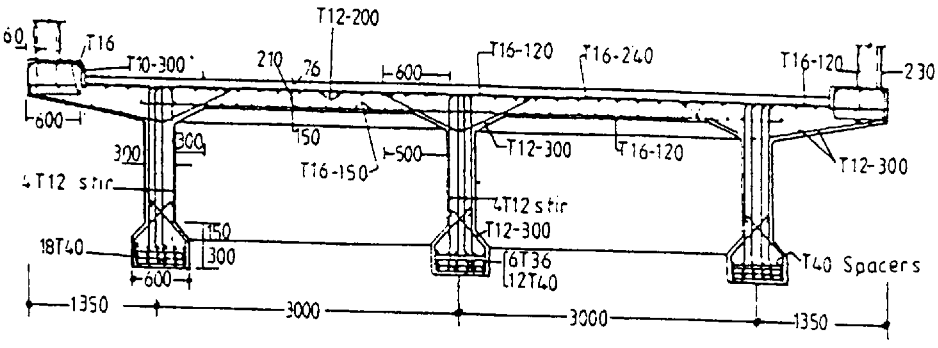
SHEET NO. VIII.1.1.a



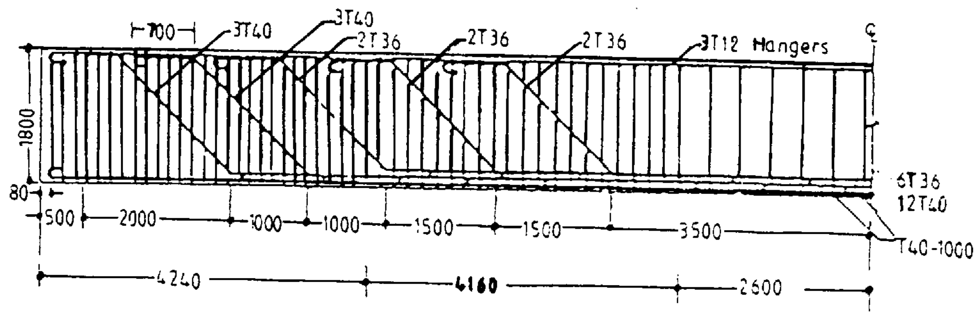
T-BEAM BRIDGE SUPERSTRUCTURE

SHEET NO. VIII.1.2

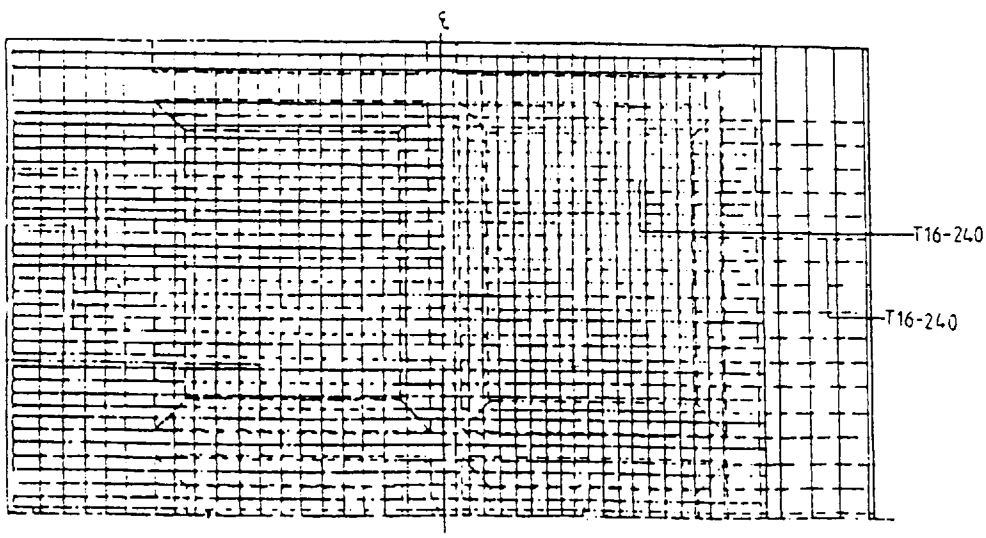
(a) Cross-section



(b) Longitudinal section of central beam



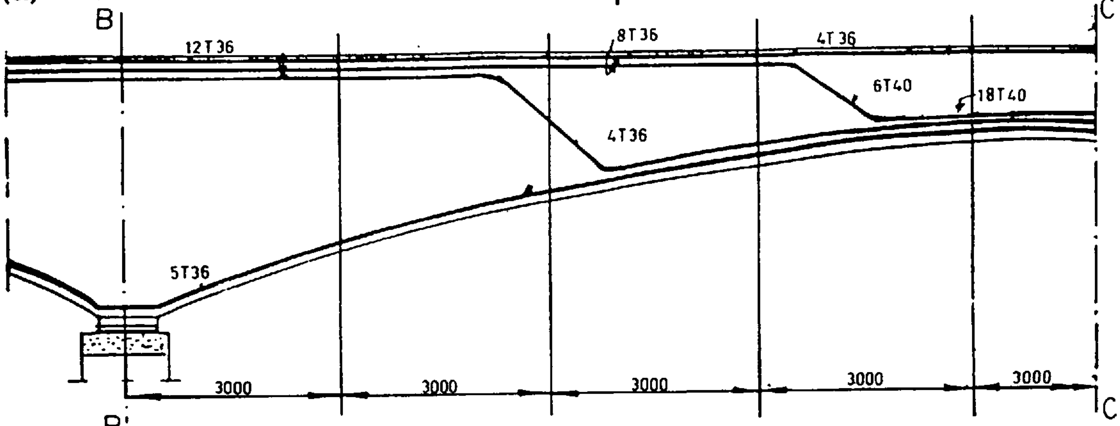
(c) Detail of deck slab

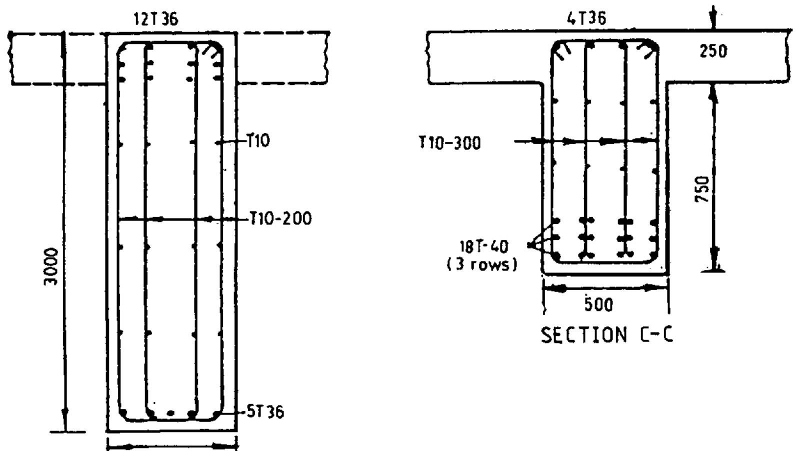


CONTINUOUS R.C. GIRDER BRIDGE

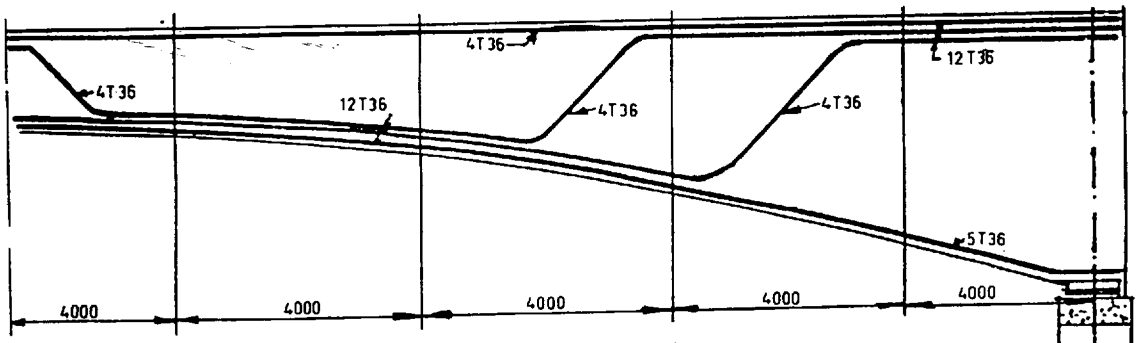
SHEET NO. VIII.1.3

(a) Reinforcement details in central span

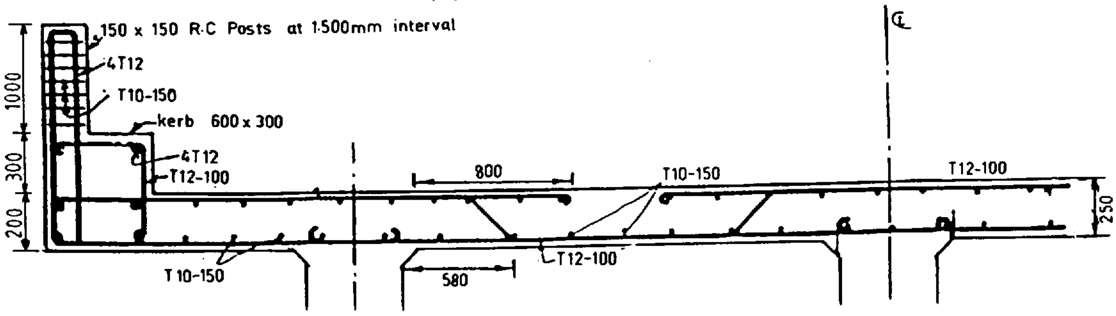




(b) Reinforcement details in end span

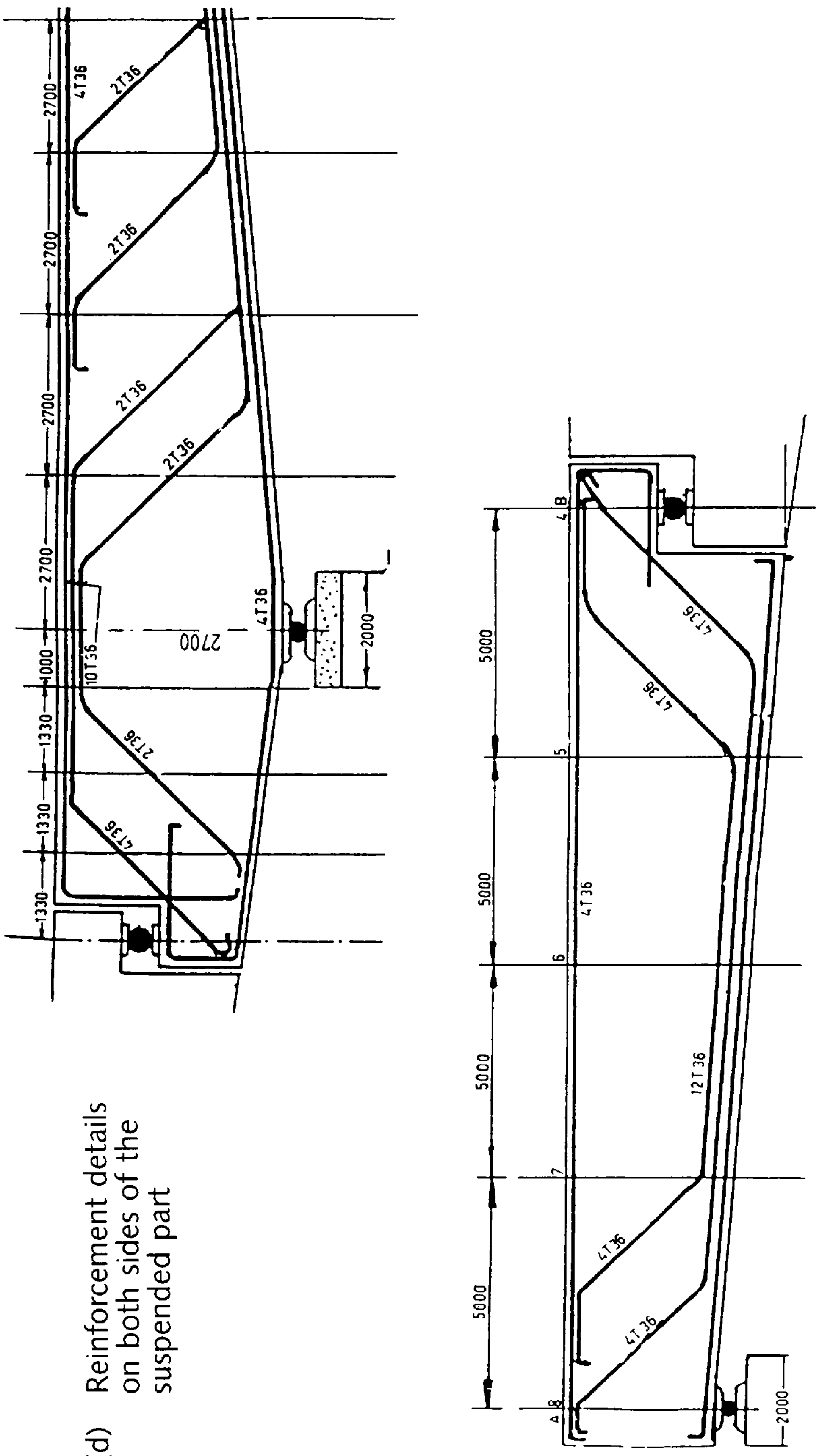


(c) Deck reinforcement



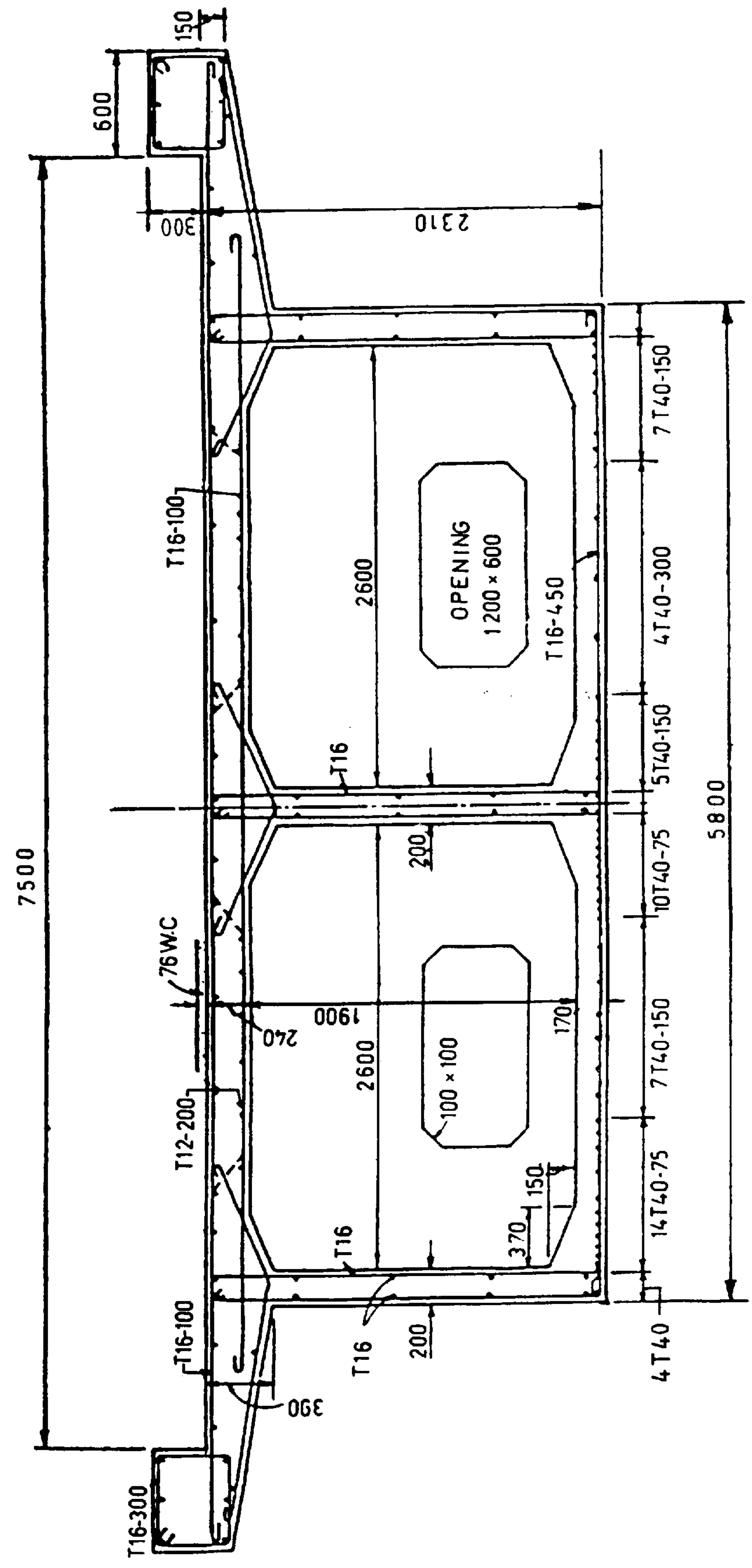
CONTINUOUS R.C. GIRDER BRIDGE (CONT.)

SHEET NO. VIII.1.4



(d) Reinforcement details on both sides of the suspended part

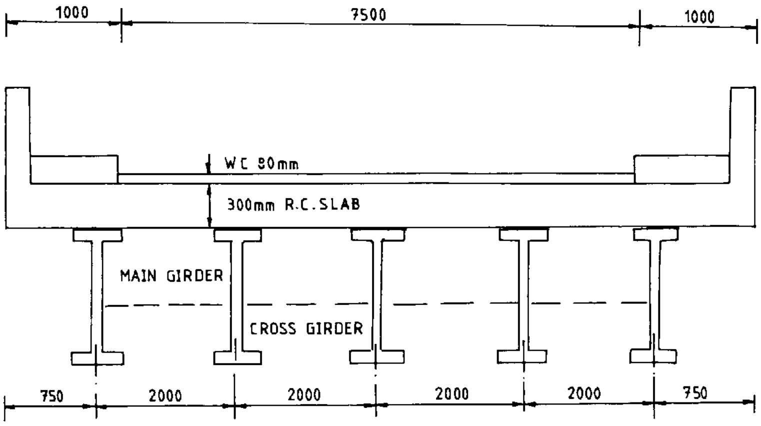
TWIN-BOX BRIDGE SHEET NO. VIII.1.5



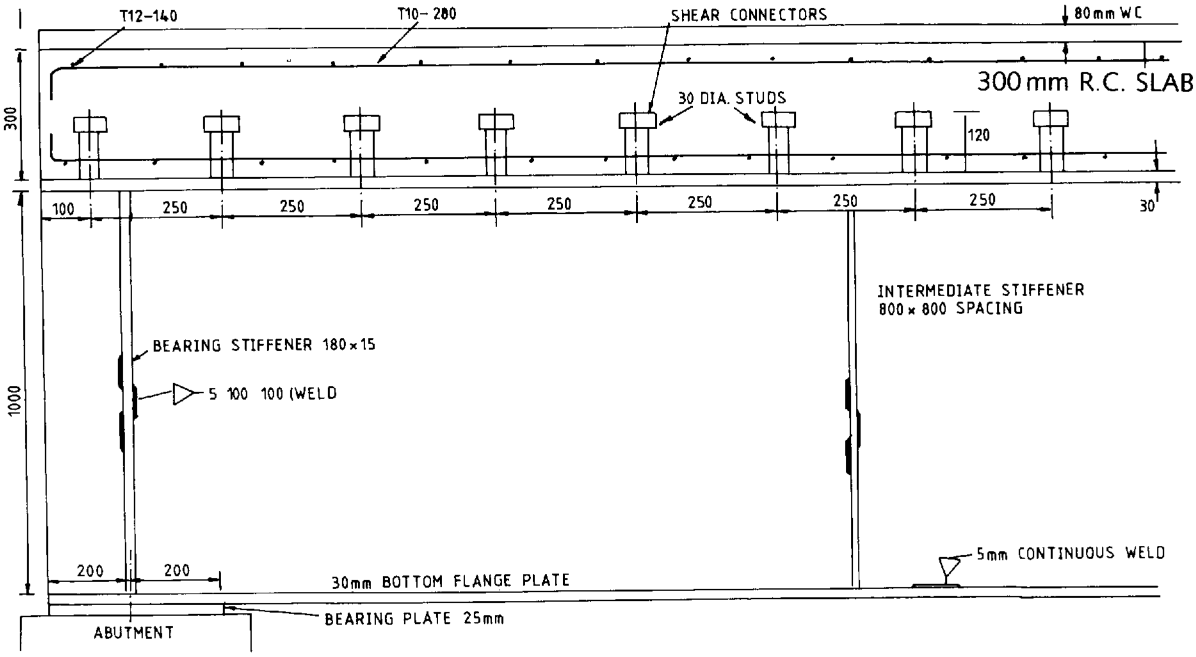
Typical cross-section of a hollow box girder

COMPOSITE STEEL BEAM CONCRETE DECK BRIDGE

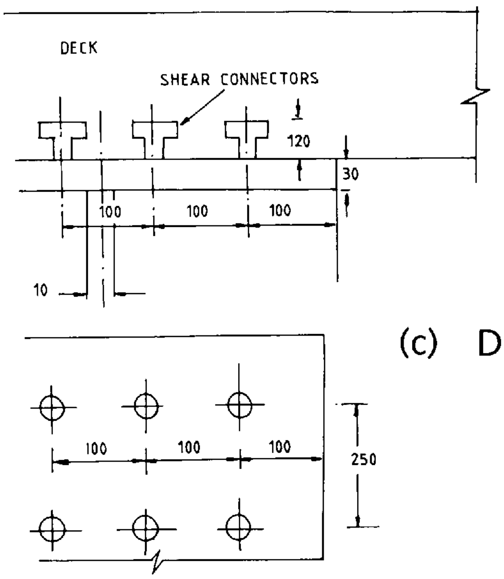
SHEET NO. VIII.1.6



(a) Cross-section of deck slab



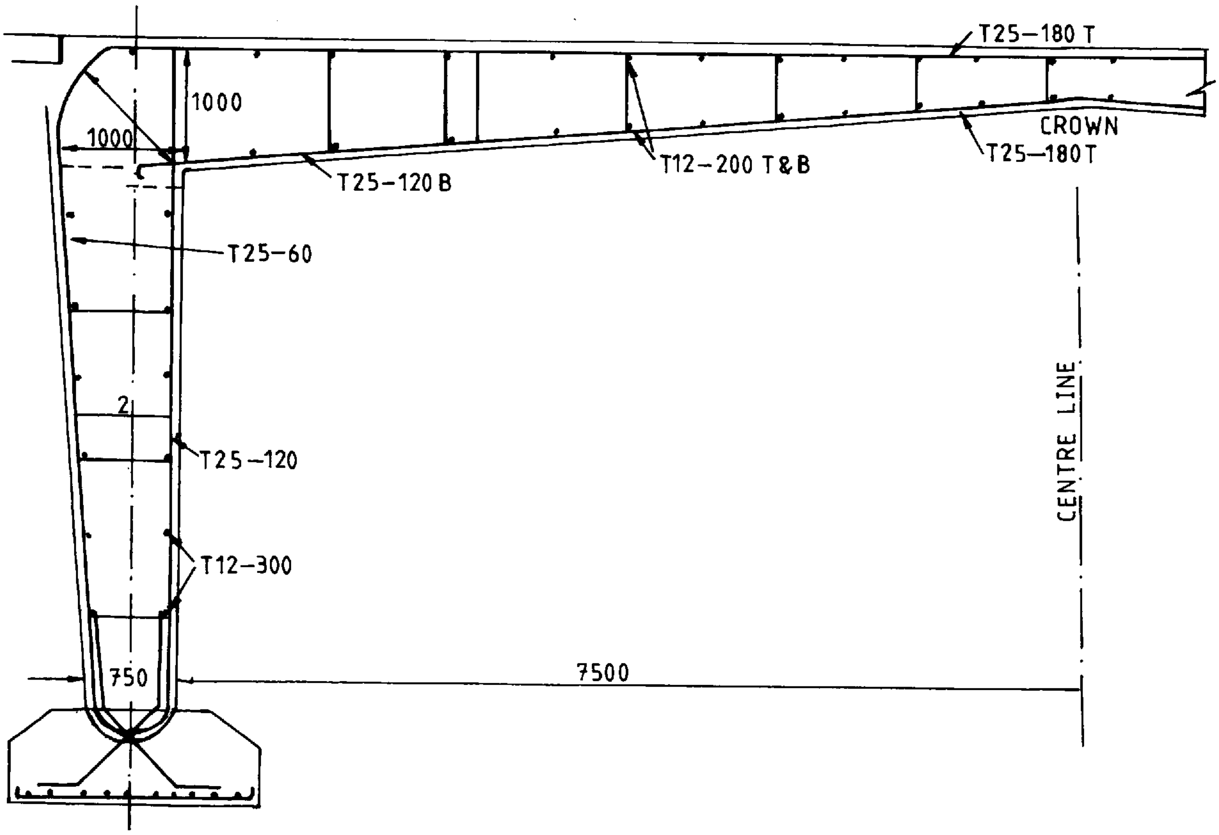
(b) Longitudinal elevation



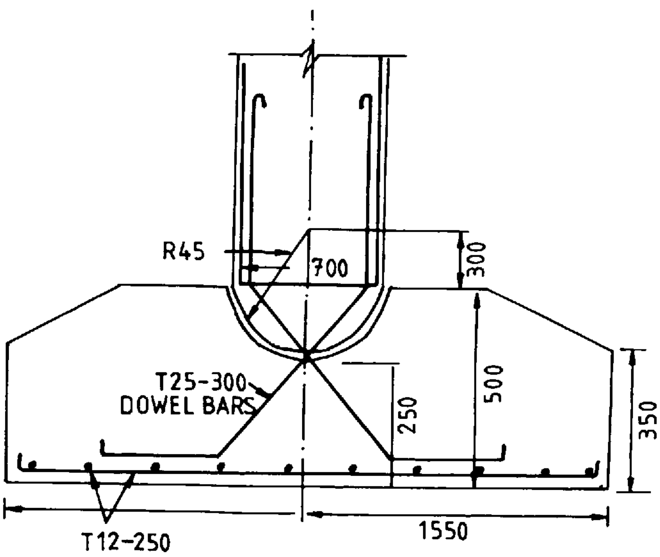
(c) Detail of shear connector

R.C. RIGID FRAME BRIDGE SHEET NO. VIII.1.7

(a) Longitudinal section of a rigid frame

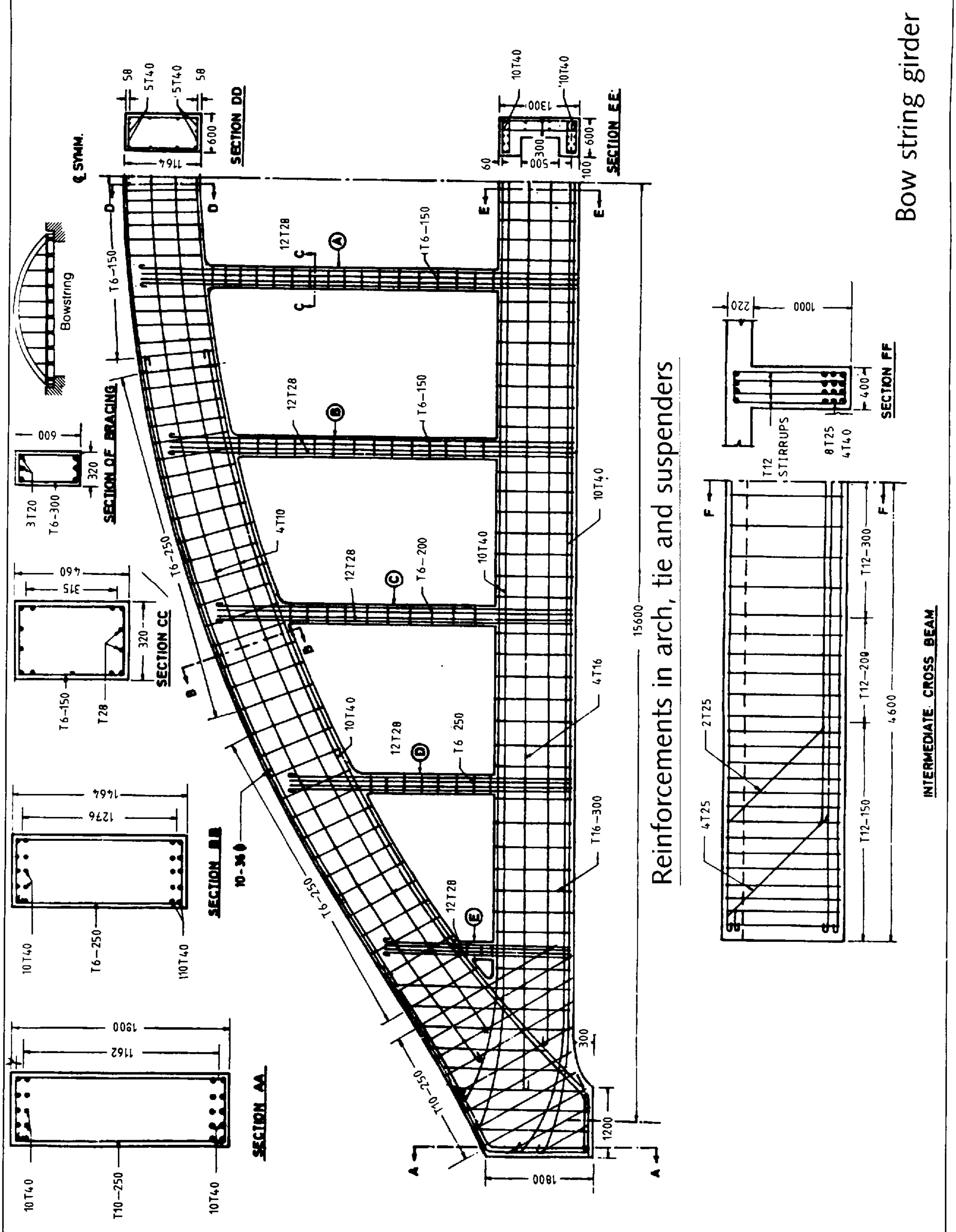


(b) Reinforcement details in footings



BOW-STRING BRIDGE WITH TYPICAL REINFORCEMENT DETAILS

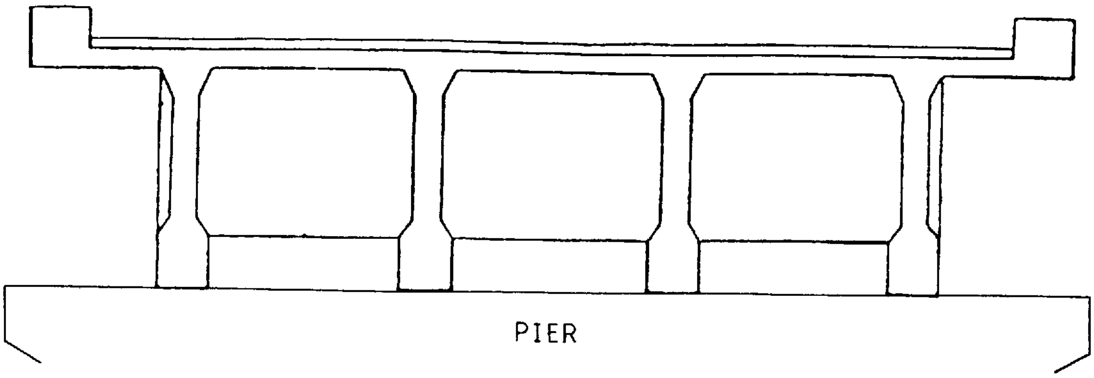
SHEET NO. VIII.1.8



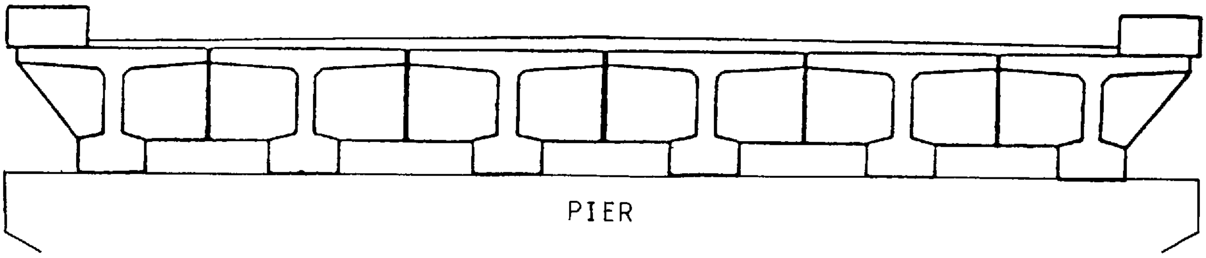
TYPICAL BRIDGE DECKS WITH POST-TENSIONED GIRDERS

SHEET NO. VIII.1.9

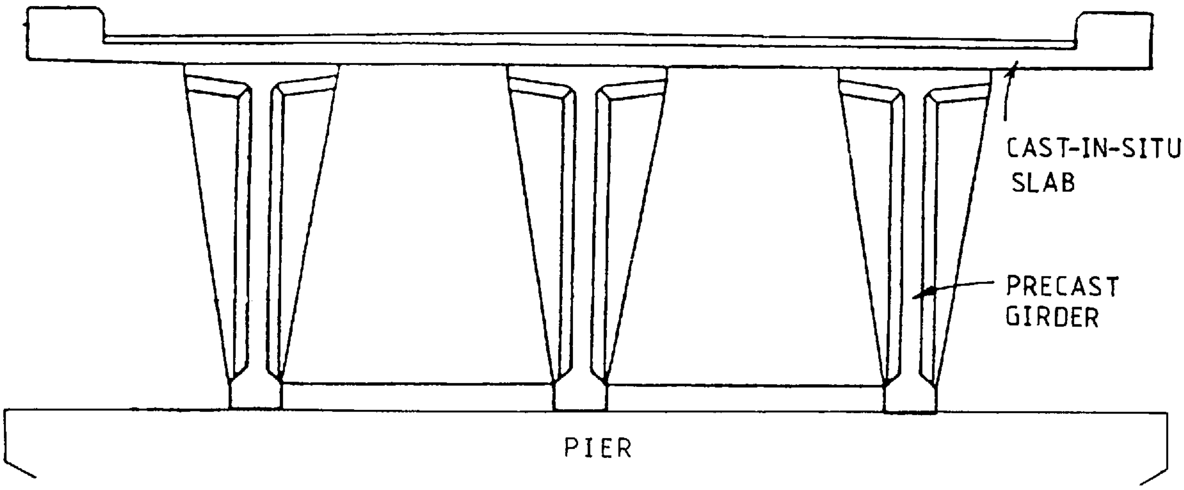
(a) Cast-*in-situ* prestressed concrete deck



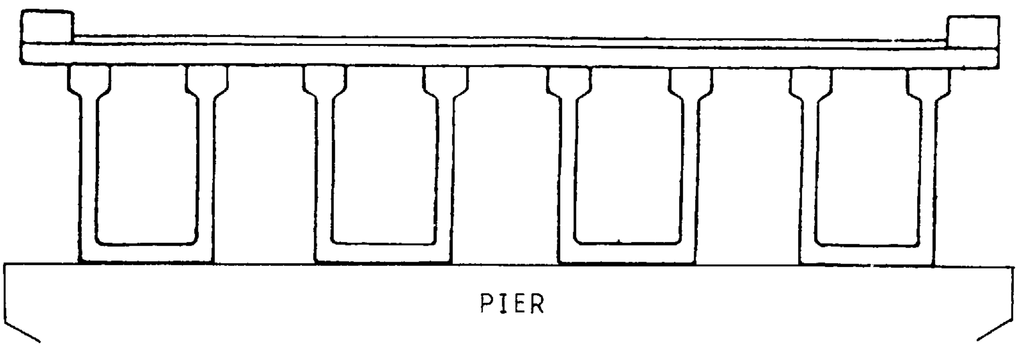
(b) Bridge with precast prestressed girders



(c) Deck with composite construction

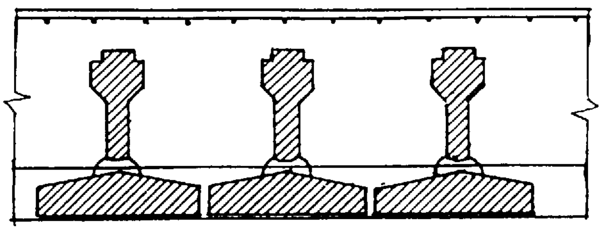


(d) Deck with composite construction

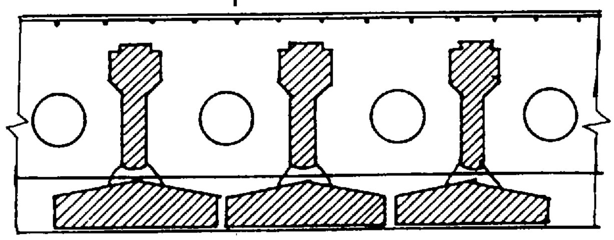


TYPICAL BRIDGE DECKS WITH POST-TENSIONED GIRDERS (CONT.) SHEET NO. VIII.1.10

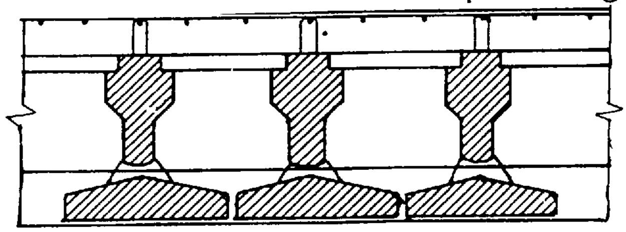
(e) Pretensioned inverted T-beam



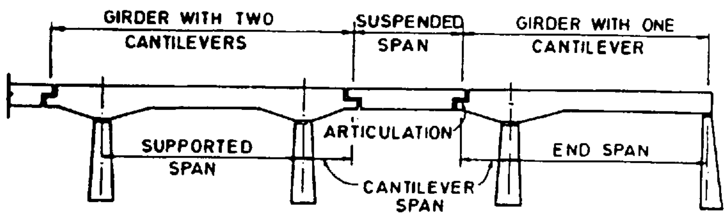
(f) Hollow cored pretensioned deck



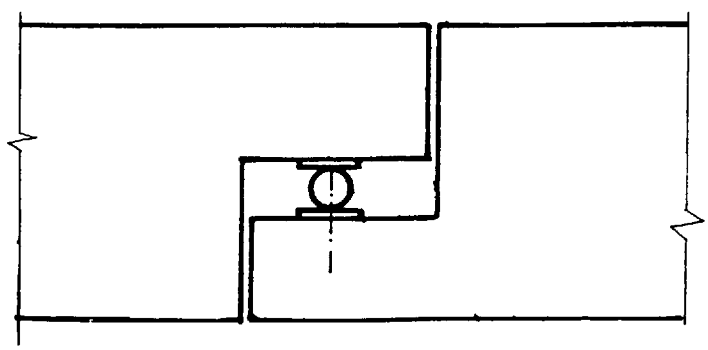
(g) Pretensioned beam with top decking



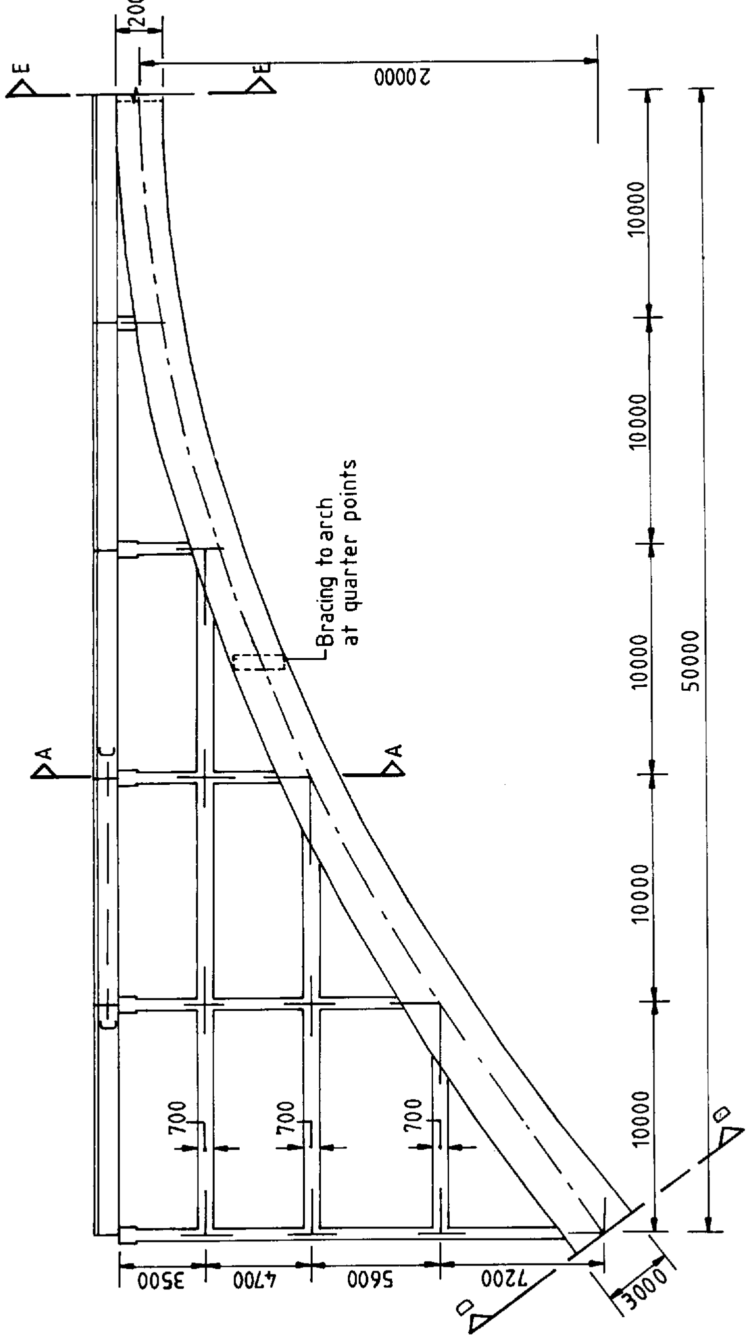
(h) Schematic diagram of balanced cantilever bridge



(i) Articulation



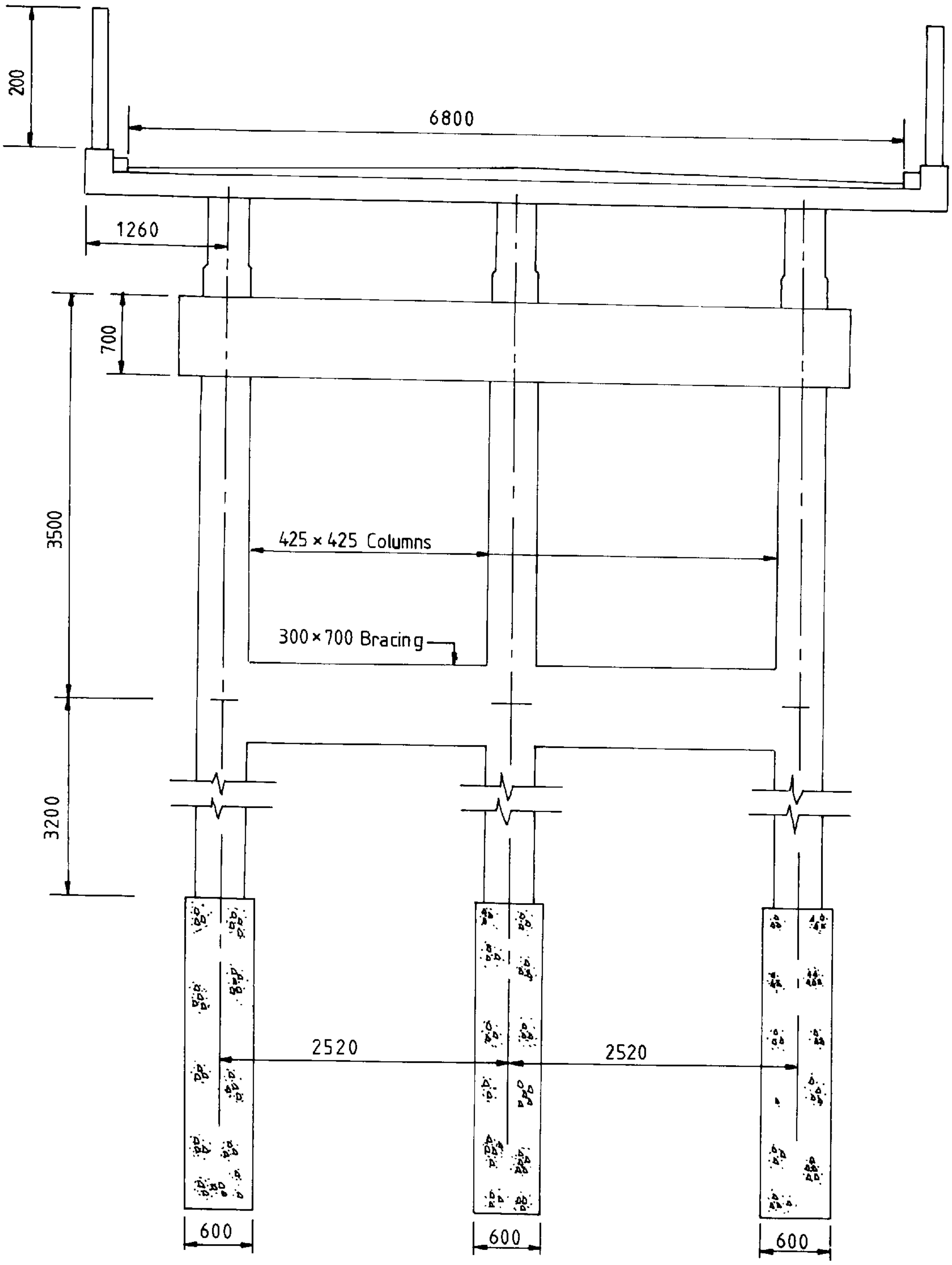
OPEN SPANDREL ARCH BRIDGE SHEET NO. VIII.1.11



ELEVATION OF HALF SPAN OF BRIDGE

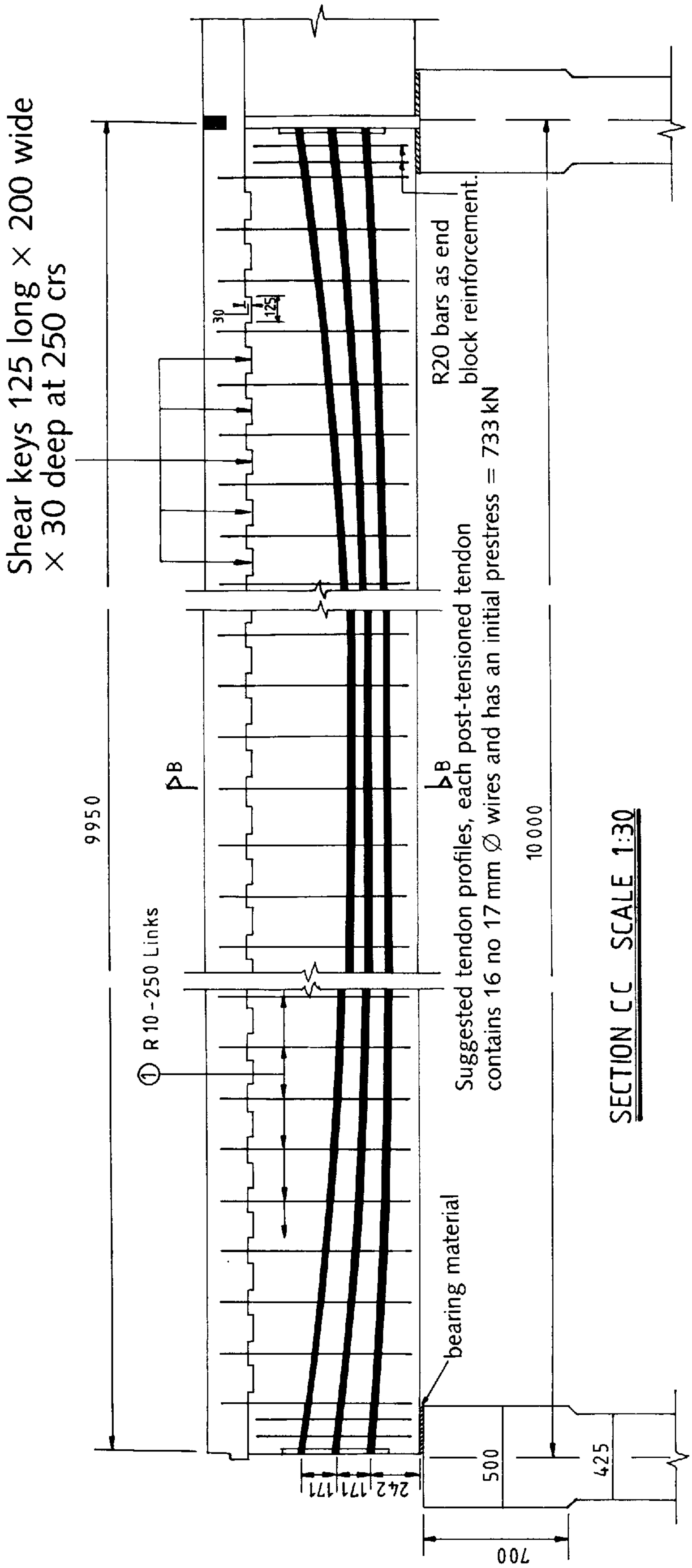
SCALE 1:200

OPEN SPANDREL ARCH BRIDGE SHEET NO. VIII.1.12



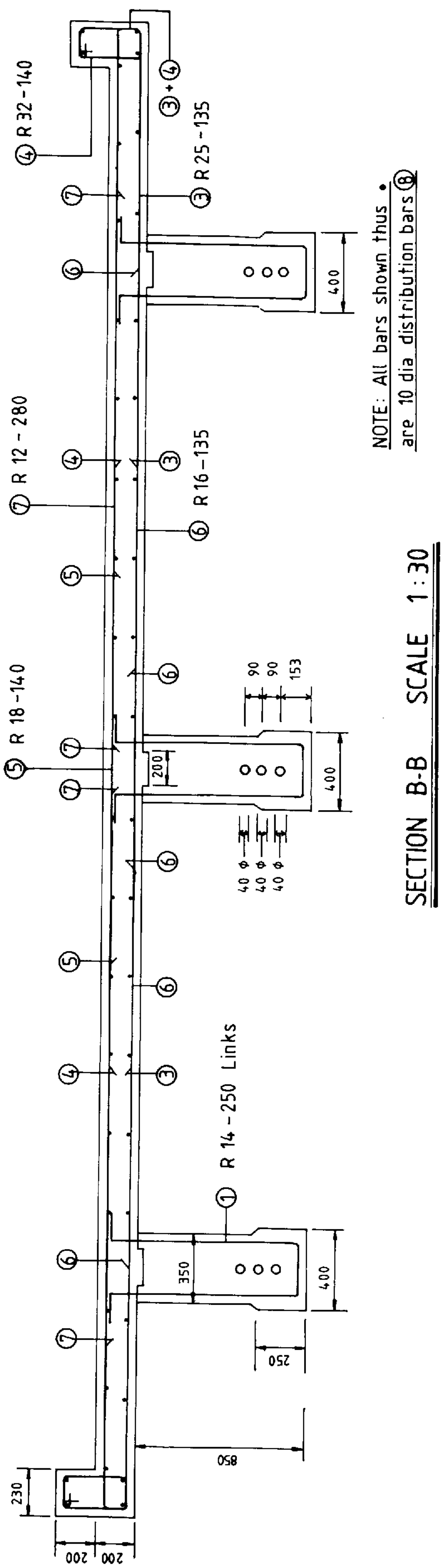
SECTION A-A SCALE 1:50

OPEN SPANDREL ARCH BRIDGE SHEET NO. VIII.1.13

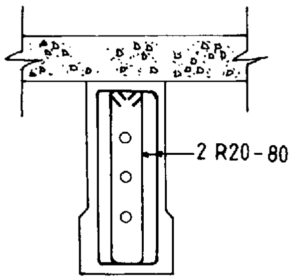


SECTION C C SCALE 1:30

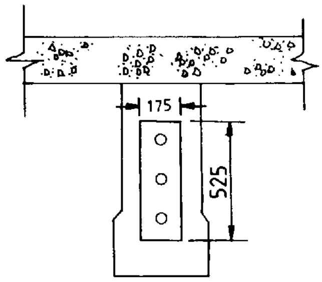
OPEN SPANDREL ARCH BRIDGE SHEET NO. VIII.1.14



OPEN SPANDREL ARCH BRIDGE SHEET NO. VIII.1.15

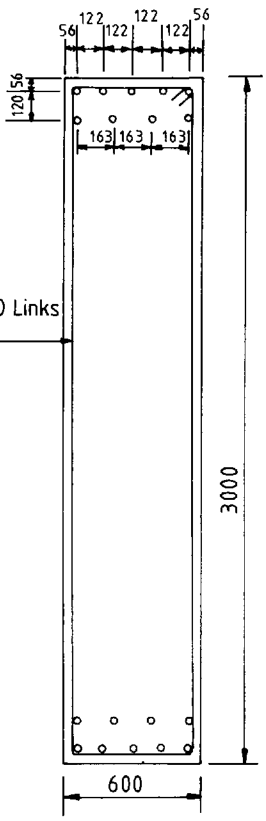


END SECTION OF POST TENSIONED
BEAM SHOWING END BLOCK REINFORCEMENT

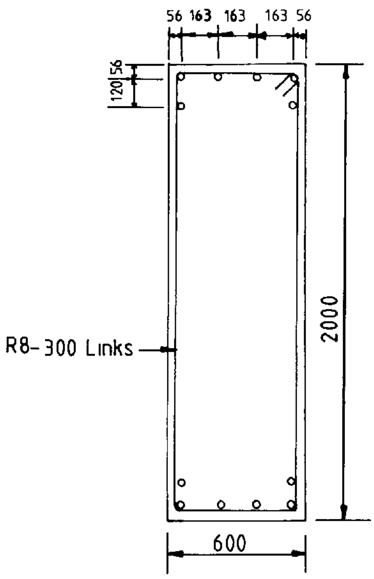


END SECTION OF POST TENSIONED
BEAM SHOWING BEARING PLATE

SCALE 1:20



SECTION D-D



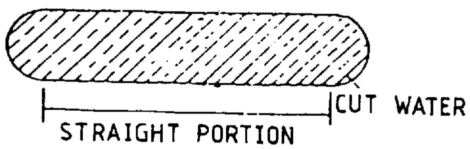
SECTION E-E

NOTE : All longitudinal steel in parabolic arches to be 32 dia.

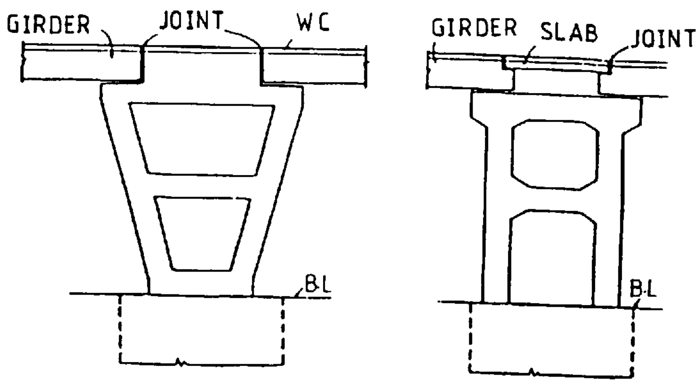
PIERS AND BED BLOCK

SHEET NO. VIII.1.16

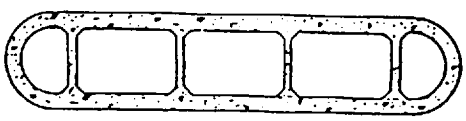
(a) Solid pier of masonry



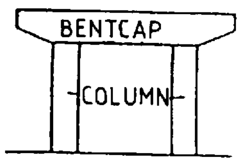
Typical framed piers



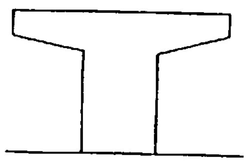
(b) Cellular R.C. pier



(c) Trestle R.C. pier

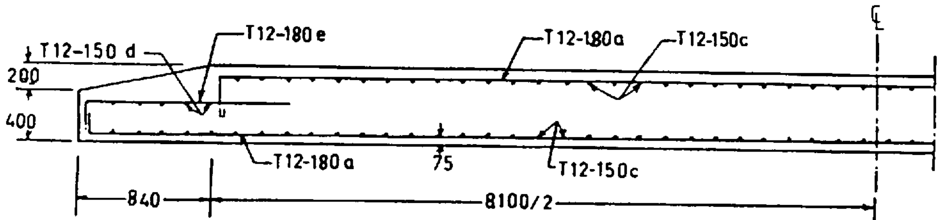


(d) Hammerhead type

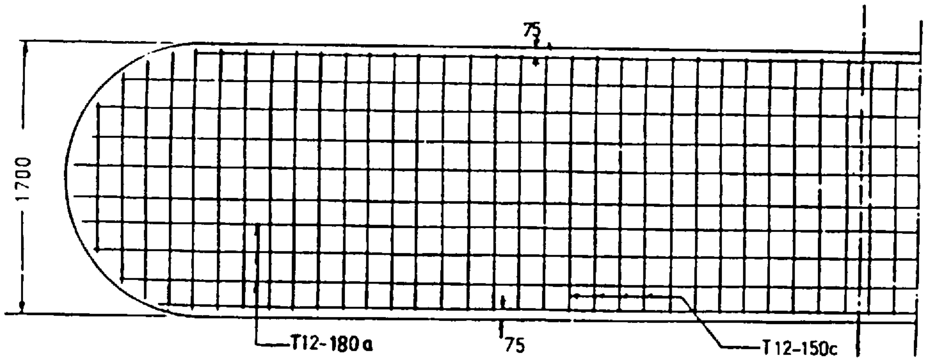


Typical shape of piers

Typical details of bed block over piers

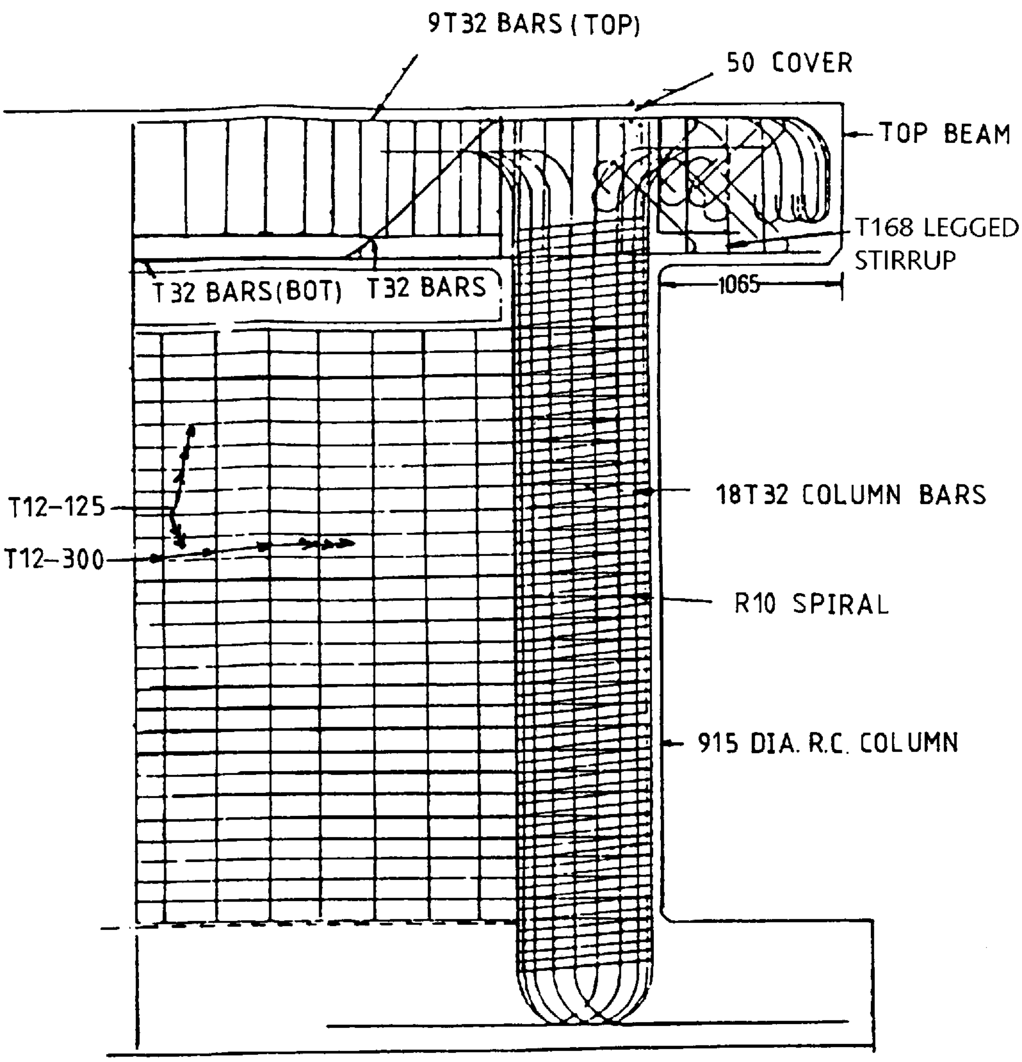


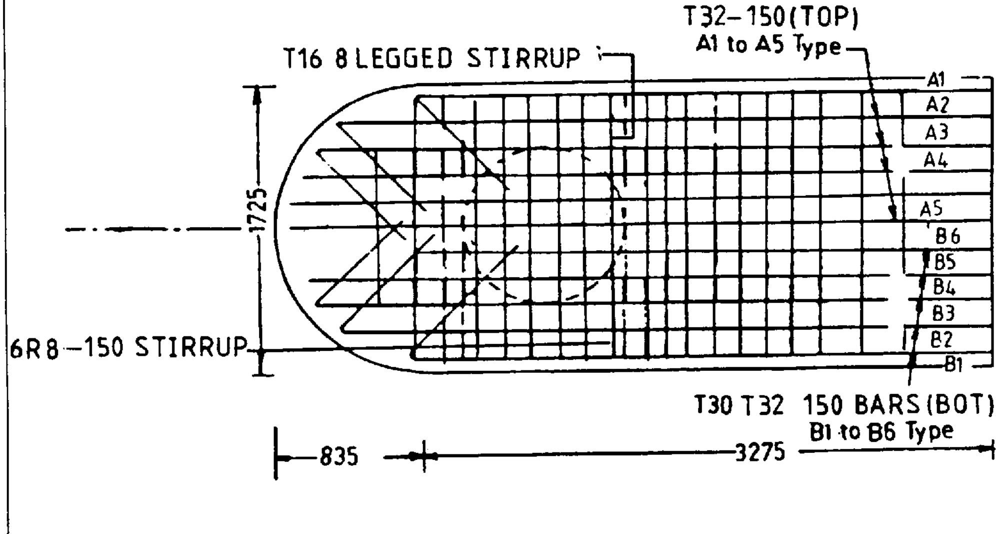
LONGITUDINAL SECTION



PLAN

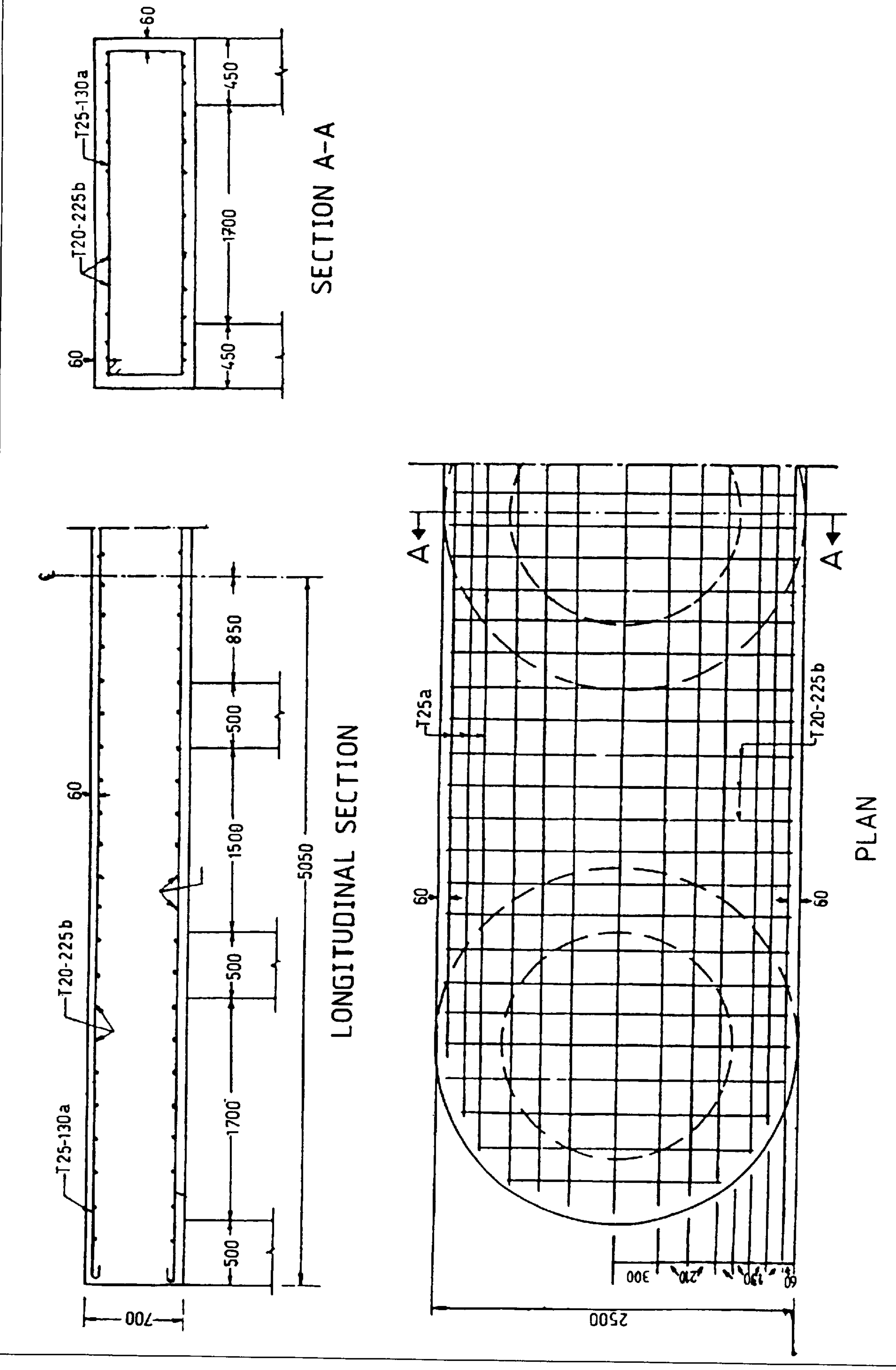
DETAILS OF PIER BENT SHEET NO. VIII.1.17





WELL CAP FOR PIER

SHEET NO. VIII.1.18

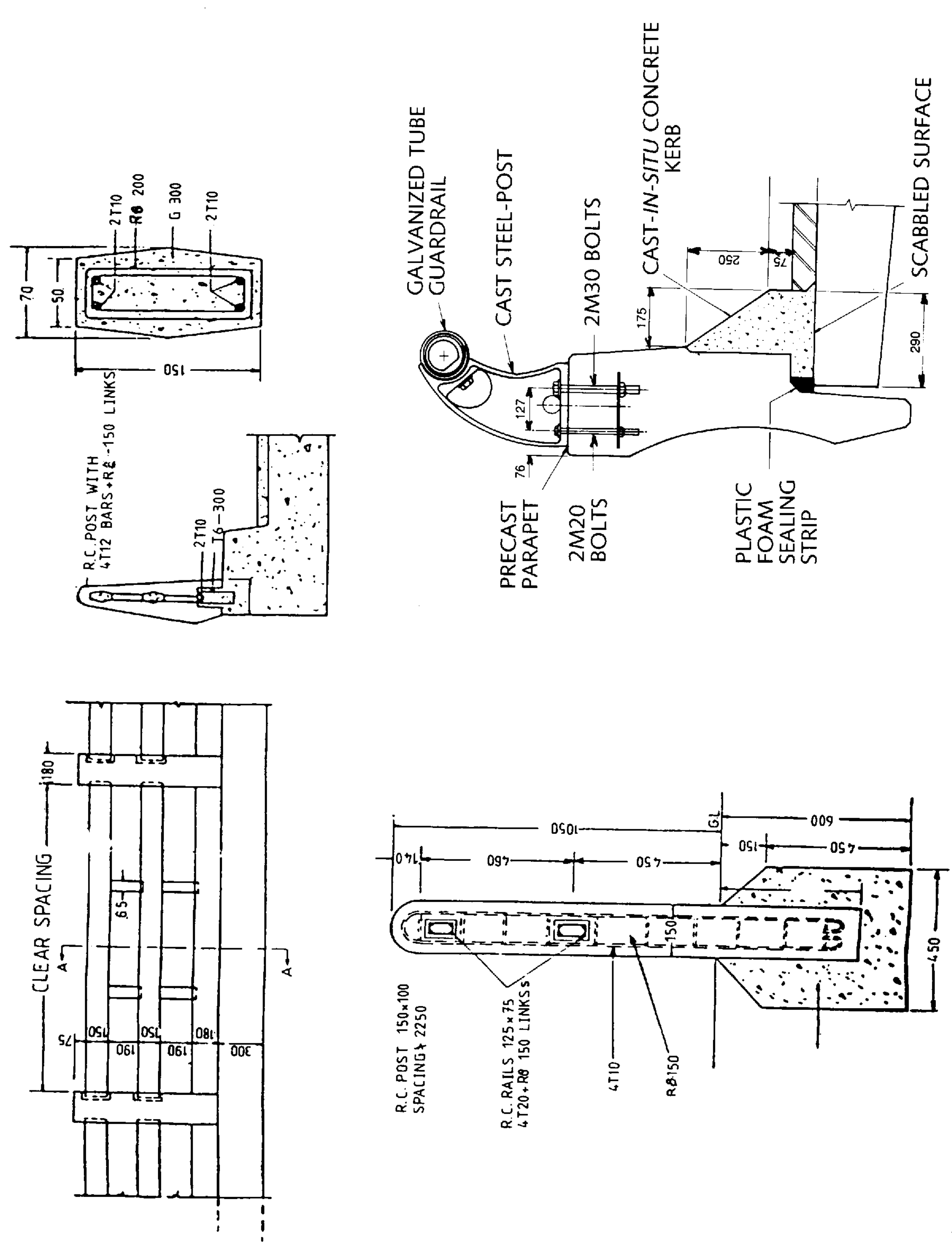


As stated earlier, in order to protect vehicles from accidents, and the pedestrians while crossing the main bridge, typical details are given for hand-rails forming the balustrades on Sheet No. VIII.1.19.

Sheet Nos. VIII.1.20 and VIII.1.21 give different types of bridge bearings. Structural engineers working on bridges and codes of practice are consulted on the use of any one of these on a specific job. The manufacturers can provide loads and specifications for individual types of bearings.

DETAILS OF HAND-RAILS

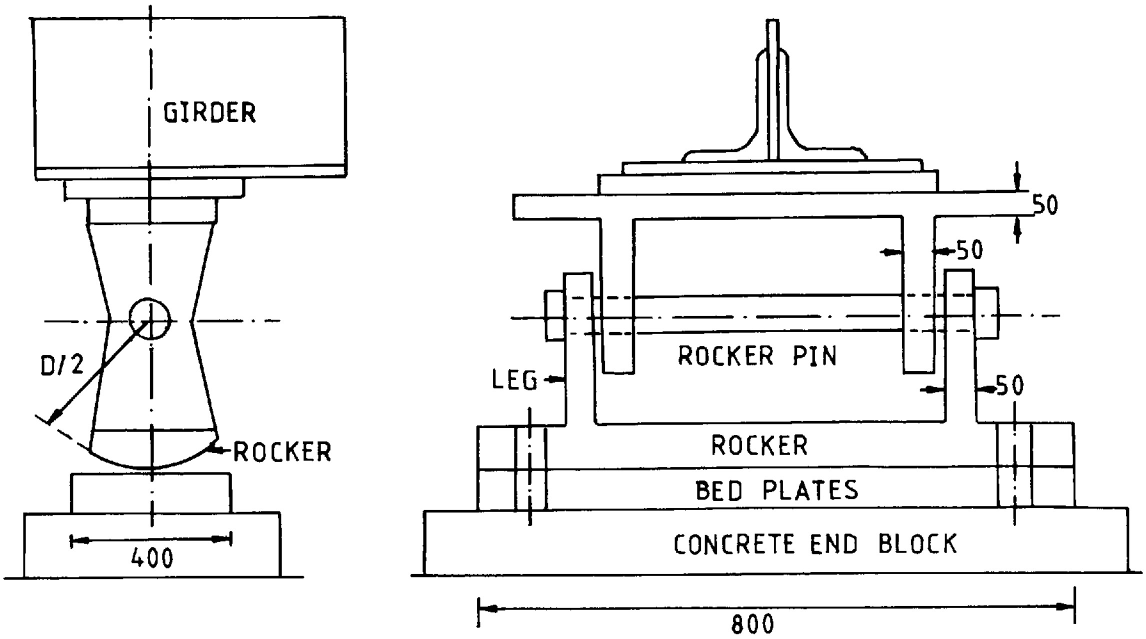
SHEET NO. VIII.1.19



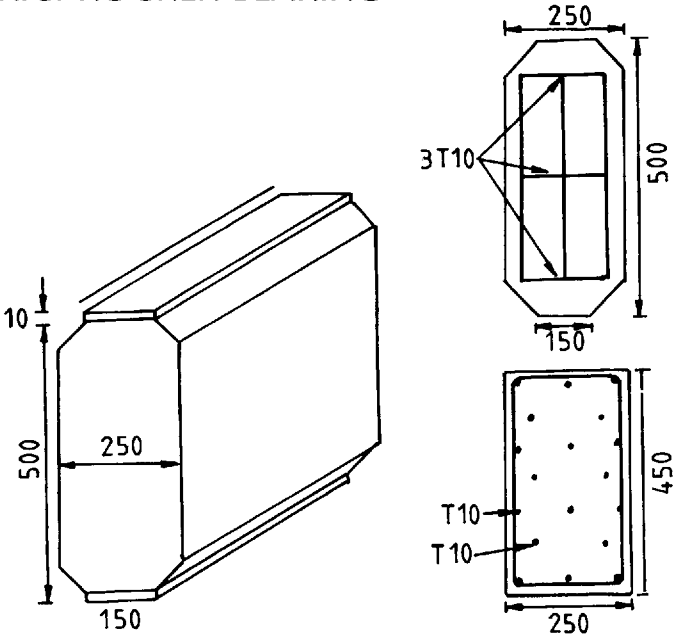
(Courtesy of Overseas Projects Corporation of Victoria, Australia)

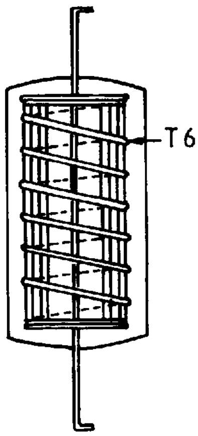
TYPICAL ROCKER BEARING FOR COMPOSITE STRUCTURES

SHEET NO. VIII.1.20

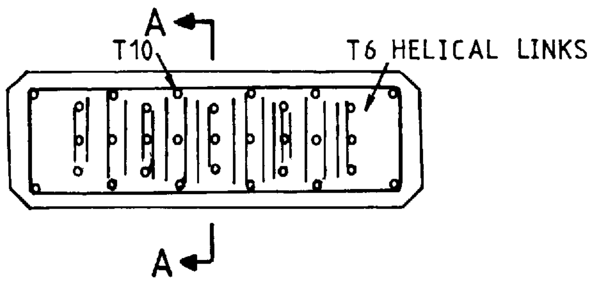


R.C. ROCKER BEARING





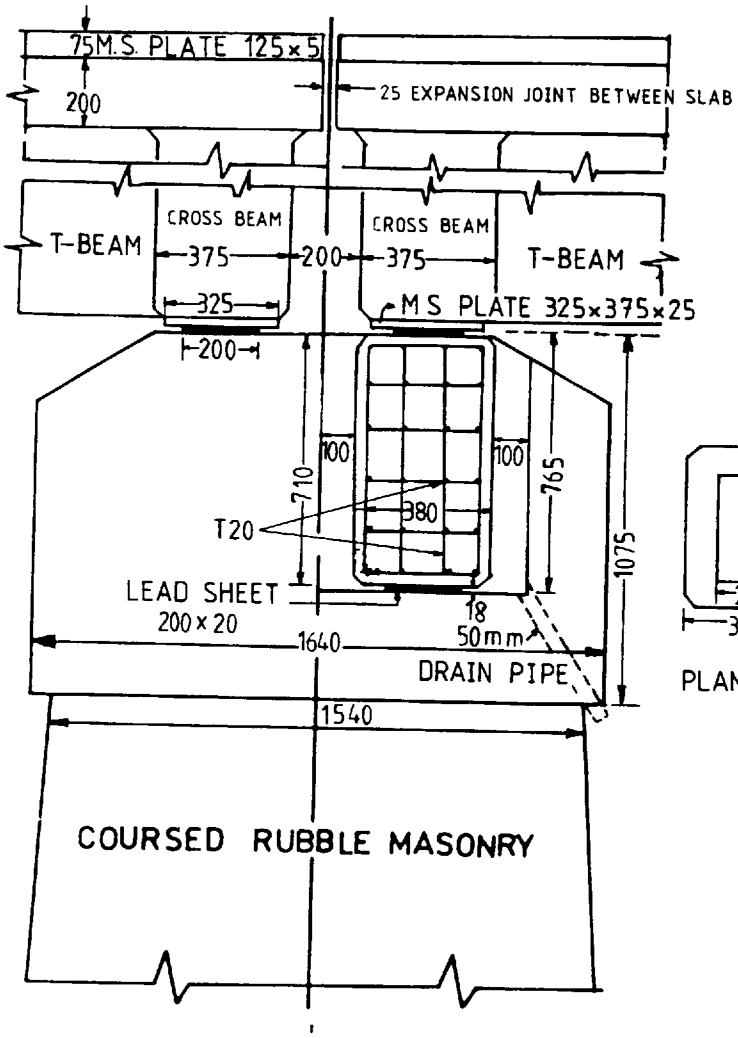
SECTION A-A



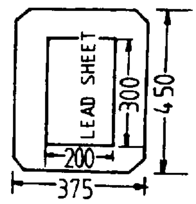
SECTIONAL PLAN

ROCKER BEARING

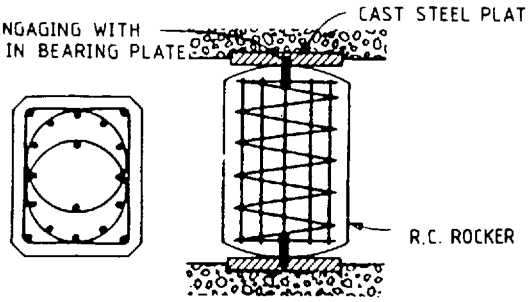
SHEET NO. VIII.1.21



DETAILS OF ROCKER BEARING



PLAN OF ROCKER



ROCKER BEARING

Section VIII.2
Concrete Shells

VIII.2.1 General introduction

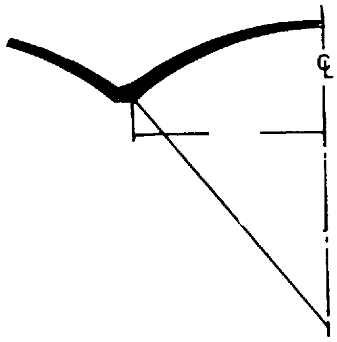
Various concrete shell roofs in reinforced concrete have been designed to provide for large uninterrupted roof spans for industrial and other buildings. Various attempts have been made to classify the types of shells. The most popular classification is based on Gaussian curvature and is given below:

(a) *Shells of Positive Gaussian Curvature (Synclastic Shells)*
Here the surface curves are away from a tangent plane at any point on the surface. They lie completely on one side of the plane. Examples are: spherical dome and elliptic paraboloids.
(b) *Shells of Negative Gaussian Curvature (Anticlastic Shells)*
They are formed by two families of curves which are opposite in direction. Examples are: hyperbolic paraboloids, conoidal shells and hyperbolas of revolution.
(c) *Shells of Zero Gaussian Curvature (Singly Curved Shells)*
They lie between positive and negative Gaussian curvature. Examples are: cylindrical shells, cylinders and cones.

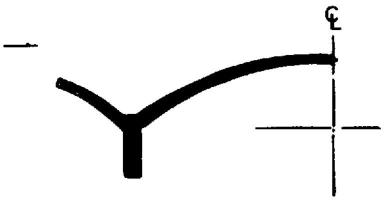
In addition to the above classification, shells are classified on the basis of shells of rotation and shells of translation. The shells of rotation are domes (spherical, elliptical, conoidal) and the shells of translation are hyperbolic paraboloids, elliptical paraboloids, etc. Sheet Nos. VIII.2.1 and VIII.2.2 give some of these examples.

CYLINDRICAL SHELL

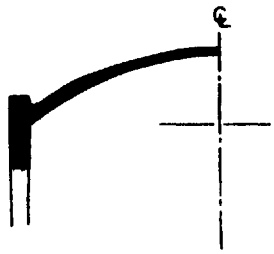
SHEET NO. VIII.2.1



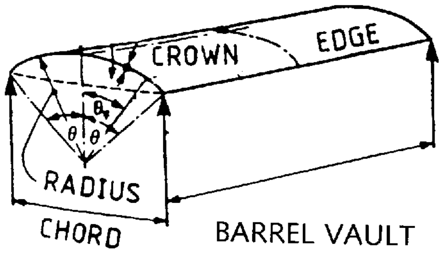
FEATHER EDGE SHELL



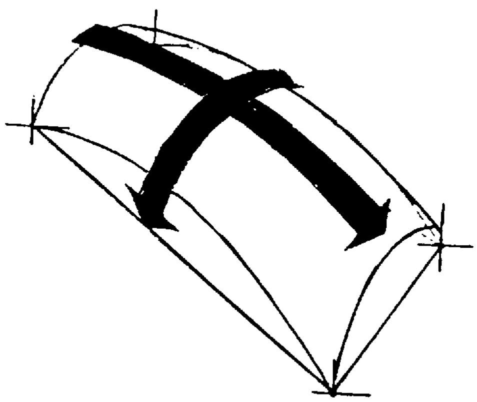
SHELL WITH VALLEY BEAM



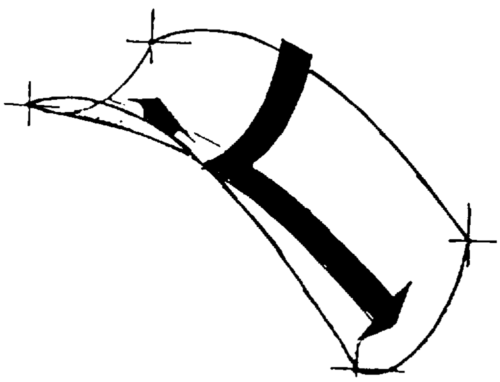
SHELL WITH
EDGE BEAM



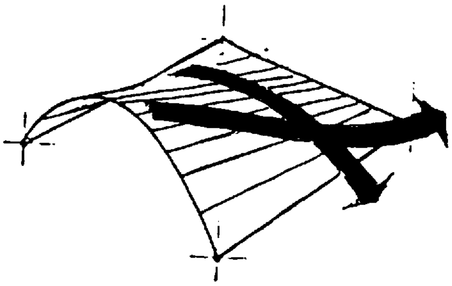
BARREL VAULT



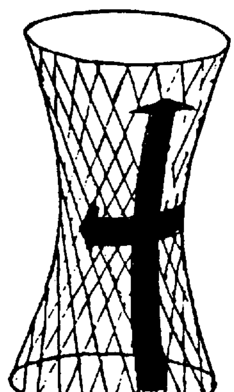
SYNCLASTIC OR ELLIPTICAL SURFACE



ANTICLASTIC OR HYPERBOLIC SURFACE



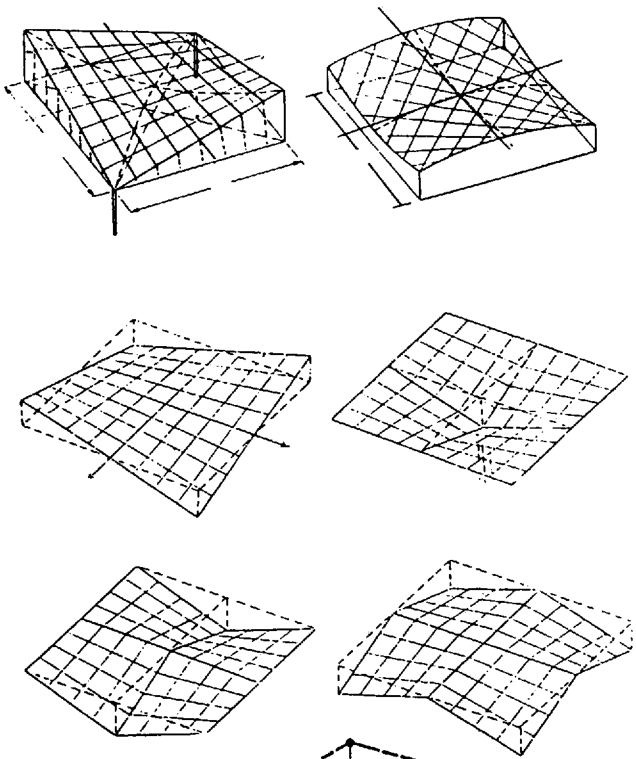
CONOID



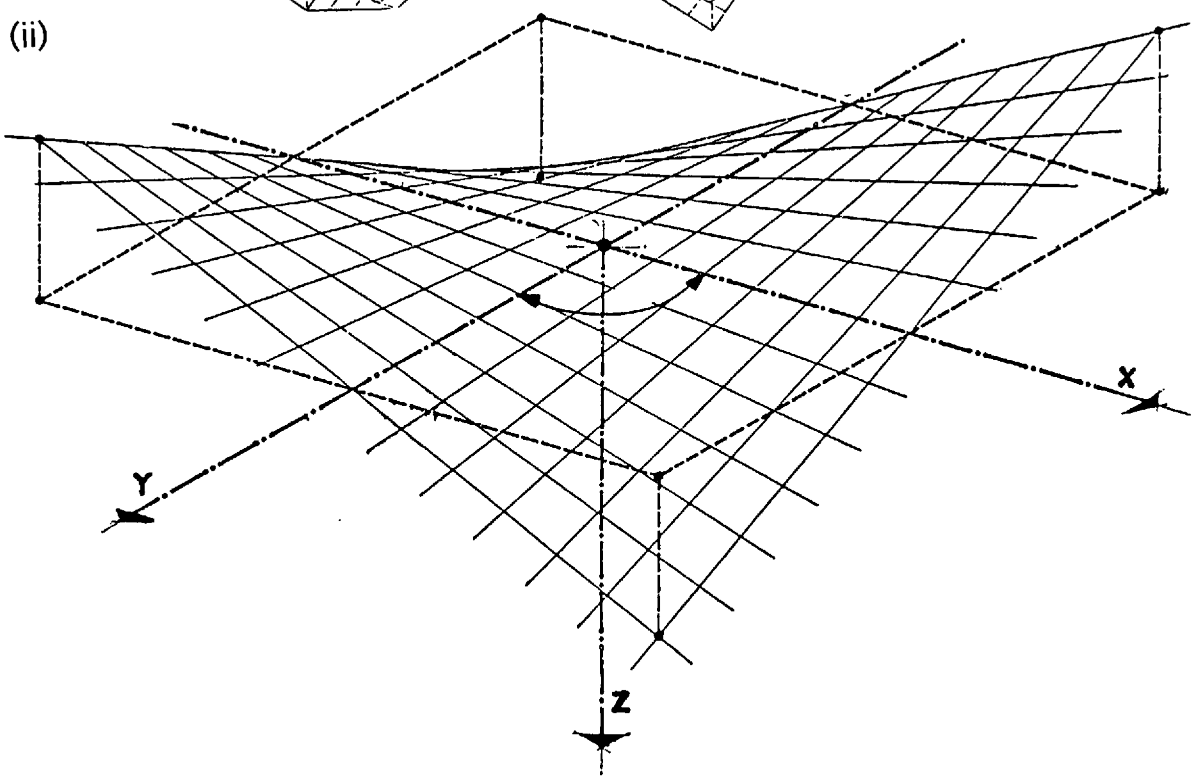
HYPERBOLOID

HYPERBOLIC PARABOLOIDS SHEET NO. VIII.2.2

(i)

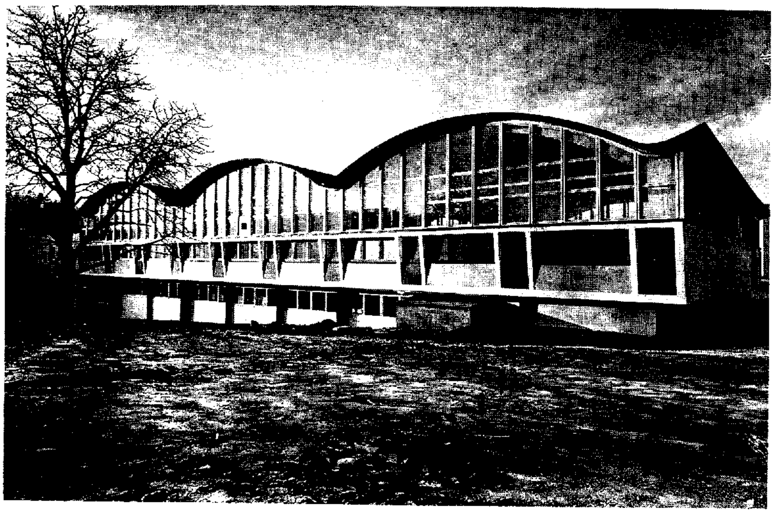


(ii)

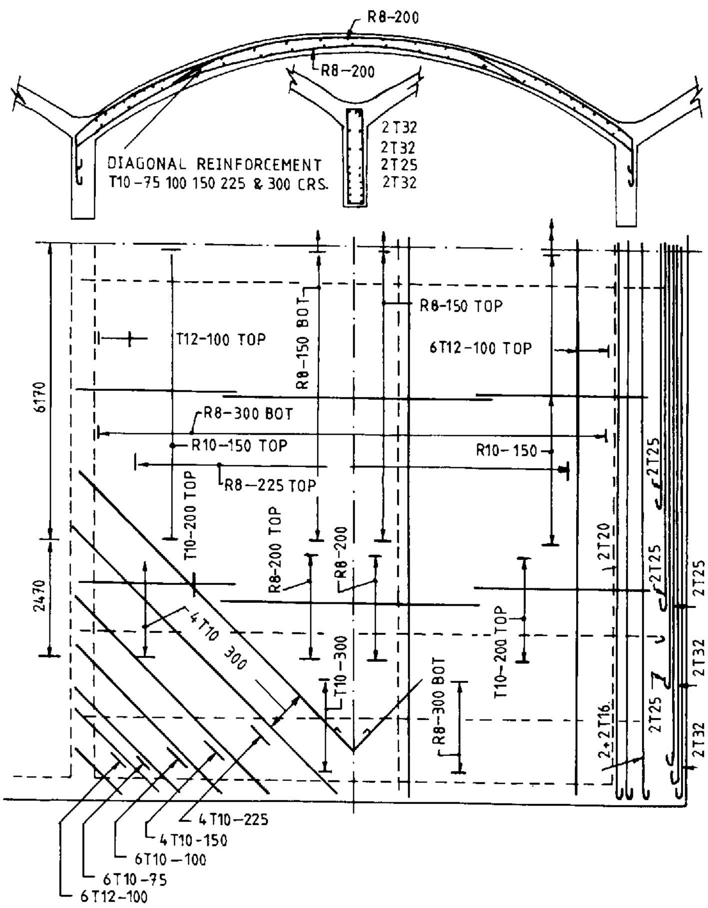


THIN CYLINDRICAL SHELL AT HELSINKI, FINLAND

SHEET NO. VIII.2.3



(Courtesy of S. Eggwertz, Consulting Engineer)



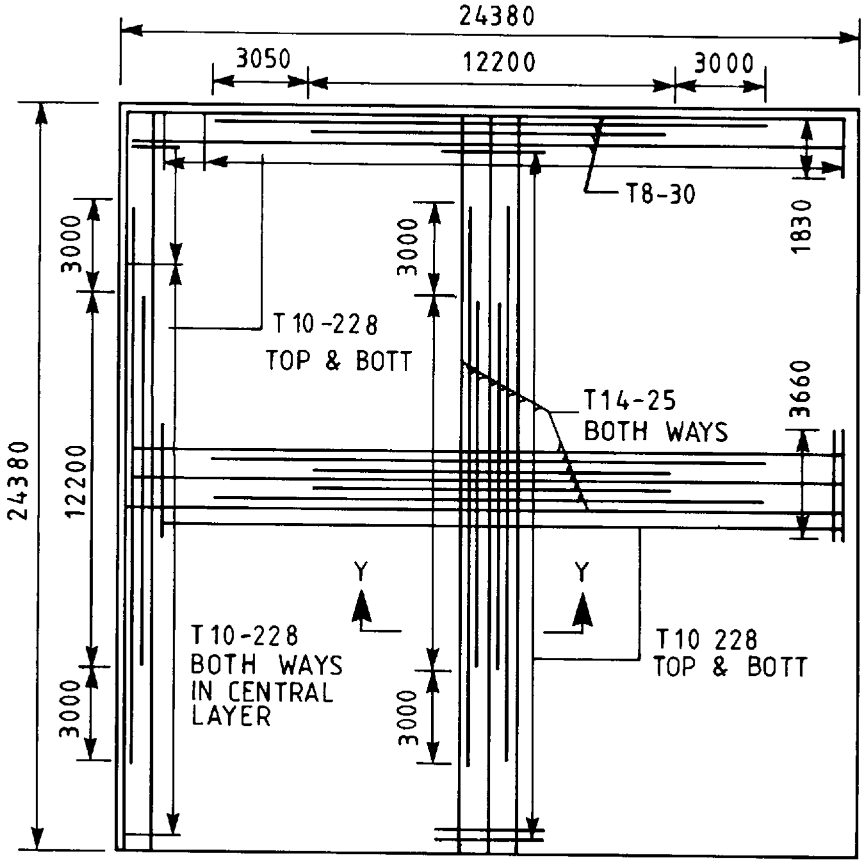
VIII.2.2 Shells

A cylindrical shell's surface is generated by moving a straight line parallel to itself along a cylindrical surface. The cylindrical surface can be a circular arc or any segment of a cylinder. At the ends, longitudinal edge beams simply supported or continuous are provided to stiffen the shell against the edge disturbance, bending and shear. These shells can be single ones spanning over many supports or can be multiple shells in transverse directions spanning over a single span. Sheet No. VIII.2.3 shows the reinforcement layout for a cylindrical shell with valley beams. The radius, thickness and span of the shell are 100 mm, 9.25 m and 22 m respectively. The edge beams are 0.25 m wide × 1.75 m deep. A similar layout will be required for non-circular cylindrical shells. Sheet No. VIII.2.3 shows a photograph of the completed structure.

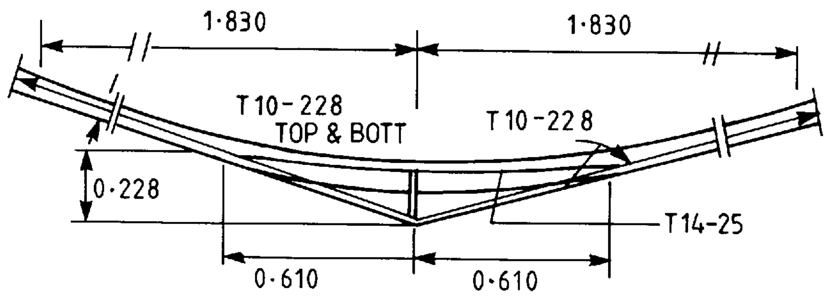
The shell shown on Sheet No. VIII.2.3 has been designed for a load of 360 kN/m^2 excluding the weight of the edge beams. Longitudinal steel has been provided because of the tensile force occurring in that direction. Transverse and diagonal steels are provided for transverse stresses and principal tensile stresses. Starter bars are provided in the end zone to connect shell and beam reinforcement and to offset stresses occurring due to edge disturbance.

INVERTED UMBRELLA-TYPE HYPAR SHELL

SHEET NO. VIII.2.4



PLAN

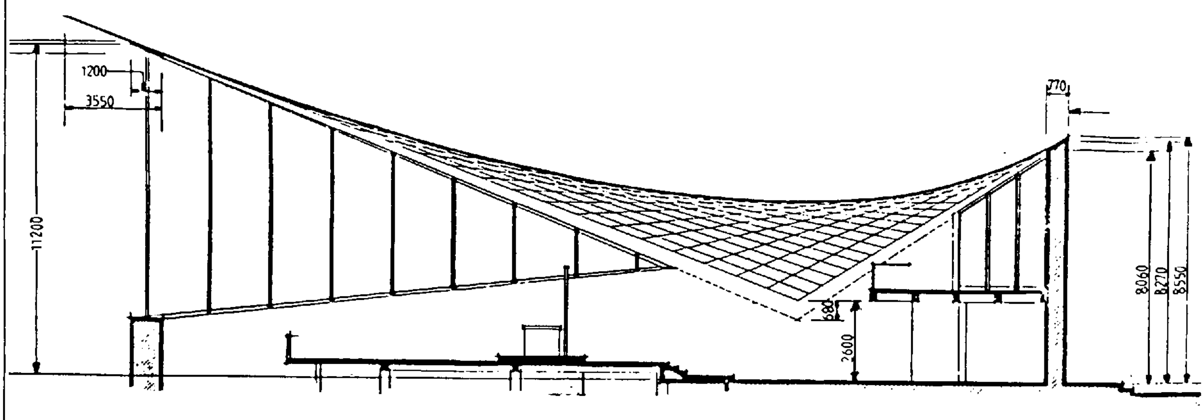


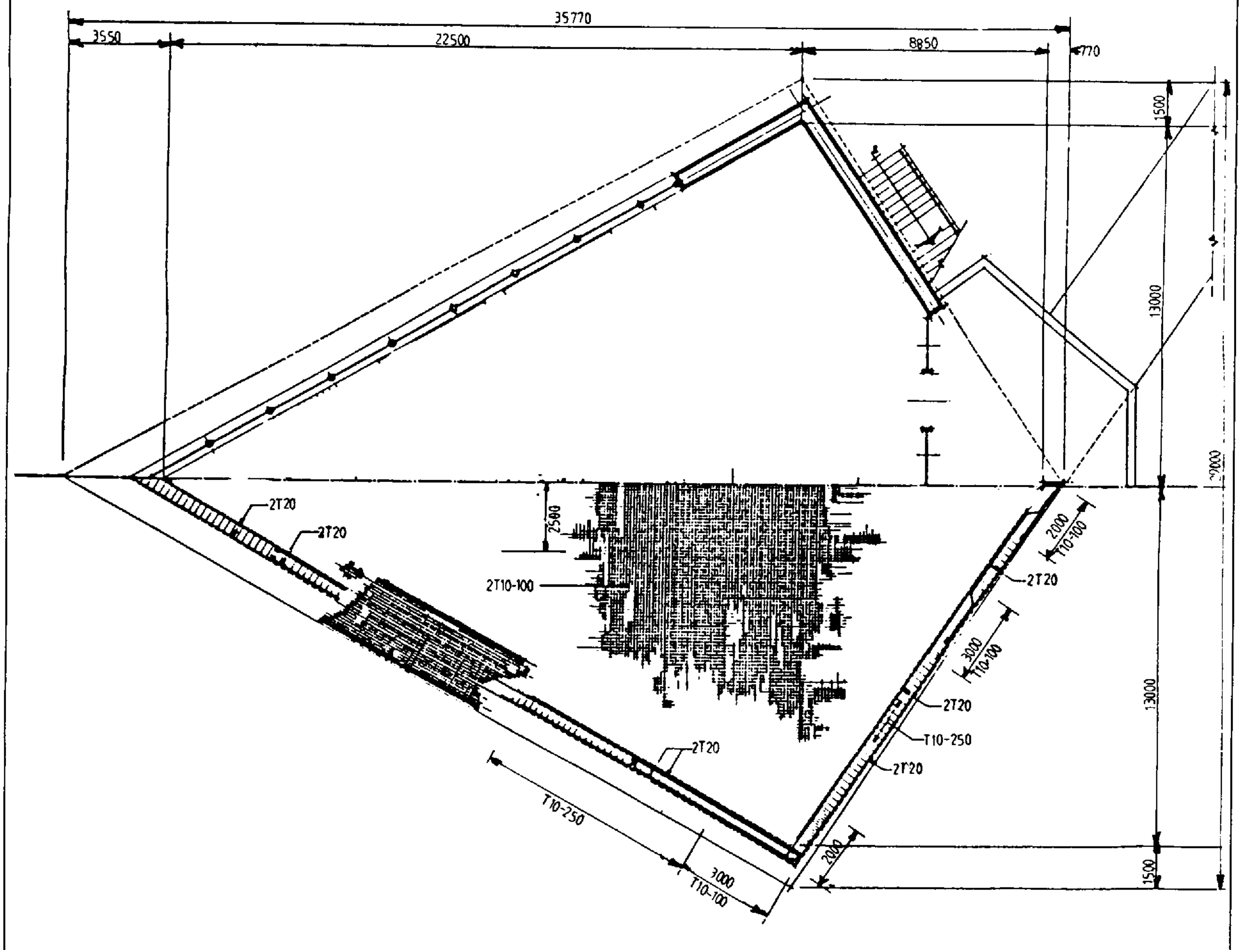
SECTION Y-Y

The hyperbolic paraboloid (hypar) shells can either be seen as a warped parallelogram or as a surface of translation. A number of these hypar shells are shown on Sheet No. VIII.2.2. The equation of the surface is first defined for the hypar types; forces and stresses are determined in the main shell and in the edge beams. Sheet No. VIII.2.4 shows an inverted umbrella-type hypar shell 24.38 m × 24.38 m. The roof is a combination of four units and of thickness 75 mm and is designed for a uniformly-distributed load of 345 kN/m^2. Sheet VIII.2.4 shows a detailed reinforcement plan and section of such a shell.

HYPAR SHELL IN BRAZIL

SHEET NO. VIII.2.5

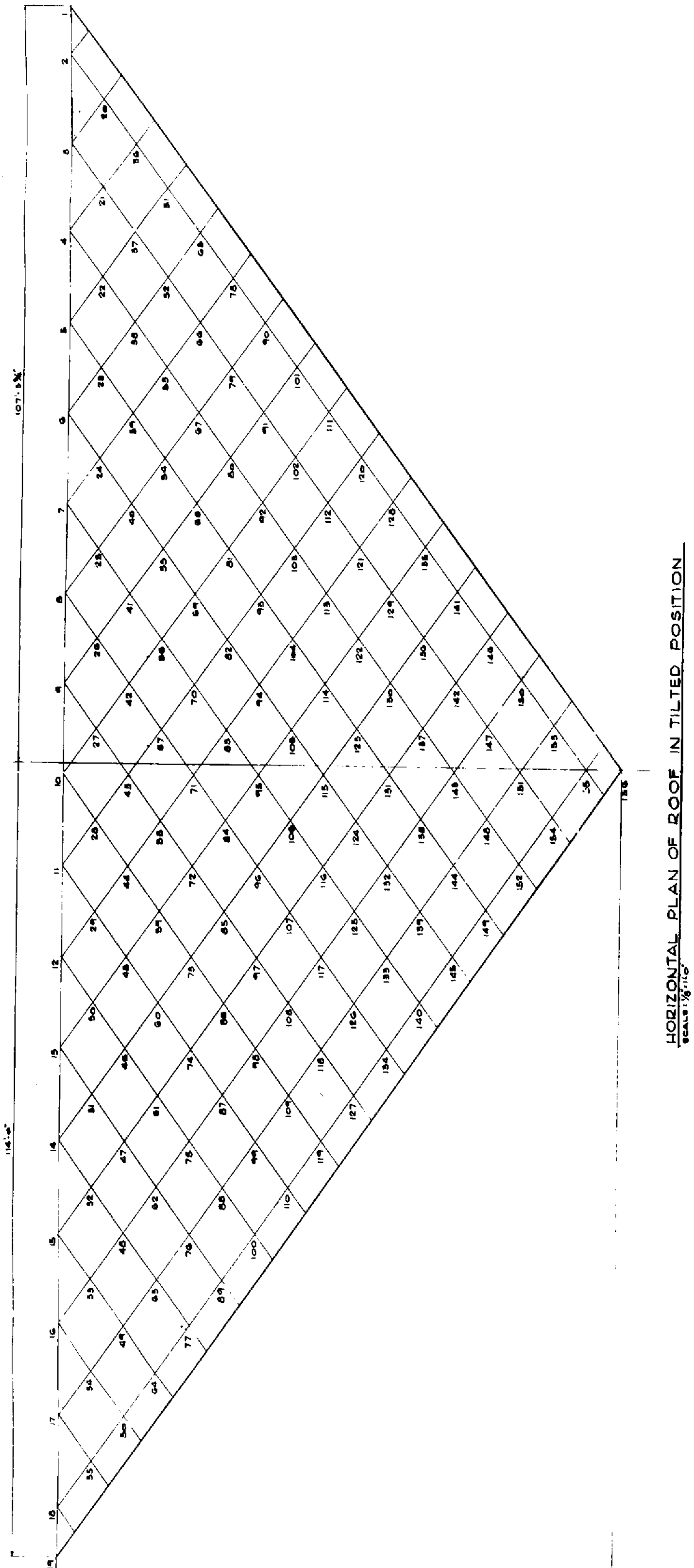




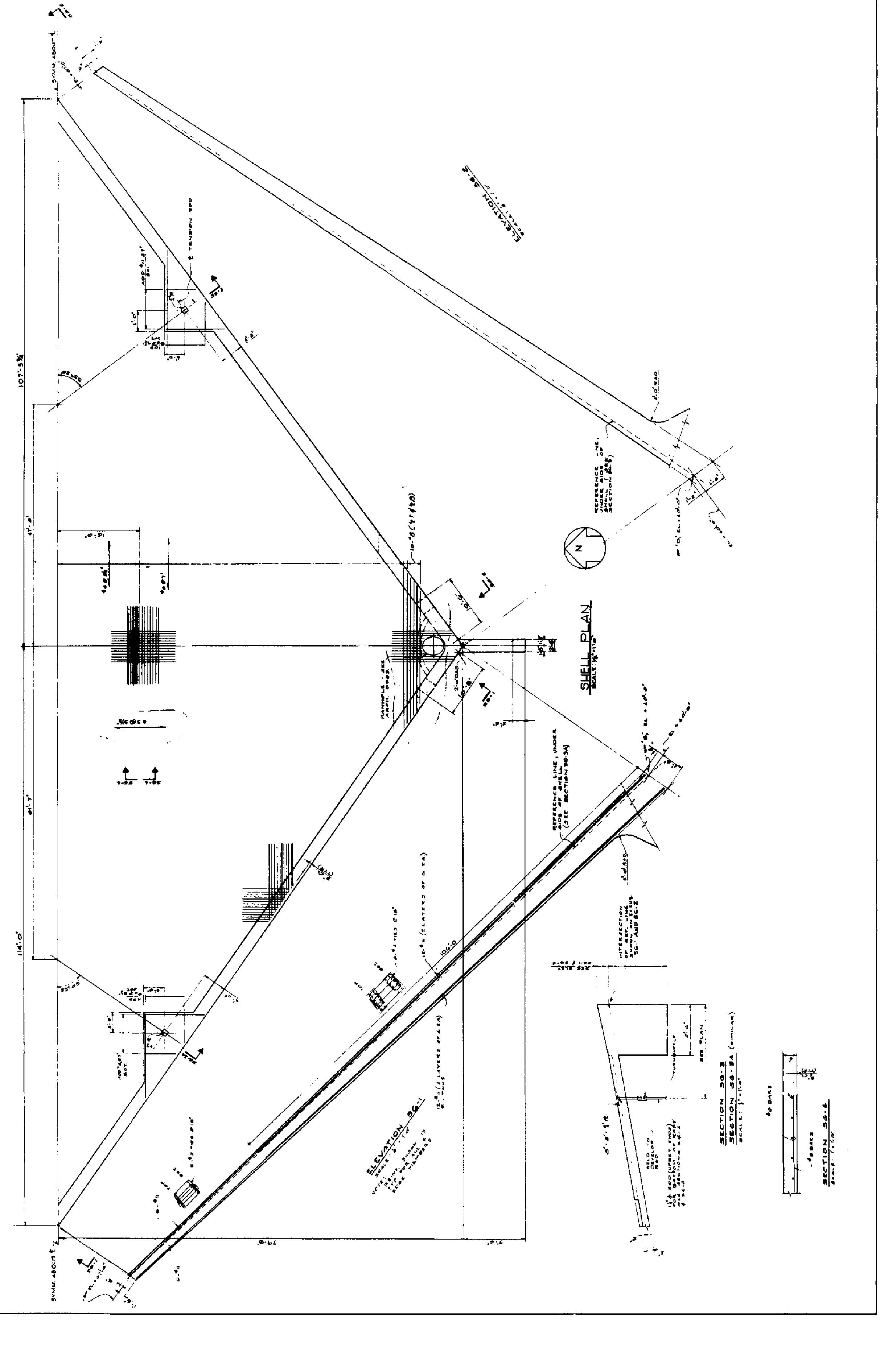
Sheet No. VIII.2.5 shows a sectional elevation and a plan indicating reinforcement details of a kite-shaped hypar shell designed for a conference hall. Sheet Nos. VIII.2.6, VIII.2.7 and VIII.2.8 show complete details of the hypar shell layouts for Edens Theatre at Northbrook, designed and detailed by Perkins and Will of Chicago. The reader is left with original drawings in empirical units. Bar sizes and dimensions, etc., are converted into metric units using a standard conversion given in the text. Both kite-shaped hypar shells adopted are identical. The one shown in Sheet No. VIII.2.5 is half the size of that one given for Edens Theatre. These shells are also known as saddle shaped hypar shells. Generally their thicknesses are no more than 75 to 100 mm. The hypar shell types given on Sheet No. VIII.2.2 can similarly be designed and detailed once the geometry of the type given on Sheet No. VIII.2.6 has been decided. A typical drawing of the saddle shaped hypar between the dimensions (heights and plane projection, i.e. shell projected plan) is shown in VIII.2.2(ii).

HYPAR SHELL (EDENS THEATRE) GEOMETRY

SHEET NO. VIII.2.6

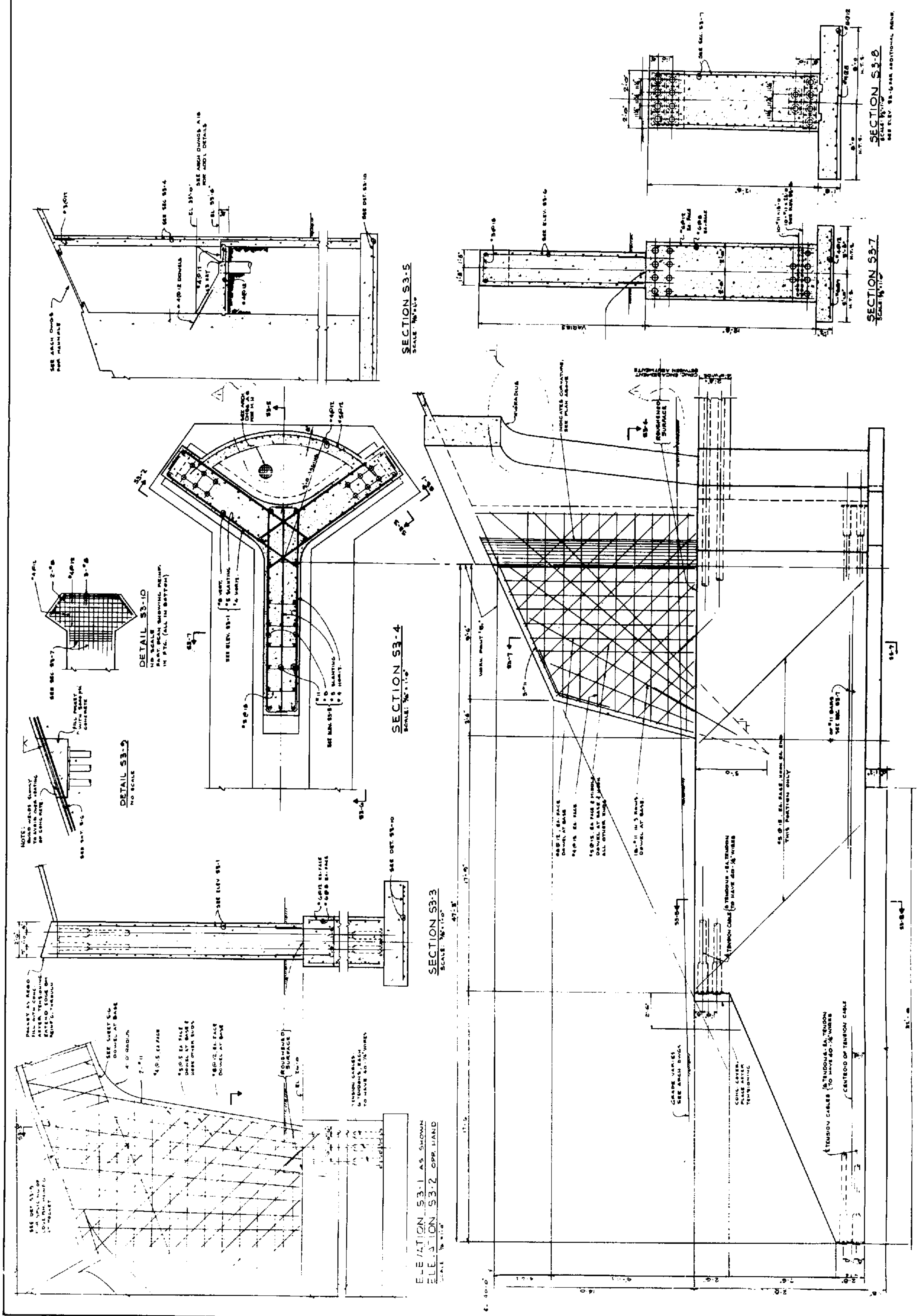


HYPAR SHELL (EDENS THEATRE) SHEET NO. VIII.2.7
REINFORCEMENT DETAILS



HYPAR SHELL (EDENS THEATRE) ADDITIONAL STRUCTURAL DETAILS

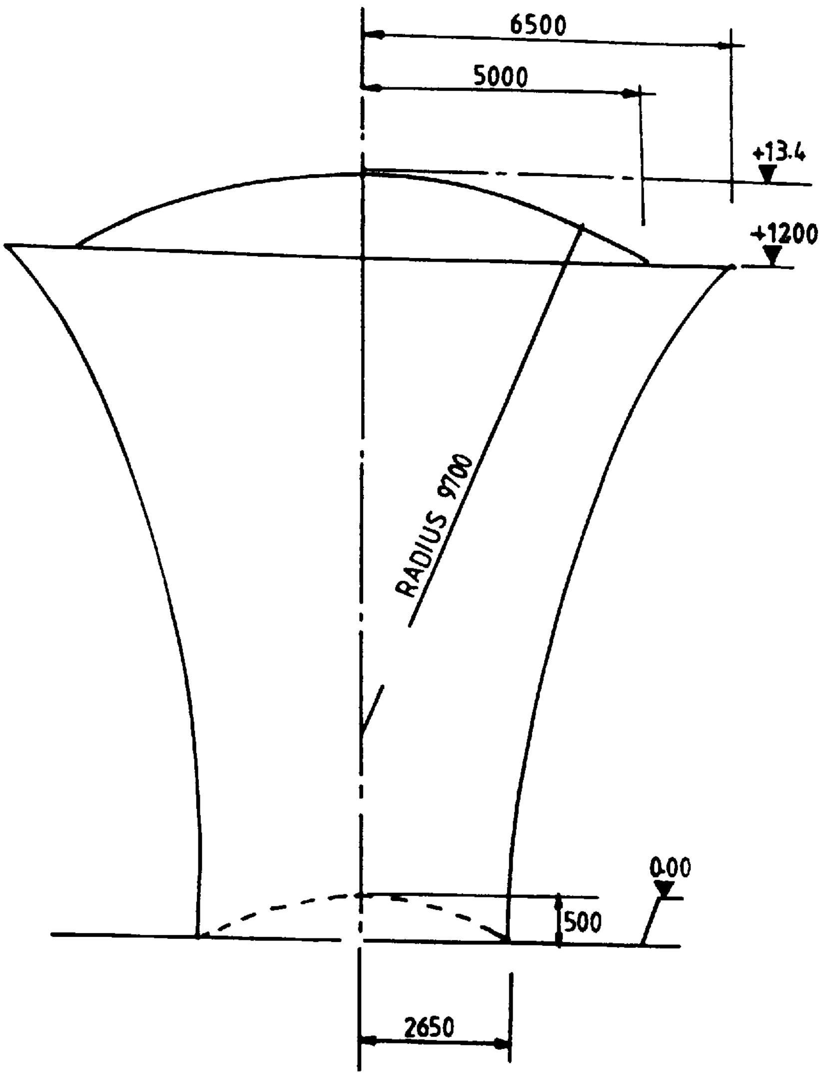
SHEET NO. VIII.2.8



Hyperbolic shells and the hyperboloid of revolution of one sheet which have a graceful appearance have been exploited. Cooling towers and water tanks are just two examples. A great advantage is that their surface is generated by two families of intersecting straight lines. A typical view of earthenware pots and the curvatures shaped by potters are the basis of such shells given on Sheet Nos. VIII.2.9 to VIII.2.12. Sheet Nos. VIII.2.9 and VIII.2.10 show general dimensions of a water tank of a hyperbolic shell and its reinforcement details with cut-off bars at specific levels. The bars are placed along the longitude and latitude of the shell. The cover is of domical type integrated with the hyperbolic shell part.

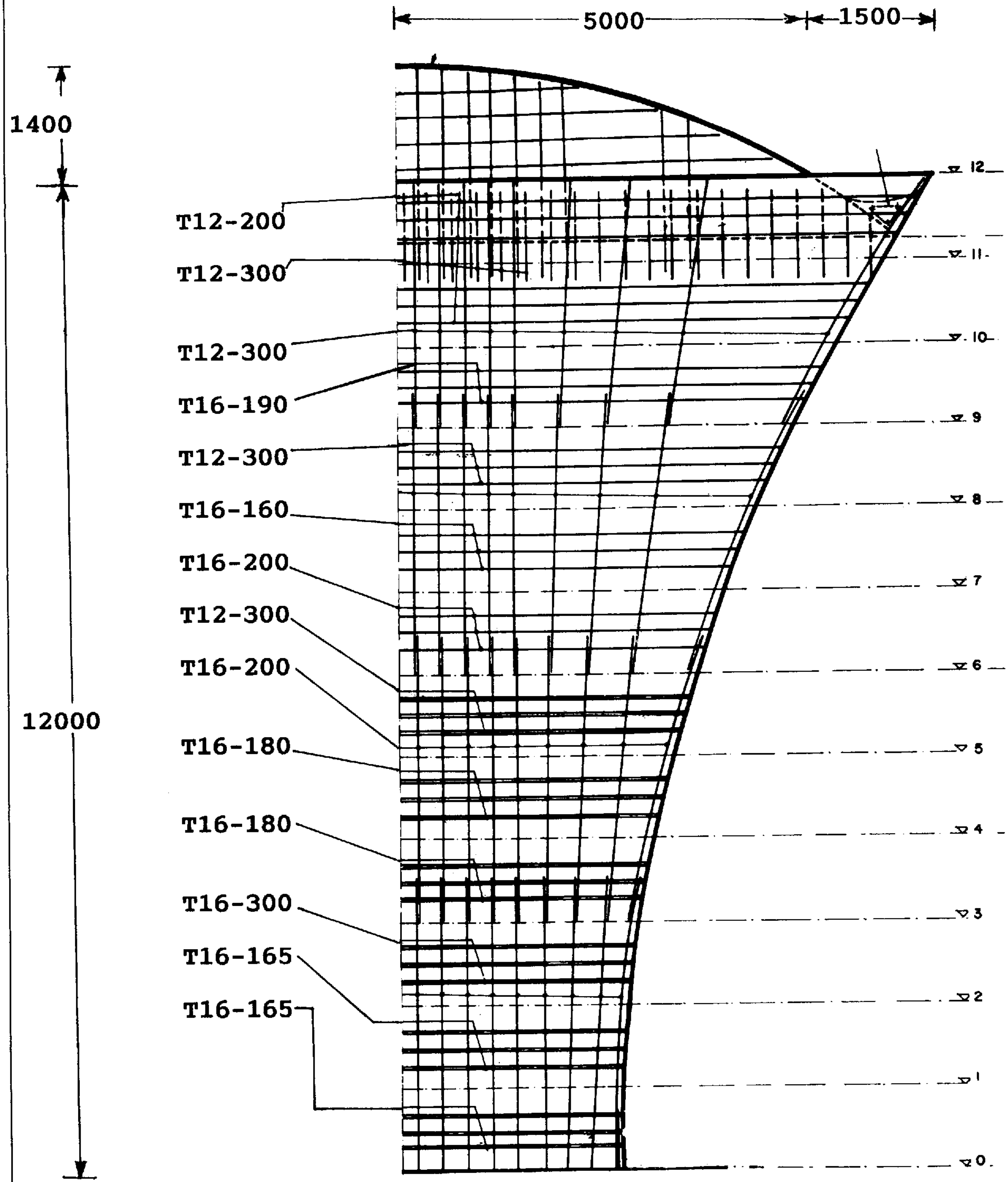
GENERAL DIMENSION
OF WATER TANK

SHEET NO. VIII.2.9



HYPERBOLIC SHELL SHEET NO. VIII.2.10

REINFORCEMENT DETAILS OF WATER TANK

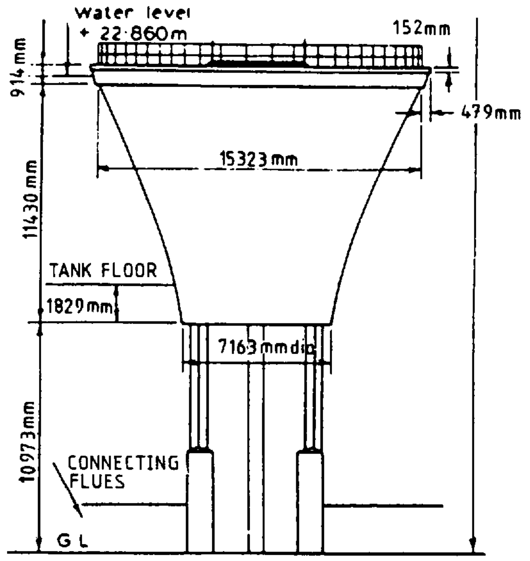


(Courtesy of S.D. Castillo)

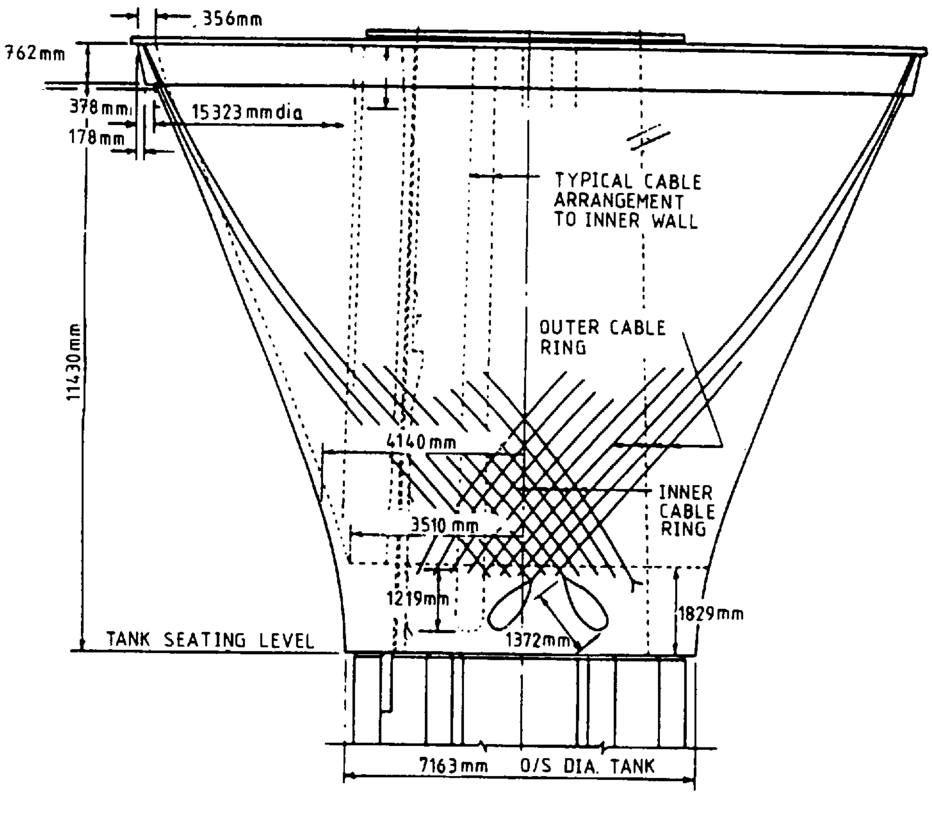
PRESTRESSED HYPERBOLIC SHELL OF WATER TANK

SHEET NO. VIII.2.11

(a) General layout



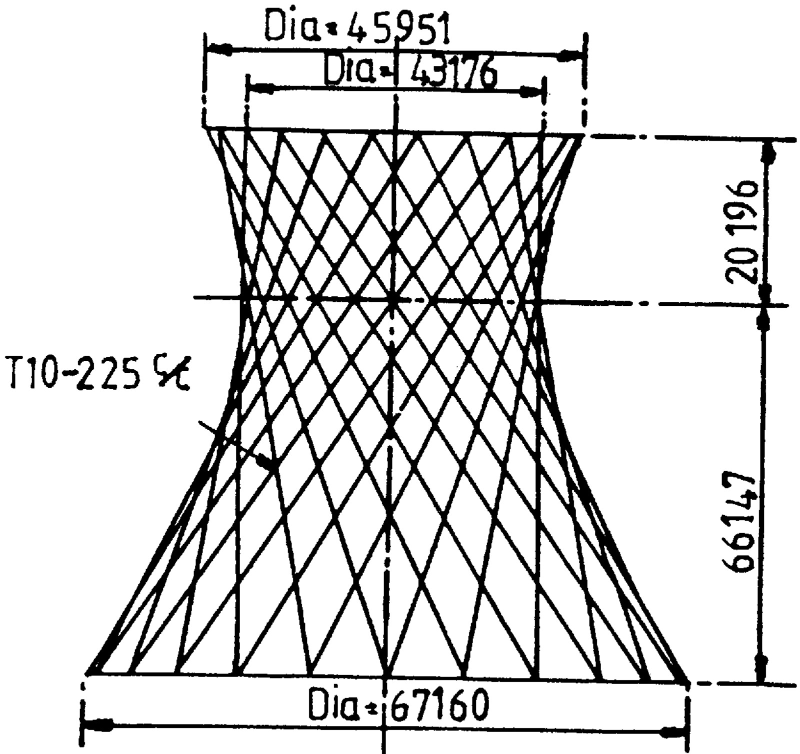
(b) Prestressing layout



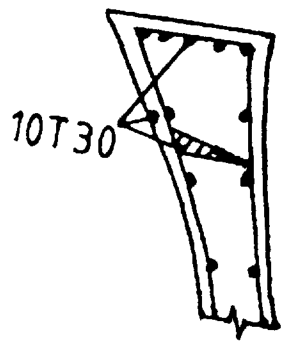
Sheet No. VIII.2.11 shows a hyperbolic shell surface of a water tank. Owing to its much larger size it became necessary to prestress the shell. The entire tank is supported on columns. Prestressing is done by continuously winding the prestressing strands around the tank. The strands are of low relaxation type given in Section V. (*Some other types of shell structures adopted for water tanks or water-retaining structures are discussed in Section VIII.3.*)

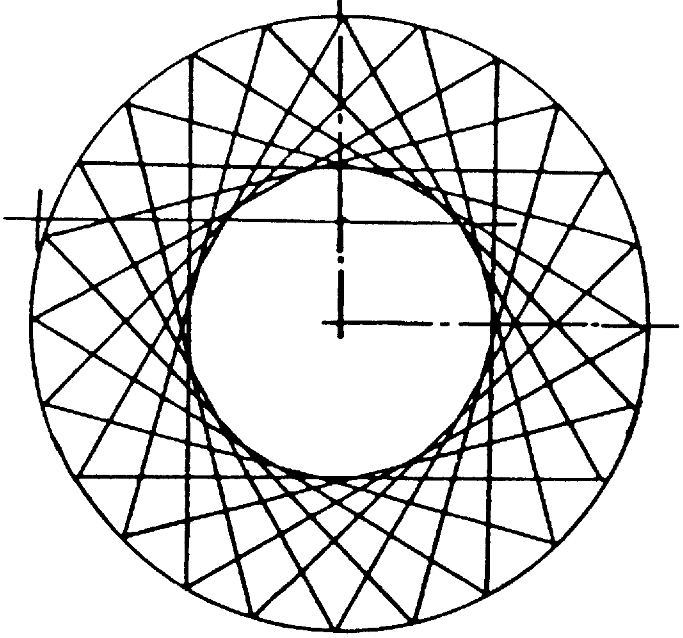
HYPERBOLIC SHELL
(COOLING TOWER
REINFORCEMENT)

SHEET NO. VIII.2.12



Sectional elevation



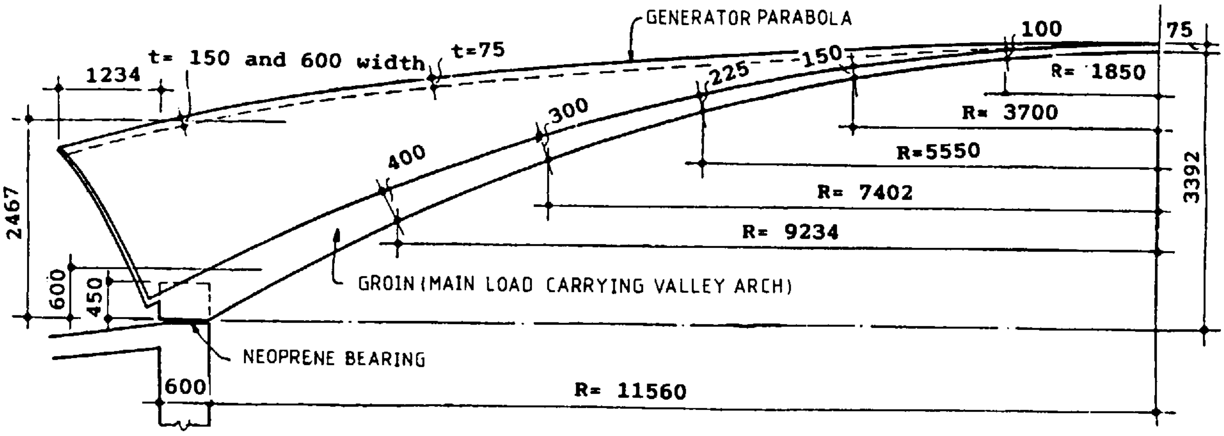


Plan

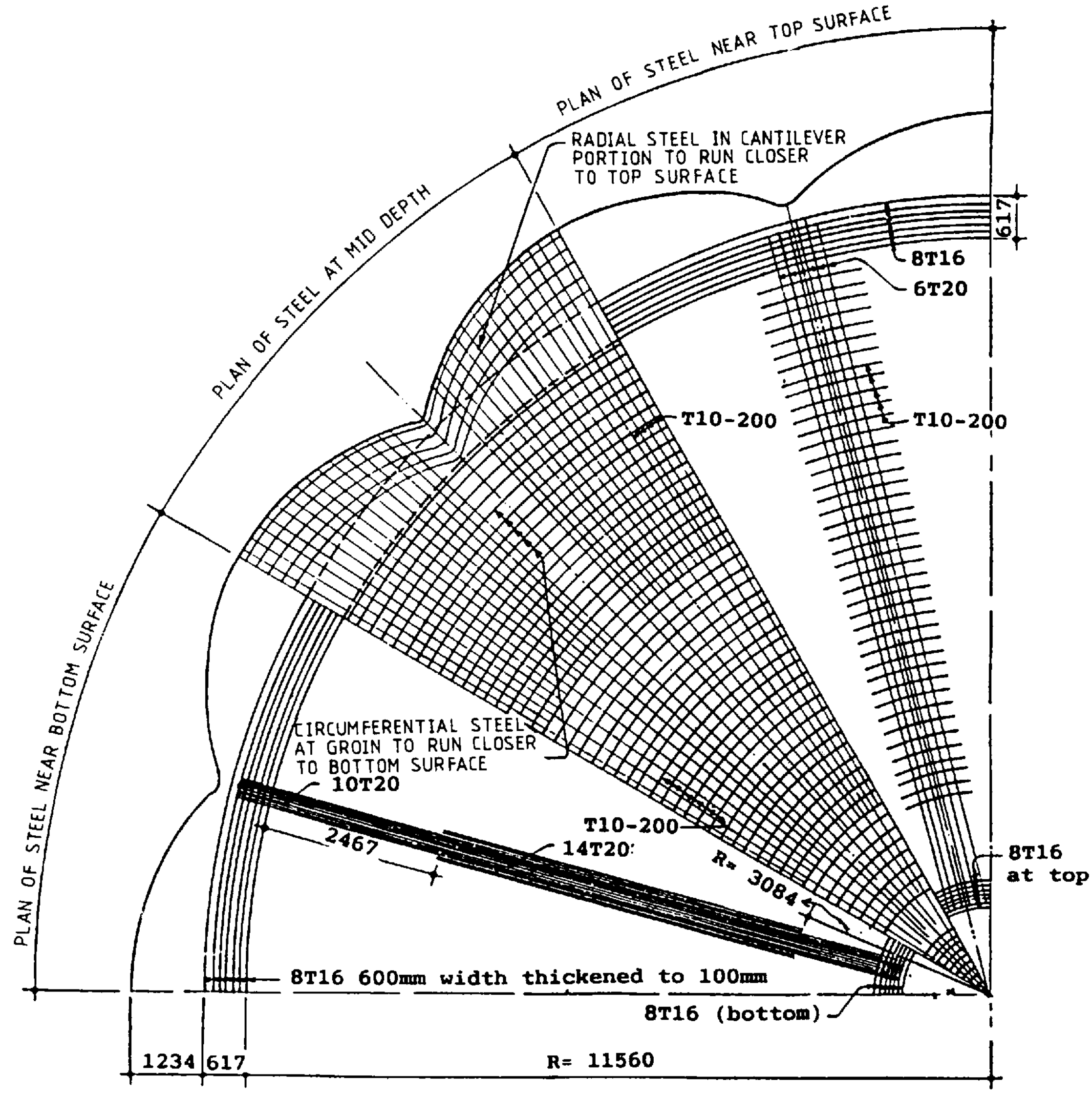
The design of the cooling towers must take into consideration buffeting wind loads and sometimes earthquake effects. They are needed as exhausts for power stations. In plan they are placed in straight or zigzag rows. They stand in the higher region of the layer of air flow, which is usually unsteady and turbulent. A special dynamic analysis has been carried out to check the reinforcement layout of the cooling tower given on Sheet No. VIII.2.12.

SHELL OF CHRIST CHAPEL (INDIA)

SHEET NO. VIII.2.13



(a) Longitudinal section of groin showing the variation of thickness

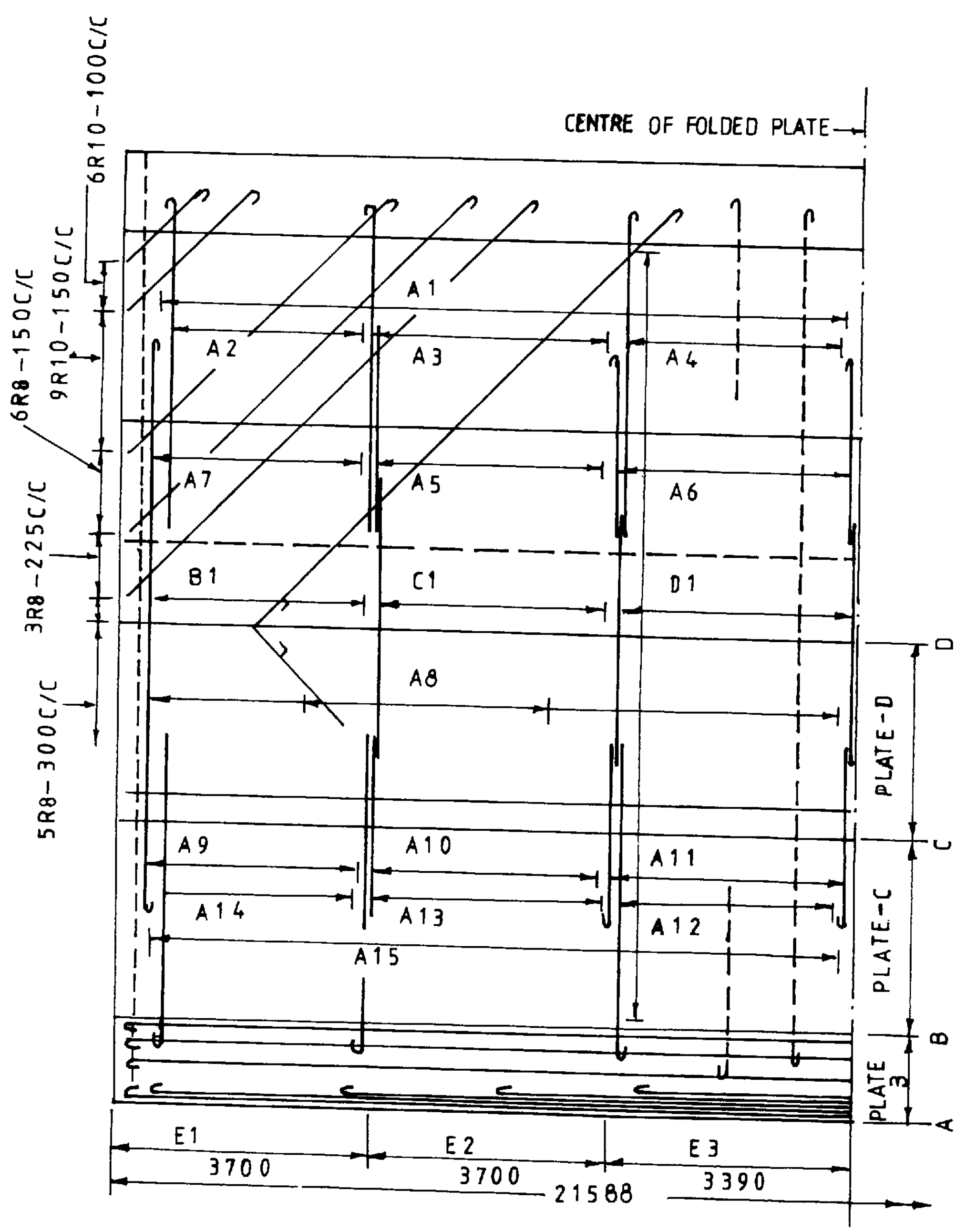


(b) Plan showing layout of reinforcement in the shell

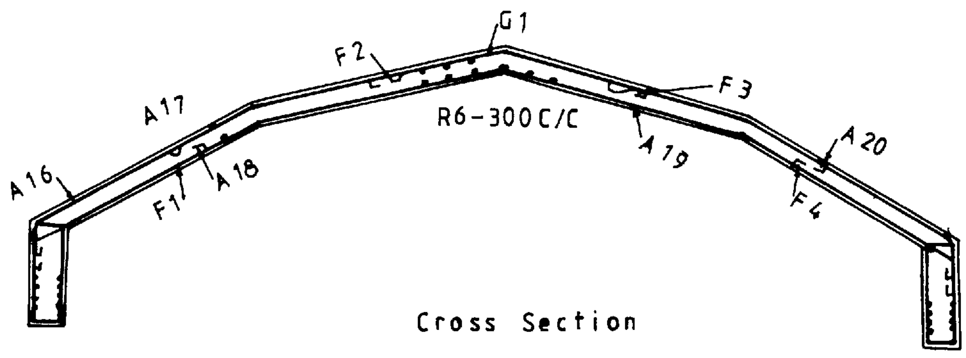
P.C. Varghese and A.C. Mathai designed Christ Chapel in Irinjalakuda, Kerala, India which was consecrated in May 1971. This wonderful shell design is unique, consisting of twelve identical shell units of groin type, each shell placed with a column at the end set at 30° intervals around the periphery of the hall. The shell roof has a varying diameter (24.38 m to 26.52 m) in plan. The columns are placed at 5.97 m centres. Sheet No. VIII.2.13 gives the longitudinal section and the plan which gives the variable shell thickness and the reinforcement details. The reinforcement layout and designation are based on current practices and are thus modified.

A FOLDED PLATE ROOF – REINFORCEMENT LAYOUT

SHEET NO. VIII.2.14



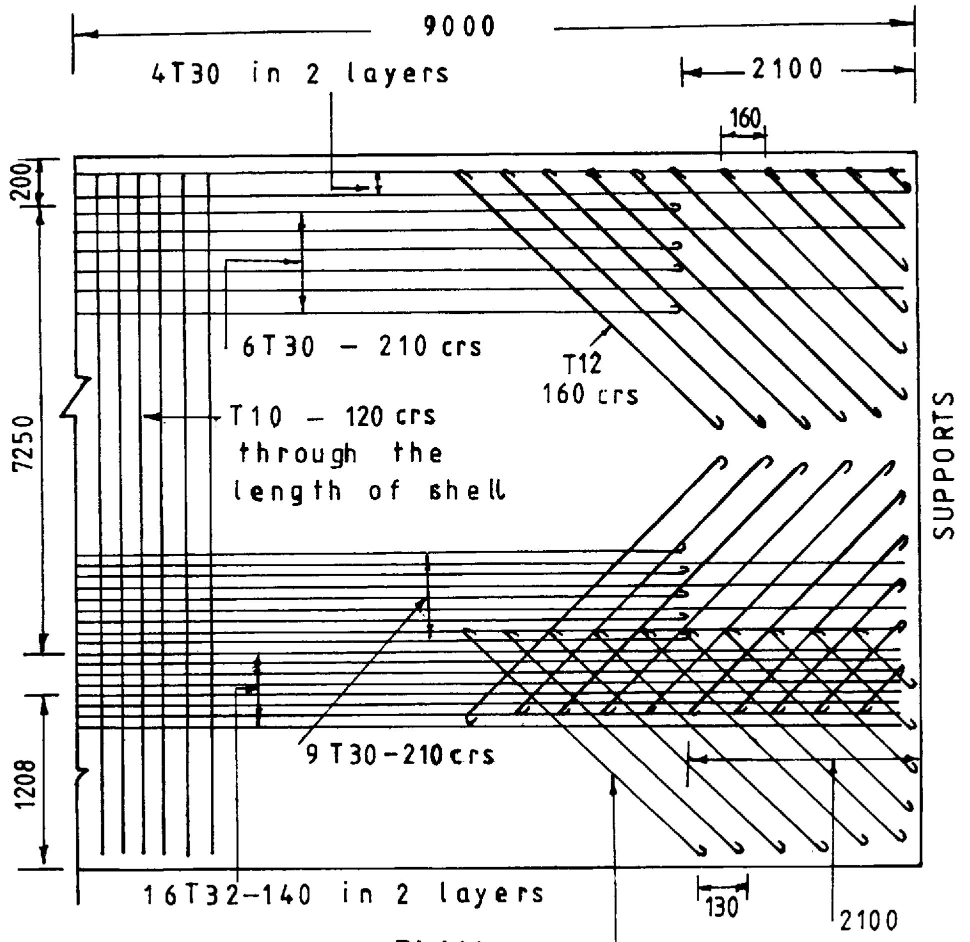
(a) Developed plan



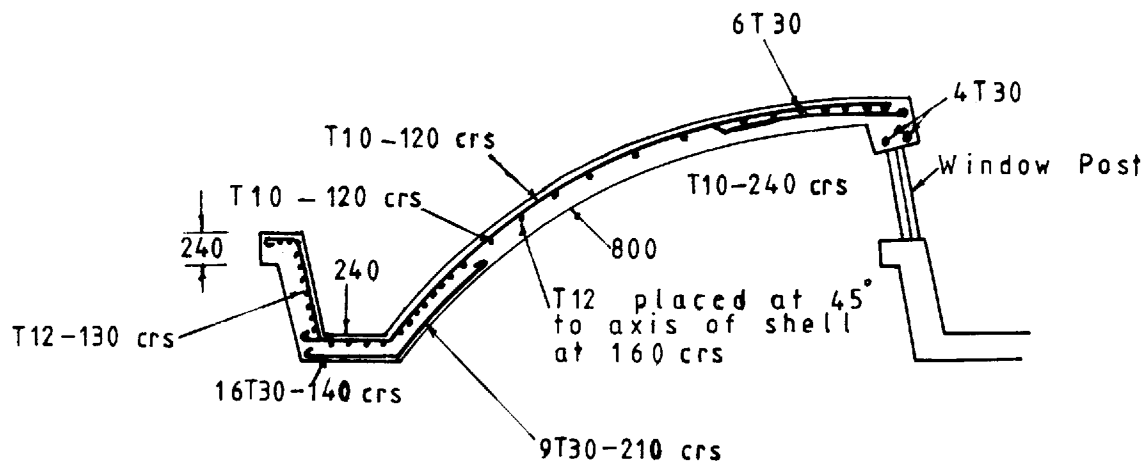
(b) Reinforcement details of folded plate 450,620,700 c/c

NORTH-LIGHT SHELL – REINFORCEMENT LAYOUT

SHEET NO. VIII.2.15



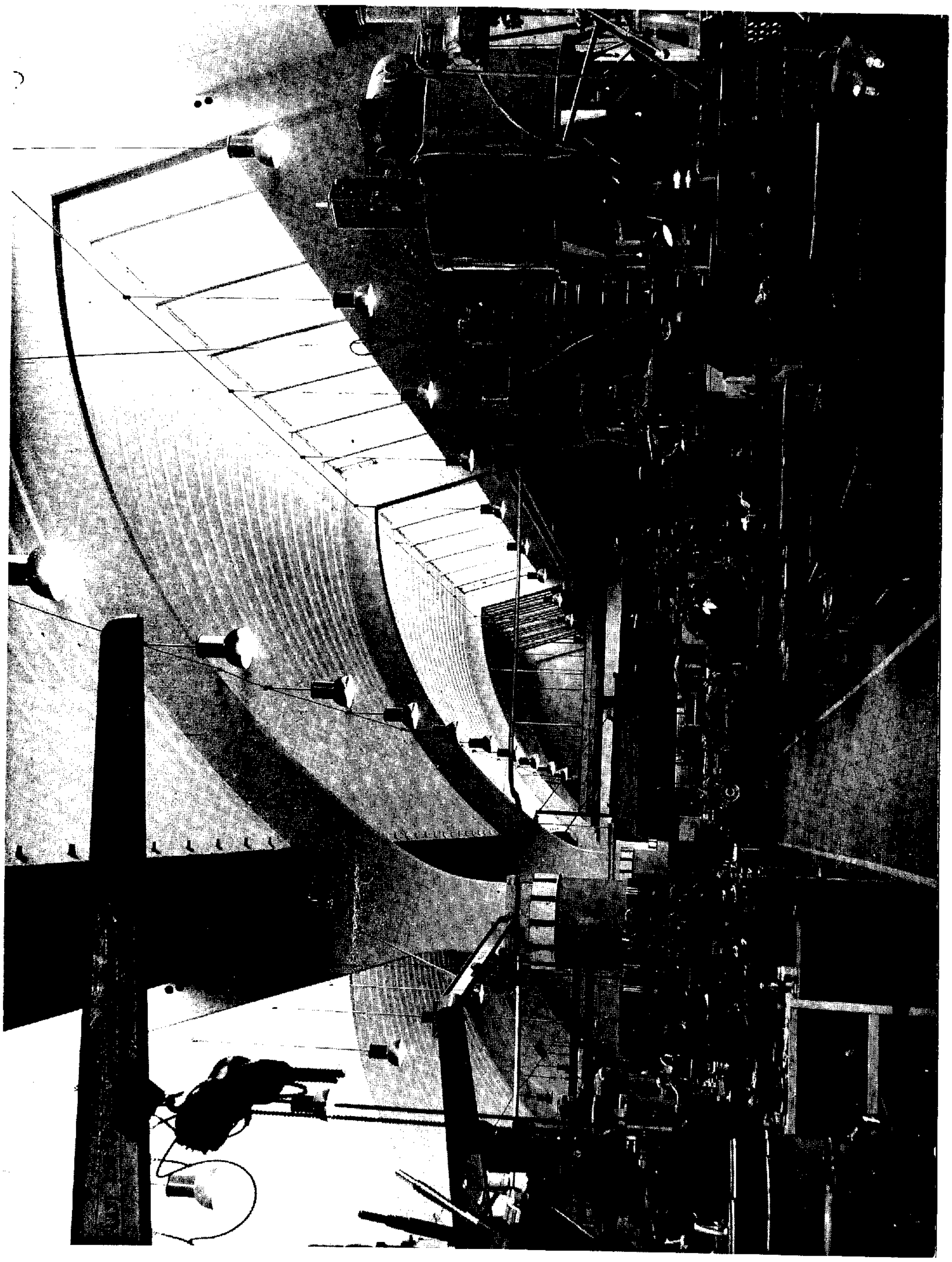
PLAN



SECTION

NORTH-LIGHT SHELL – (HELSINKI)

SHEET NO. VIII.2.16

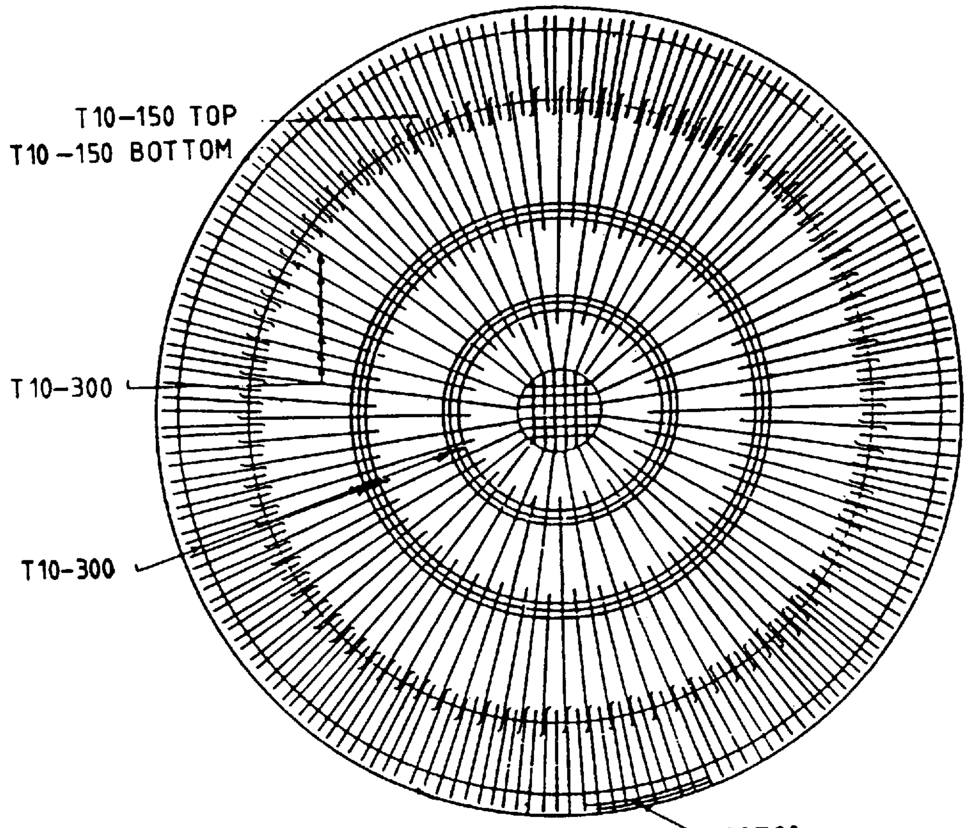


(Courtesy of S. Eggwertz)

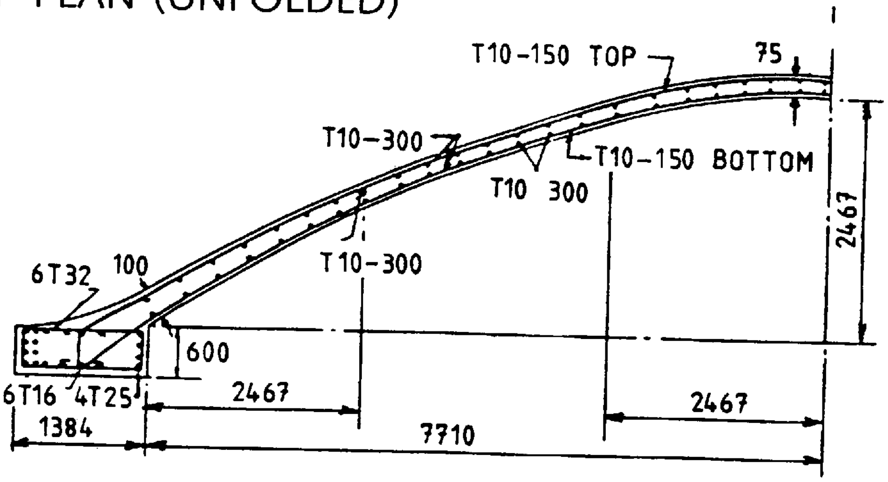
Folded plates, known as hipped plates, are developed by joining a series of rectangular slabs at suitable angles of inclination. They are monolithic along their common edges and they span between diaphragms. The various types formed are V-type, trough type, cylindrical type, Z-shaped type, north-light roofs, bunker shaped and troughs with lights at the top. Sheet Nos. VIII.2.14 and VIII.2.15 give the reinforcement details for a cylindrical hipped plate and the north-light shell. Sheet No. VIII.2.16 shows an interior photograph of the completed north-light shell.

SHALLOW DOME

SHEET NO. VIII.2.17



TOP PLAN (UNFOLDED)



SECTION

Spherical domes are common in structural engineering. Reinforced concrete domes are comparatively popular. A constant thickness is considered. The reinforcement details are shown on Sheet No. VIII.2.17 for a segment of a spherical dome and its ring beam.

When the following modifications are carried out a similar layout can be prepared for either conoidal or elliptical domes in reinforced concrete:

Conoidal dome: The central line of revolution is moved outward from the centre line of revolution of the spherical dome to a distance ($r\cos\phi - r'$), r is the radius of the spherical dome and r′ is the distance moved beyond this. The angle ϕ is the latitude of the dome.

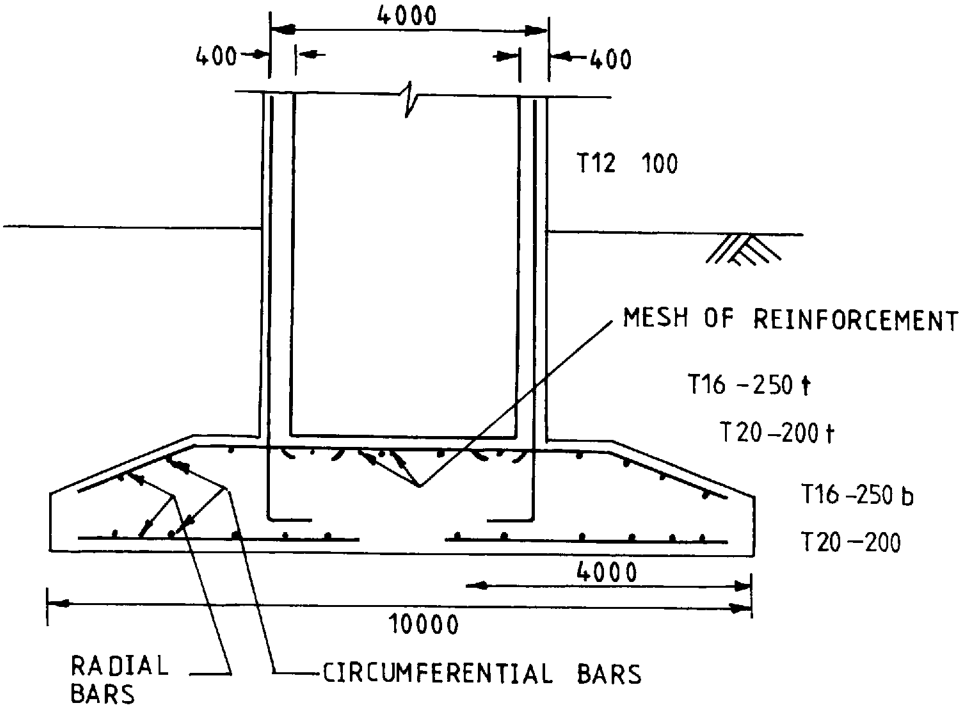
Elliptical dome: The dome surface is defined as

$$x^2/a^2 + y^2/b^2 = 1$$

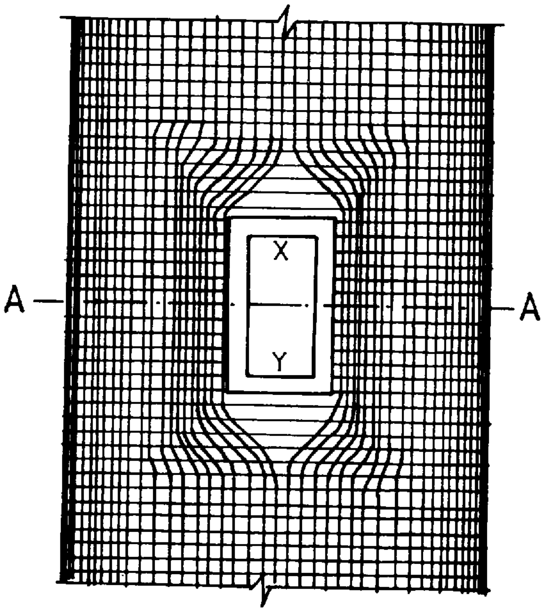
where a and b are major and minor axes, x and y are co-ordinates.

Reinforced concrete chimney shells are generally lined with steel liners so that the flue gases which are too hot and corrosive are prevented from having direct contact with the reinforced concrete. The chimneys are about 180 to 215 m tall and their minimum diameter is about 4 m. They are subjected to wind and earthquake loads and thermal gradients. Sheet No. VIII. 2.18 gives a basic reinforcement layout for a chimney. The size of reinforcement depends on the height and the wind/seismic loads.

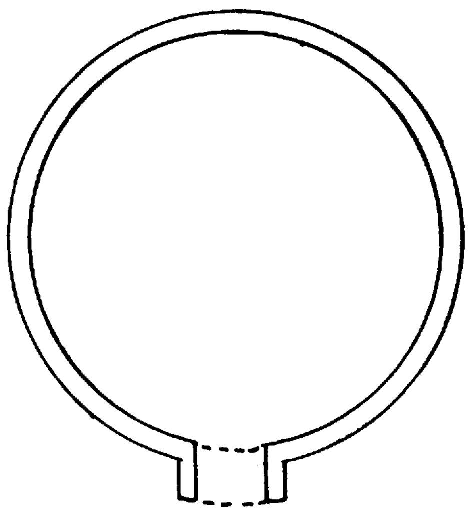
CHIMNEY SHEET NO. VIII.2.18



(a) Section through foundation of chimney



(b) Front view of reinforcement round an opening in a chimney shell



(c) Section A–A through opening

Section VIII.3
Water Retaining Structures and Silos

VIII.3.1 Water-retaining structures

VIII.3.1.1 General introduction

Water-retaining structures must be designed for serviceability, stability, flotation and settlement. For these structures watertightness and durability are especially required. Cracking due to external loads and early thermal and shrinkage effects must be assumed as a major design criterion.

Tanks as water-retaining structures are situated on the ground, underground and above ground supported on towers. Ground tanks and reservoirs can be circular or rectangular in shape. They must withstand pressure from the water they contain. If such structures are constructed on or below ground they must withstand external forces due to lateral earth pressure, uplift due to water in the surrounding ground and the weight of the earth cover if provided. The roof may be of the beam and slab or the flat slab type. In the case of large tanks, domical or truncated conical roofs are used. The walls can be cantilevered, pinned at the top or fixed at the top. Where floor slabs are involved, a polythene sheeting or similar may be used between the ground slab and the sub-base and a neoprene or rubber strip or similar between the roof and the top of the wall.

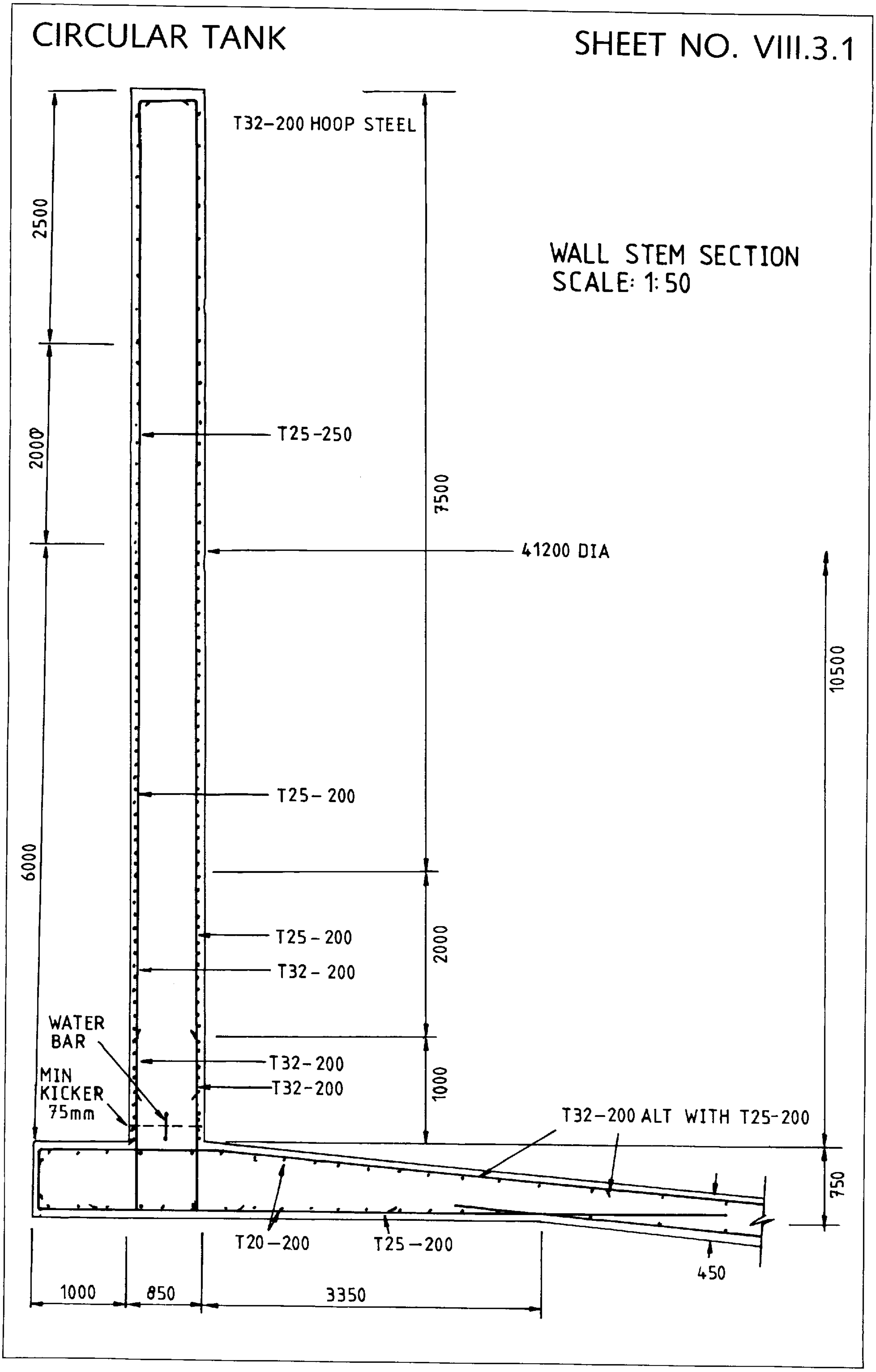
In-serviceability requirements for cracking have been seen to depend on the exposure conditions. Some basic data is given below.

Class A: exposure (exposed to moist or to corrosive atmosphere or subject to wetting and drying), the crack width $w \leq 0.1$ mm.
Class B: exposed to continuous contact with liquid, the crack width $w \leq 0.2$ mm.
Class C: not exposed as severely as for either Class A or B, the crack width $w \leq 0.3$ mm.

The slab thickness in millimetres ranges between 200 and 500 plus.

Wall thickness (mm)	Layers	Bar type (mm)	*Partial joint spacing (m) (1)	(2)	(3)
200	single	MS 12–16	2.3–2.44	2.86–3.50	3.41–4.05
250	double	MS 12	1.73	2.29	2.84
500	double	MS 12, 16, 20	2.60–3.5	3–3.92	4.33
Over 500	double	20	1.92	2.34	2.75

*(1) = no cracks (2) = 0.1 mm cracks (3) = 0.2 mm cracks
Where construction joints are used for:
all thickness less than 400 mm: (1) = 4.8 m; (2) = 5.3 m; (3) = 5.9 m
all thickness equal to or greater than 500 mm: (1) = 4.8 m; (2) = 5.3 m; (3) = 5.6 m



CIRCULAR TANK
SHEET NO. VIII.3.1
T32–200 HOOP STEEL
WALL STEM SECTION
SCALE: 1:50
2500
2000
6000
7500
T25-250
41200 DIA
10500
T25-200
2000
T25-200
T32-200
1000
WATER BAR
T32-200
T32-200
MIN KICKER 75mm
T32–200 ALT WITH T25-200
750
T20–200
T25–200
450
1000
850
3350

The recommended concrete grades are 25 and 30.

Jointing material may be joint fillers, water stops, joint sealants and joint stress inducers. All jointed material must be chosen by the structural engineer and must accommodate repeated movements in all weathers. It must never be soft in summer or brittle in winter. A reference is made in Section VI to types of watertight joints.

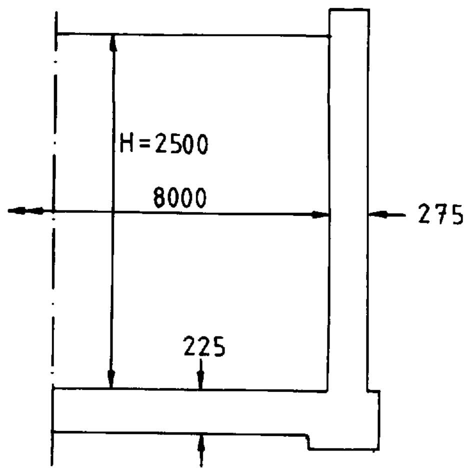
VIII.3.1.2 Typical structural detailing of water-retaining structures

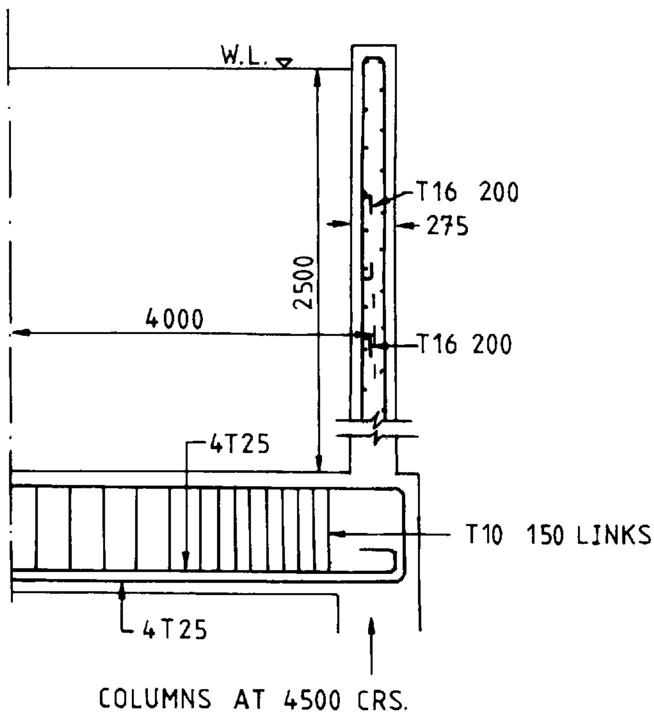
Section VIII.2.2 gives some examples of water-retaining structures. They have been included in that section owing to the importance given to the shell surfaces and reinforcement layouts. Sheet No. VIII.3.1 shows the structural detailing of the wall stem section of a reinforced concrete tank of internal diameter 41.2 m and internal height 10.5 m. The floor slab is sloping towards the centre. It is placed underground. Sheet No. VIII.3.2 shows the sectional elevation of a reinforced concrete rectangular-shaped tank. A double domed INTZE tank is given on Sheet No. VIII.3.3. Two types of reinforcement details are given for two different INTZE tanks. These tanks can be supported on elevated towers. A typical substructure for such towers is given on Sheet No. VIII.3.4. Sometimes a circular tank is supported on towers with columns. These columns can be arranged in a number of ways in plan. Some layouts of the supporting towers are given on Sheet No. VIII.3.5.

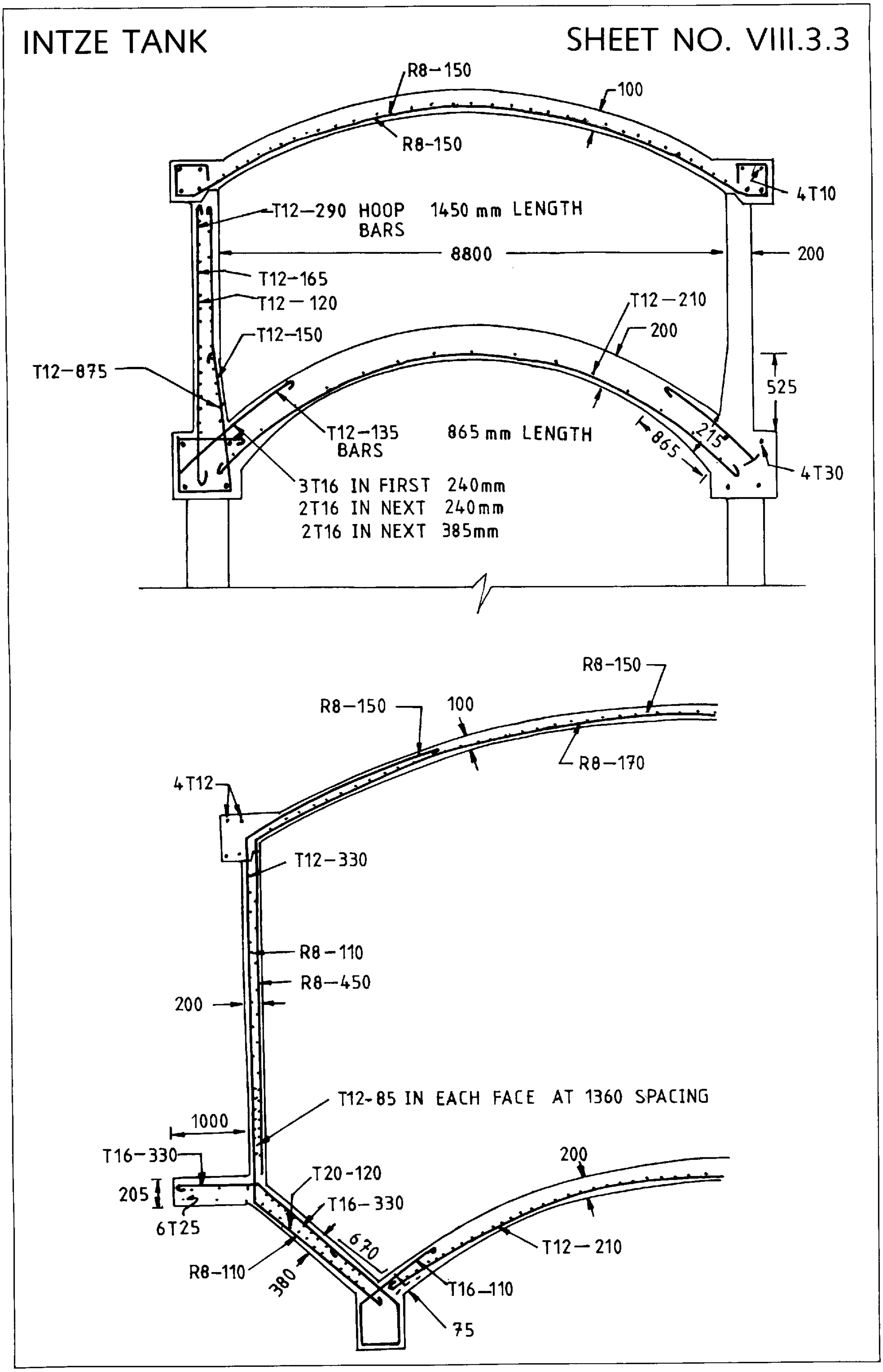
Many other tanks with novel shapes have been designed. A bibliography is given for the reader to study such tanks and to follow the rules established in this book.

ELEVATED RECTANGULAR WATER TANK

SHEET NO. VIII.3.2



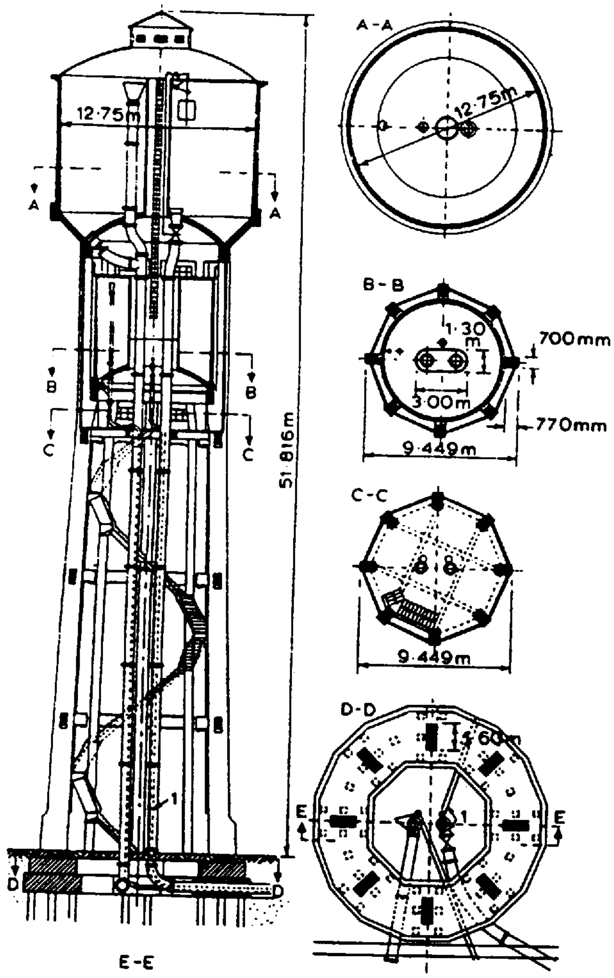



INTZE TANK
SHEET NO. VIII.3.3
R8-150
100
R8-150
4T10
T12-290 HOOP BARS
1450 mm LENGTH
8800
200
T12-165
T12 - 120
T12-150
T12-210
200
T12-875
525
T12-135 BARS
865 mm LENGTH
865
215
4T30
3T16 IN FIRST 240mm
2T16 IN NEXT 240mm
2T16 IN NEXT 385mm
R8-150
R8-150
100
R8-170
4T12
T12-330
R8-110
R8-450
200
T12-85 IN EACH FACE AT 1360 SPACING
1000
T16-330
200
205
T20-120
T16-330
6T25
670
T12-210
R8-110
380
T16-110
75

ELEVATED WATER TOWERS

SHEET NO. VIII.3.4

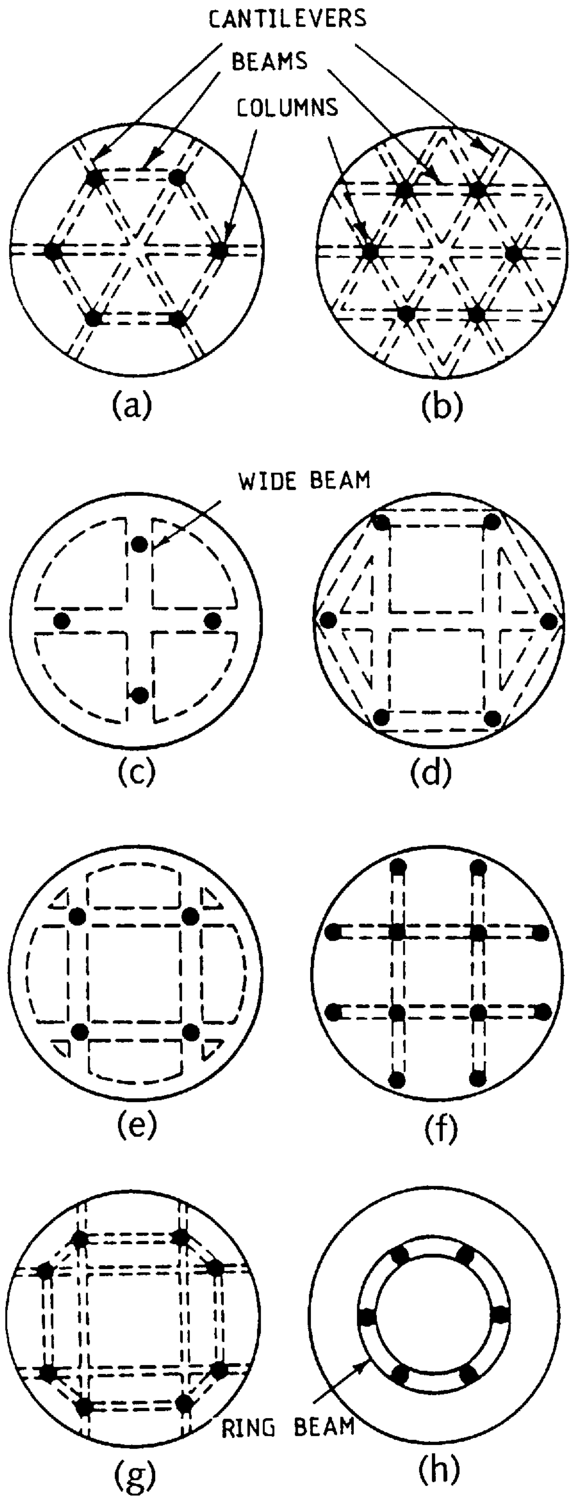
(a) Typical sectional elevation (b) Cross-section



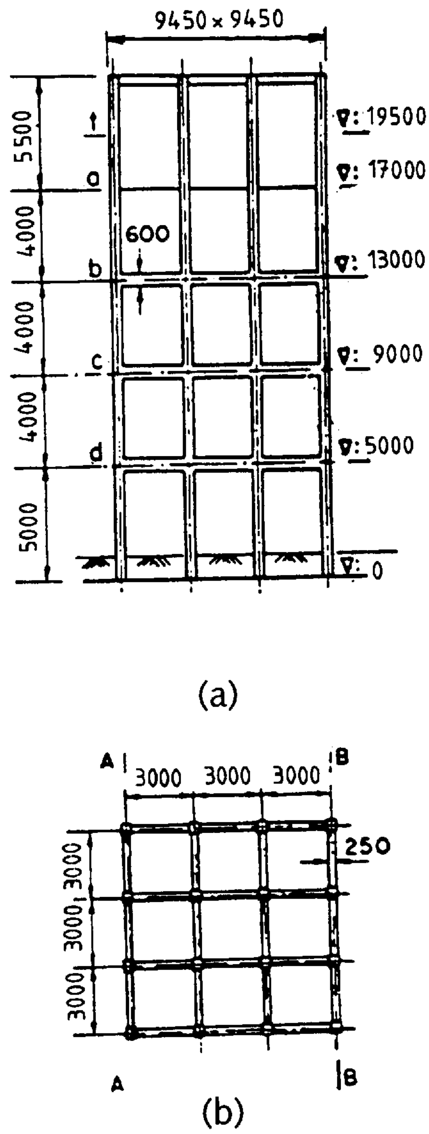
SUPPORTS FOR OVERHEAD TANKS

SHEET NO. VIII.3.5

(a) Plans

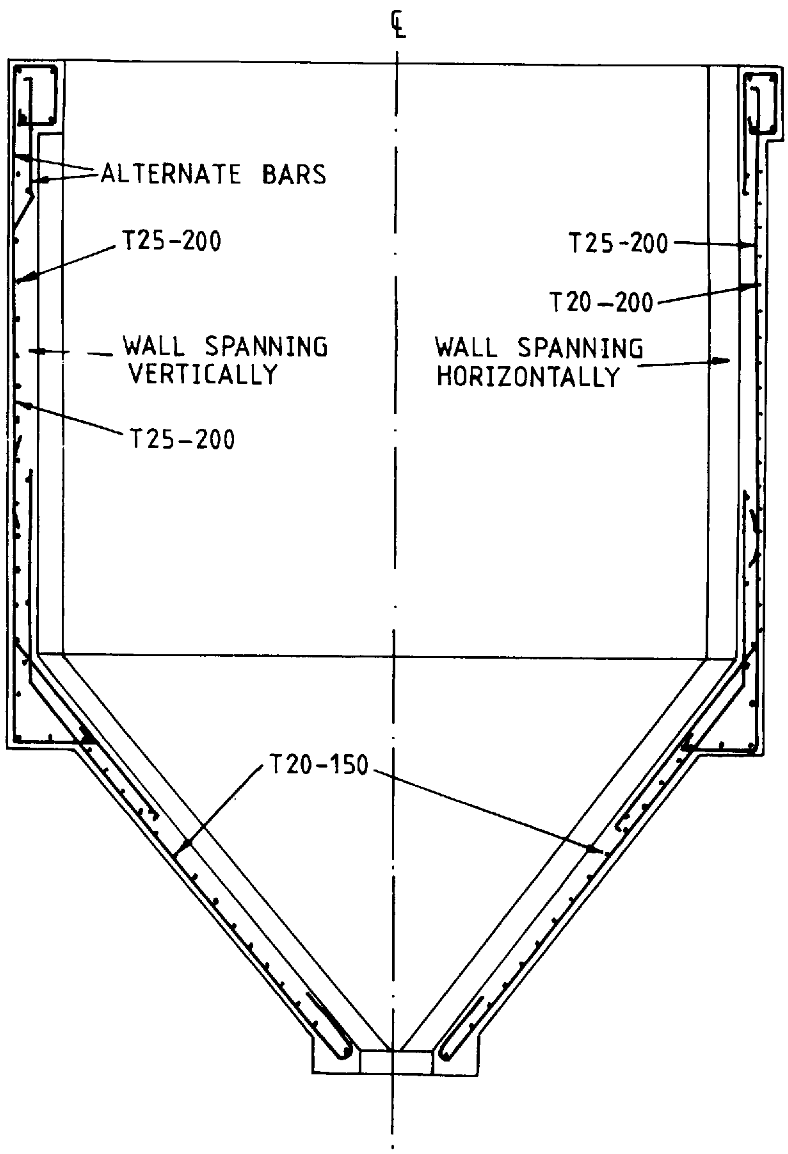


(b) Typical elevations



REINFORCED CONCRETE HOPPER SHEET NO. VIII.3.6

Section through hopper



VIII.3.2 Silos

VIII.3.2.1 General introduction

The irregularity of the crop yield and the uneven distribution of harvests can lead to a building-up of stocks which are best held in silos made in reinforced and prestressed concrete. They comprise tall cells of various cross-sections placed side by side. At the bottom they have discharge hoppers and at the top they are enclosed by a floor carrying the silo-filling equipment.

The silos have triangular, square, cylindrical or polygonal shapes. The walls of these silos are subject to maximum pressure due to the infilled or ensiled materials. The accurate values of these pressures depend on:

(a) internal friction: grain upon grain;
(b) friction on smooth or rough walls;
(c) natural angle of repose of the material and the angle of material wall friction;
(d) bulk density of the material and the unconfined compressive strength of concrete.

A number of expressions have been developed to evaluate pressure on side walls and in the hopper area.

Hoppers are generally lined with stainless steel, mild steel and other types of abrasion-resistant materials. Various types of silo bottoms are used which include an elevated floor on columns, and a conical steel hopper attached to a concrete ring girder, integral with the silo wall or independently supported on columns or supported on pilasters.

VIII.3.2.2 Typical structural detailing of silos

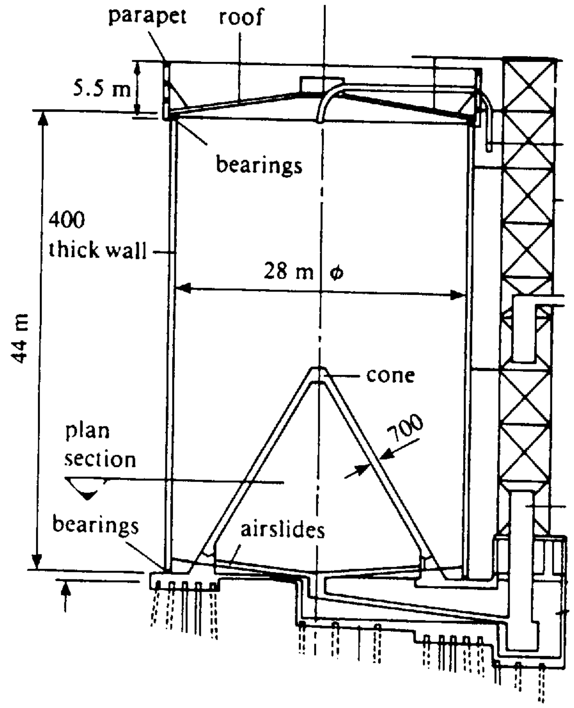
A number of textbooks and proceedings have been published on the design of silos. In this section two examples are given for the structural detailing of silos. Sheet No. VIII.3.6 shows a sectional elevation of a reinforced concrete silo. This silo is supported on columns and is a part of a group of silos. The walls are 200 mm thick. The internal height (above the hopper line) and the internal height respectively are 35 m and 6 m. The hopper angle is 45°.

Horizontal reinforcement is provided to take the tension in each wall due to the pull of walls perpendicular to it. Owing to the continuity at corners, a horizontal bending moment is induced. For this bending moment it is sufficient to provide horizontal reinforcement equal to the vertical reinforcement of the vertical bending moment. Generally this reinforcement is limited to the vertical reinforcement at $\frac{1}{3}$ of the wall height. Horizontal reinforcement is also provided at the bottom of the wall to resist direct tension. In the case of walls spanning horizontally, direct tension is considered and the section is designed for combined axial load and bending. The following additional data will be considered in the design of this silo:

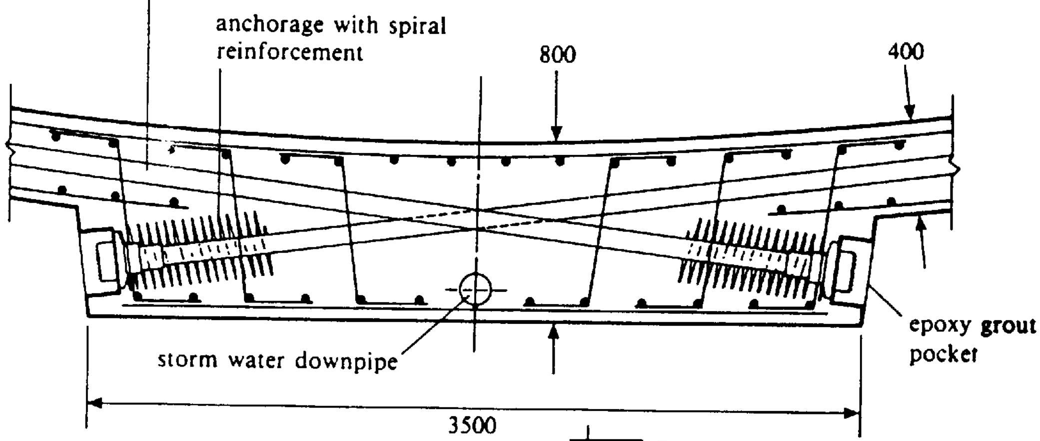
Coefficient of friction	0.35
Angle of repose	28°
Roof load	30 tonnes
Density of material	890 kg/m^3.

PRESTRESSED CONCRETE SILO

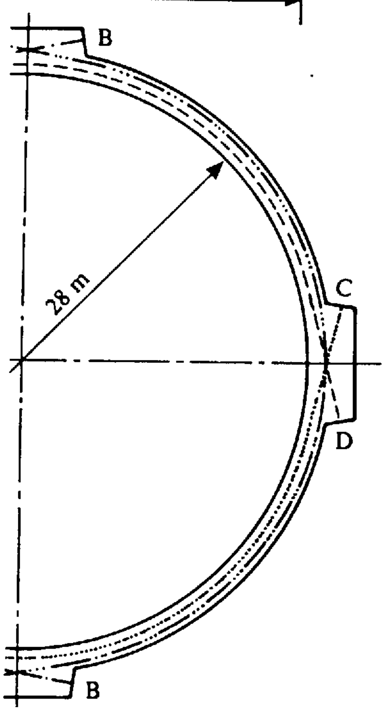
SHEET NO. VIII.3.7



(i)



(ii)

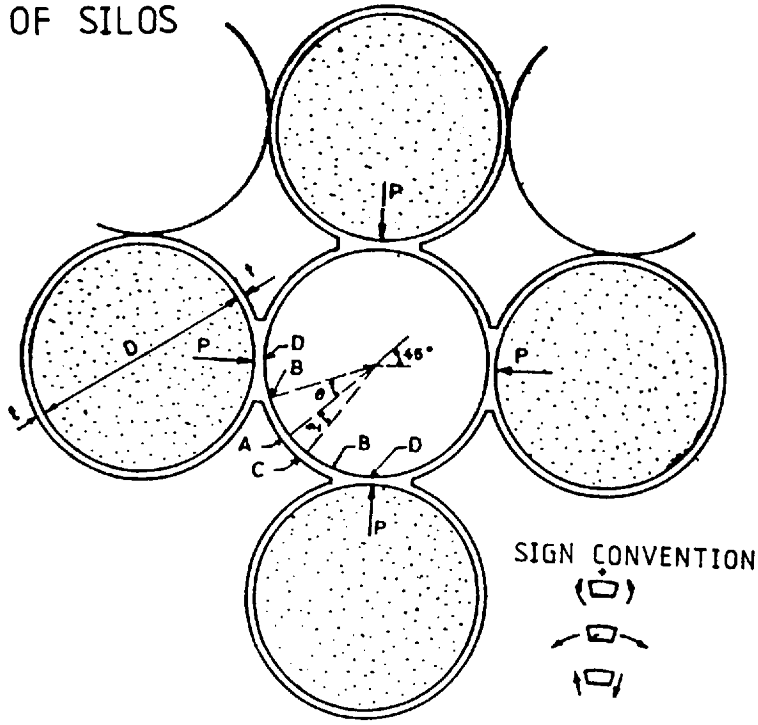


Sheet No. VIII.3.7 shows a prestressed concrete silo with its major dimensions. Circumferential tendons are introduced between buttresses to resist the hoop tension. The cables are anchored at buttresses using the VSL multi-strand prestressing system having 19 prestressing anchorages. A guaranteed minimum breaking force of 184 kN was adopted for each cable. This silo has been designed on a wharf in Birkinhead, South Australia. Sheet No. VIII.3.8 shows a plan of a group of silos of the type shown on Sheet No. VIII.3.6. Two silos are interconnected using a 'cross' reinforcement. The connection is detailed on the lines suggested in the given section on Sheet No. VIII.3.8.

SILOS

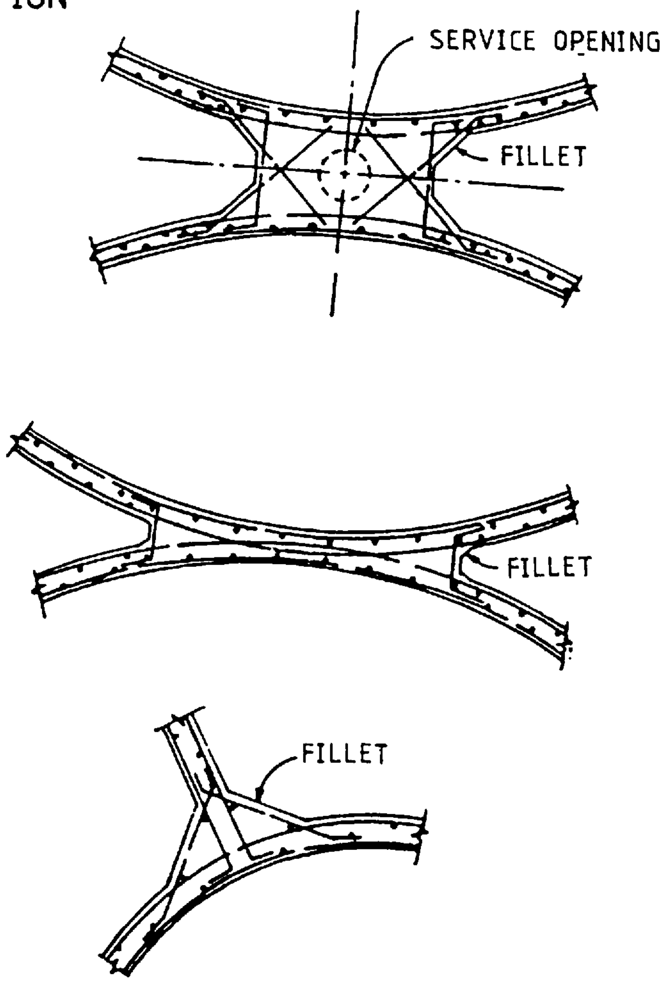
SHEET NO. VIII.3.8

GROUP OF SILOS



PLAN

SECTION



Section VIII.4
Nuclear Shelter

VIII.4.1 General introduction

A nuclear shelter is just one of many devices designed to protect and shield humans from the effects of nuclear explosion and associated nuclear hazards. The nuclear blast can be in air, on the ground or underground. The characteristics of the blast waves and dynamic pressures caused by them have been well documented. Standard charts and numerous formulae are available to design such structures for any weapon yield. Blast loads and stresses (static and dynamic) have been fully documented in many texts, some of which are given in the bibliography.

VIII.4.2 Generalized data for a domestic nuclear shelter

A shelter for a family of six has been designed by the author. The following data is considered:

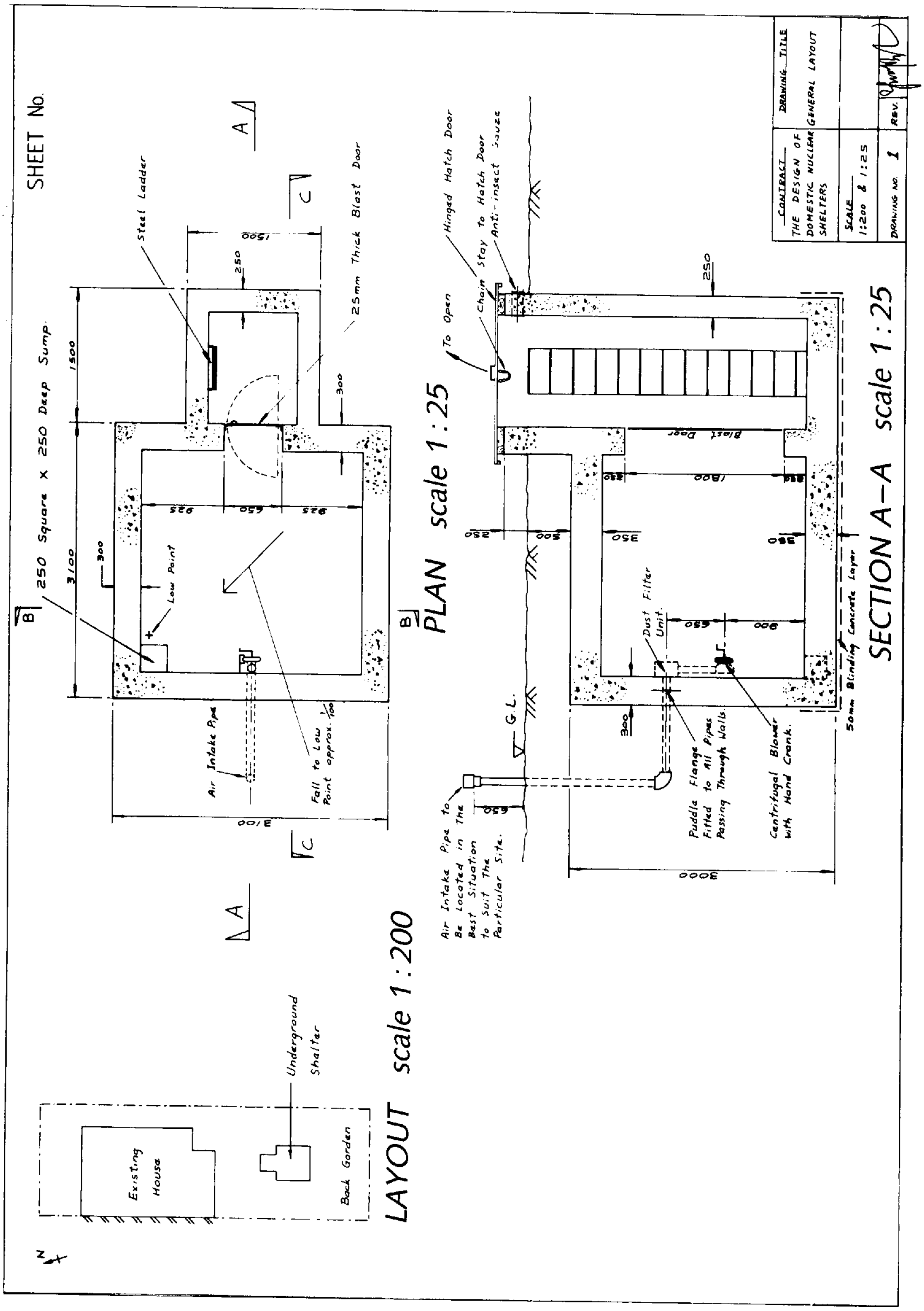
1 megatonne burst at a distance of 3 km from ground zero
Velocity of the shock front = 500 m/s
Ductility ratio $\mu = 5$
Drag coefficient: roof = −0.4; wall = +0.9
Yield strength of reinforcement = 425 N/mm^2
f_{cu} (dynamic) = 1.25 f_{cu} (static)
f_y (dynamic) = 1.10 f_y (static)
Main reinforcement $\nless 0.25\%$ bd (b = width, d = effective depth)
Secondary reinforcement $\nless 0.15$ bd
The ultimate shear stress $\ngtr 0.04 f_{cu}$
The dynamic shear stress for mild steel $\ngtr 172$ N/mm^2.

VIII.4.3 Design of the scheme and structural detailing

Sheet No. VIII.4.1 shows a layout for an underground nuclear shelter for a family of six. All important provisions are indicated on this sheet including the locations and types of doors. Sheet No. VIII.4.2 shows a complete layout of the reinforcement details at various sections and a detail of the hatch opening.

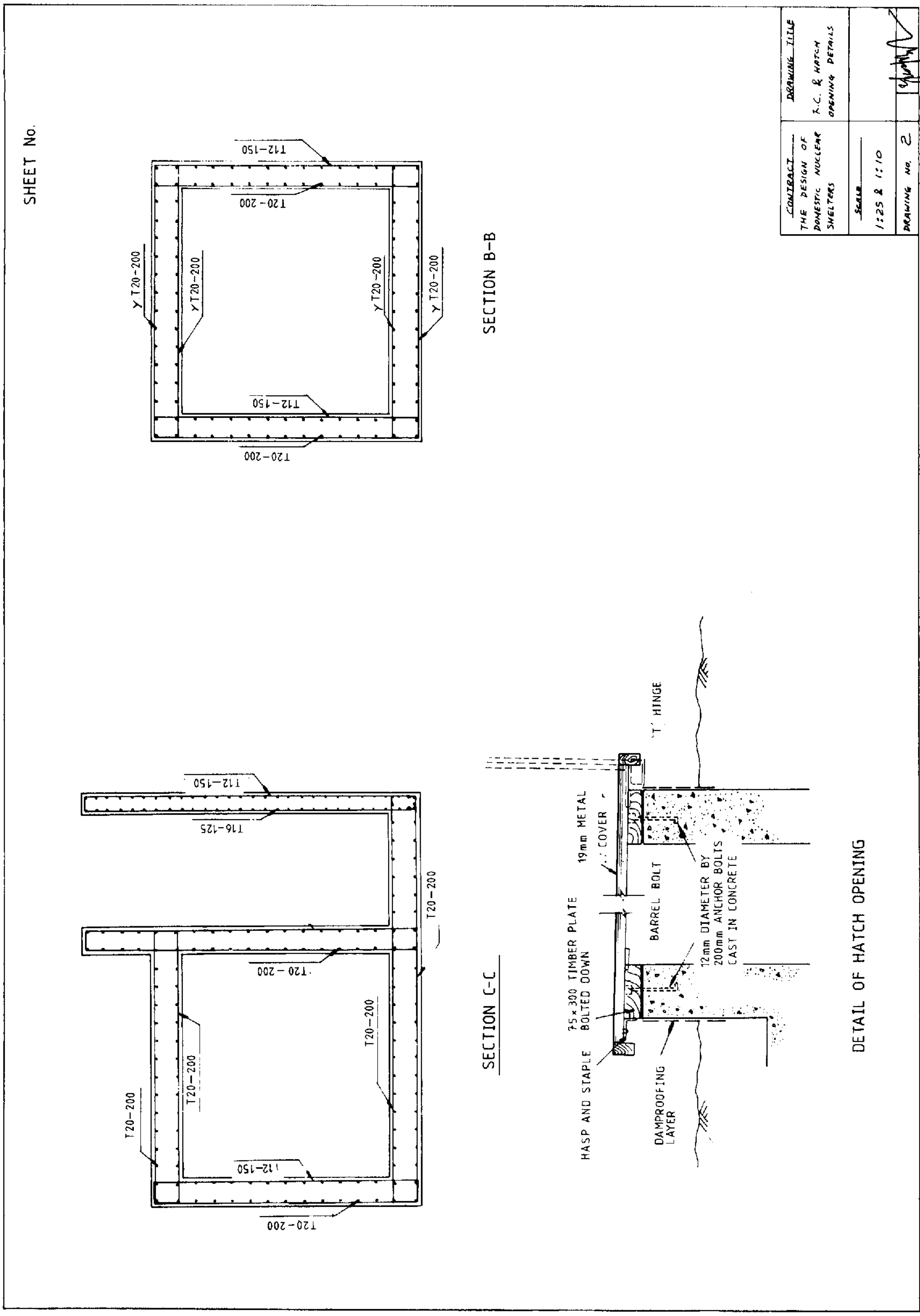
UNDERGROUND NUCLEAR SHELTER

SHEET NO. VIII.4.1



REINFORCEMENT DETAILS AND HATCH OPENING

SHEET NO. VIII.4.2



Section VIII.5
Nuclear, Oil and Gas Containments

VIII.5.1 Nuclear power and containment vessels

Nuclear reactors are generally housed in large prestressed concrete pressure and containment vessels. Some of the pressure vessels containing gas-cooled reactors with their respective parameters are listed below.

Plant	H_I (m)	D_I (m)	d_T (m)	d_B (m)	d_W (m)
Oldbury	18.3	23.45	6.40	6.71	4.58
Dungeness B	17.70	19.95	3.66	5.95	3.81
Hinkley Point B / Hunterston B	19.40	18.90	6.33	7.51	5.03
St Laurent 1, 2	36.30	19.00	5.70	6.00	4.75
Bugey 1	38.25	17.08	7.46	7.46	5.49
Fort St Vrain	22.85	9.45	4.73	4.73	2.74
Ventrop THTR	15.75	15.90	5.10	5.10	4.45

where H_I = internal height; D_I = internal diameter; d_T, d_B = top and bottom cap thickness; d_W = wall thickness.

In all the above-constructed vessels the gas boilers or circulators are either inside the vessel or placed elsewhere along the periphery of the vessel in an annular space. In addition multi-cavity vessels are proposed in which boiler and circulators are placed vertically inside the thickness of the vessel. The internal surface of these vessels is covered by a steel liner about 20 to 40 mm thick, the latter is for certain critical areas. These vessels are designed for an internal design pressure of 2.66 MN/m^2 to 7 MN/m^2. The prestressing tendons are arranged in vertical and circumferential directions to withstand external loads and internal gas pressure. Vertical tendons are slightly curved to offset extreme stresses at the corners. The circumferential tendons are anchored at buttresses. Sheet No. VIII.5.1 shows the prestressed tendon layout for the Dungeness B vessel. In the case of the Oldbury vessel, a single helical prestressing system is used to replace vertical and hoop tendons and their effects are similar to the Dungeness B vessel. In the case of multi-cavity vessels, owing to the placement of boilers and circulators in vertical directions, the circumferential tendons are replaced by a wire strand winding system as shown on Sheet No. VIII.5.2.

The main purposes of the containment structures are (i) to prevent the escape of radioactive materials, (ii) to protect the reactor system from damage due to external hazards, e.g. aircraft crashes, missile impact, tornadoes and hurricanes and explosion, and (iii) to provide biological shielding against nuclear radiation. A number of these vessels have been designed for Boiling Water Reactors and Pressurised Water Reactors. Some of them are listed below.

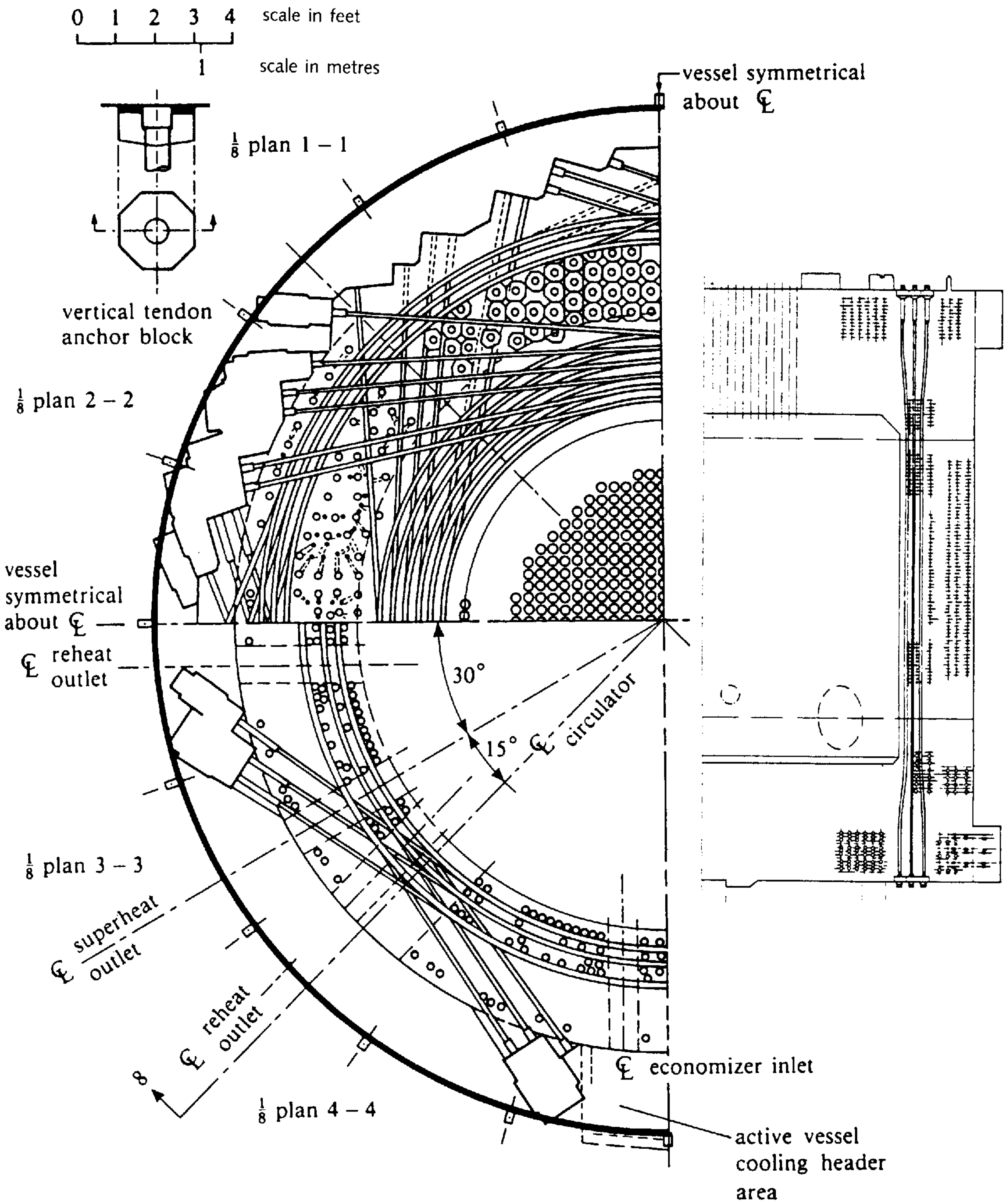
Plant	H_I (m)	D_I (m)	d_W (m)	Description
Palisades Wall	57.90	35.40	1.07	Spherical dome on circular wall
Monts d'Arree	56.00	46.00	0.60	" " " " "
Fessenheim	51.30	37.00	1.00	" " " " "
Super-Phenix*	90.00	64	1.00	" " " " "
TVA	(see Sheet No. VIII.5.4)		0.915	Elliptical dome on circular wall
Sizewell B	63 (see Sheet No. VIII.5.3)	41.88	1.00	" " " " "

* = total height H; ($H_I = H - D_I$ − thickness)

The internal pressure is about 344.75 kN/m^2 for Sizewell B, as shown on Sheet No. VIII.5.3. The number of vertical tendons are about 76 at 0.97 m centres in the wall. The number of circumferential tendons in the wall are about 120 at 0.317 m centres. In the dome latitude the circumferential tendons are 38 No. and along the longitude 24 No. with 16 No. in the rings.

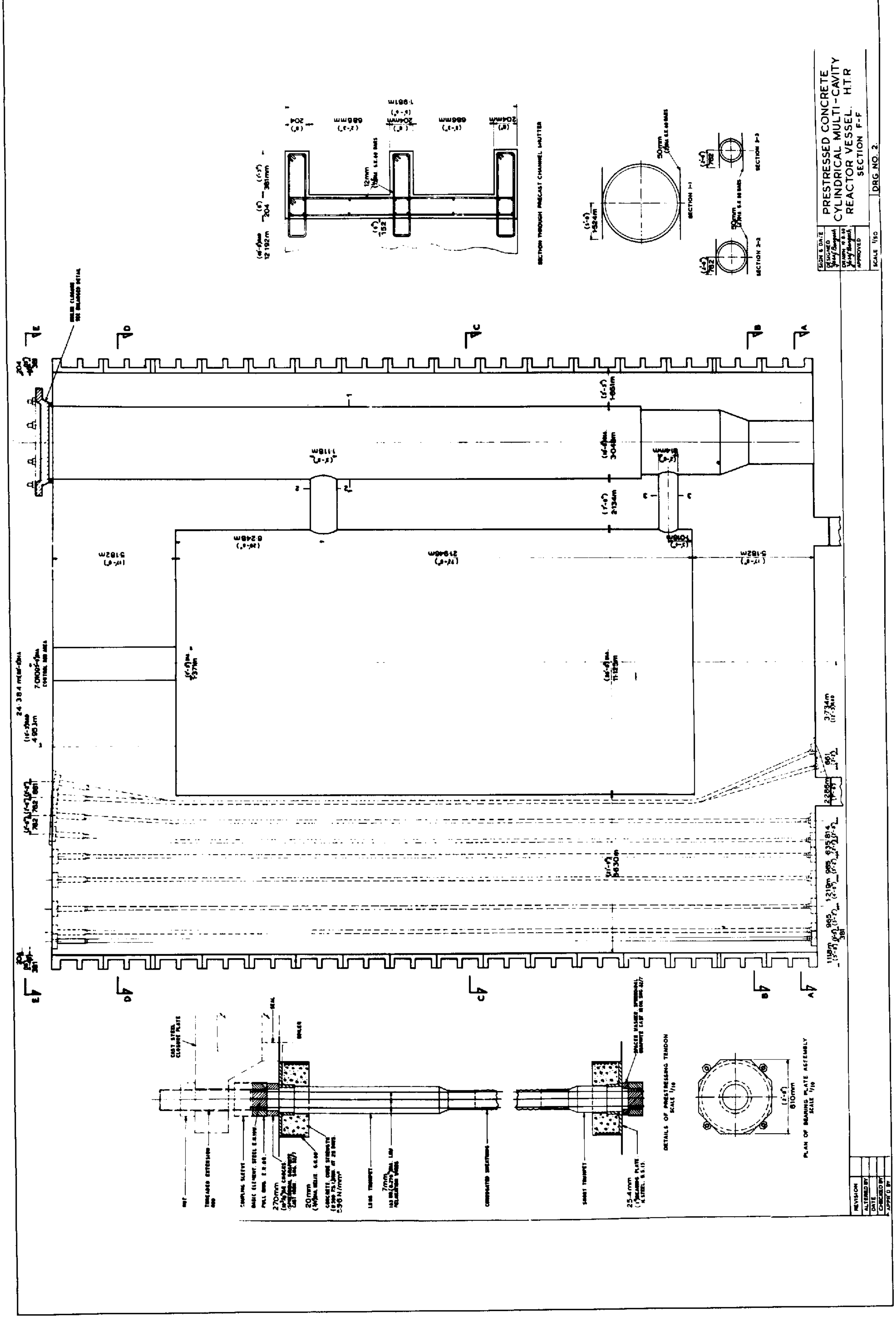
PRESSURE VESSEL – DUNGENESS B TYPE

SHEET NO. VIII.5.1



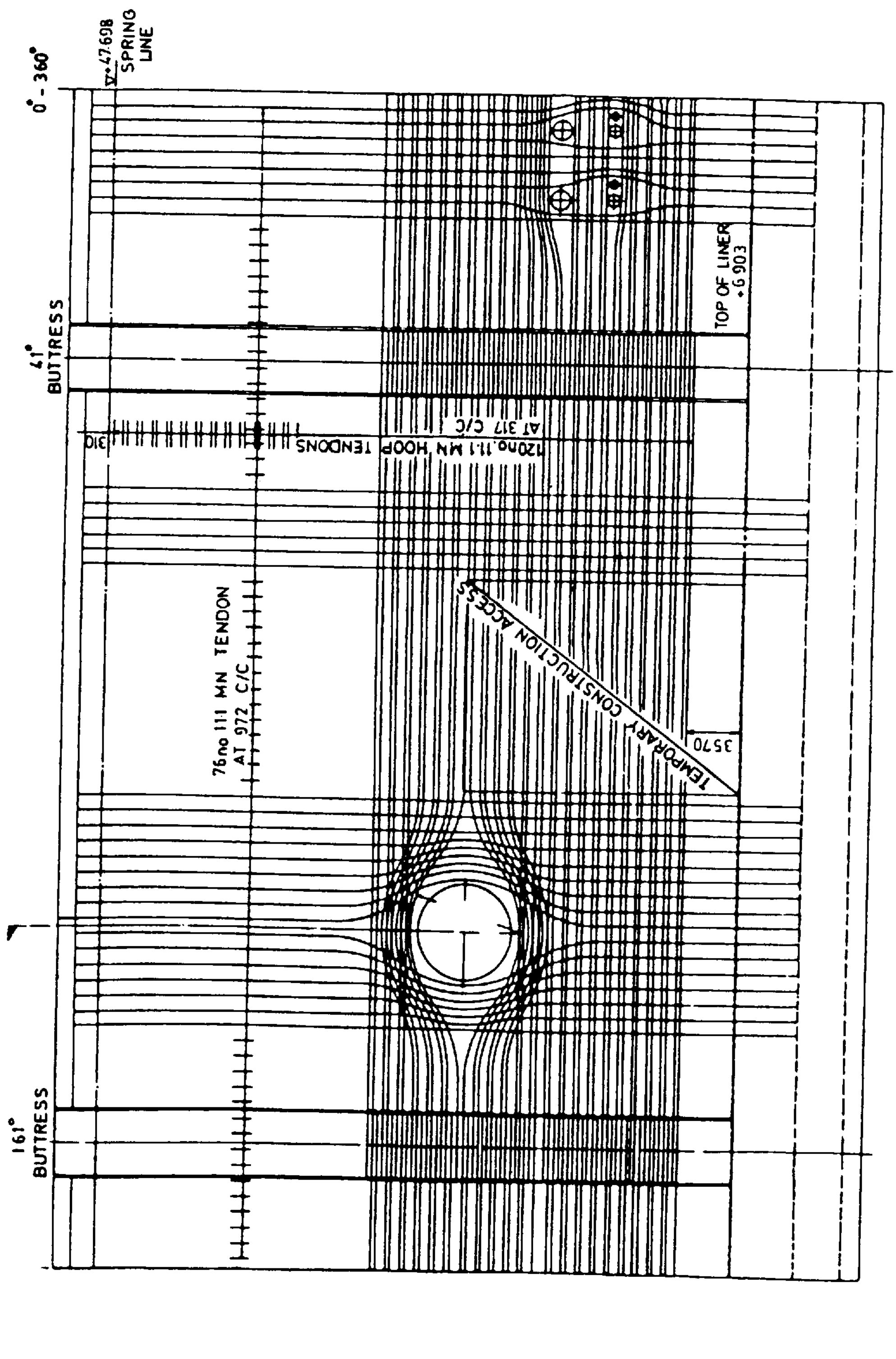
HTGCR VESSEL

SHEET NO. VIII.5.2



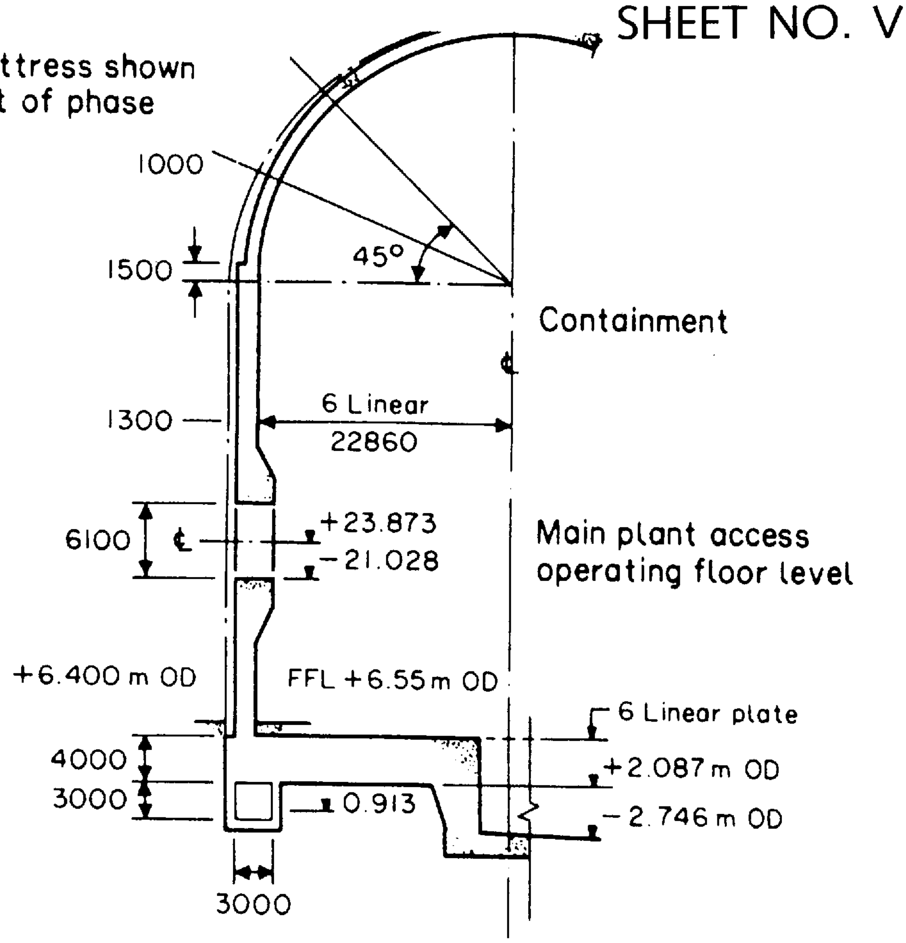
SIZEWELL B CONTAINMENT WITH SPHERICAL DOME – MAIN DIMENSIONS AND PRESTRESSING LAYOUT

SHEET No. VIII.5.3(a)

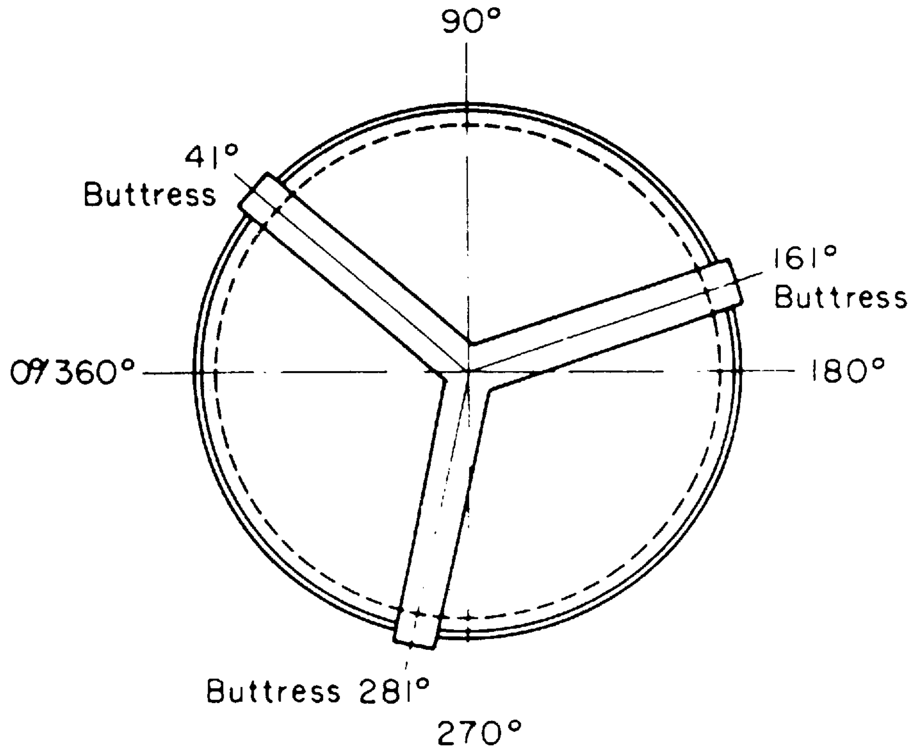


Developed elevation

SHEET NO. VIII.5.3.(b)



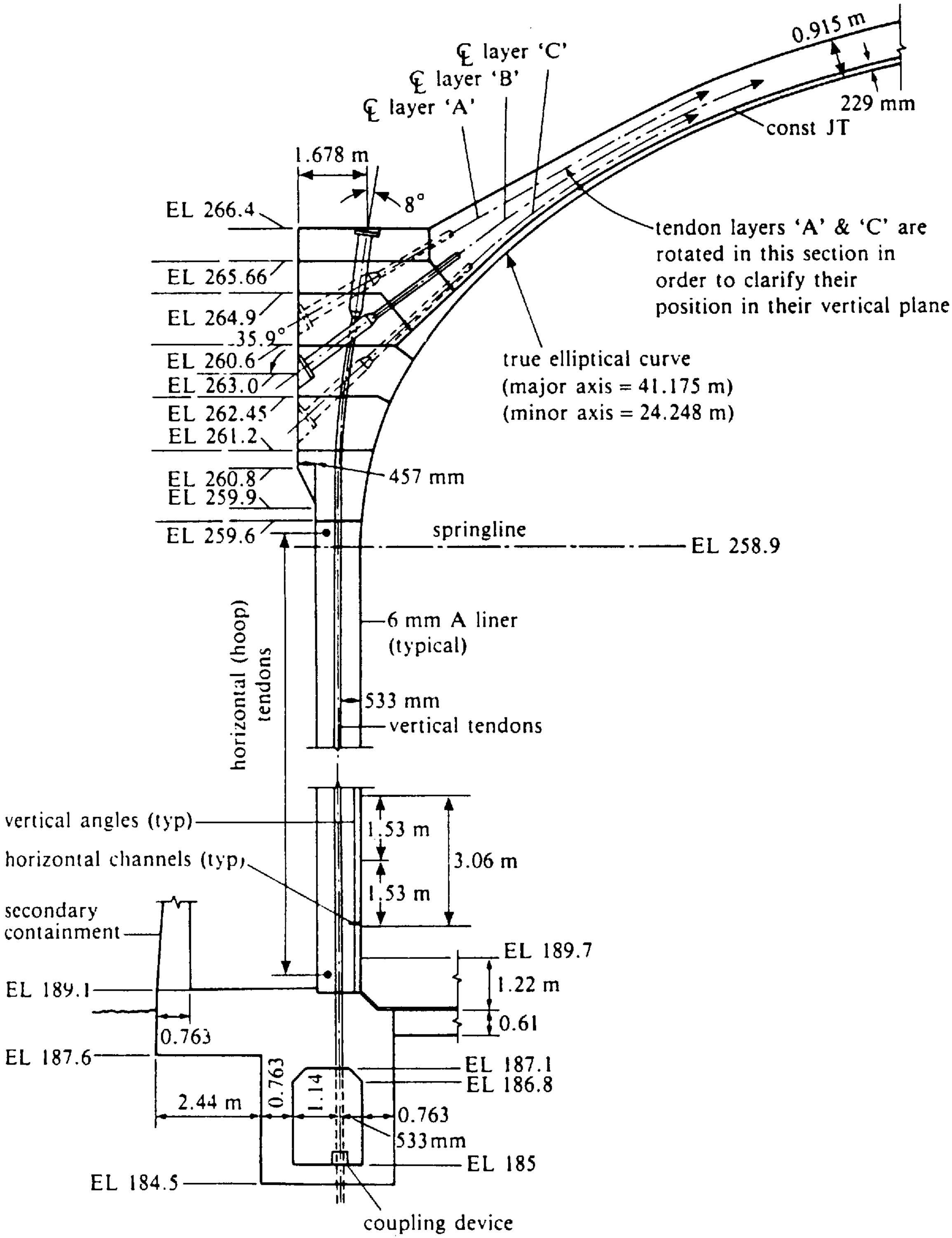
Vertical section through main plant access



Plan of dome

TVA CONTAINMENT BUILDING WITH ELLIPTICAL DOME – PRESTRESSING LAYOUT

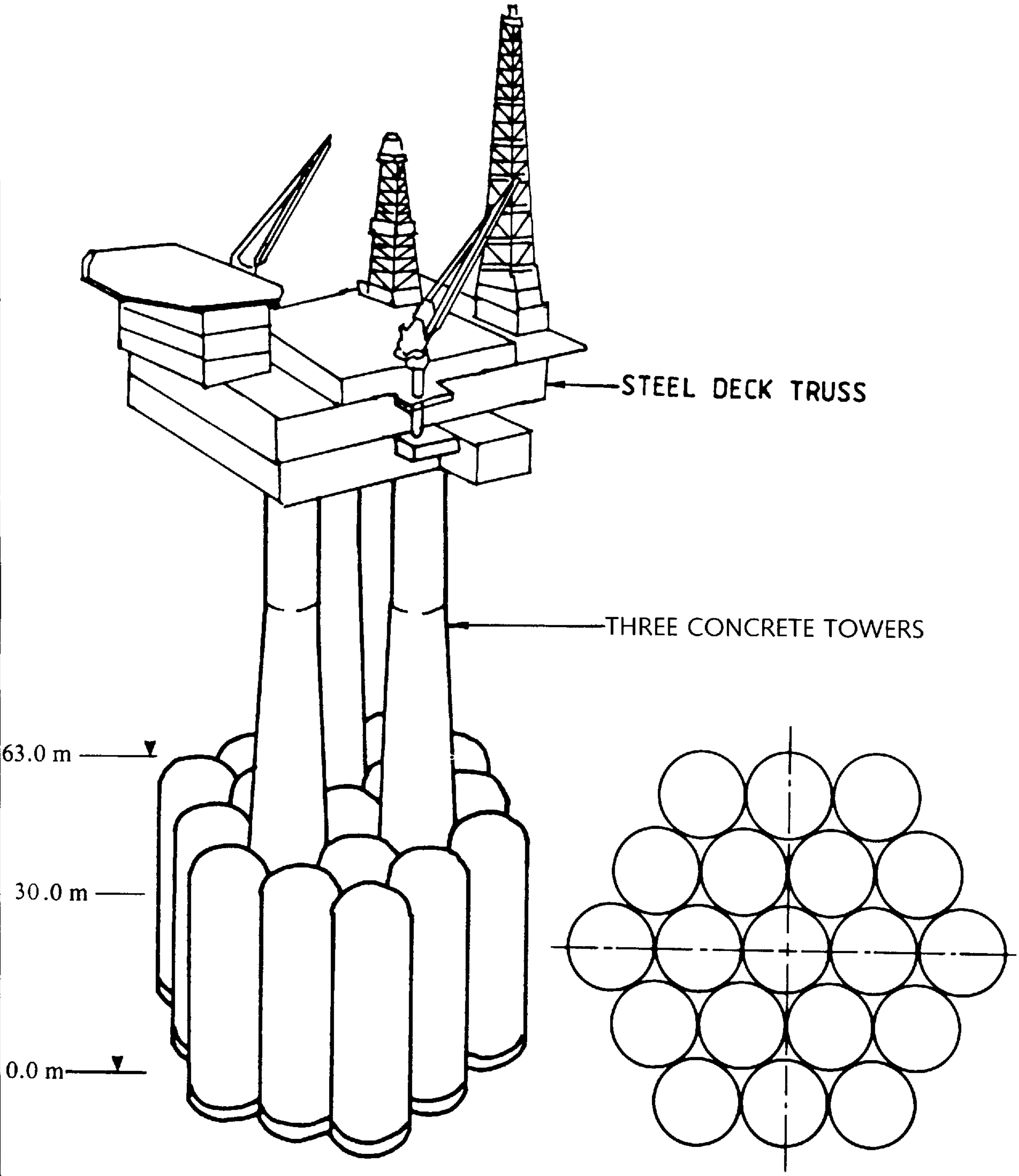
SHEET NO. VIII.5.4



A sectional elevation for Tennessee Valley Authority (TVA) with prestressing tendons in the elliptical dome and the wall is shown on Sheet No. VIII.5.4. The Sizewell containment has 11 MN tendons. Almost all containments are protected by a steel liner lugged to concrete and the thickness of the line varies from 6 mm to 12 mm.

OIL CONTAINMENT

SHEET NO. VIII.5.5



VIII.5.2 Oil containment structures

Most concrete platforms for offshore facilities have been provided with hollow caissons for oil storage (approximately one million barrels) to allow continuous production over an emergency period such as the stoppage of tanker loading in bad weather or pipeline shutdown during the operation of the platform. In the design, apart from the environmental loads, tanker collision, drop weights on the deck and explosion, significant thermal stresses must be included which can be caused by the difference between the ambient sea water temperature (about 5°C) and the stored oil in the cell (about 40°C).

Sheet No. VIII.5.5 shows a sectional elevation and plan of a group of cells designed in reinforced concrete. Alternatively, these cells can be designed and constructed using prestressed tendons on the lines suggested for the TVA and Sizewell B containments as shown on Sheet Nos. VIII.5.3 and VIII.5.4 respectively. The Dungeness B Vessel layout can be adopted with approximate concrete thickness of barrel walls and caps for storing oil. These cells have domes resting on cylindrical walls with drill shafts and decks at the centre. They are constructed in a dry dock and are towed to the installation site. A number of these platforms have been designed, detailed and constructed, the most well known are Condeep, Ninean, Statfjord, Murchison and Tor. Some basic data are given below.

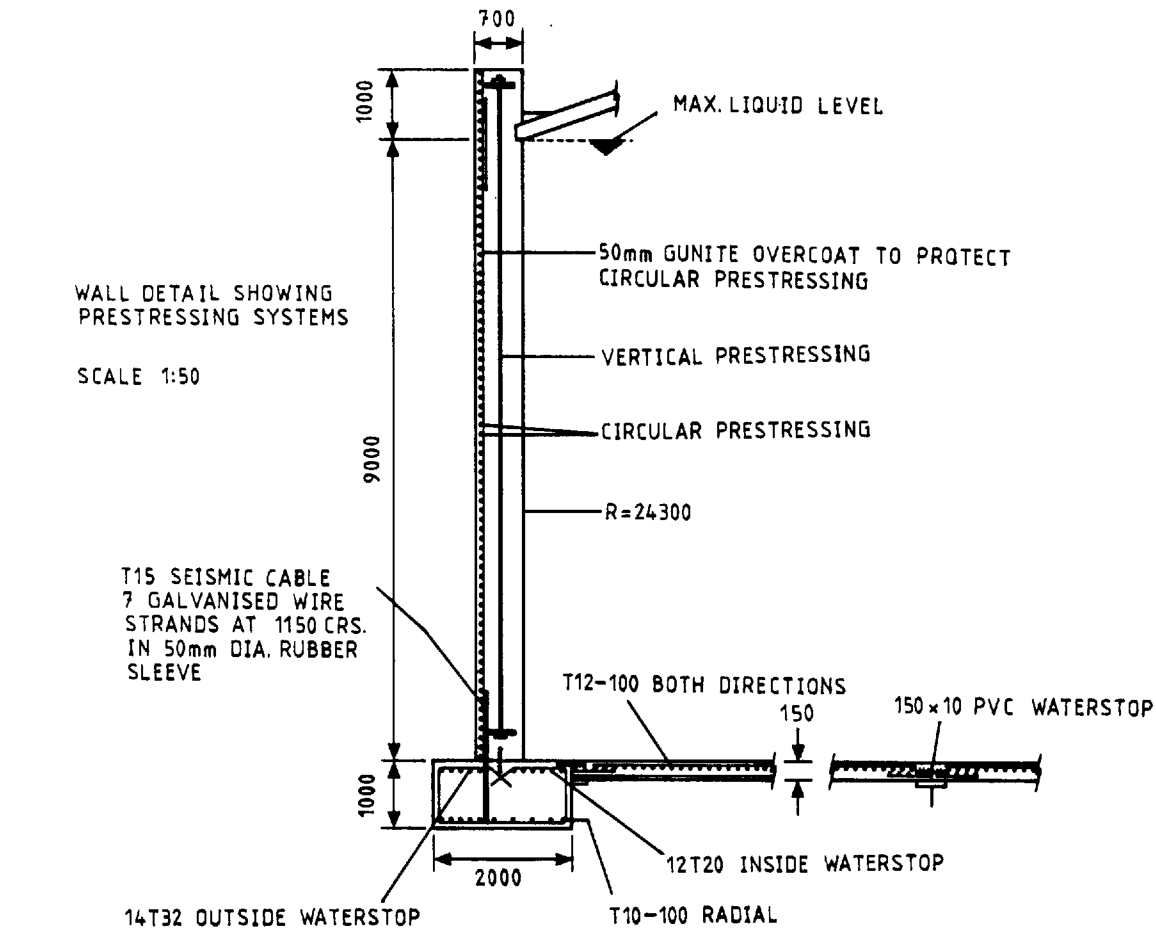
Condeep
Water depth (in the area) 145 m to 188 m
Cells (hollow 16 No.) 20.1 m diameter × 50 m high
Cell walls, etc. 0.61 m thick, 109 m high with three main shafts above cells with outside diameter tapered from 20.1 m to 11.9 m
Deck weight with equipment 22.68 million kilogram
Weight of the support structure 2.72 million kilogram
Reinforcement bar size 12 and 25.

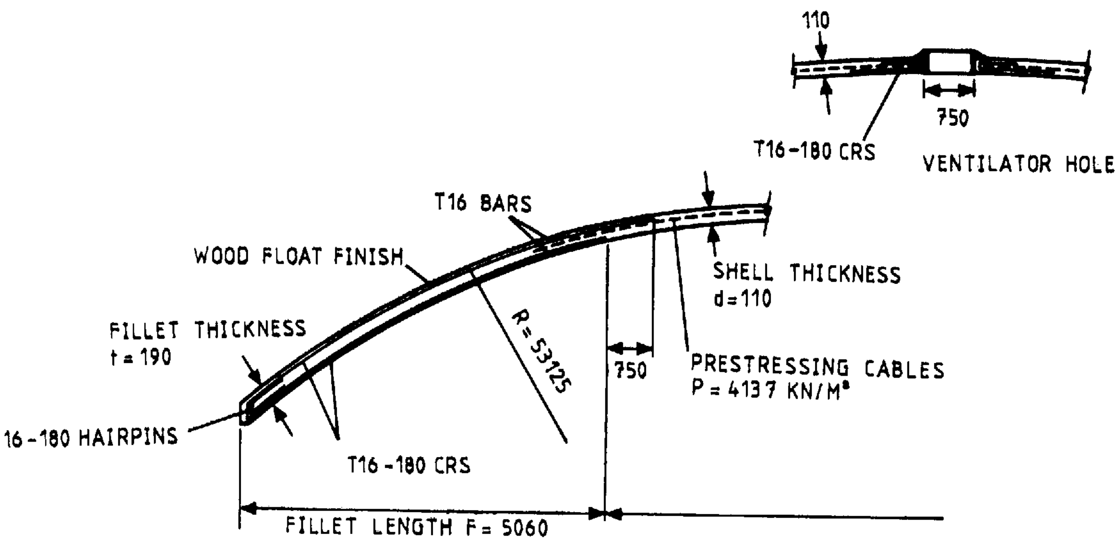
Platform	Water depth (m)	Caisson plan (area/height)	No. of towers	Ext/int dia. (m)	Steel (tonne)
Frigg	104	$72\,m^2/42\,m$	2	14/13.4	5800
Brent	140	$91\,m^2/57\,m$	4	15/14.4	11400
Cormorant A	152	$100\,m^2/56\,m$	4	16/15.4	13930

Concrete grade 50 is always recommended.

PRESTRESSED CONCRETE LNG TANK

SHEET NO. VIII.5.6





VIII.5.3 Liquefied natural gas containments

Liquefied natural gas (LNG) can be contained in a fixed concrete storage structure in the form of a vessel on shore or can have a series of mobile marine structures for its storage offshore. The most common way to store large quantities of gas in preparation for marine transportation is to liquefy it. It is well known that liquefied gases are stored and shipped at low temperatures, e.g., propane at −46°C and LNG at −160°C. The need for special materials, insulation etc., imposes constraints on the mobile structure design: sea conditions, wind, current directions, seismic conditions and soil conditions. For on-shore conditions, wind, temperatures, seismic and soil conditions must be included in the design of these containments or storage structures. Dykman's BBR of San Diego, California, USA are the designers and constructors of a large number of such structures worldwide. These containments can be of a single walled or doubled walled type, reinforced or prestressed.

Sheet No. VIII.5.6 shows typical details of the LNG concrete containments of 50 m diameter with 10 m wall height and an elliptical dome of maximum height at the centre of 5.5 m. The maximum liquid height is 9 m.

Section VIII.6
Hydro-Electric and Irrigation/Hydraulic Structures

VIII.6.1 Hydro-electric structures

VIII.6.1.1 General introduction

Hydro-electric structures are designed for use in water supply, electricity generation and navigation. Ecological and environmental considerations have a great influence on the planning, design and operation of such structures. Next in turn is hydrological studies and the economical selection of dams and other structures for multi-purpose hydro-electric schemes. Dams may be classified into a number of different categories – classification by use, by hydraulic design and by materials. Here only concrete dams and other relevant concrete structures are considered.

(a) *Concrete gravity dams*
They are suitable for sites where there is a sound rock foundation, although low structures may be founded on alluvial foundations if suitable cut-offs are provided. They are well suited for use as overflow spillway crests. They may be either straight or curved in plan.

(b) *Concrete arch dams*
They are suitable for sites where the ratio of the width between abutments to the height is not great and where foundations at the abutments are solid rock capable of resisting arch thrusts. There are two types of arch dams – the single and the multiple arch dam. A single arch dam spans a canyon (crest height/length = 1/10) as one structure and its design includes small thrust blocks on both abutments. A multiple arch dam may be either a uniformly thick cylindrical barrel shape spanning 15 m or so between buttresses or it may have single arch dams supported on massive buttresses spaced several hundred metres on centres. The loads considered are water pressure, ice pressure, silt pressures, dead loads, earthquakes and ice combinations and other imposed loads.

(c) *Spillways*
Spillways are provided for storage and detention dams to release surplus or flood water that cannot be contained in the allotted storage space. They are also used as diversion dams to by-pass flows exceeding those turned into the diversion systems. The safety of the spillway is of paramount importance since many failures of dams have been caused by improperly designed spillways. The layout is influenced by many factors including spillway size, type, overflow characteristics, the selection of location, and terrain. It may be an integral part of the dam (overflow section of the concrete dam) or it may be

a separate structure. A major component is the control device which prevents outflows below a fixed reservoir level and regulates releases when the reservoir rises above that level. The control drives may be straight, curved, semi-circular, U-shaped, or round. The flow is conveyed to the stream bed below the dam in a discharge channel or waterway. Spillways may be (i) free overfall (straight drops), (ii) Ogee (overflow), (iii) side-channel type, (iv) labyrinth, (v) chute (open channel or trough), (vi) conduit and tunnel, (vii) drop inlet (shaft or Morning Glory), (viii) baffled B chute or (ix) culvert.

(d) *Intakes and penstocks*
This type of structure is an *inlet* or the entrance to the outlet work and accommodates a control device already discussed above. The intake structures are of different shapes and are each selected according to several factors: (i) the range in reservoir head under which it must operate, (ii) the discharge it must handle, (iii) reservoir ice and wave conditions and (iv) frequency of reservoir draw down (the frequency of cleaning trash racks).

An *intake* may be either submerged or extended in the form of a tower above the maximum reservoir surface. The former is considered only where it is an entrance to outlet conduits or where trash cleaning is unnecessary. A tower must have a control and is needed where an operating platform is needed for trash removal or installing stop logs. The conduit may be placed vertically, inclined or horizontally. The sill level must be higher than the conduit level. Trash bars of thin flat steel are placed on edge from 75 mm to 150 mm apart and assembled in a grid pattern. The shape of trash rack structures may vary according to their mounting techniques and the shape of the intake.

Penstocks are large concrete pipes or conduits, mounted at suitable intervals on the slopes to deliver water to turbines in the power plant. They can be made in steel.

(e) *Power plant*
The penstocks are connected to turbine casings in the hydro-electric plant producing electricity.

(f) *Spillway bridge*
A bridge is generally provided for traffic on the dam spillway.

VIII.6.1.2 Hydro-electric structures – typical data on dams

(a) *Djen Djen Dam, Algeria*

Crest length	530 m
Maximum height	85 m
Span of barrels	35 m
Barrel thickness	2.3 m
No. of buttresses	11
Minimum thickness at buttress	3.084 m

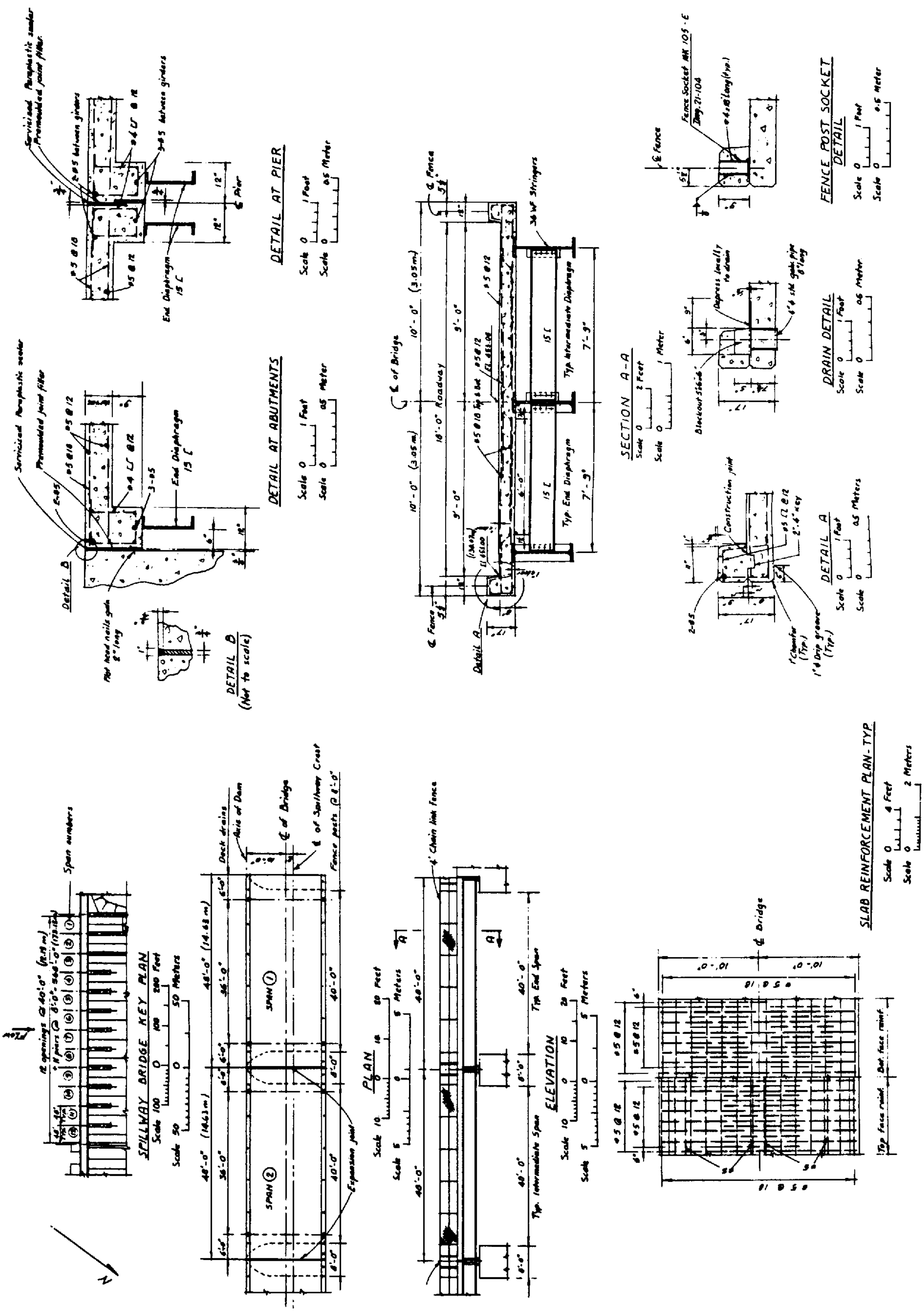
(b) *Sefid Rud Dam, Iran*

Crest length	384 m
Maximum height	107 m
No. of buttresses	14
Buttress thickness and width	5 m, 14 m

Many others have been constructed; see the bibliography in this book, where additional information is available.

DAM-SPILLWAY BRIDGE – CONCRETE OUTLINE AND REINFORCEMENT

SHEET NO. VIII.6.1



VIII.6.1.3 Hydro-electric structures – structural detailing

Note: The author has kept the details in their original forms. They can easily be converted into SI units.

Sheet No. VIII.6.1 gives a typical layout and structural details of a dam-spillway steel-concrete (composite) bridge for traffic in and out of the site. Sheet No. VIII.6.2 shows a dam-spillway and its piers.

Here reinforcement details are provided for a typical dam-spillway and its piers which hold revolving steel gates. The bars shown can easily be converted from the American system to SI units using conversion or similar bar sizes given in Section 1.

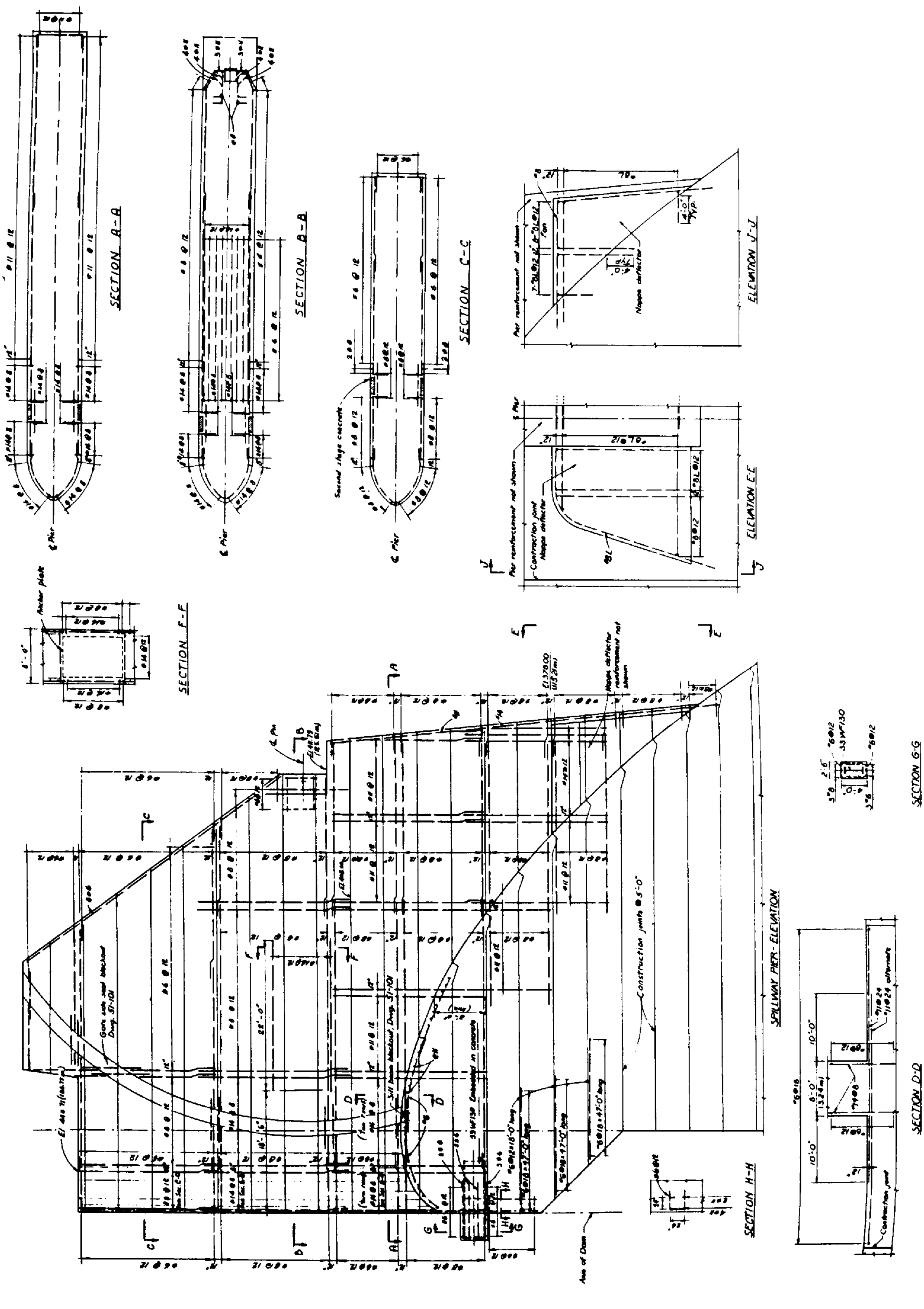
Sheet No. VIII.6.3 shows a typical plan for spillway intakes, penstocks and power house units. Sheet Nos. VIII.6.4 and VIII.6.5 indicate sectional elevations of the layout given on Sheet No. VIII.6.3. For a very different job a different type of intake is shown with upstream and downstream elevations and a section on Sheet No. VIII.6.6. For this intake various reinforcement details are shown on Sheet No. VIII.6.7 which include sectional plans, elevations and particular reinforcement details for piers and gate slots. Sheet No. VIII.6.8 gives the complete reinforcement details for the training wall of the dam intake. A complex reinforced concrete detailing of a typical unit bay of a power house is shown on Sheet No. VIII.6.9. The conduit is transitioned to suit the turbine casings. It also shows the legend for two stages of concrete.

Sheet No. VIII.6.10 shows structural plans and sections for electric manholes for the same switchyard. These details are practically universal for any switchyard.

Sheet No. VIII.6.11 gives a comparative study of different shaped tunnels used in various multi-purpose hydro-electric schemes.

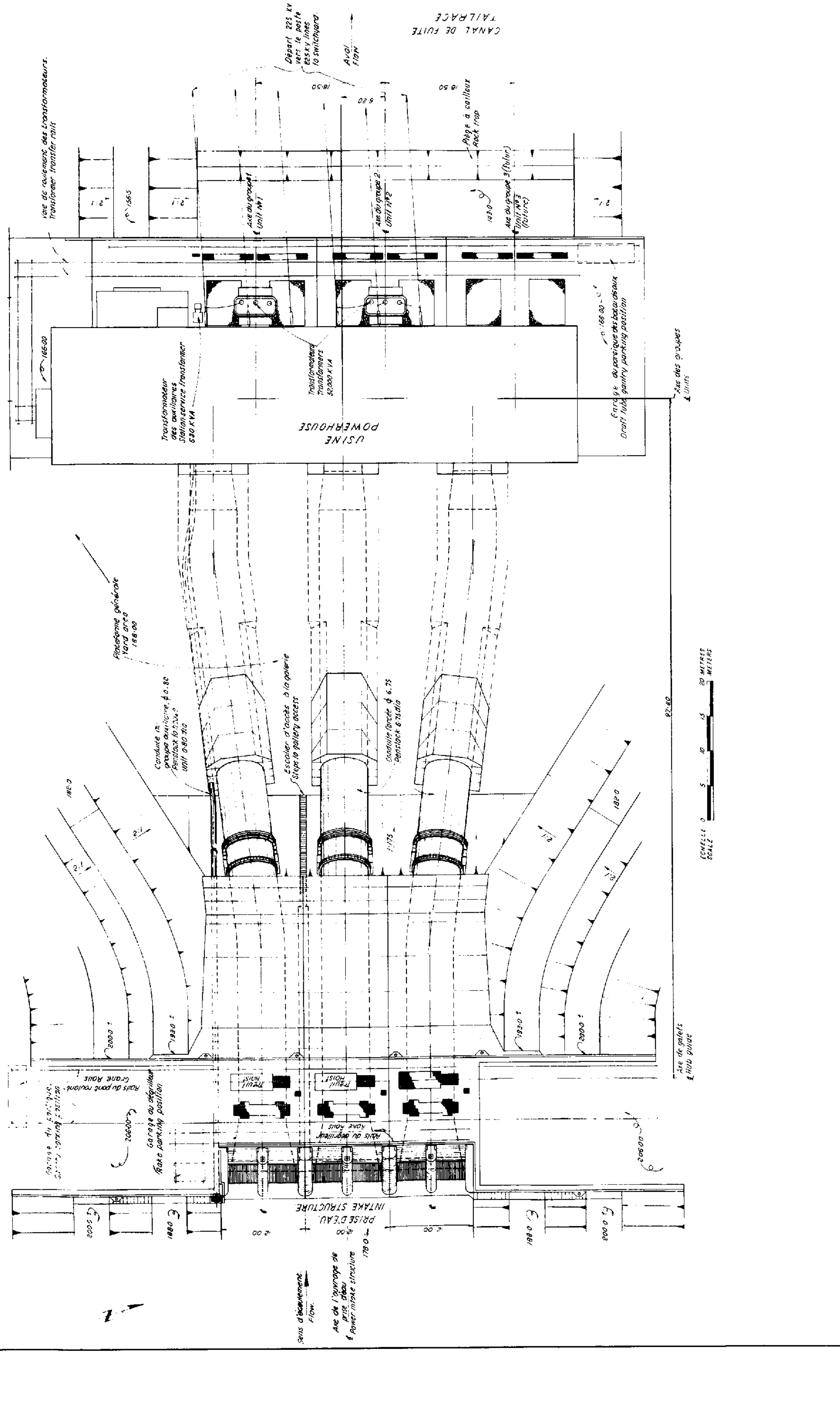
DAM-SPILLWAY AND PIERS – ABOVE EL.253.00 REINFORCEMENT

SHEET NO. VIII.6.2



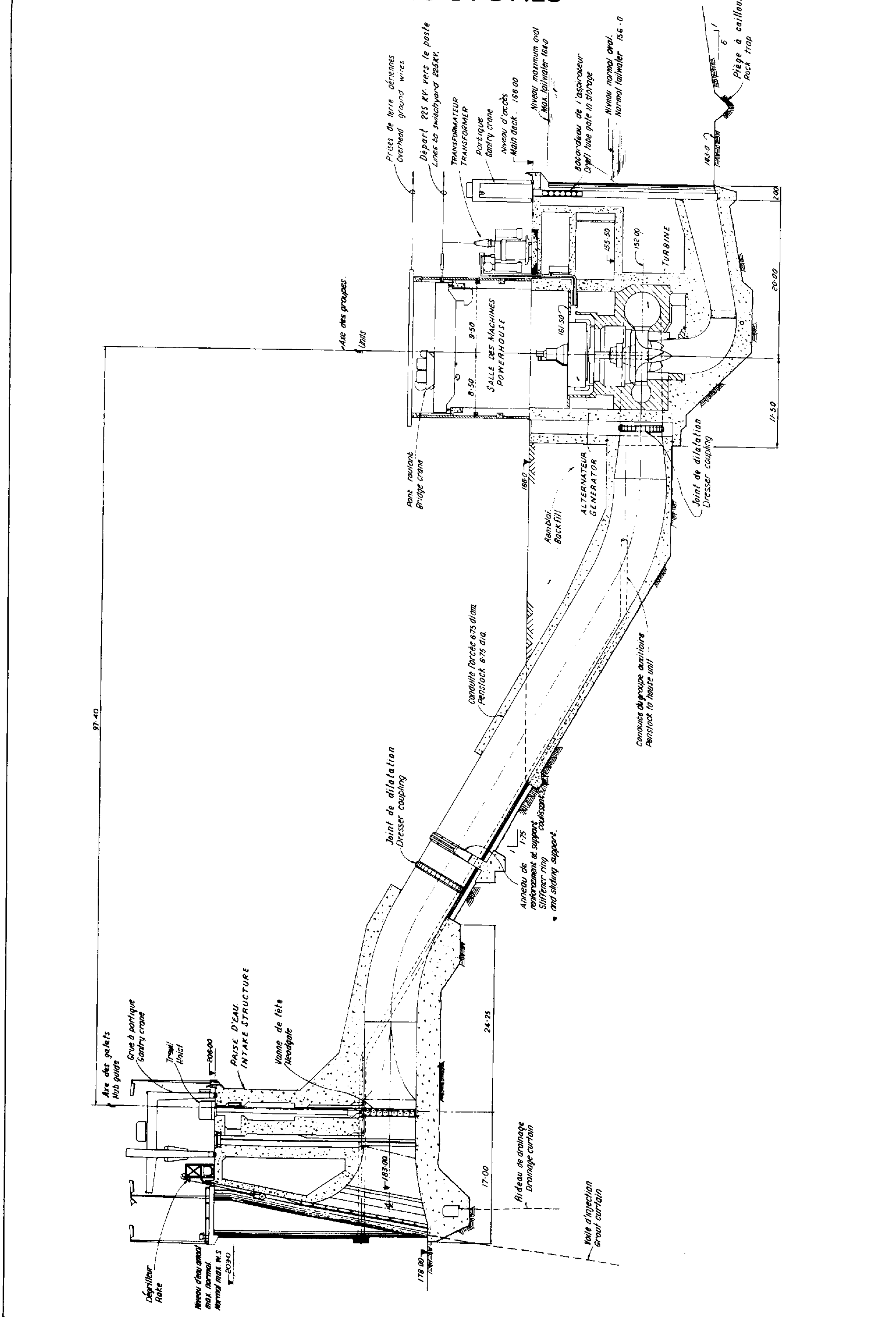
DETAILED PLAN OF HYDRO POWER STRUCTURES

SHEET NO. VIII.6.3



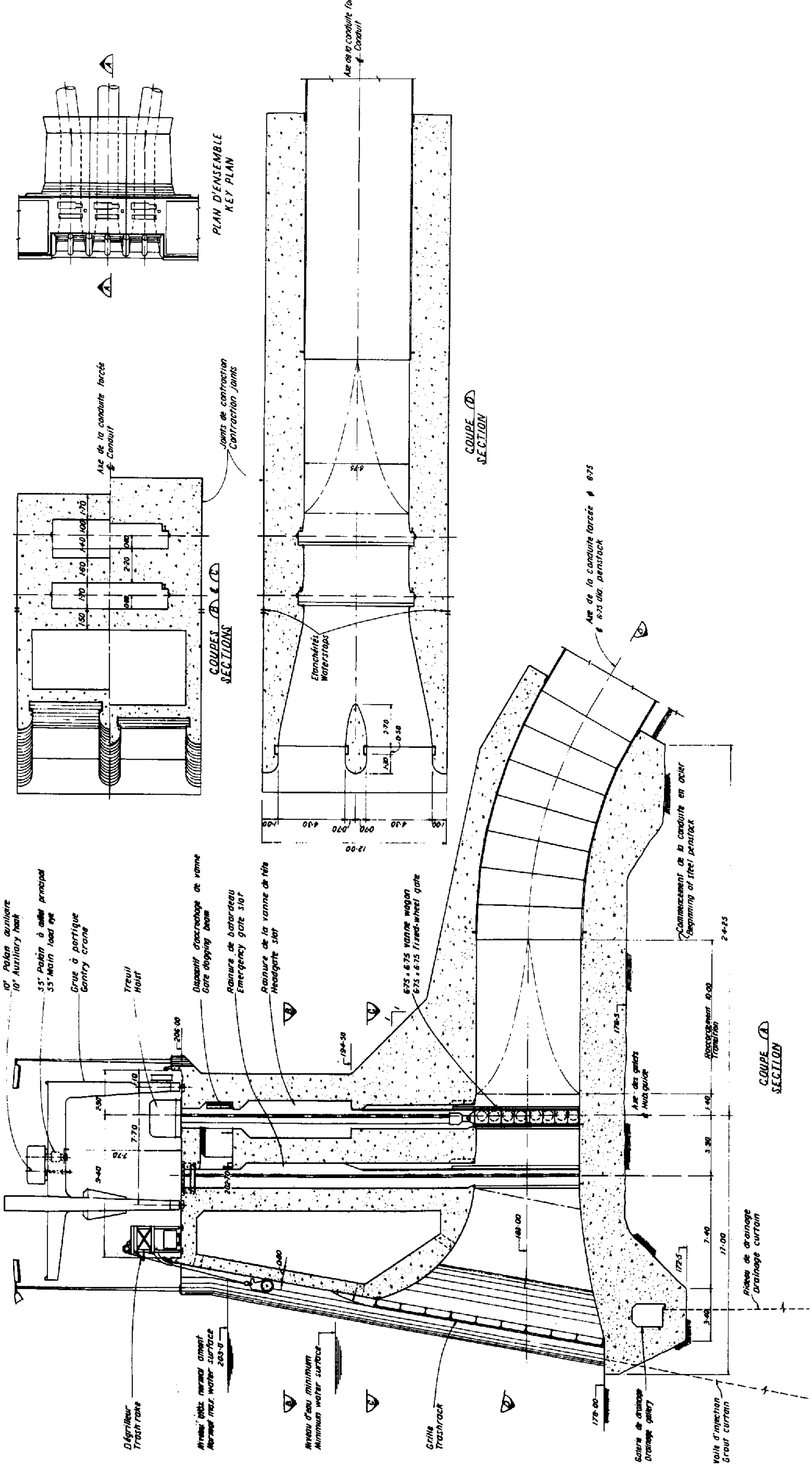
DETAILED SECTIONAL ELEVATION OF HYDRO POWER STRUCTURES

SHEET NO. VIII.6.4



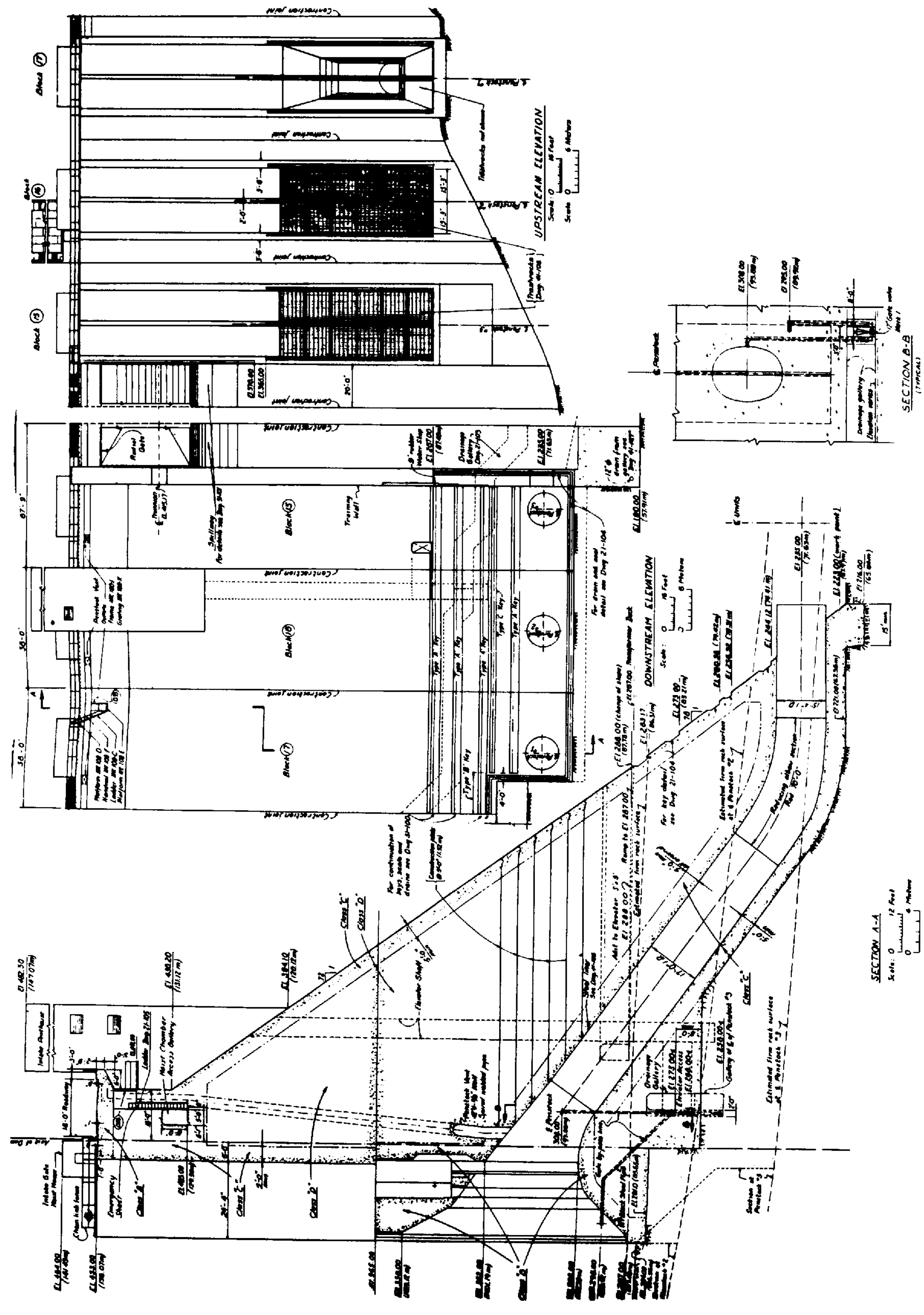
DAM–INTAKE SECTIONAL ELEVATION AND PLAN

SHEET NO. VIII.6.5



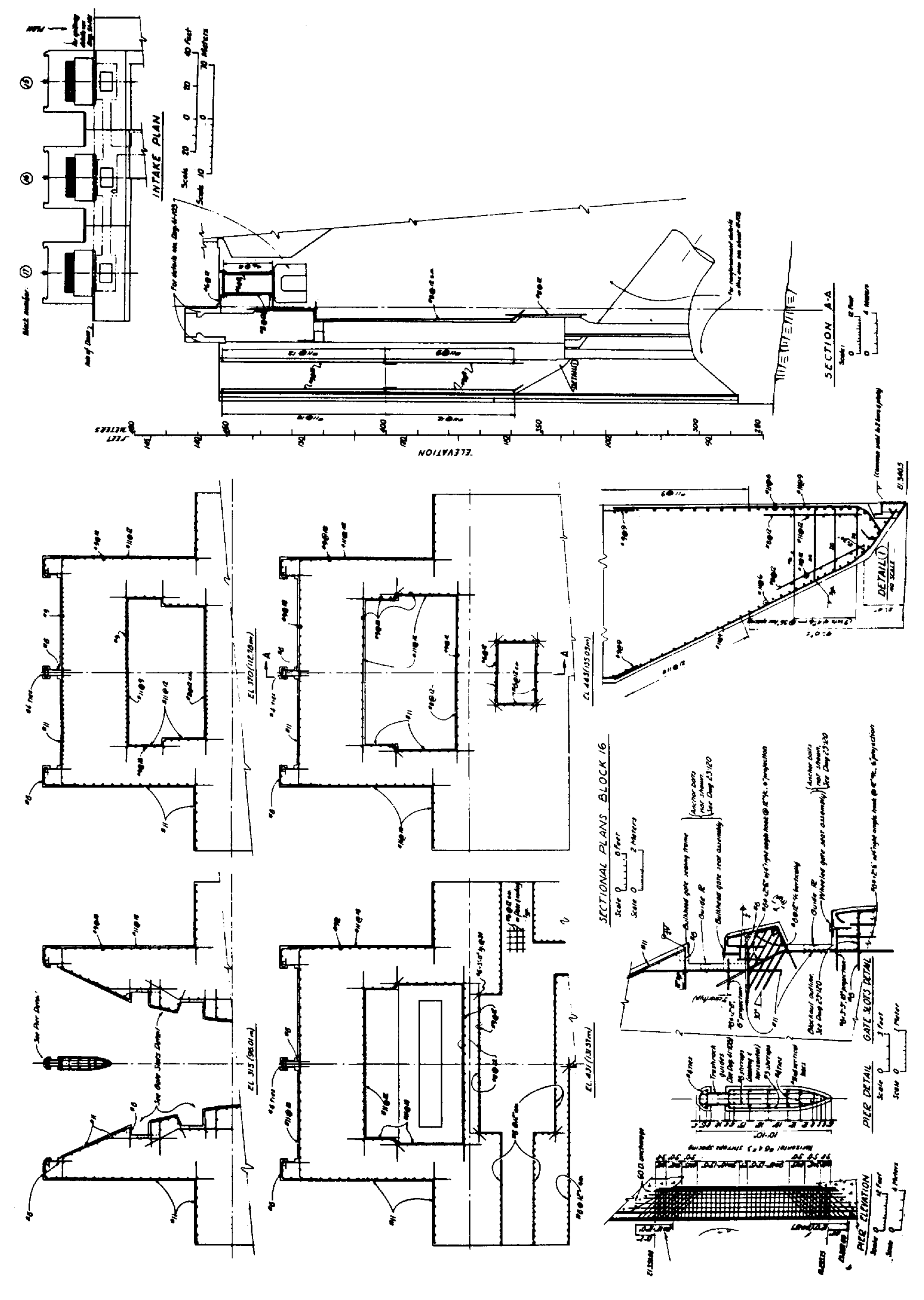
DAM–INTAKE SECTION AND ELEVATIONS CONCRETE OUTLINE

SHEET NO. VIII.6.6



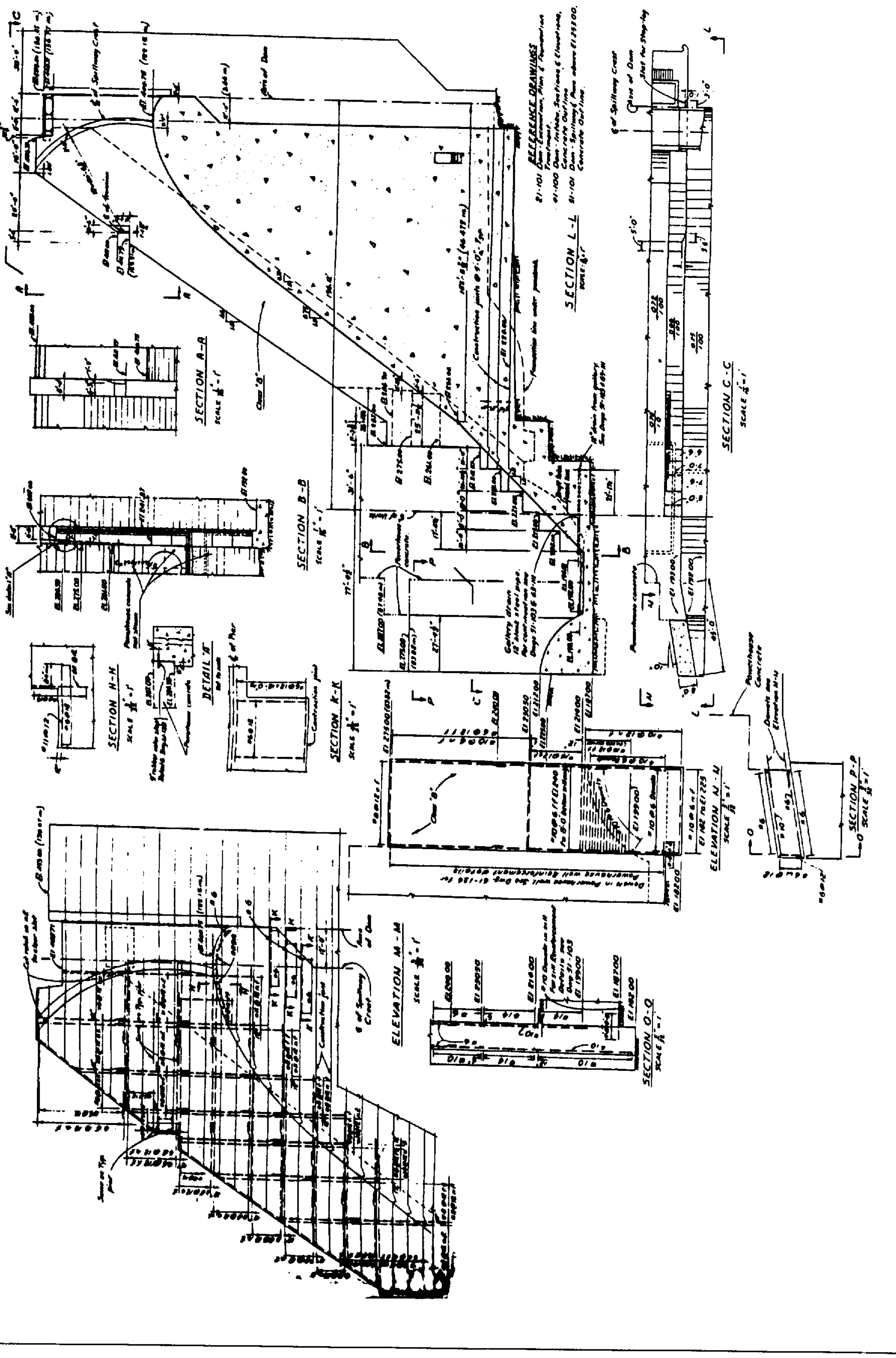
DAM–INTAKE SECTIONS AND DETAILS CONCRETE OUTLINE AND REINFORCEMENTS

SHEET NO. VIII.6.7



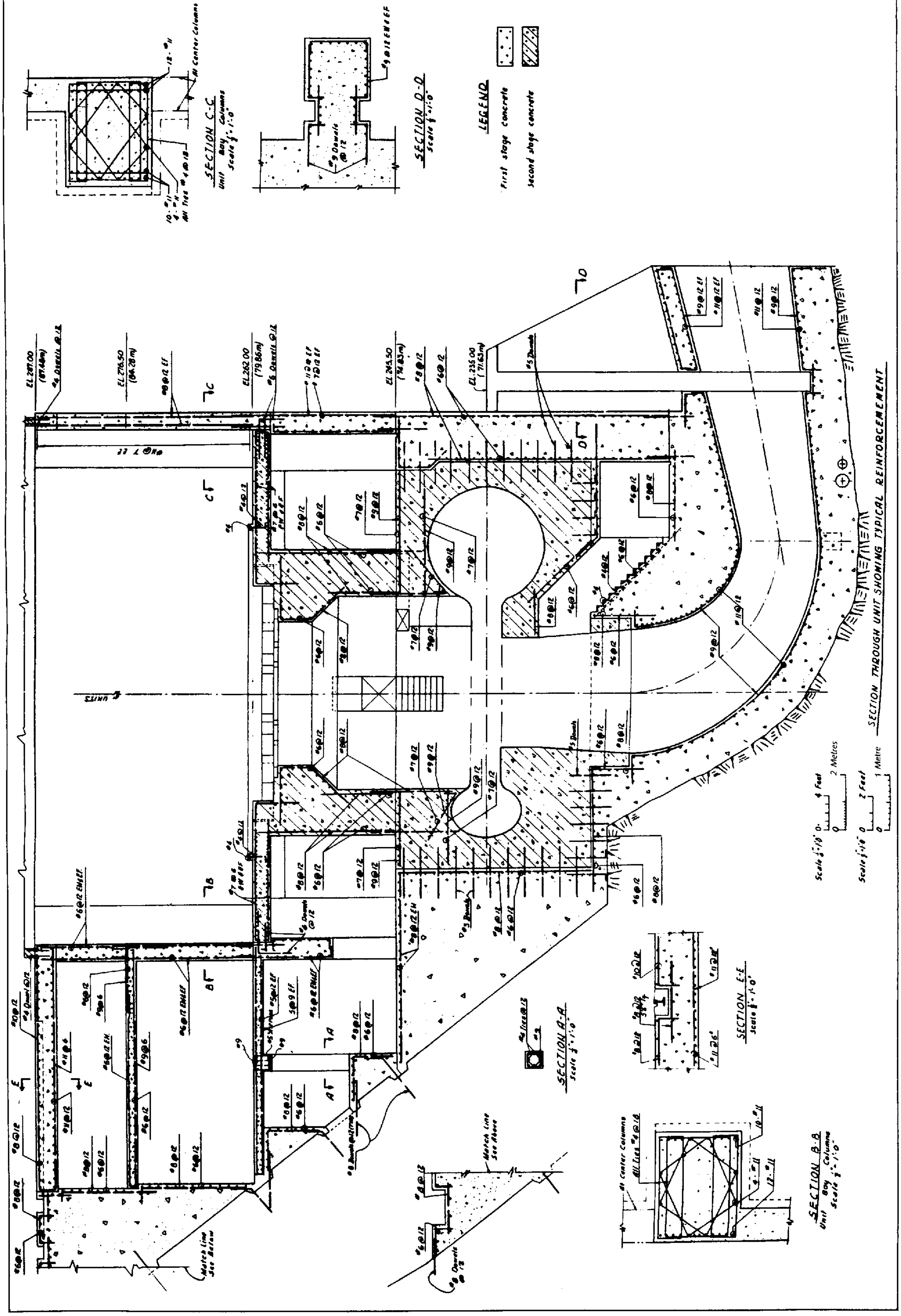
DAM–INTAKE TRAINING WALL CONCRETE OUTLINE AND REINFORCEMENTS

SHEET NO. VIII.6.8



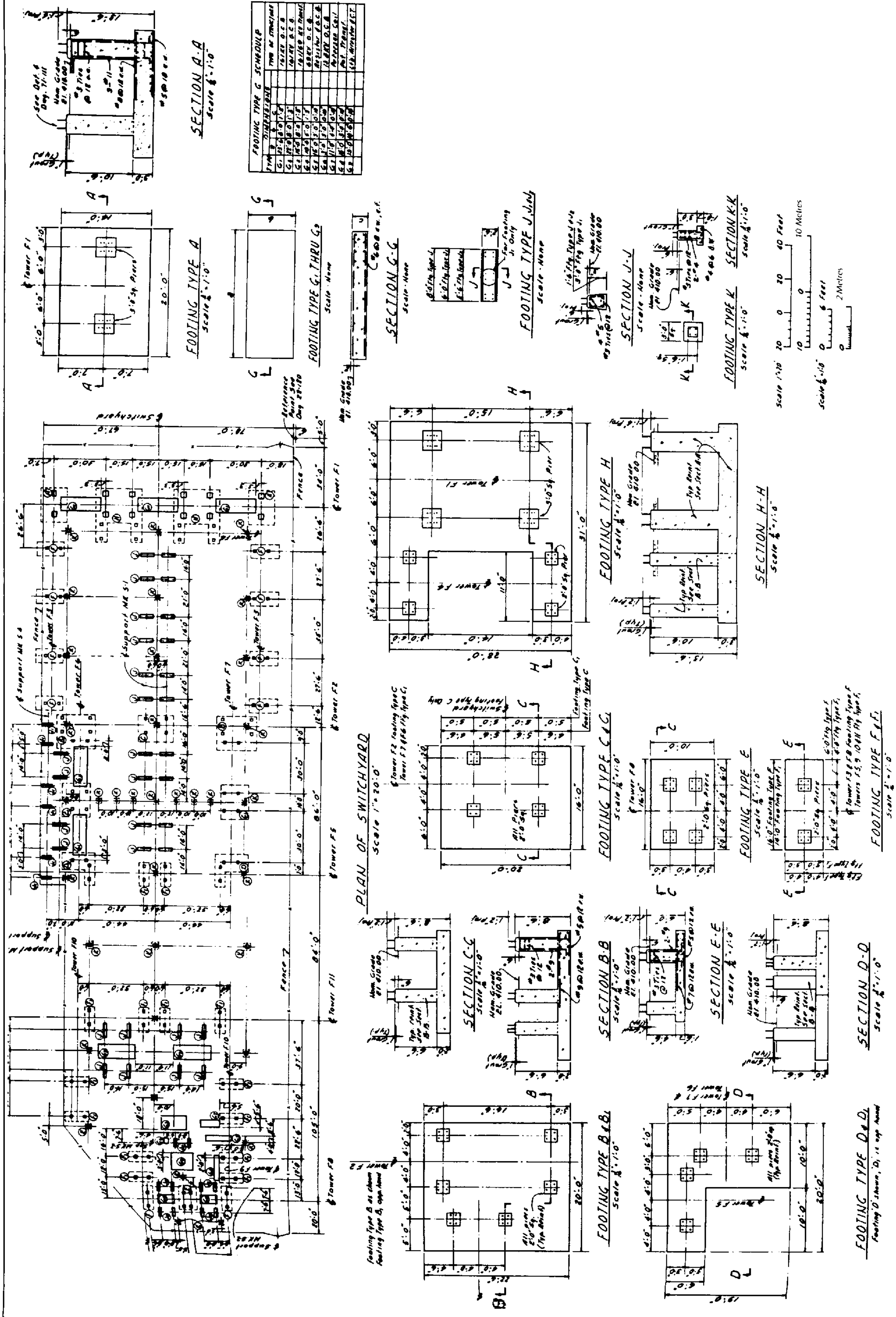
POWERHOUSE UNIT BAYS TYPICAL REINFORCEMENT

SHEET NO. VIII.6.9



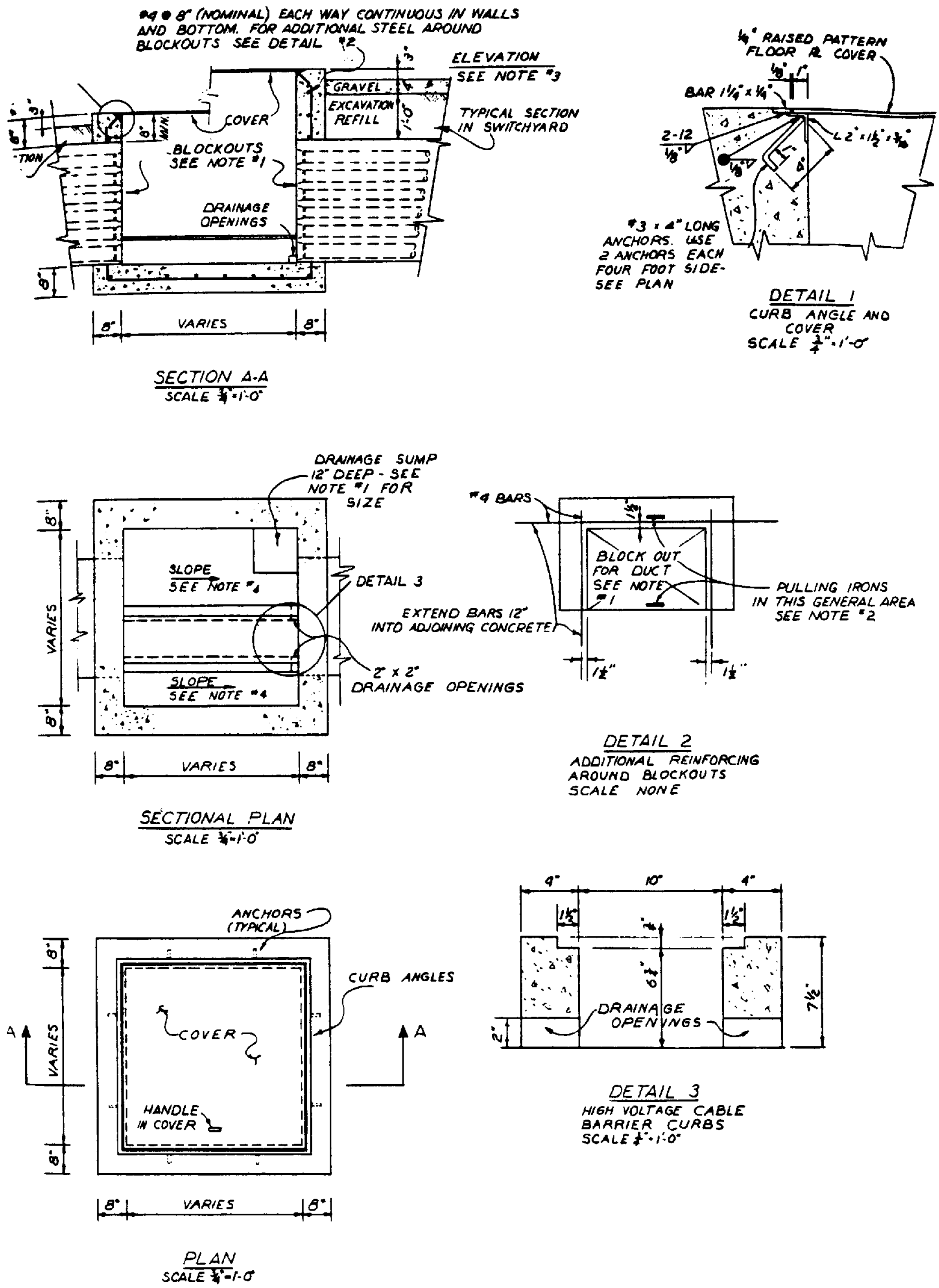
161 KV SWITCHYARD CONCRETE FOOTINGS

SHEET NO. VIII.6.10



161 KV SWITCHYARD ELECTRICAL MANHOLES

SHEET NO. VIII.6.11



Section VIII.6.2
Hydraulic and Irrigation Structures

VIII.6.2 Irrigation structures

VIII.6.2.1 General introduction

Irrigation structures are extremely important and they must be properly designed and detailed. Some selected structures will be outlined later to inform the reader about their specific aspects of structural detailing. The general requirements include the following: (a) water demand, (b) acreage to be irrigated, (c) duty of water, (d) seepage losses, (e) evaporation, (f) flow capacity, (g) site layout and structural curvatures and lining, (h) free board, (i) bank top width and beam, (j) flow formulae, (k) membrane lining and slopes, (l) loadings and (m) design considerations.

VIII.6.2.2 Main structures

(a) Spillway sections
(b) Dam with control gates
(c) Buttress overflow sections
(d) Cut-off walls
(e) Wing walls
(f) Stop logs
(g) Overchute and chutes
(h) Feeder canal
(i) Sluice
(j) Trash rack
(k) Outlets
(l) Siphons and tunnels
(m) Flumes and drops.

Some of these have already been disscussed in Section VIII.6.1. To accomplish an irrigation project (for producing crops or increasing crop production), water delivery to specific sites must be provided by a reliable and efficient irrigation system. A canal is frequently used to convey water to meet requirements for municipal, industrial and outdoor recreational uses. Canal head-work structures are needed to regulate canal discharge at the source of the water supply. These structures must also be able to raise the canal water level higher than it would normally be when the canal is flowing at less than design capacity. Most of these structures, apart from water pressures, must withstand dead and imposed loads, lateral soil pressures, loads such as ice and wind loads, wheel loads and railroad loads.

Spillways, dams with control gates, buttress overflow sections cut-off and wing walls, trash racks, etc. have been dealth with in Section VIII.6.1. The functions of others are given below.

(f) *Stop logs are control structures*
They are control structures and their layout is different but their performance is identical to chute which is described below.

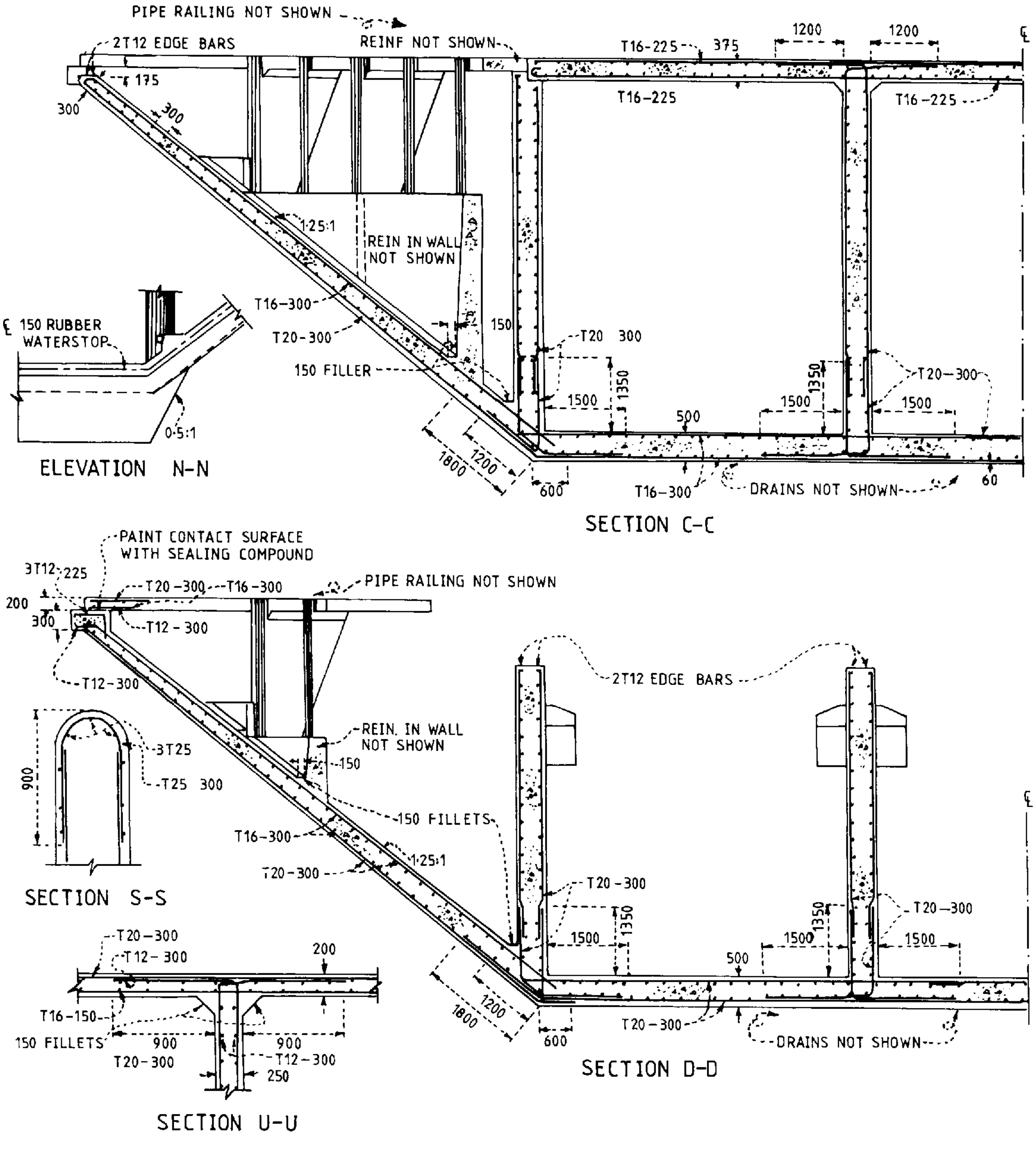
(g) *Overchute and chute*
These are structures that carry flood or drainage water across and above the canal prism. They are used where the cross-drainage gradient is sufficiently high to provide a free board over the canal water surface without excessive ponding at the inlet. A rectangular concrete flume is generally used for large flows. Chutes are used to convey water from a higher elevation to a lower elevation. A chute structure may consist of an inlet, a chute section, an energy dissipater and an outlet transition. The inlet is provided with a control to prevent racing and scouring in the channel. Control is achieved by combining a check, a weir or a control notch with the inlet.

(h) *A feeder canal*
This is a canal that feeds water, it is often related to an overchute type structure. Sheet No. VIII.6.12.a shows the sectional elevation and R.C. details for a feeder canal.

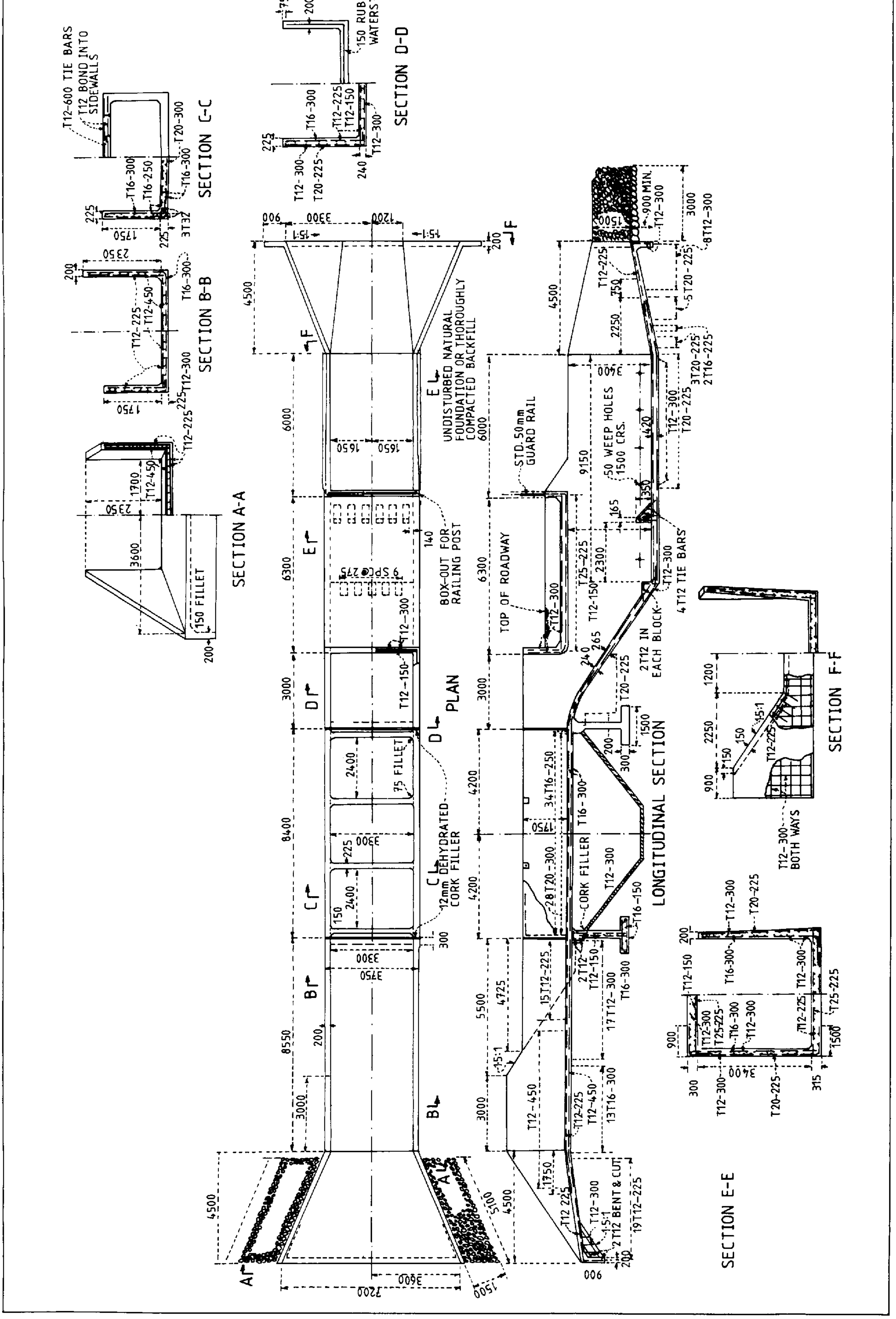
Sheet No. VIII.6.12.b shows structural details of a typical feeder canal and an over-chute. Reinforcement details are given at important sections.

SECTIONAL ELEVATION AND R.C. DETAILS OF A FEEDER CANAL

SHEET NO. VIII.6.12(a)

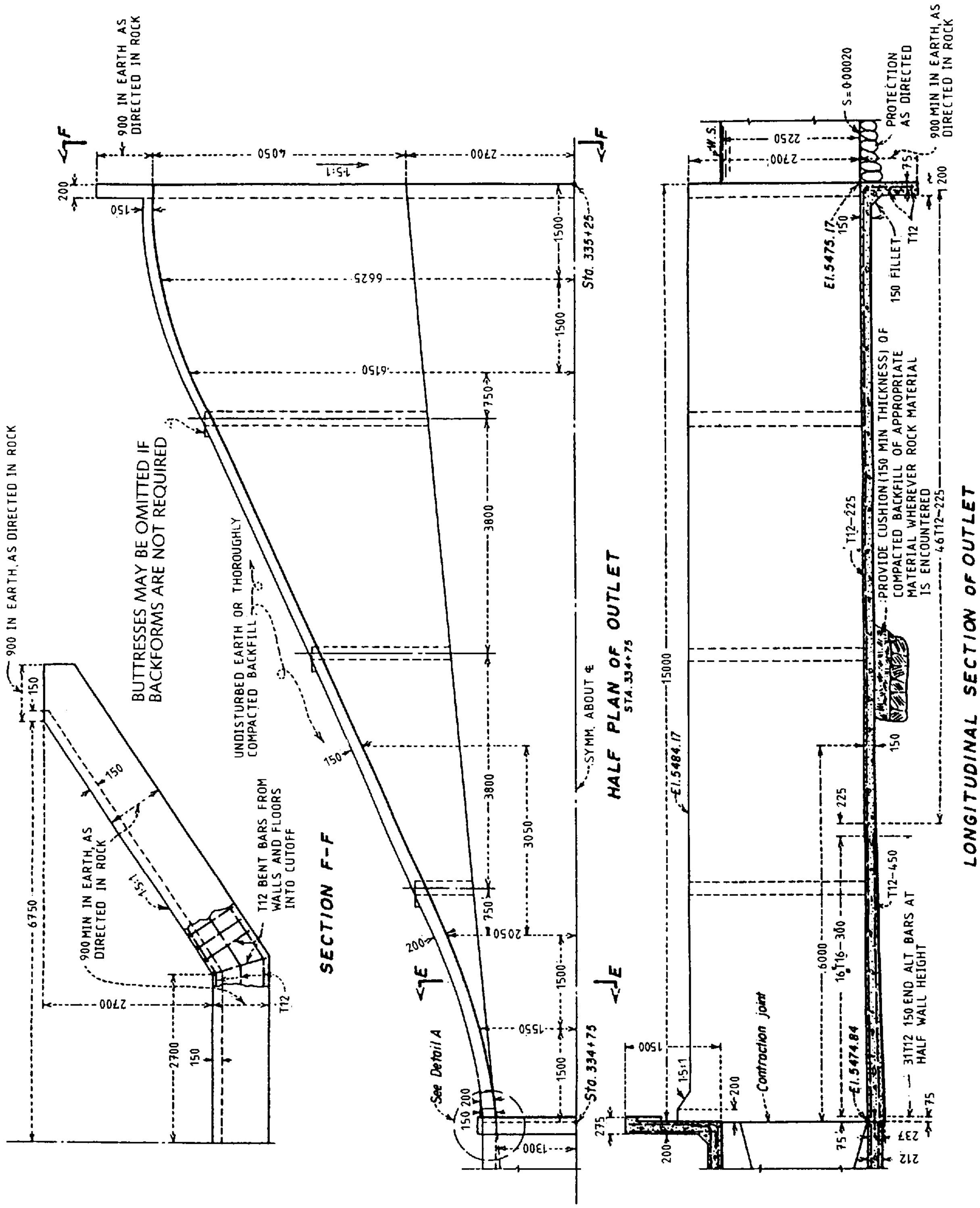


OVERCHUTE-HORSETOOTH FEEDER CANAL SHEET NO. VIII.6.12(b)



TYPICAL OUTLET

SHEET NO. VIII.6.13



(k) *Outlets*
Sheet No. VIII.6.13 gives structural details (plan and sections) for a typical outlet. Reinforcement details of the base slab and of the construction joint near to the transition zone are shown at the longitudinal section.

(l) *Siphons and tunnels*
Tunnels are described in Section VIII.6.1, inverted siphons or sagpipes are used to convey canal water by gravity under roads, railroads and other structures. Typical cross-sections are given for various tunnel shapes with support systems on Sheet No. VIII.6.14. All reinforcement details are given for various sections.

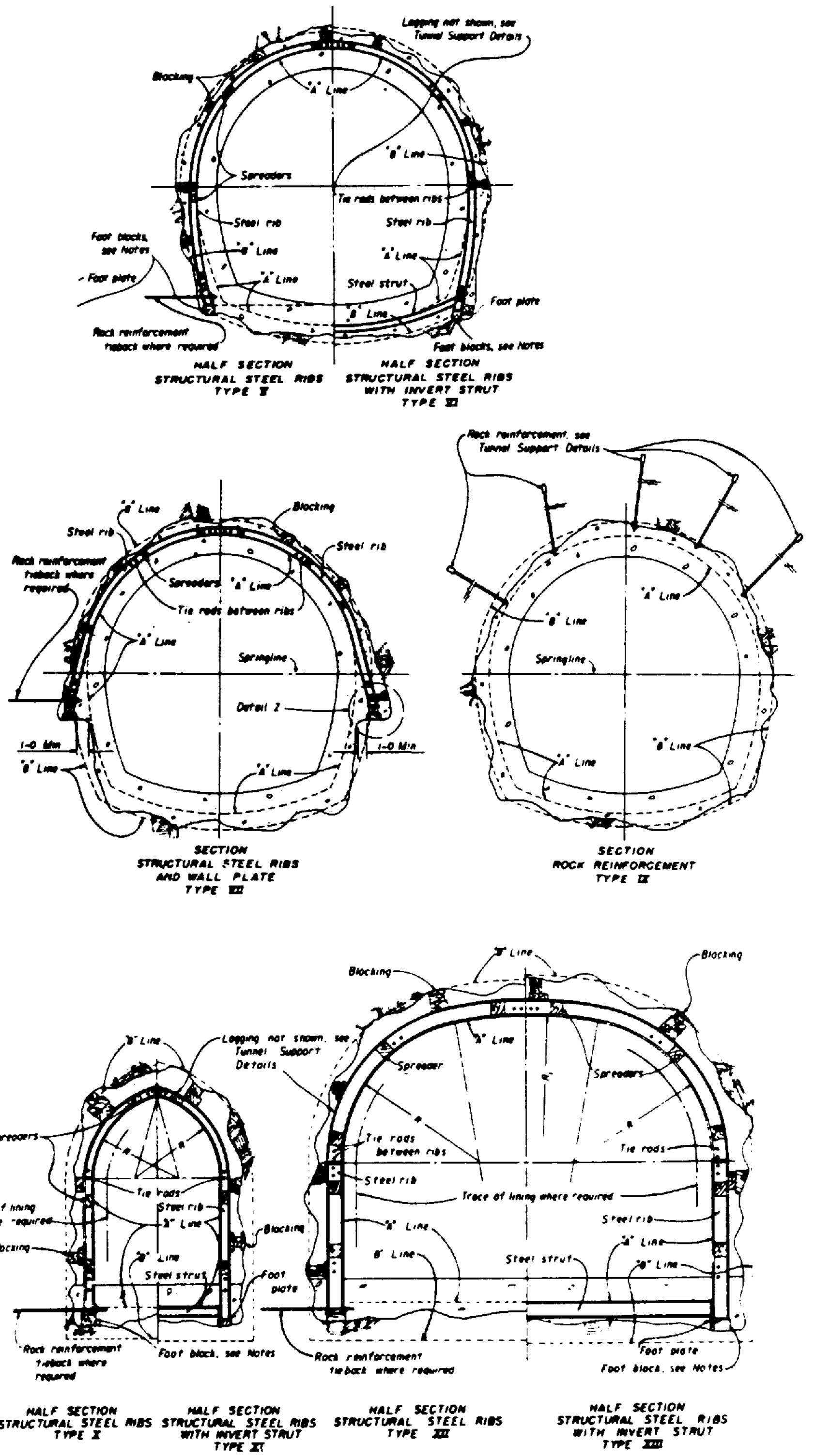
(m) *Flumes and drops*
Flumes are specially designed in-line open channel structures in which canal water flows along a broad, flat converging section through a narrow downward sloping throat section and then diverges on an upward sloping roof. A drop is to convey water from a higher to a lower elevation. Check drops are those without blocks. For drops where the drop elevation is greater than 4.5 m and where the water is conveyed for a long distance, drops are replaced by chutes.

Where gates are used on spillways, Sheet No. VIII.6.15 gives the structural details of a gate and reinforced concrete supporting structure.

Hydraulic structures cannot overlook culverts. Typical reinforcement details are given for a culvert on Sheet No. VIII.6.16.

OUTLET WORKS

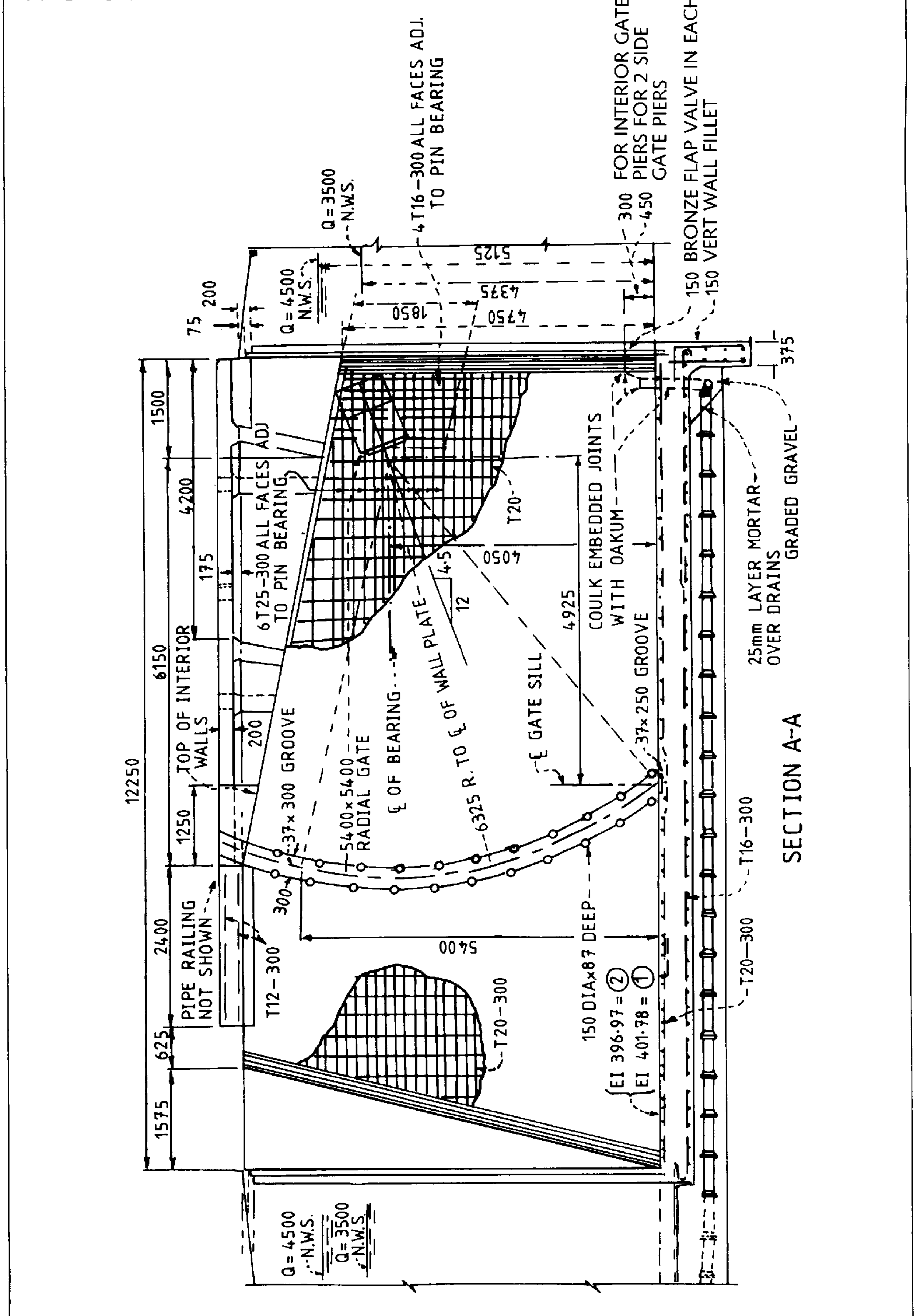
SHEET NO. VIII.6.14



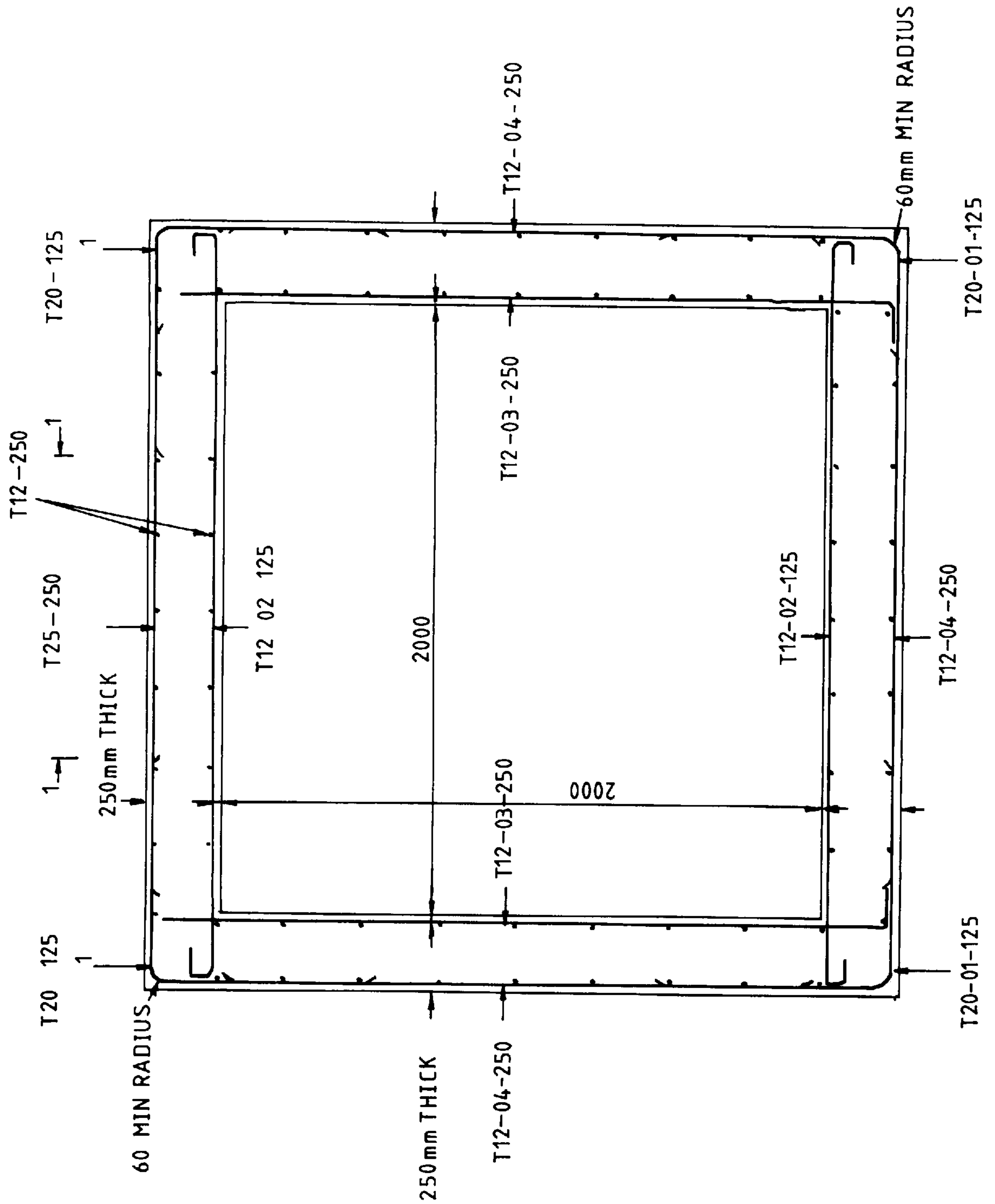
Typical tunnel support sections

SPILLWAY GATE AND R.C. SUPPORTING STRUCTURE

SHEET NO. VIII.6.15



CULVERT REINFORCEMENT SHEET NO. VIII.6.16



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Index

This book provides a comprehensive manual of details in reinforced, prestressed, precast and composite concrete, including:

- reinforced concrete beams and slabs
- stairs and staircases
- columns, frames and walls
- prestressed concrete details
- composite construction, precast concrete elements, joints and connections
- concrete foundations and earth retaining structures.

A further specialised section of case studies provides a range of integrated structures, including:

- bridges
- concrete shells
- water retaining structures
- silos
- nuclear shelter
- nuclear, oil and gas containments
- hydroelectric and irrigation/hydraulic structures.

This book will be invaluable for design offices who are increasingly concerned with producing structural details and for contractors responsible for preparing construction drawings. It will also be a useful reference for students of civil and mechanical engineering.

Dr M.Y.H. Bangash is a chartered civil and structural engineer and is in practice as a consulting engineer. He is the director of Ban and Del Educational Consultants Ltd. He has recently completed another reference book for Blackwell Scientific Publications, *Impact and Explosion*.

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