APPENDIX

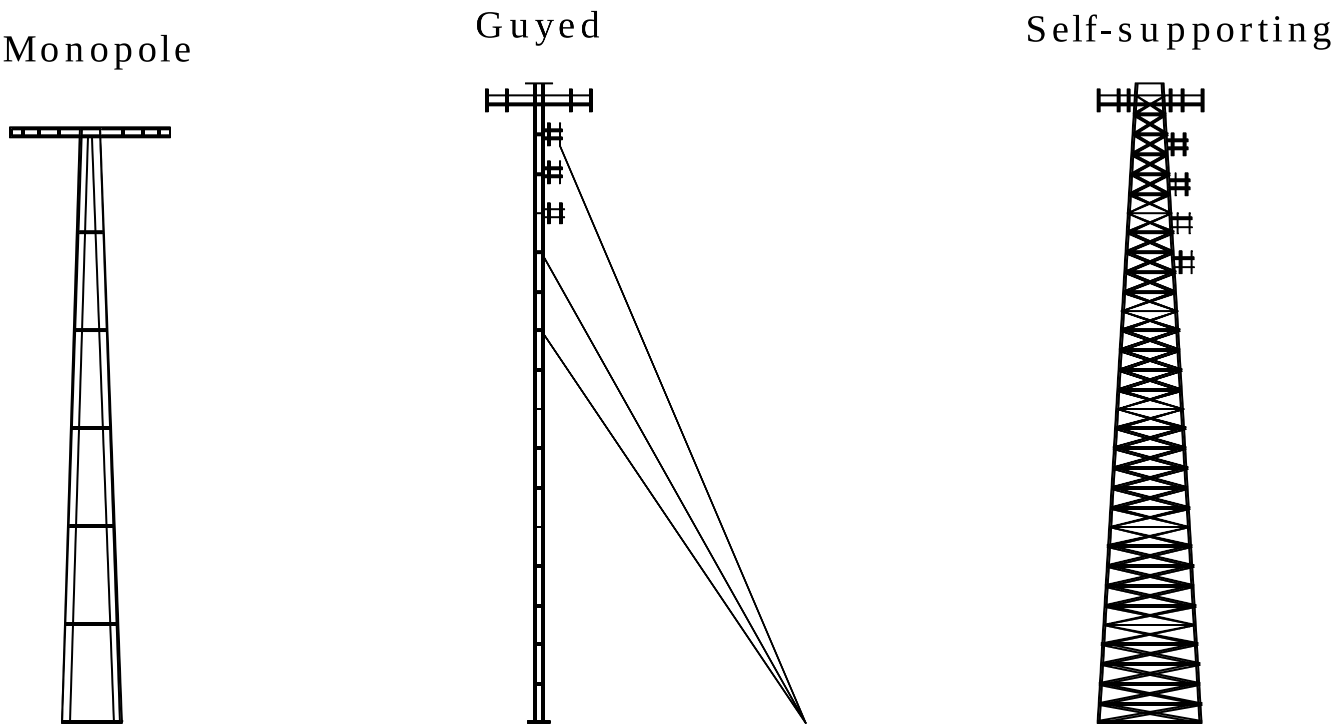


Figure 1 .1 Tower Types

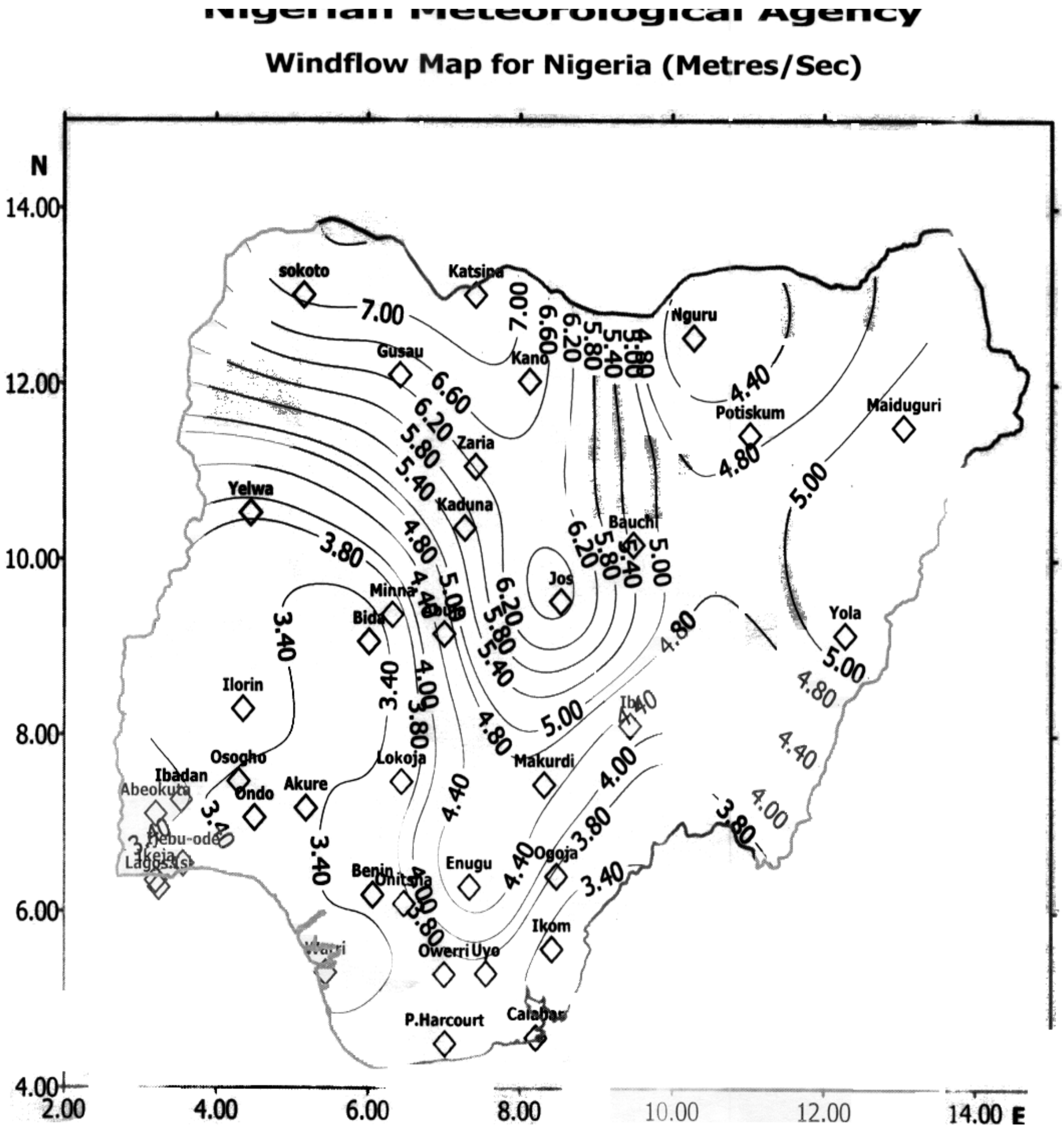


Figure 1.2

Notes on Figure 1.2

i. *map shows the average wind speeds*

ii. *Wind loading for a structure is to be considered over the full length of the structure and is to be measured in Newton's per square metre (N/m^2).*

iii. *The basic wind speeds depicted in this map are measured at 10 metres above the ground.*

iv. *These values increase with height and need to be so corrected when making computations.*

The wind speeds shown in figure 1.2 above were measured from the stations listed in Table 1.1. Engineers who desire greater accuracy in their wind speed calculations are encouraged to use figure 1.2 in conjunction with Table 1.1.

Table 1.1

S/N	STATION NAME	LAT.	LONG.	STATE	ELEV.
1	**YELWA**	10.53'N	04.45'E	KEBBI	244.0
2	**BIRNI KEBBI**	12.28'N	04.13'E	KEBBI	220.0
3	**SOKOTO**	13.01'N	05.15'E	SOKOTO	350.8
4	**GUSAU**	12.10'N	06.42'E	ZAMFARA	463.9
5	**KADUNA**	10.36'N	07.27'E	KADUNA	645.4
6	**KATSINA**	13.01'N	07.41'E	KATSINA	517.6
7	**ZARIA**	11.06'N	07.41'E	KADUNA	110.9
8	**KANO**	12.03'N	08.12'E	KANO	472.5
9	**BAUCHI**	10.17'N	09.49'E	BAUCHI	609.7
10	**NGURU**	12.53'N	10.28'E	YOBE	343.1
11	**POTISKUM**	11.42'N	11.02'E	BORNO	414.8
12	**MAIDUGURI**	11.51'N	13.05'E	BORNO	353.8
13	**ILORIN**	08.29'N	04.35'E	KWARA	307.4
14	**SHAKI**	08.40'N	03.23'E	OYO	
15	**BIDA**	09.06'N	06.01'E	NIGER	144.3
16	**MINNA**	09.37'N	06.32'E	NIGER	256.4
17	**ABUJA**	09.15'N	07.00'E	FCT	343.1
18	**JOS**	09.52'N	08.54'E	PLATEAU	1780.0
19	**IBI**	08.11'N	09.45'E	TARABA	110.7
20	**YOLA**	09.14'N	12.28'E	ADAMAWA	186.1
21	**ISEYIN**	07.58'N	03.36'E	OYO	330.0
22	**IKEJA**	06.35'N	03.20'E	LAGOS	39.4
23	**OSHODI MET.AGRO**	06.30'N	03.23'E	LAGOS	19.0
24	**LAGOS (HQ) ROOF**	06.27'N	03.24'E	LAGOS	14.0

25	LAGOS (MARINE)	06.26'N	03.25'E	LAGOS	2.0
26	**IBADAN**	07.26'N	03.54'E	OYO	227.2
27	**IJEBU-ODE**	06.50'N	03.56'E	OGUN	77.0
28	**ABEOKUTA**	07.10'N	03.20'E	OGUN	104.0
29	**OSHOGBO**	07.47'N	04.29'E	OSUN	302.0
30	**ONDO**	07.06'N	04.50'E	ONDO	287.3
31	**BENIN**	06.19'N	05.06'E	EDO	77.8
32	**AKURE**	07.17'N	05.18'E	ONDO	375.0
33	**WARRI**	05.31'N	05.44'E	DELTA	6.1
34	**LOKOJA**	07.47'N	06.44'E	KOGI	62.5
35	**ONITSHA**	06.09'N	06.47'E	ANAMBRA	67.0
36	**PORT-HARCOURT**	04.51'N	07.01'E	RIVERS	19.5
37	**OWERRI**	05.29'N	07.00'E	IMO	91.0
38	**ENUGU**	06.28'N	07.33'E	ENUGU	141.8
39	**UYO**	05.30'N	07.55'E	AKWA IBOM	38.0
40	**CALABAR**	04.58'N	08.21'E	CROSS RIVER	61.9
41	**MAKURDI**	07.44'N	08.32'E	BENUE	112.9
42	**IKOM**	05.58'N	08.42'E	CROSS RIVER	119.0
43	**OGOJA**	06.40'N	08.48'E	CROSS RIVER	117.0

Table 1.2 – Meteorological Stations in Nigeria

Table 1.2 – Meteorological Stations in Nigeria

The above data obtained from the National Meteorological Services indicate that the highest recorded wind speed over a period of 20 years is 7 ms^{-1}, which translates to a mere 420 mhr^{-1}. However, wind gusts of the order of 55 km hr^{-1} have been recorded infrequently. Since these data form our worst-case scenario, masts and towers in Nigeria shall be designed to withstand a minimum ground wind speed of 70 km hr^{-1}.

Structural types for self-supporting lattice

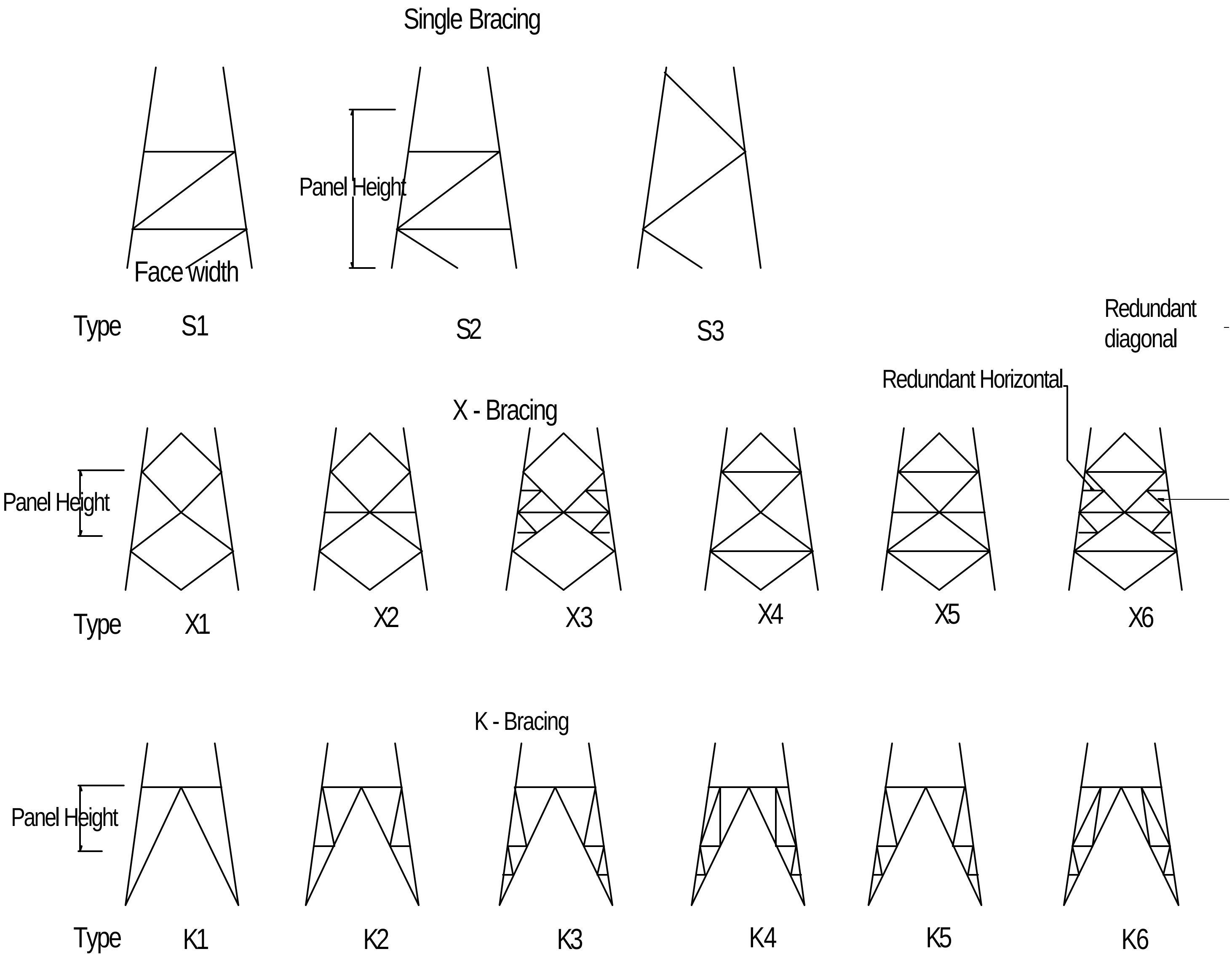
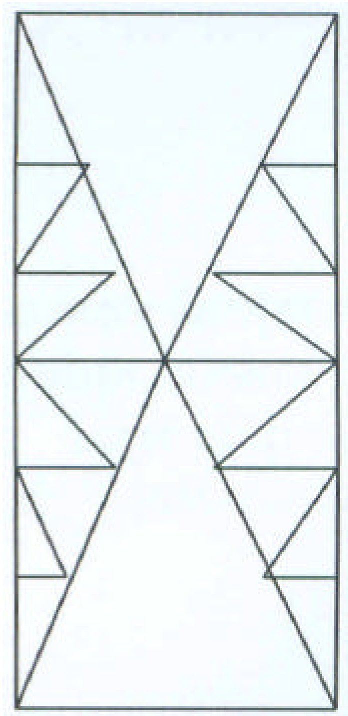


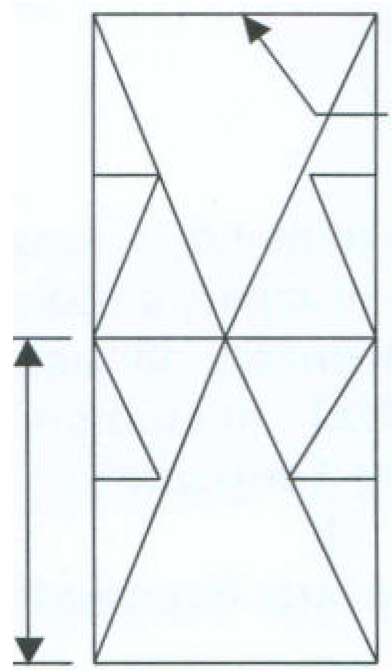
Figure 2.1 – Bracing Types

Members shall be made from solid rod, pipe or angles.

Engineer must specify wall thickness if design is of pipes and sizes and thickness of legs if of angles.

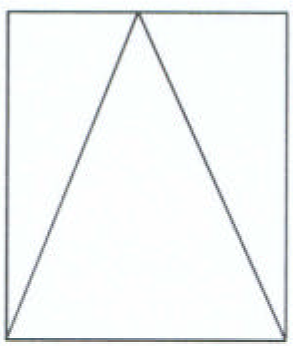


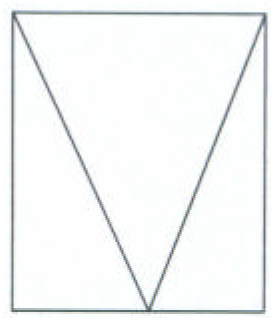
Diagonal Spacing



Double K 1 Down

Double K2 Down
Double K3, K3A, K4





K – Brace Down

K – Brace up

Figure 2.2

Members shall be made from solid rod, pipe or angles.
Engineer must specify wall thickness if design is of pipes and sizes and thickness of legs if of angles

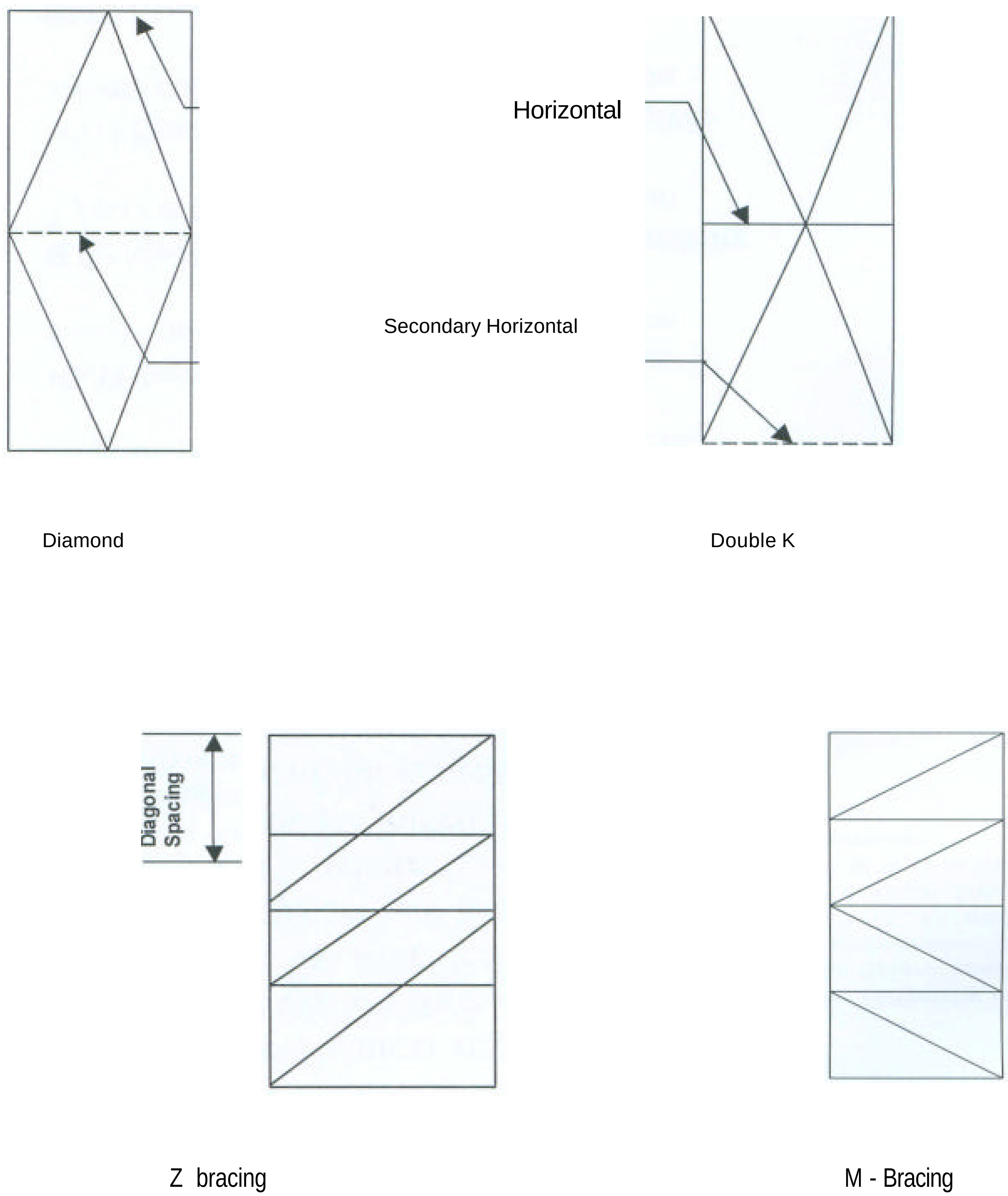
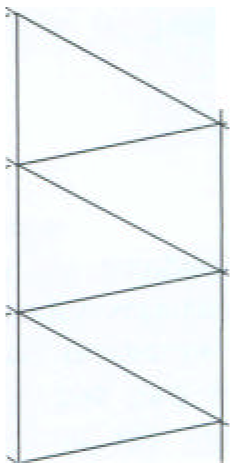


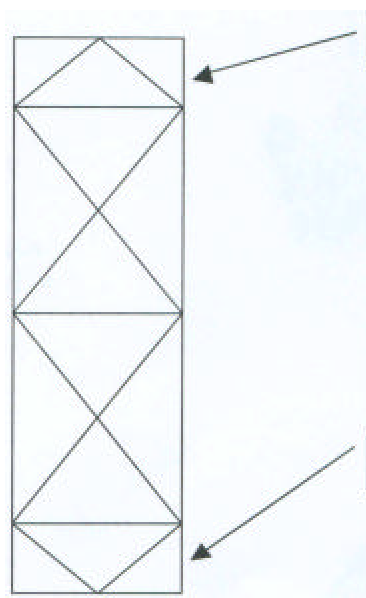
Figure 2.3

Members shall be made from solid rod, pipe or angles.
Engineer must specify wall thickness if design is of pipes and sizes and thickness of legs if

of angles.



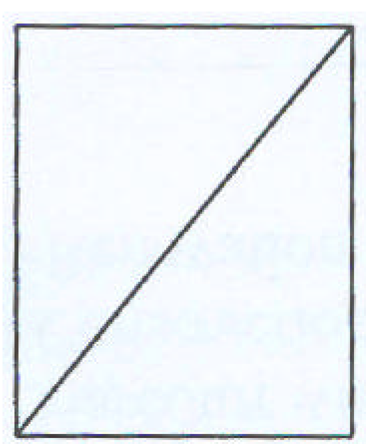
K-Brace End panel



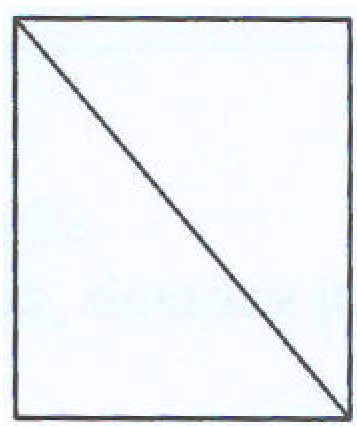
K-Brace End panel

Face A

Double Slope-Bracing



Diagonal Up Z-Brace



Diagonal Down Z-Brace

Figure 2.4

Members shall be made from solid rod, pipe or angles.
Engineer must specify wall thickness if design is of pipes and sizes and thickness of

legs if of angles.

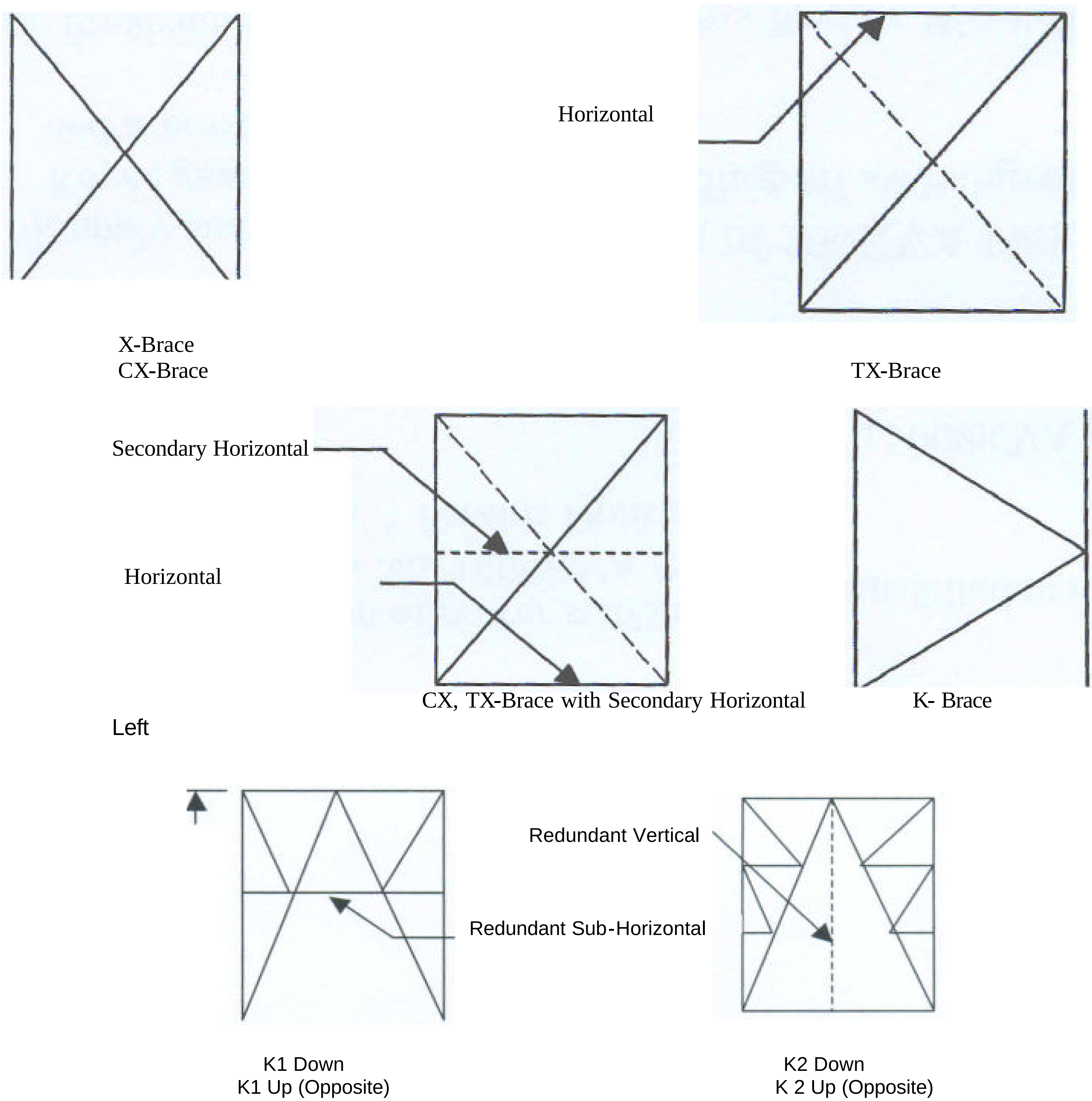
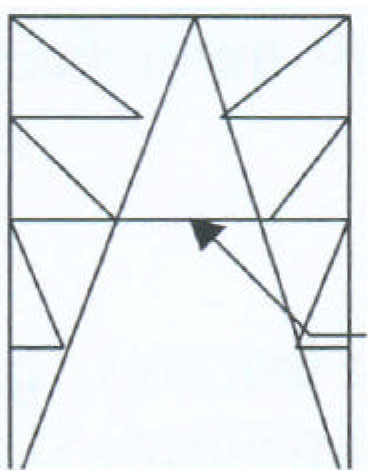
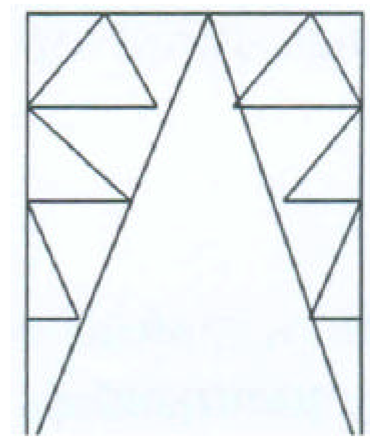


Figure 2.5

Members shall be made from solid rod, pipe or angles. Engineer must specify wall thickness if design is of pipes and sizes and thickness of legs it of angles.

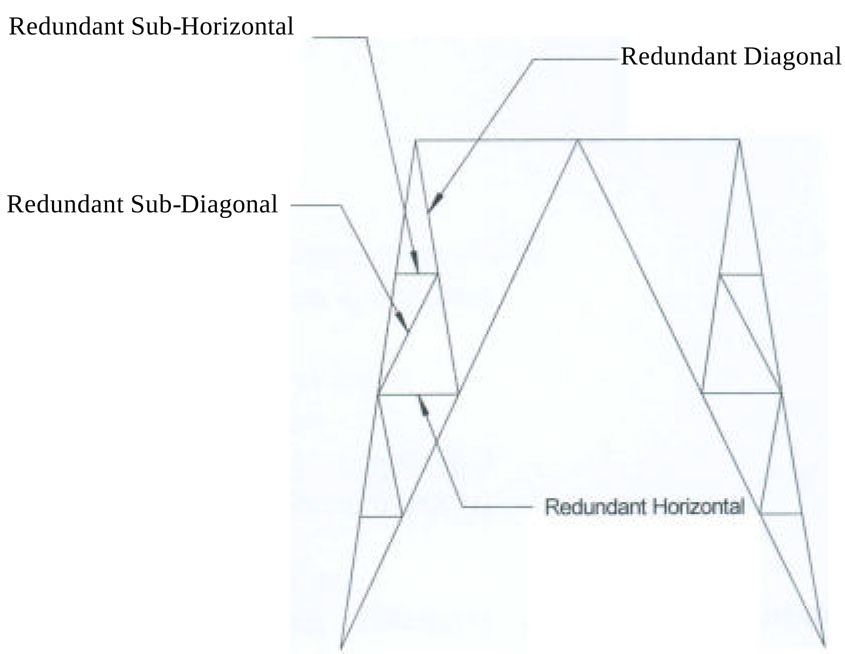


Redundant Sub Horizontal



K 3 Down
K 3 Up (opposite)

K 3A Down
K 4 Up (Opposite)



K 1B Down

Figure 2.6

Members shall be made from solid rod, pipe or angles.
Engineer must specify wall thickness if design is of pipes and sizes and thickness of legs if of angles.

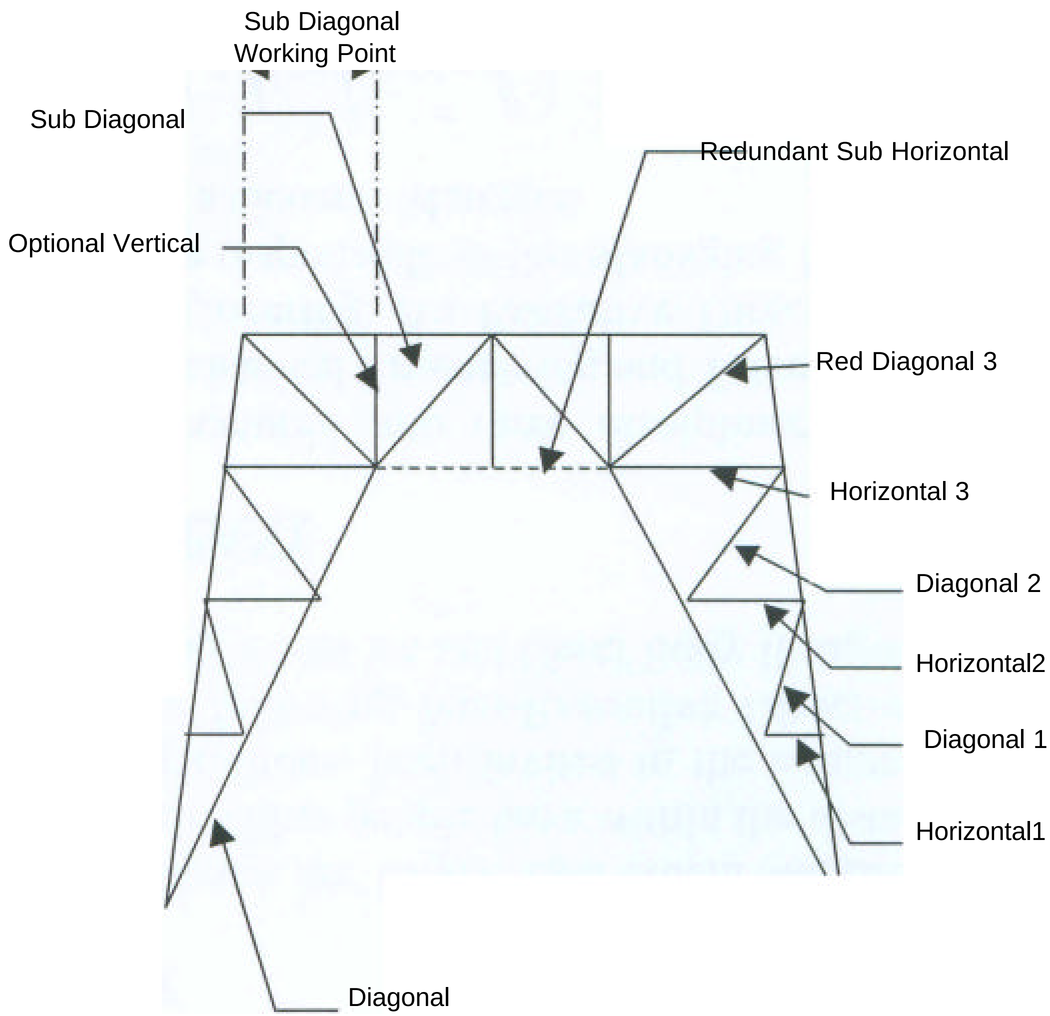


Figure 2.7

Members shall be made from solid rod, pipe or angles.
Engineer must specify wall thickness if design is of pipes and sizes and thickness of legs if of angles.

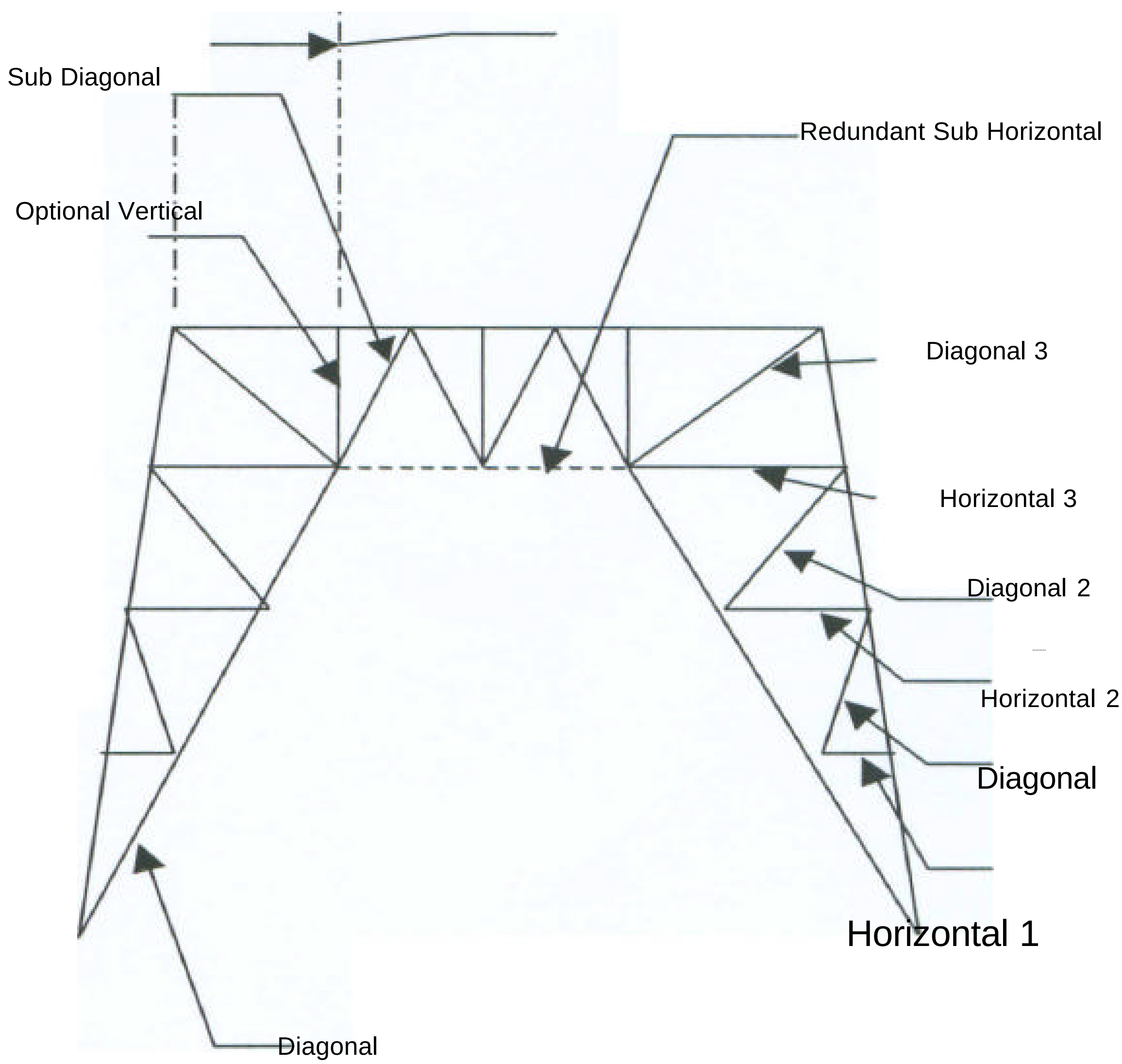


Figure 2.8 Portal Bracing

Members shall be made from solid rod, pipe or angles.

Engineer must specify wall thickness if design is of pipes and sizes and thickness of legs if of angles.

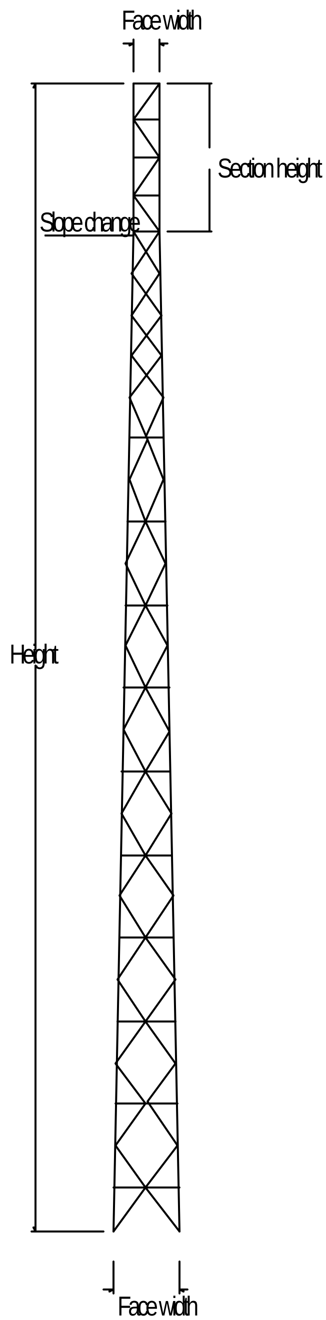
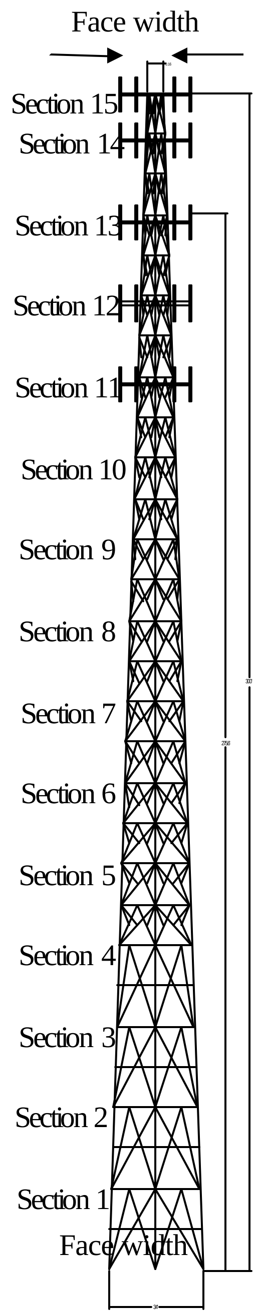


Figure. 2.9

X-braced, self-supporting, lattice design showing face width, slope change and tower height



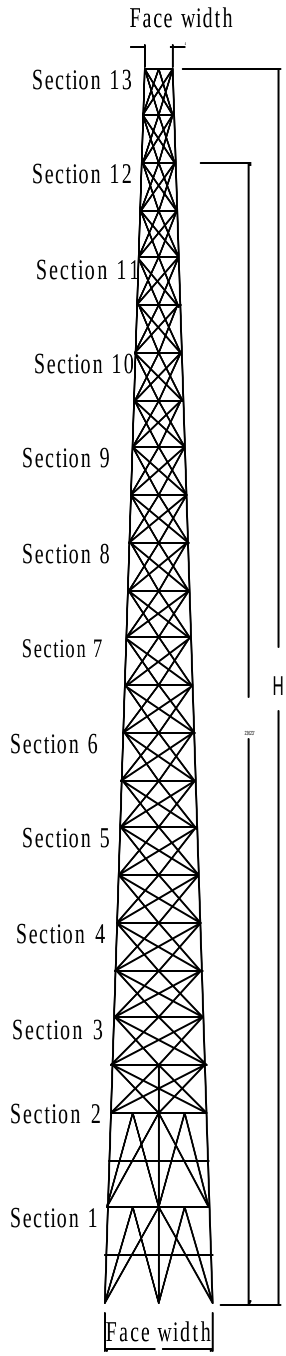
This represents a generalized design of a 15 section, 6m length per section tower.

Loading considerations to be taken into account in the specification of bracing sizes, bracing configuration (double or single), bracing bolt sizes, leg size and type, face widths at top and base, etc are: -

- Wind speed to include gust factor if applicable
- Total anticipated antenna load
- Maximum Shear per leg
- Maximum uplift reaction
- Maximum compression

Figure 2.10

Superstructure of a 15 section X - Braced Steel Tower, showing antenna mounts. Tower can be designed and fabricated as a three or four legged self-support structure. New sections that are intended to result in higher towers shall be added below section 1 with the design philosophy as to face widths being maintained.



Generalized prototype design of a 13 section, 6m lengths per section tower.

Loading considerations to be taken into account in the specification of bracing sizes, bracing configuration (double or single), bracing bolt sizes, leg size and type, face widths at top and base, etc are: -

- Wind speed to include gust factor if applicable
- Total anticipated antenna load
- Maximum Shear per leg
- Maximum uplift reaction
- Maximum compression

Figure 2.11
Superstructure of a 13 section X - Braced Steel Tower

Tower can be designed and fabricated as a three or four legged self-support structure. New sections that are intended to result in higher towers shall be added below section 1 and the design philosophy as to face widths maintained.

78 metre Tower

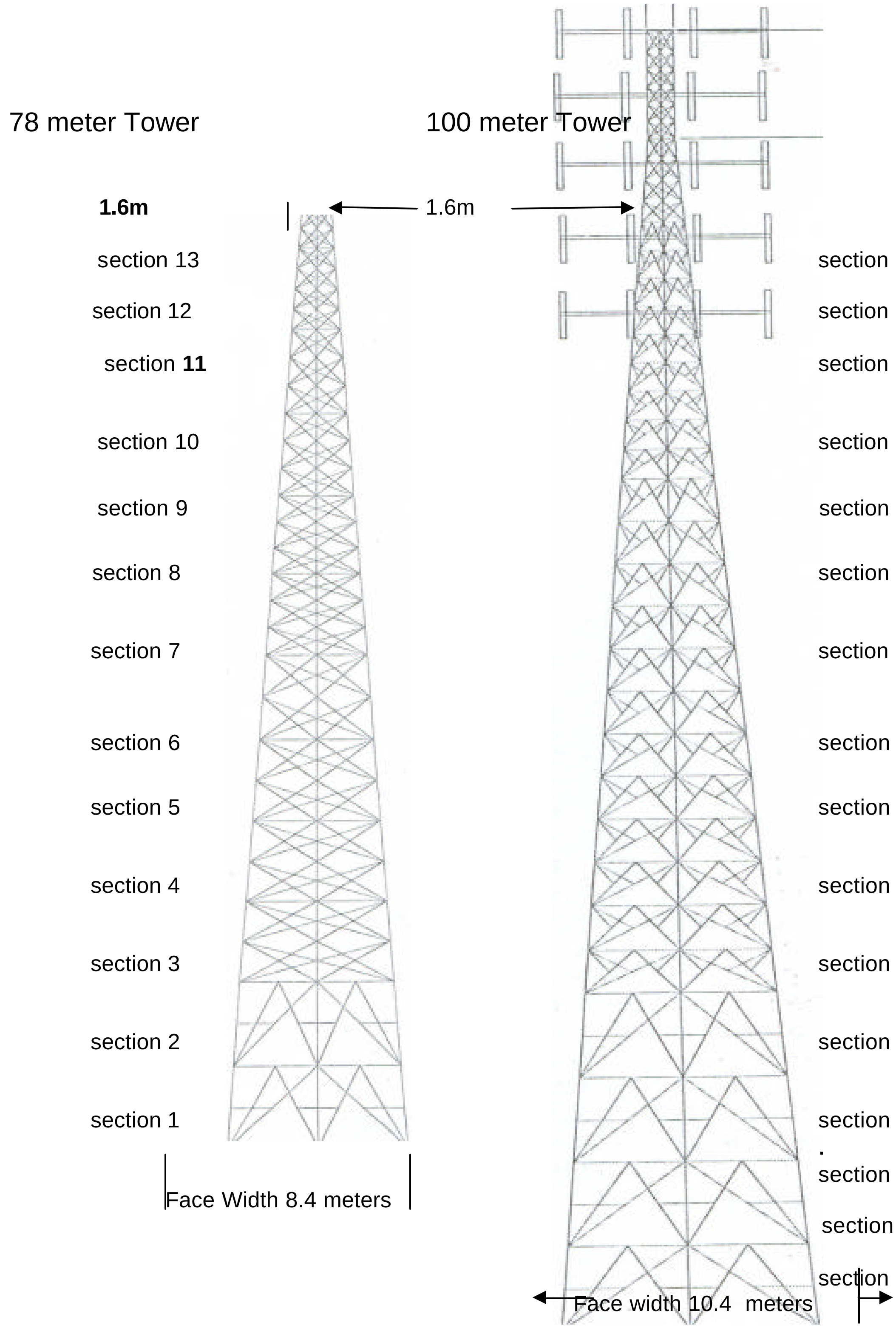


Figure 2.12 - Self Support Lattice Towers of different heights

Two towers of different heights illustrating the general relationships between lattice tower height, number of sections and the face widths at the top and bottom. Both towers are of identical design but have different heights

Structural Design of a 12-section self-support tower in single or Z bracing. Face width decreases from base to top of the tower

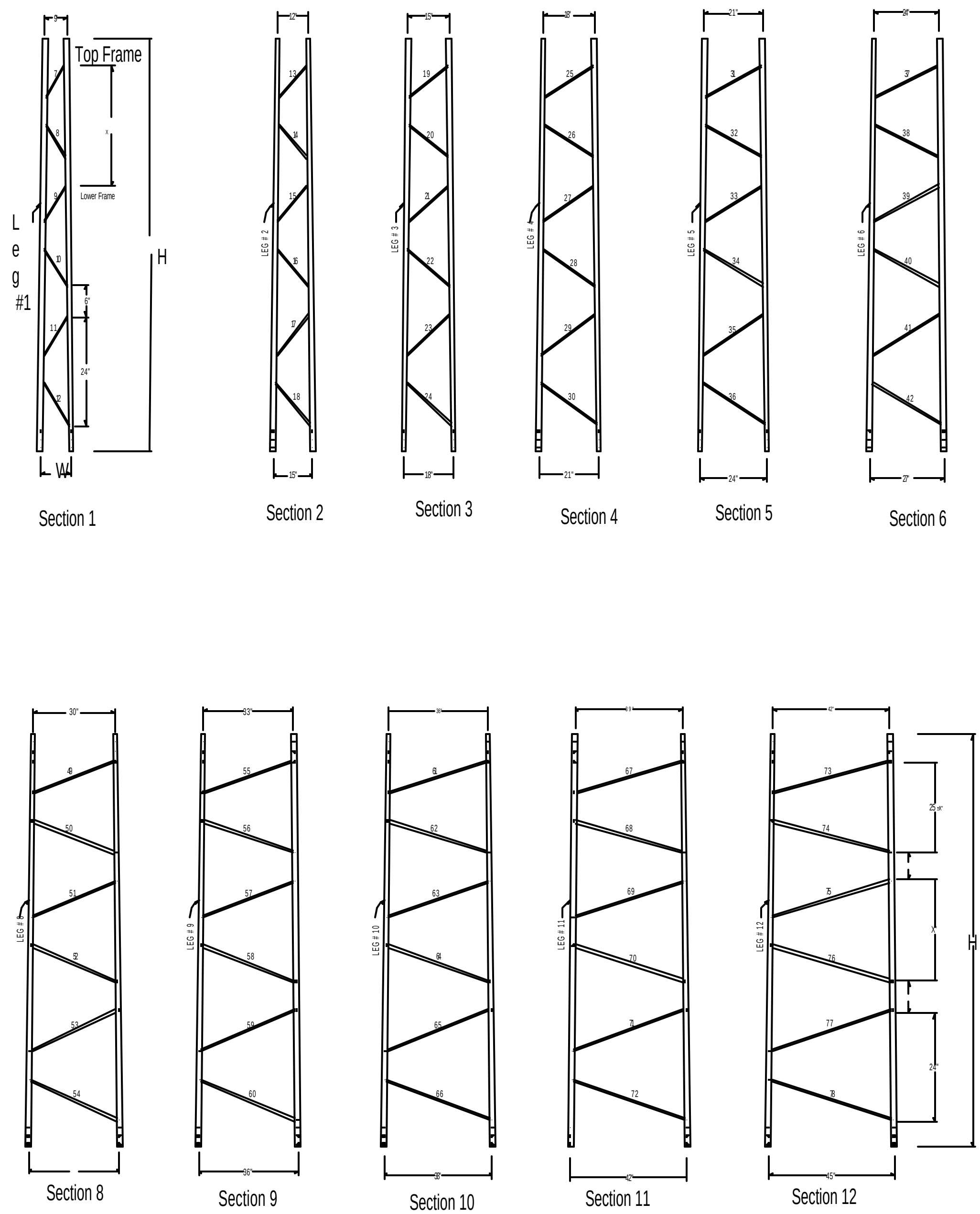


Figure 2.13

A 12-section, single braced, lattice tower. Each section is tapered to produce an overall tapered structure. Additional sections, if the tower has to be higher shall be of greater face width than section 12 until the tower reaches required height.

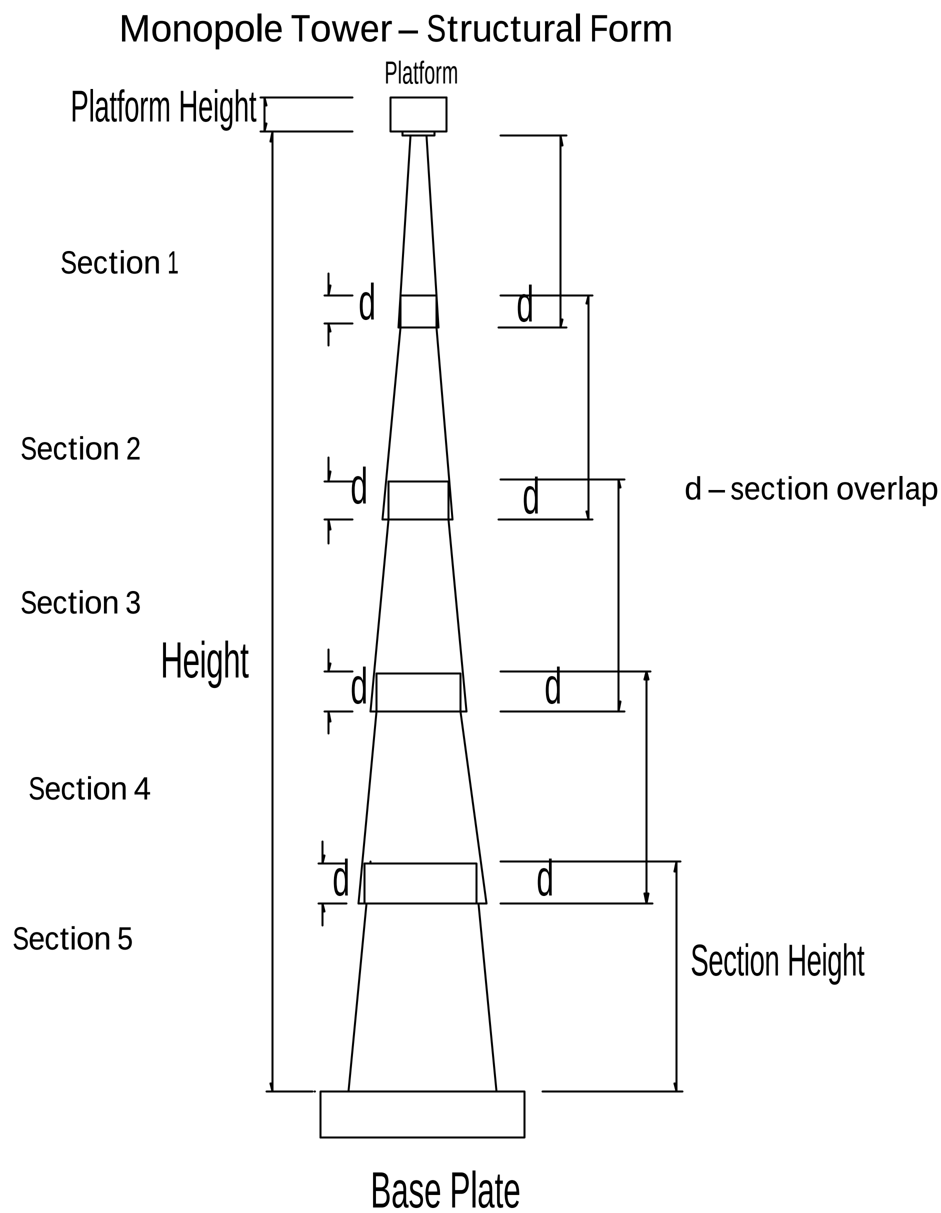


Figure 2.14

Sections fit into each other with an overlap (d). Base diameter, section height, depth of overlap between sections and total mast height are all structural stability issues determined by the structural design engineer. For higher towers, additional sections are added below section 5 until the required height is reached but there must be corresponding increases in base width as the number of sections and consequently the height increases.

TOWER SCHEDULE

Section Number	Spread Dimension		Tower Legs**	Tower Braces	Bolts
	Upper	Lower	36 KSI Yield STR	36 KSI YIELD STR	A 325 GRADE
1 (Top)	30 cm	30 cm	5.0 cm^2	2.5cm x 2.5cm x 0.32cm	8mm
2	30 cm	30 cm	5.0 cm^2	2.5cm x 2.5cm x 0.32cm	8mm
3	30 cm	50 cm	5.0 cm^2	2.5cm x 2.5cm x 0.32cm	8mm
4	50 cm	72 cm	5.0 cm^2	3.2cm x 3.2cm x 0.5cm	10mm
5	72 cm	94 cm	5.0 cm^2	3.2cm x 3.2cm x 0.5cm	10mm
6	94 cm	114 cm	5.0 cm^2	3.2cm x 3.2cm x 0.5cm	10mm
7	114 cm	135 cm	5.75 cm^2	3.2cm x 3.2cm x 0.5cm	10mm
8	135 cm	156 cm	5.75 cm^2	3.2cm x 3.2cm x 0.5cm	10mm
9	156 cm	176 cm	5.75 cm^2	3.2cm x 3.2cm x 0.5cm	10mm
10(Grnd)	176 cm	198 cm	5.75 cm^2	3.2cm x 3.2cm x 0.5cm	10mm

**Cross-sectional area

Design Data of a Ten Section Light Duty Self-Supporting Tower

Table 2.1

SECTION HEIGHTS AND WEIGHTS

Section Number	Height	Legs	Braces	Lap Links	Total
1	3.0 m	36 Kg	8.5 Kg	4.5 Kg	65 Kg
2	3.0 m	36 Kg	8.5 Kg	4.5 Kg	65 Kg
3	3.0 m	36 Kg	10 Kg	4.5 Kg	70 Kg
4	3.0 m	36 Kg	17.7 Kg	4.5 Kg	101 Kg
5	3.0 m	36 Kg	27.5 Kg	4.5 Kg	111 Kg
6	3.0 m	36 Kg	29 Kg	4.5 Kg	127 Kg
7	3.0 m	40 Kg	30 Kg	4.5 Kg	153 Kg
8	3.0 m	40 Kg	33 Kg	4.5 Kg	162 Kg
9	3.0 m	40 Kg	34 Kg	4.5 Kg	171 Kg
10	3.0 m	40 Kg	37 Kg	N/A	216 Kg

Table 2.2

SUPERSTRUCTURE DESIGN AND LOADING

HEIGHT ABOVE GROUND	WIND SPEED	ALLOWABLE DEAD WEIGHT PER SECTION	MAX COAX QTY/SIZE	MAX COAX 9m BELOW QTY/SIZE	WIND LOAD TOP (M^2)		WIND LOAD 9m BELOW TOP (M^2)	
	Km/ hr	Kg.			FLAT	ROUND	FLAT	ROUND
30 m	110	90	3 / 25mm	3 / 25mm	0.9	1.4	1.1	1.7
	125	90	3 / 25mm		0.46	0.7		
24 m	110	135	3 / 25mm	6 / 25m	1.67	2.51	1.86	2.79
	125	135	3 / 25mm	6 / 25mm	0.70	1.05	0.88	1.32
	145	135	3 / 25mm	?	0.74	1.11	?	?
18 m	110	180	6 / 25mm	6 / 25mm	2.14	3.21	2.32	3.48
	125	180	6 / 25mm	6 / 25mm	1.11	1.67	1.25	1.88
	145	180	3 / 25mm	6 / 25mm	0.64	0.95	0.85	1.13
12 m	110	360	12 / 25mm	?	4.83	7.25	?	?
	125	360	12 / 25mm	?	3.35	5.30	?	?
	145	360	9 / 25mm	?	2.69	4.04	?	?

Table 2.3

FOUNDATION DESIGN AND LOADING

HEIGHT ABOVE GROUND	WIND SPEED Km / hr	MAX VERTICAL (KIPS)	MAX UPLIFT (KIPS)	MAX SHEAR/LEG (KIPS)	TOTAL SHEAR (KIPS)	AXIAL (KIPS)
30 m	145	23.0	19.0	2.12	3.50	2.34
24 m	145	22.0	18.2	1.92	3.42	2.09
18 m	145	17.0	14.7	1.40	2.50	1.82
12 m	145	24.1	22.4	1.73	3.30	1.52

Table 2.4

Below 145 ms^{-1} wind speed; shear, vertical and uplift forces are negligible.
All foundation designs shall be in accordance with maximum reaction loads indicated above. Modification of loading locations and equipment can be made provided reaction loads do not exceed indicated values.

Design Data of a Fifteen Section Medium Duty Self-Supporting Tower

SELF-SUPPORTING TOWER SCHEDULE

Section Number	Spread Dimension		Tower Legs** 36 KSI Yield STR	Tower Braces 36 KSI YIELD STR	Bolts A 325 GRADE
	Upper	Lower			
1	46 cm	46 cm	5.0 cm^2	3.2cm x 3.2cm x 0.5cm	10 mm
2	46 cm	46 cm	5.0 cm^2	3.2cm x 3.2cm x 0.5cm	10 mm
3	46 cm	76 cm	5.0 cm^2	3.2cm x 3.2cm x 0.5cm	10 mm
4	76 cm	1.04 m	5.75 cm^2	3.8cm x 3.8cm x 0.5cm	10 mm
5	1.04 m	1.32 m	5.75 cm^2	3.8cm x 3.8cm x 0.5cm	10 mm
6	1.32 m	1.6 m	5.75 cm^2	3.8cm x 3.8cm x 0.5cm	10 mm
7	1.6 m	1.88 m	9.30 cm^2	4.4cm x 4.4cm x 0.5cm	12 mm
8	1.88 m	2.16 m	9.30 cm^2	4.4cm x 4.4cm x 0.5cm	12 mm
9	2.16 m	2.43 m	9.30 cm^2	4.4cm x 4.4cm x 0.5cm	12 mm
10	2.43 m	2.72 m	10.8 cm^2	5cm x 5cm x 0.5cm	12 mm
11	2.72 m	3.0 m	10.8 cm^2	5cm x 5cm x 0.5cm	12 mm
12	3.0 m	3.27 m	10.8 cm^2	5cm x 5cm x 0.5cm	12 mm
13	3.27 m	3.56 m	16 cm^2	6.4cm x 6.4cm x 0.5cm	16 mm
14	3.56 m	3.84 m	16 cm^2	6.4cm x 6.4cm x 0.5cm	16 mm
15	3.84 m	4.11 m	16 cm^2	6.4cm x 6.4cm x 0.5cm	16 mm

Table 2.5

SECTION HEIGHTS AND WEIGHTS

Section Number	Height	Legs	Braces	Brace Plates	Total
1	3.0 m	36 Kg	25 Kg	N/A	65 Kg
2	3.0 m	36 Kg	25 Kg	N/A	65 Kg
3	3.0 m	36 Kg	29 Kg	N/A	70 Kg
4	3.0 m	40 Kg	57 Kg	N/A	102 Kg
5	3.0 m	40 Kg	67 Kg	N/A	112 Kg
6	3.0 m	40 Kg	78 Kg	N/A	127 Kg
7	3.0 m	65 Kg	79 Kg	N/A	153 Kg
8	3.0 m	65 Kg	88 Kg	N/A	162 Kg
9	3.0 m	65 Kg	98 kg	N/A	171 Kg
10	3.0 m	76 Kg	123 Kg	8.0 Kg	216 Kg
11	3.0 m	76 Kg	134 Kg	8.0 Kg	227 Kg
12	3.0 m	76 Kg	145 Kg	8.0 Kg	246 Kg
13	3.0 m	111 Kg	148 Kg	12.7 Kg	288 Kg
14	3.0 m	111 Kg	156 Kg	12.7 Kg	296 Kg
15	3.0 m	111 Kg	166 Kg	12.7 Kg	306 Kg

Table 2.6

SUPERSTRUCTURE DESIGN AND LOADING								
HEIGHT	WIND SPEED	ALLOWABLE DEAD WEIGHT PER LEVEL	MAX COAX QTY/SIZE	MAX COAX 9m BELOW QTY/SIZE	WIND LOAD TOP (SQ. M)		WIND LOAD 9m BELOW TOP (SQ. M)	
	KPH	KGS.			FLAT	ROUND	FLAT	ROUND
45 m	110	135	3 / 22 mm	3 / 22 mm	2.09	3.14	3.07	4.60
	125	135	3 / 22 mm	3 / 22 mm	1.40	2.09	2.42	3.62
	145	135	3 / 22 mm	3 / 22 mm	0.37	0.56	0.56	0.84
39 m	110	205	3 / 22 mm	3 / 22 mm	2.14	3.21	3.16	4.74
	125	205	3 / 22 mm	3 / 22 mm	1.58	2.37	2.60	3.90
	145	205	3 / 22 mm	3 / 22 mm	1.02	1.53	1.30	1.95
33 m	110	270	6 / 22 mm	6 / 22 mm	2.23	3.34	4.09	6.13
	125	270	6 / 22 mm	6 / 22 mm	1.58	2.37	3.25	4.88
	145	270	6 / 22 mm	6 / 22 mm	1.20	1.81	2.32	3.48
27 m	110	360	6 / 22 mm	6 / 22 mm	2.23	3.34	4.09	6.13
	125	360	6 / 22 mm	6 / 22 mm	1.53	2.30	3.25	4.88
	145	360	6 / 22 mm	6 / 22 mm	1.02	1.53	2.32	3.48
	110	400	9 / 22 mm	?	2.14	3.21	?	?
21 m	125	400	9 / 22 mm	?	1.95	2.93	?	?
	145	400	9 / 22 mm	?	1.72	2.58	?	?
	110	400	9 / 22 mm	?	2.14	3.21	?	?
15 m	125	400	9 / 22 mm	?	1.49	2.23	?	?
	145	400	9 / 22 mm	?	1.11	1.62	?	?

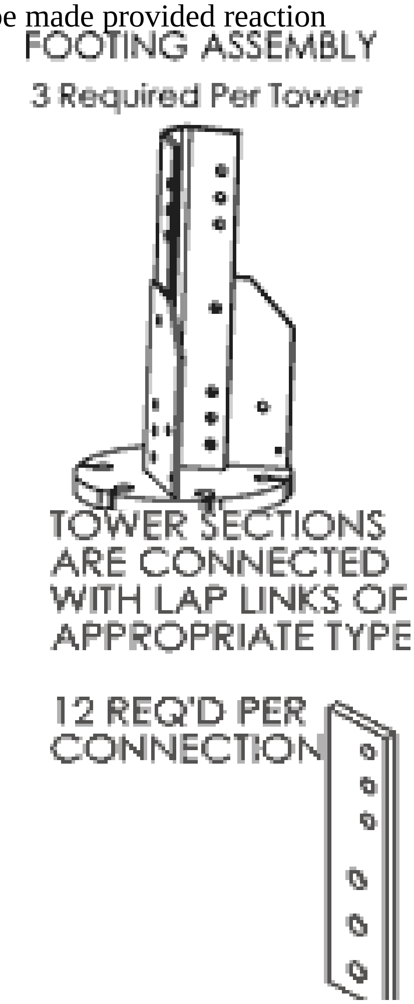
Table 2.7

TOWER FOUNDATION DESIGN & LOADING

TOWER HEIGHT	WIND SPEED	MAX VERTICAL	MAX UPLIFT	MAX SHEAR/LEG	TOTAL SHEAR	AXIAL
	KPH	(KIPS)	(KIPS)	(KIPS)	(KIPS)	(KIPS)
45 m	145	63.13	48.14	6.9	13.54	7.5
40 m	145	51	40	5.1	10	5.39
35 m	145	40	33	4.45	7	4.27
30 m	145	29.21	24.21	2.92	4.68	3.97
25 m	145	17.29	14.02	1.79	2.65	2.53
20 m	145	15.94	12.9	1.73	2.6	2.14

Table 2.8

Below 145 ms^{-1} wind speed; shear, vertical and uplift forces are negligible.
All foundation designs shall be in accordance with maximum reaction loads indicated above. Modification of loading locations and equipment can be made provided reaction loads do not exceed indicated values.



Footing Assembly Weight Table

Weight (Kg/m)	Weight x 12 (Kg/m)
43	17.16
1.43	17.16
1.43	17.16
2.23	26.76
2.40	28.8
2.40	28.8
1.61	19.32
3.06	36.72
3.02	36.24

Table 2.9

Lap Link Weight Table

Weight (Kg/m)	Weight x 3 (Kg/m)
55.63	166.89
58.01	174.03
62.63	187.89
65.55	196.65

Table 2.10

STRUCTURAL DESIGN DATA FOR A TYPICAL LATTICE TOWER

80 metre Tower (Pipe) Configuration				
Section	Height	Leg Size (cm)	Brace	
	m	Grade A500 steel	Configuration	Size (mm)
1	6	20 Schedule 80	Double Angle A	90 x 80
2	12	20 Schedule 80	Double Angle A	90 x 80
3	18	20 Schedule 80	Single 2x	100 x 100 x 4
4	24	20 Schedule 80	Single 2x	100 x 100 x 4
5	30	15 Schedule 80	Single 2x	100 x 100 x 4
6	36	15 Schedule 80	Single 2x	100 x 100 x 4
7	42	13 Schedule 80	Single 3x	75 x 75 x 1.5
8	48	13 Schedule 80	Single 3x	75 x 75 x 1.5
9	54	13 Schedule 80	Single 3x	60 x 60 x 6
10	60	8 Schedule 80	Single 3x	60 x 60 x 6
11	66	8 Schedule 80	Single 4x	60 x 60 x 6
12	72	6.5 Schedule 80	Single 4x	50 x 50 x 5
13	80	6.5 Schedule 80	Single 3x	50 x 50 x 5

Table 2.11

All brace connections shall be bolted and provided with locking pal nuts. Sections are in typical 6-metre lengths Leg strength minimum 46 KSI yield.
Max Share/Leg: 40.11 KIPS
Max Uplift: 288.26 KIPS
Max Compression: 345.76 KIPS
Design Wind Speed is 120 Km hr^{-1}

STRUCTURAL DESIGN DATA FOR A TYPICAL LATTICE TOWER

100 metre Configuration Lattice Tower						
Section	Height (m)	Leg Thickness (cm) 50 KSI	Brace		Redundant	
			Bolt Size	Diag. Config.	Size (mm)	Size (cm)
1	6	16	(2) 20mm	Double A	90 x 75 x 6	6 x 6 x 60
2	12	16	(2) 20mm	Double A	90 x 75 x 6	6 x 6 x 60
3	18	16	(2) 20mm	Double A	90 x 75 x 6	6 x 6 x 60
4	24	16	(2) 20mm	Double A	90 x 75 x 6	6 x 6 x 60
5	30	13	22mm	Single 2A	10 x 10 x 6	6 x 6 x 60
6	36	13	22mm	Single 2A	10 x 10 x 6	6 x 6 x 60
7	42	13	22mm	Single 2A	10 x 10 x 6	6 x 6 x 60
8	48	13	22mm	Single 2A	75 x 75 x 8	6 x 6 x 60
9	54	10	22mm	Single 2A	75 x 75 x 8	6 x 6 x 60
10	60	10	20mm	Single 2A	75 x 75 x 8	6 x 6 x 60
11	66	9	20mm	Single 3A	75 x 75 x 8	6 x 6 x 60
12	72	7.5	20mm	Single 3A	60 x 60 x 600	6 x 6 x 60
13	78	7.5	20mm	Single 3A	60 x 60 x 600	6 x 6 x 60
14	84	5	16mm	Single 4X	50 x 50 x 6	-
15	90	5	16mm	Single 5X	25 SOLID	-
16	96	5	16mm	Single 1X	25 SOLID	-
BRACE						
					Internal Triangle	
1	6				75 x 75 x 6	
2	12				75 x 75 x 6	
3	18				75 x 75 x 6	
4	24				75 x 75 x 6	

Table 2.12

- *Sections are in typical 6 metre lengths*
- *All brace connections shall be bolted and provided with locking pal nuts.*
- *All X-Braces shall be center bolted.*
- *Structure is designed for a maximum wind speed of 160 Km hr^{-1}*
- *Total structure design weight (unloaded) is 38,000 Kgs*
- *Maximum design shear / Leg is 80 KIPS*
- *Total shear at the Base is 155 KIPS*
- *Maximum design uplift is 627 KIPS*
- *Maximum design Compression is 733 KIPS*

Design details of a four section, 45 metre Monopole (Typical)

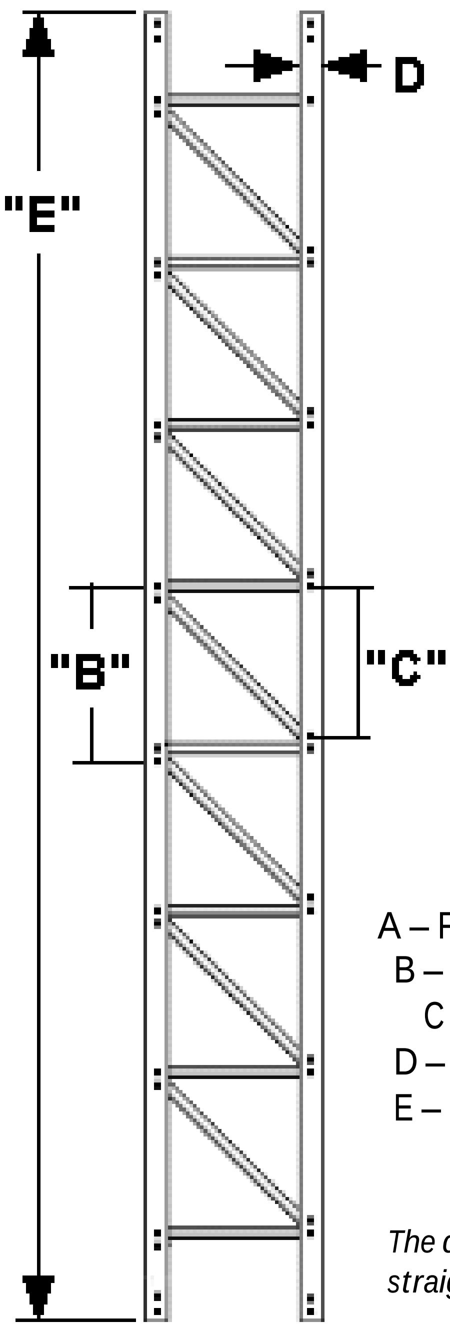
Section	4	3	2	1
Length (m)	13.7	12	12	11.2
Number of Sides	18	18	18	18
Thickness (mm)	10	8	6.5	5.5
Lap splice / section overlap (m)		1.7	1.45	1.14
Top Dia (cm)	106	80	75	56
Bottom Dia (cm)	130	110	93	75
Grade of Steel	A572-65			
Weight (Kg)	8.4	5.3	3.5	2.3
Material Strength	80 ksi	80 ksi	65 ksi	65 ksi

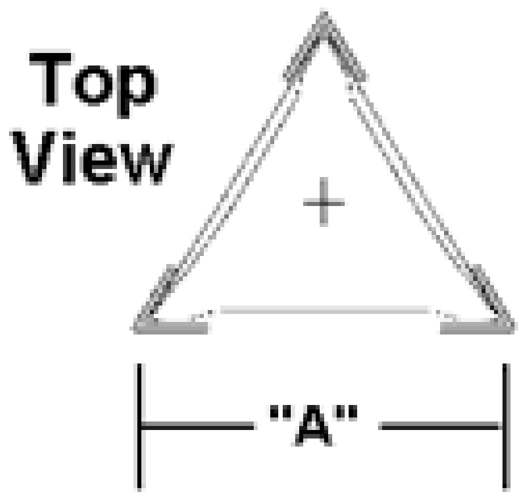
Table 2.13

Tower above is designed for a 100 Km hr^{-1} basic wind

Section of a Typical Guyed three-legged Mast

(Single or Z bracing)





A – Face Width (uniform throughout the mast
B – Vertical brace height
C – Bolt spacing
D – Steel member width
E – Section height

The design of a guyed mast must be such that it is very straight, easily connected and erector-friendly

Figure 2.16

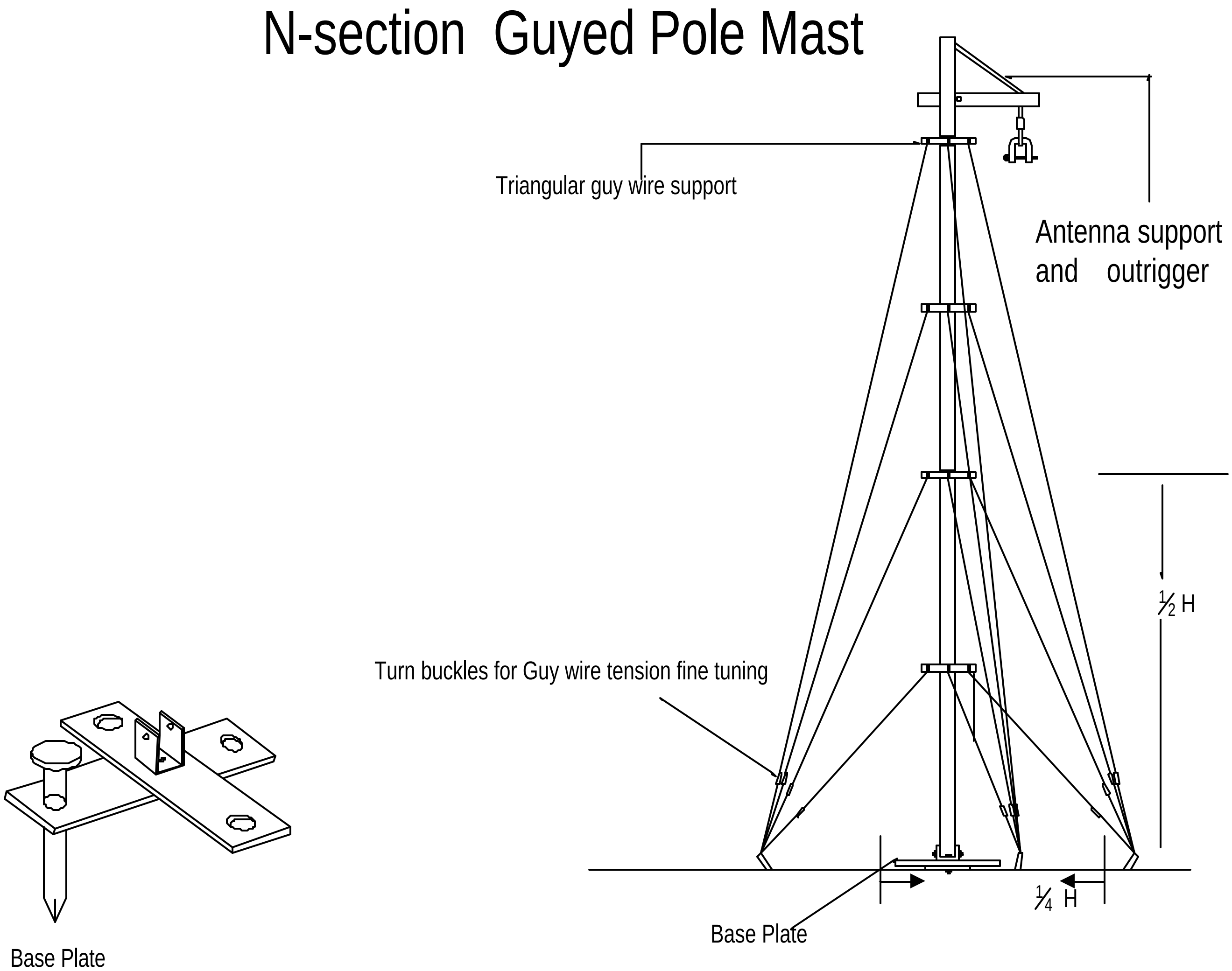


Figure 2.17

A four section guyed monopole illustrating the relationship between tower height (H) and the horizontal distance from tower base to the guy anchor
(1/4 H). Tower can be installed in many sections.
This design of masts is ideal for the installation of HF-SSB dipole antennas.

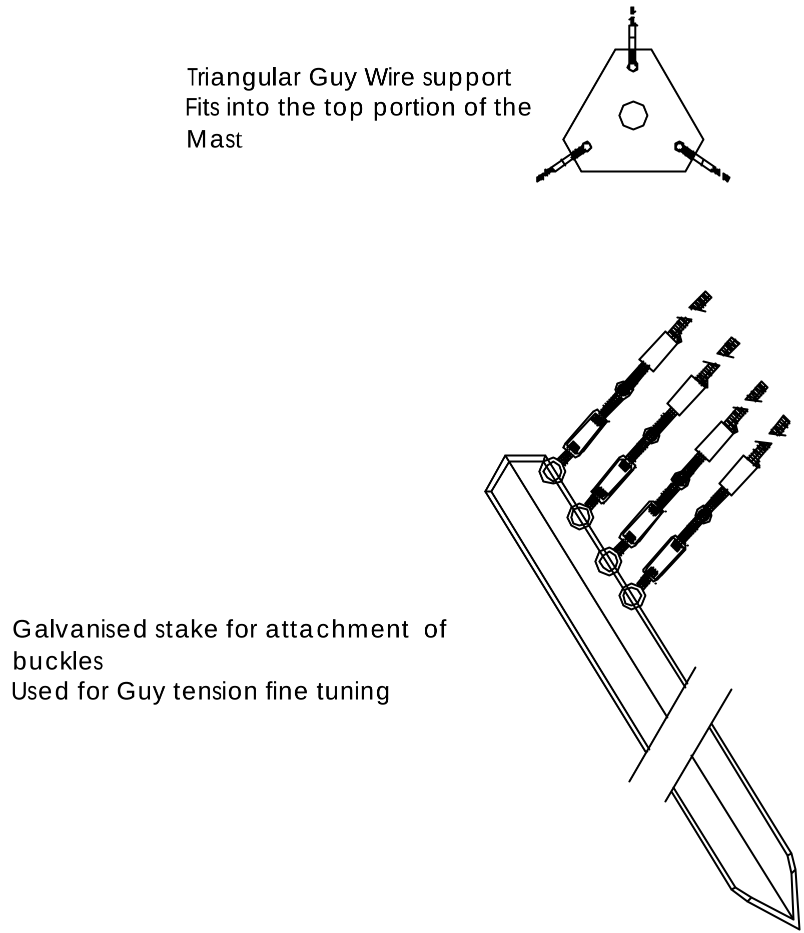
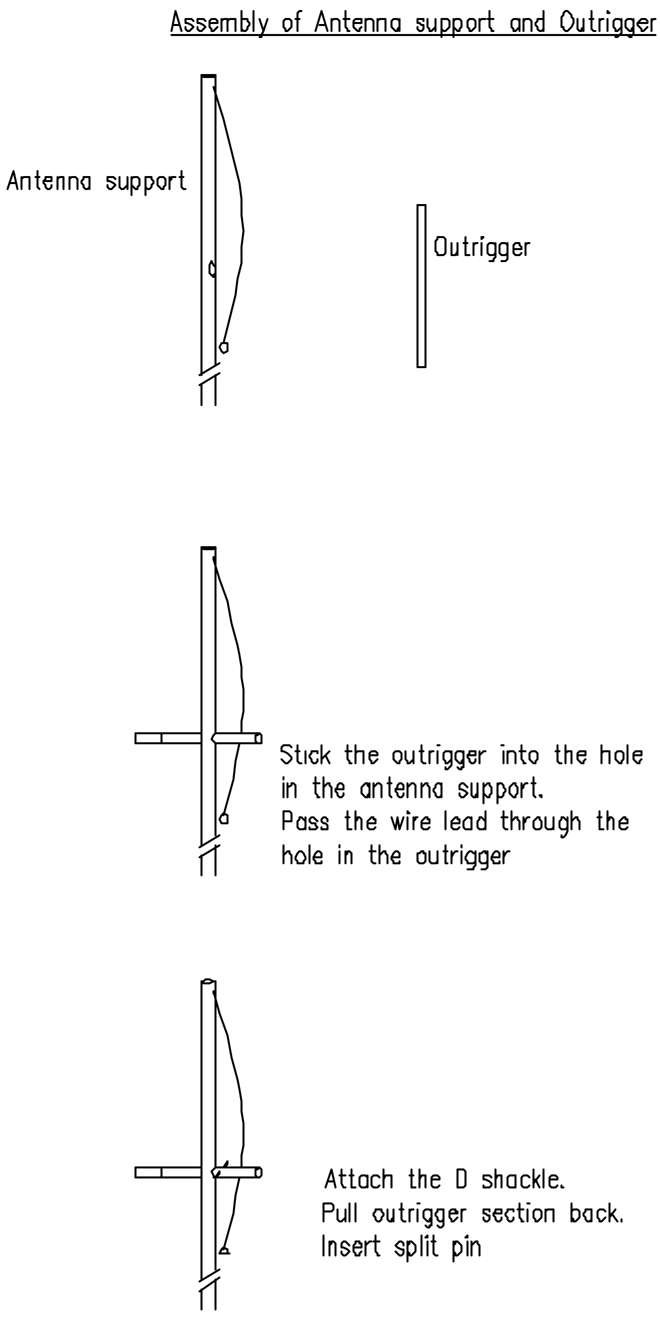


Figure 2.18

Details of parts of the guyed pole mast in figure 2.17 above



Assembly of Antenna support and Outrigger
Antenna support
Outrigger
Stick the outrigger into the hole
in the antenna support.
Pass the wire lead through the
hole in the outrigger
Attach the D shackle.
Pull outrigger section back.
Insert split pin

Figure 2.19

Shows in detail, the antenna support outrigger shown in figure 2.17 above.

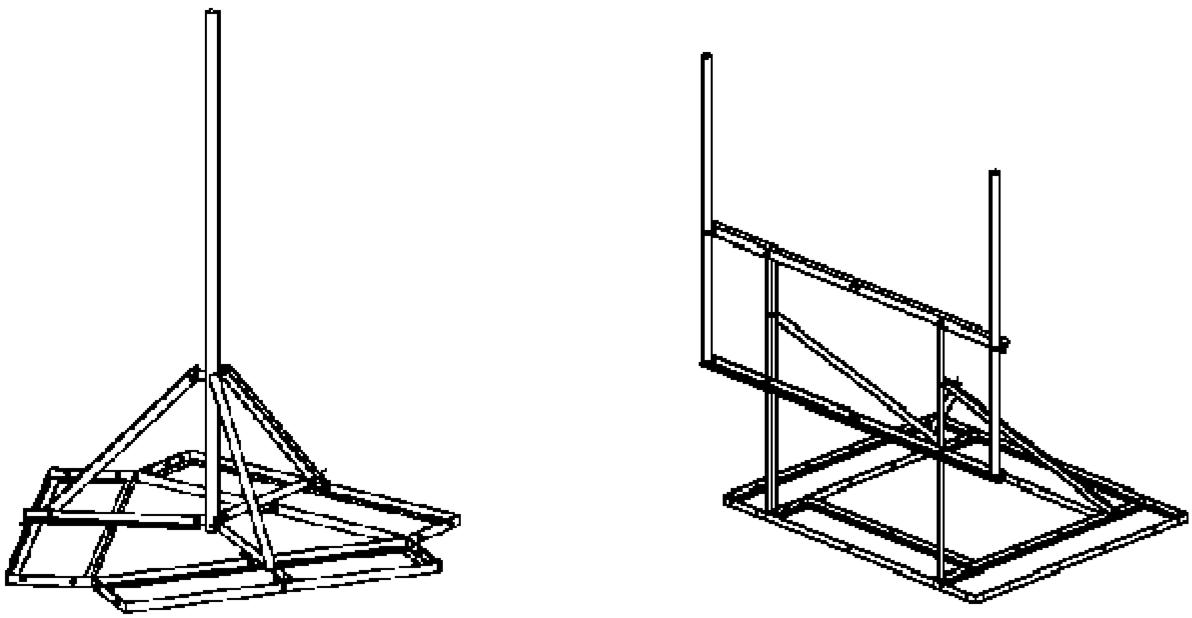


Figure 2.20

Examples of Non-Penetrating Roof Mounts
These can be implemented where possible with mass or reinforced concrete bases.

NAMA / ICAO Lighting Regulation

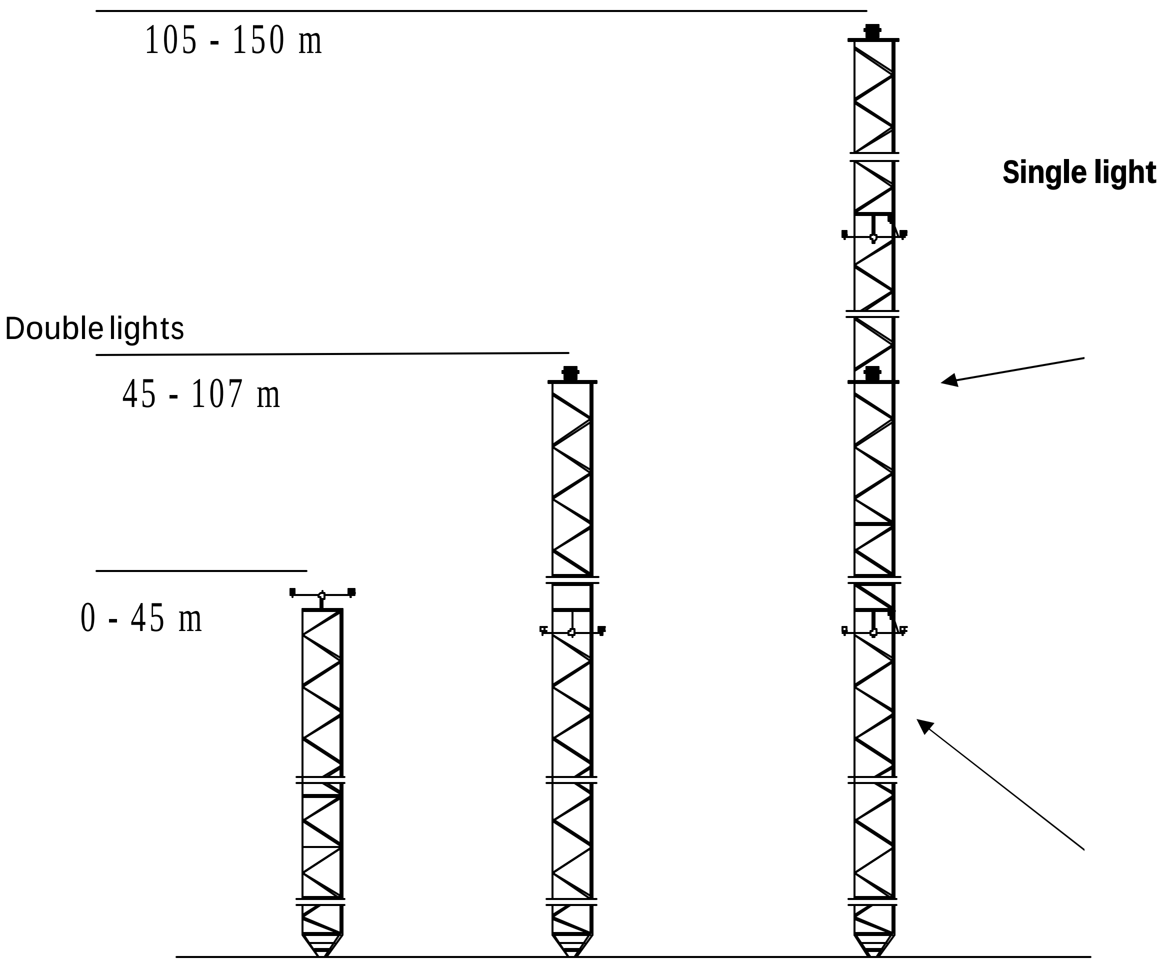
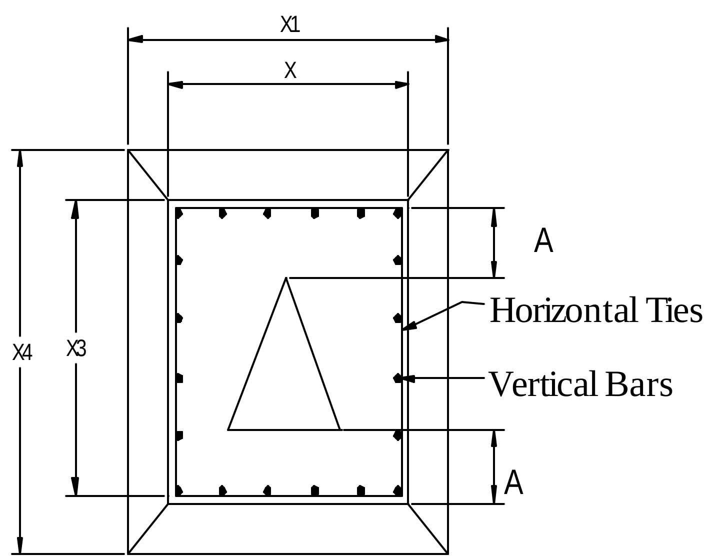


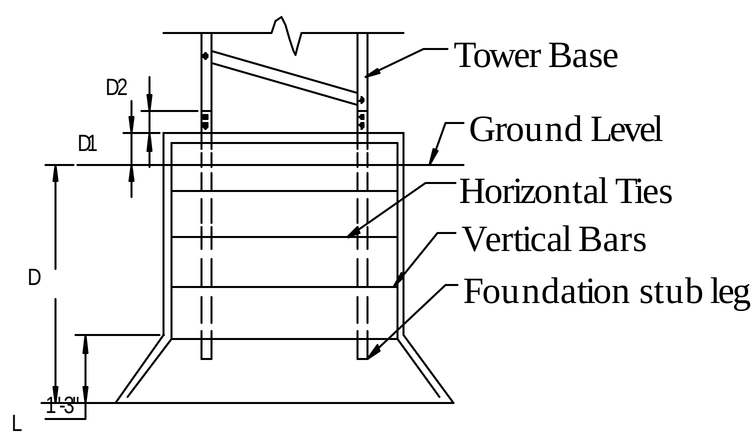
Figure 2.21

Schematic representation of the ICAO / NAMA obstruction lighting regulations.

SECTION VIEWS – SHOWING SUBSTRUCTURE ARRANGEMENT
(Raft Foundation)



FOUNDATION PLAN



SECTION THROUGH FOUNDATION

Figure 2.22

This foundation type can be used for all types of towers. It is applied for individual legs for a three or four-legged structure. Type of soil and the overall dynamic loading determine the dimensions. These shall be determined for each particular site by the geo-technical engineer.

BASIC RAFT FOUNDATION DESIGN FOR TOWERS

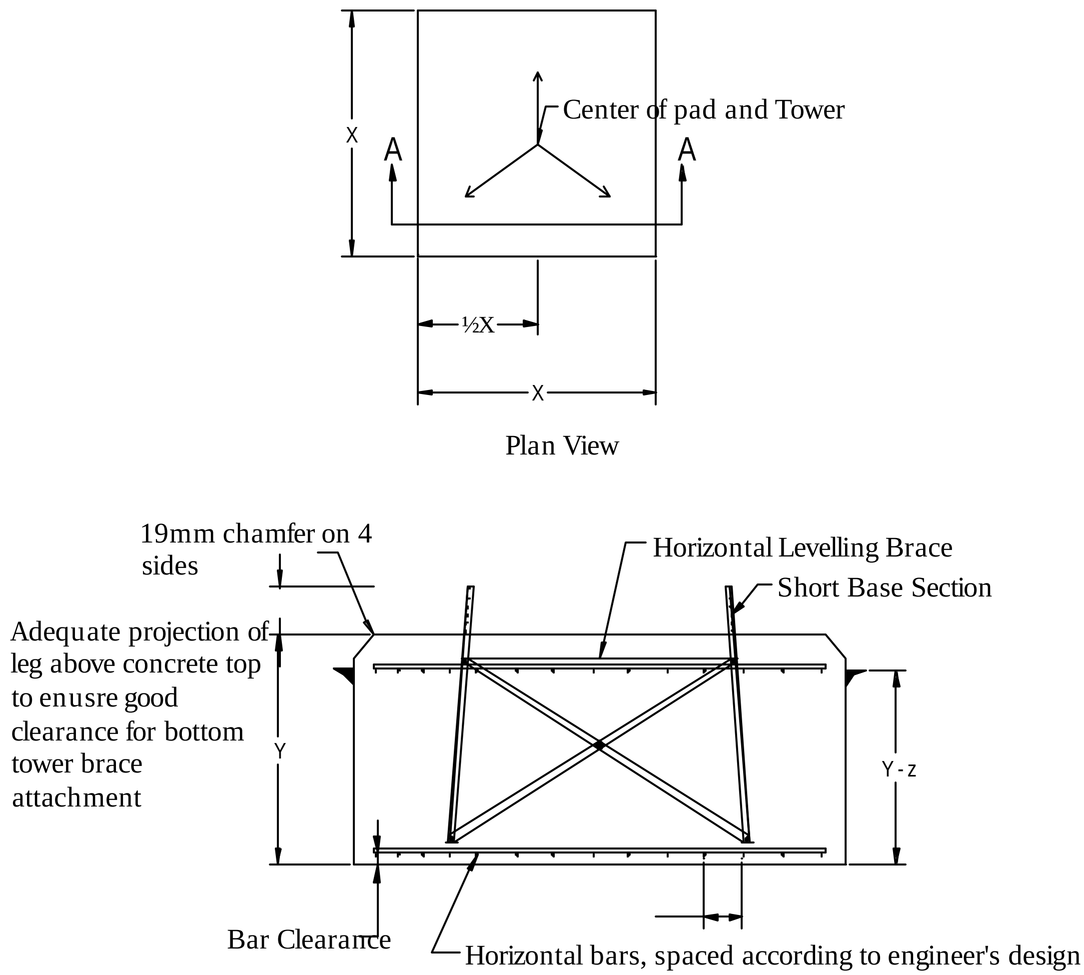


Figure 2.23

All dimensions, reinforcement steel sizes and quantities shall be according to the engineer's design, which will be dependent on the soil characteristics, dead loading of mast, its height and worst case calculated wind loading

Drilled Pier Foundation Design for Towers in Swamps
(Three Legged)

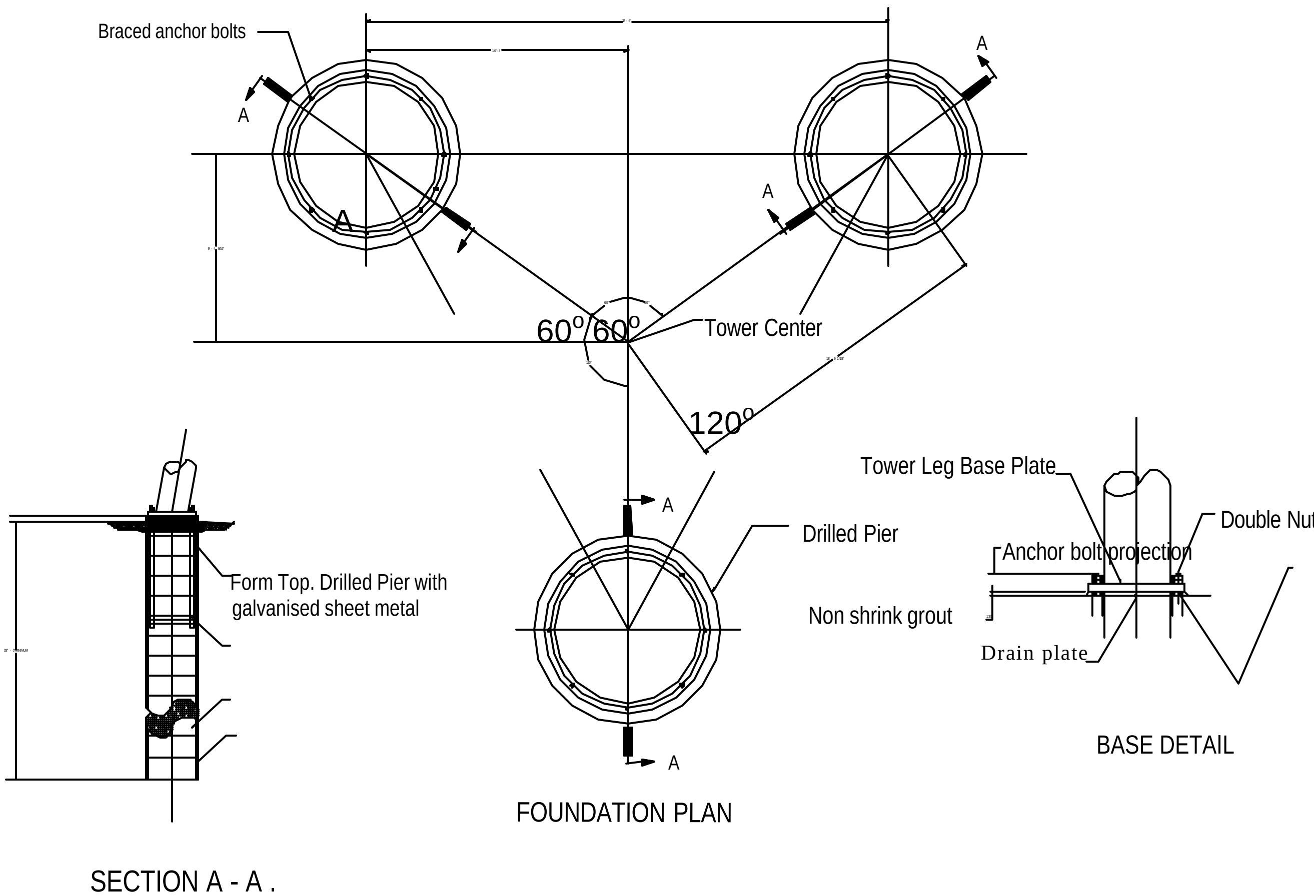


Figure 2.24

Plan of a typical foundation type for unconsolidated soils.

All dimensions are to be specified by a geo-technical engineer and are strictly dependent on the site soil characteristics, expected maximum dynamic loads, shear stress, uplift and compression.

Typical Micro pile in an unconsolidated Formation

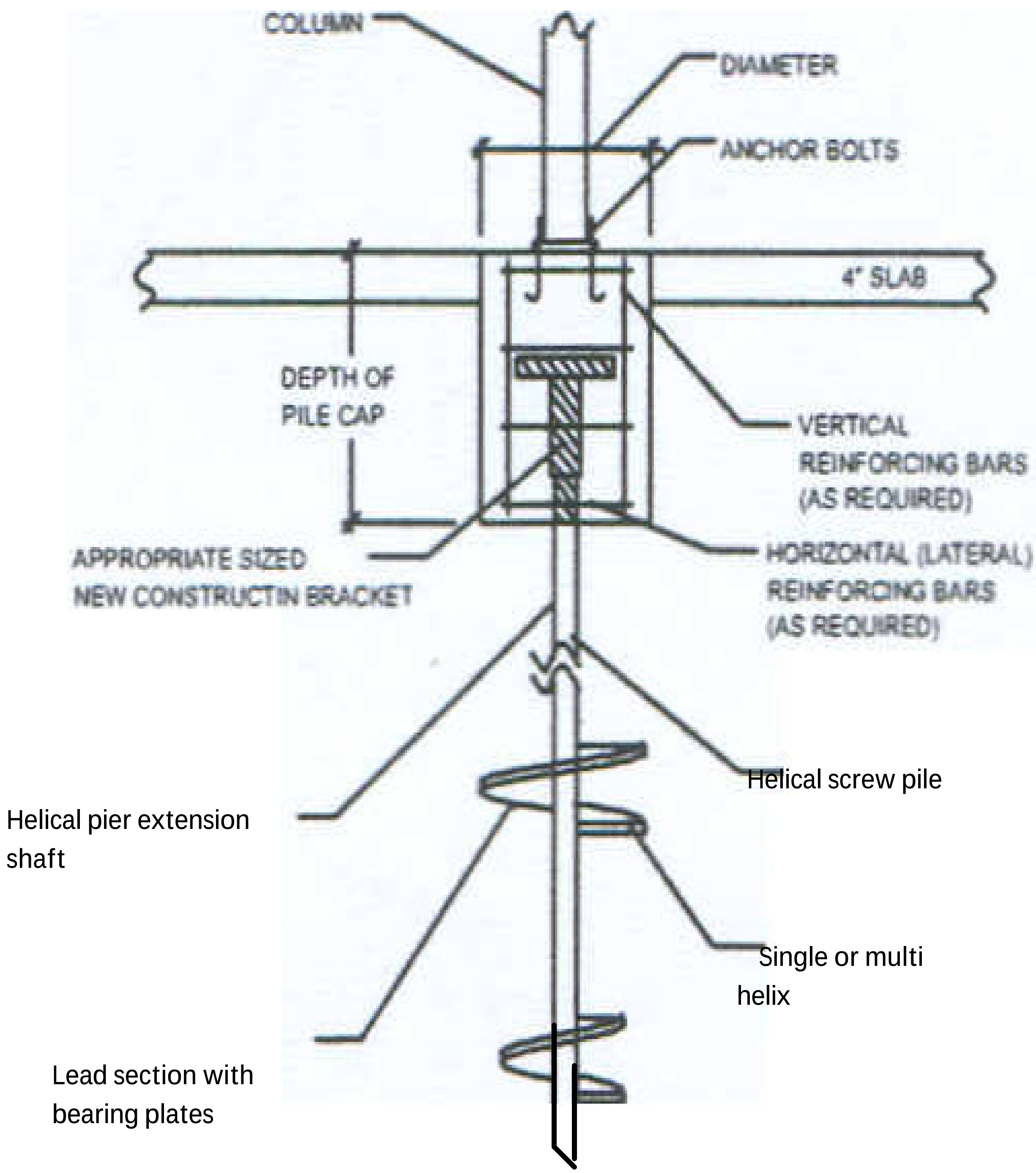


Figure 2.25

Section of drilled Pier Foundation

Foundation design for Self- Supporting Post Mast

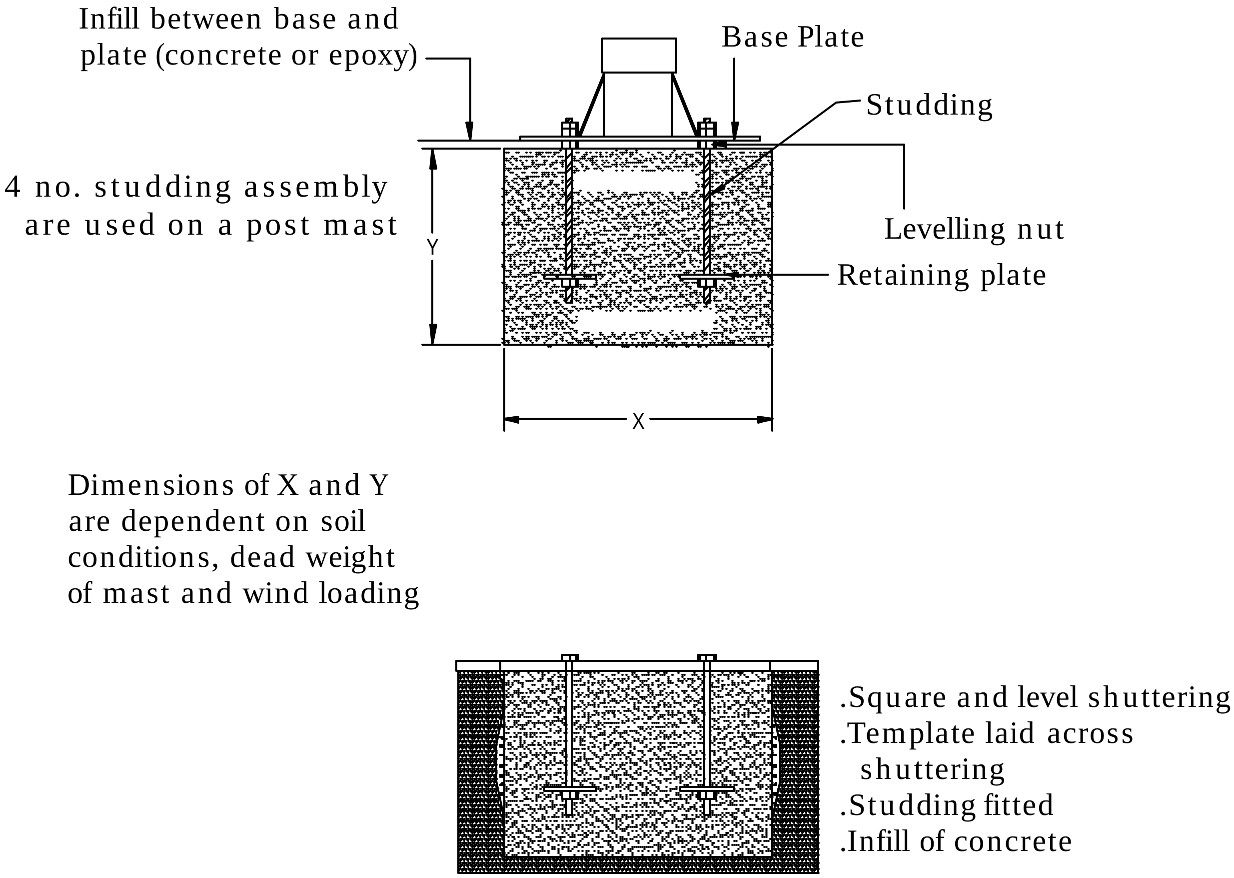


Figure 2.26

Basic Foundation Design - Four Legged Tower

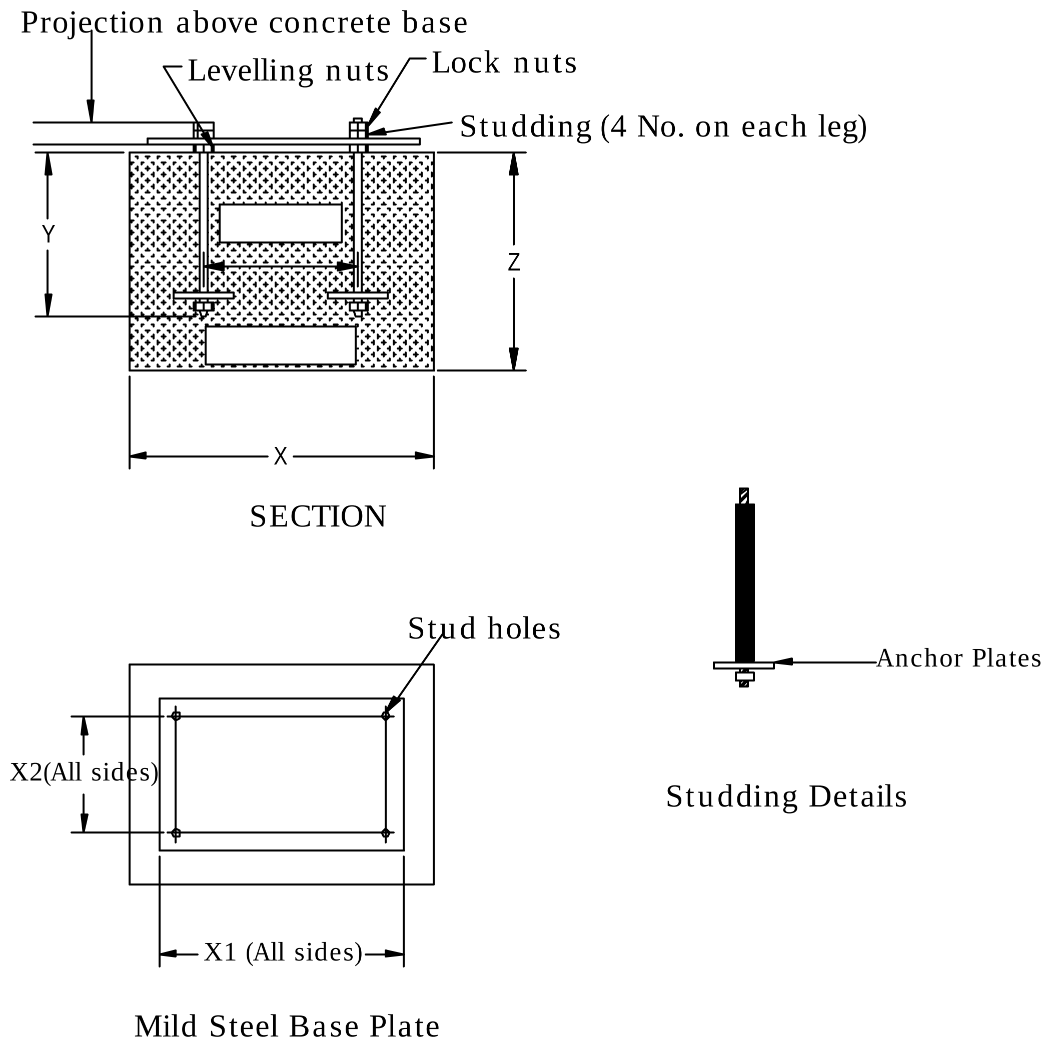


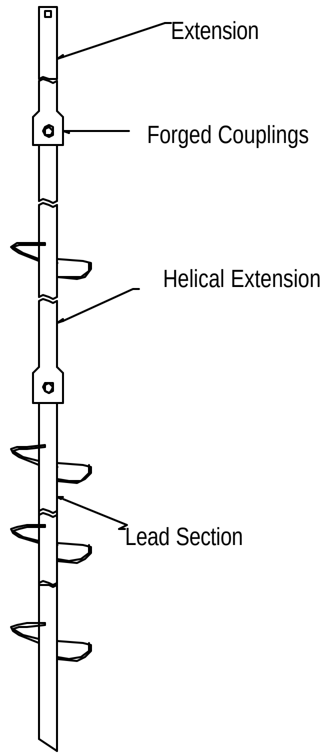
Figure 2.27

Design for lightweight mast in normal soil

Foundation design for one leg in a three or four legged tower configuration.

This is a galvanised steel tower socket base for installation on a concrete foundation. Each corner of the base is provided with a clearance hole for studs that provide a levelling method. Typical values for a lightweight tower in a normal soil are as follows:

Concrete Depth	1.2 metre
Concrete Width	1.8 metre
Face Width	0.65 metre
Base Width	1. metre

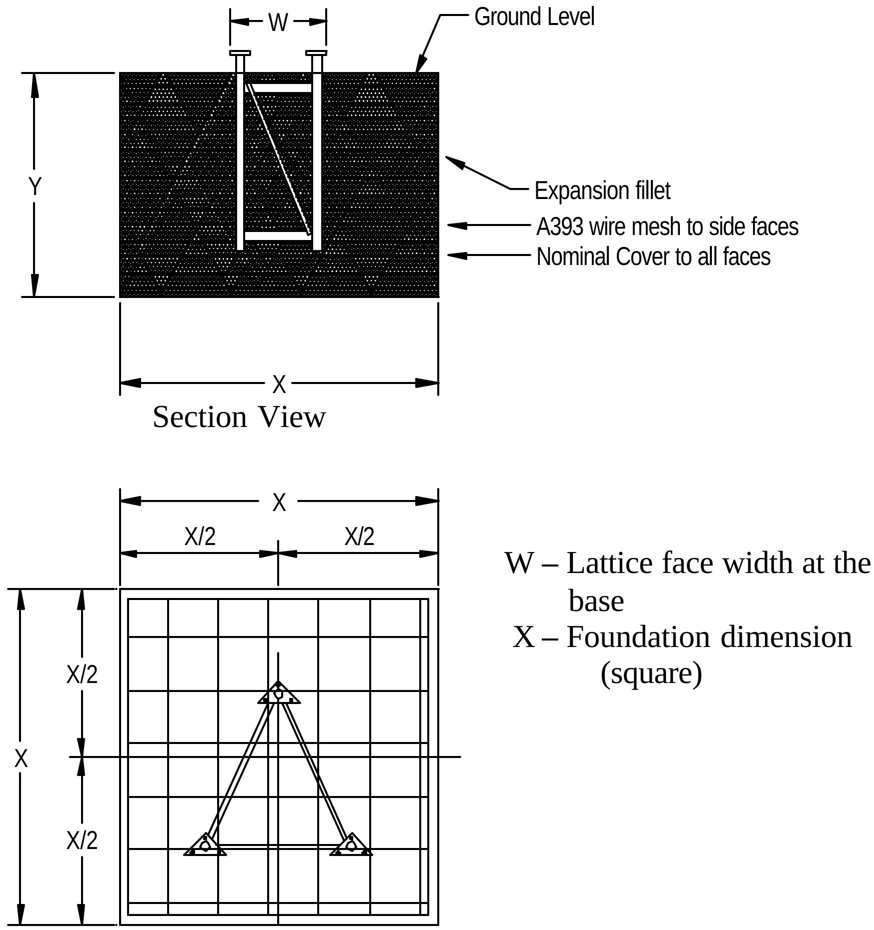


TYPICAL ANCHOR ASSEMBLY

Figure 2.28

This is easily deployed in unconsolidated formations for guy anchors, in drilled pier and micro-pile foundations. They exist in a lot of configurations.
Lengths can be varied according to the soil characteristics. Lengths are increased by the use of extensions.

Basic Foundation Design for a three-legged slim lattice Mast



Plan View

Figure 2.29

All dimensions are to be specified by a geo-technical engineer and are strictly dependent on the site soil characteristics, expected maximum dynamic loads, shear stress, uplift and compression.

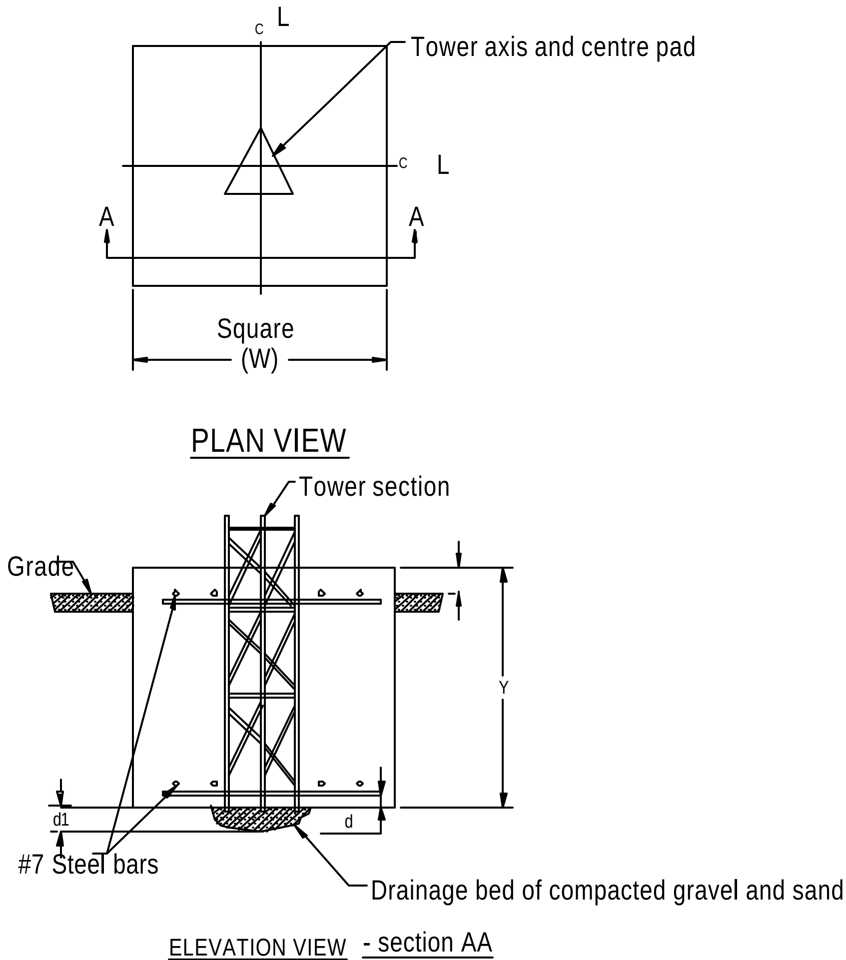


Figure 2.30

Tower Foundation using micropiles

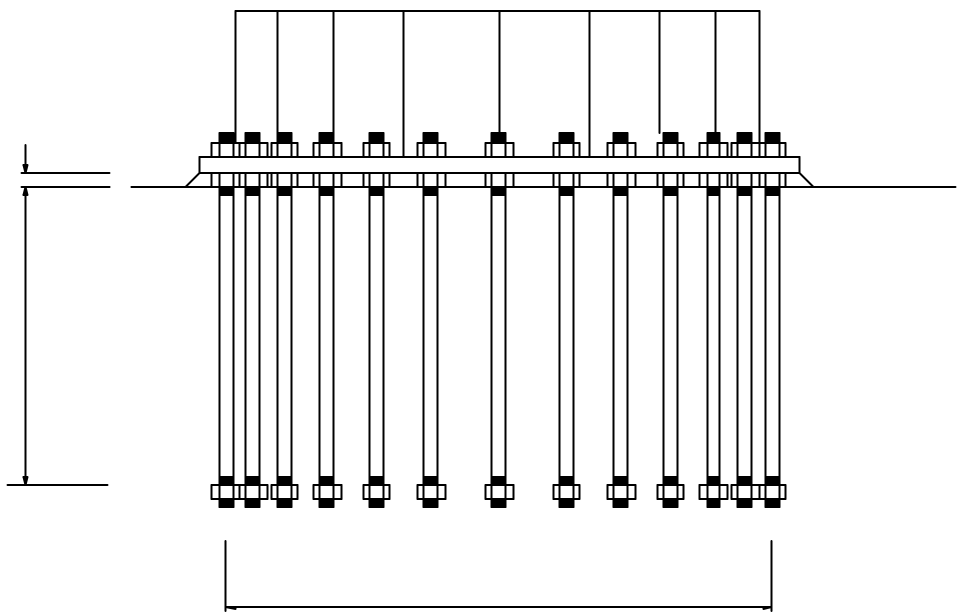
All dimensions are to be specified by a geo-technical engineer and are strictly dependent on the site soil characteristics, expected maximum dynamic loads, shear stress, uplift and compression. Typical values in normal soil for a 45-metre lightweight steel tower are:

Concrete Depth	1.2 metres
Concrete Width	1.8 metres
Face Width	0.57 metres
Base Width	1.0 metres

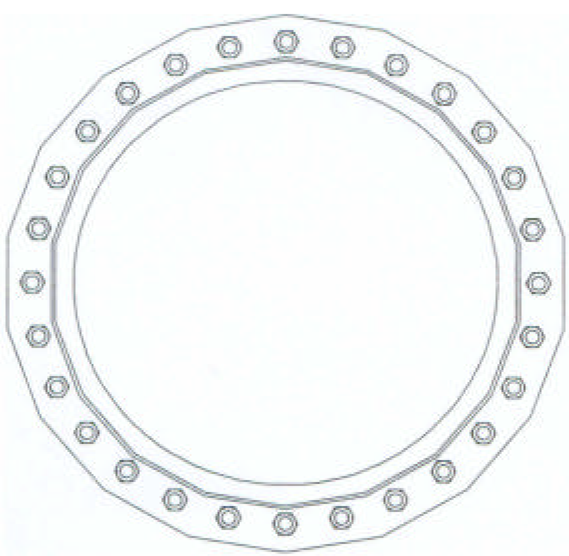
This design does not give room for leveling after concrete has been poured

Foundation Design for a Self –Support Monopole Tower

Section



Plan



Design basic wind speed is 100 $Kmhr^{-1}$

Plate thickness is 6 Plate grade is A36.

Anchor Bolt Grade is A325 X.

Yield Strength is 4 ksi.

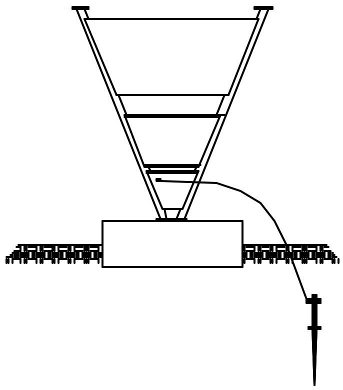
Bolt Length is a minimum of 1metre

Base Plate outer diam is 1.5 m

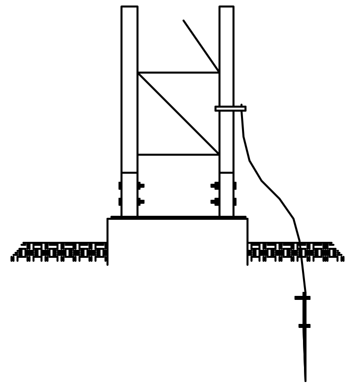
Base plate inner diam is 1.1 m

Figure 2.31

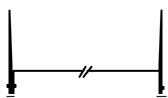
Dimensions given above vary with the peculiarities of the monopole and the soil

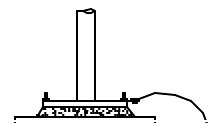


Tapered Base, Guyed Tower - Grounding



Guyed Tower Leg Grounding



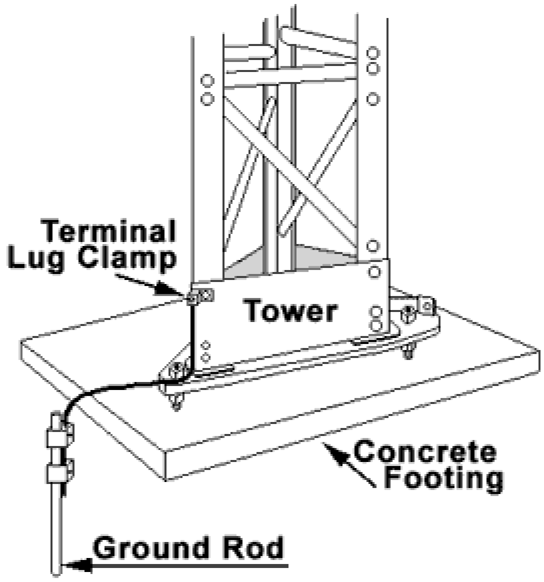


t Tower

ALTERNATE WAYS OF GROUNDING AT GUY - ANCHORS

Figure 2.32

Earthing and lightning protection methods



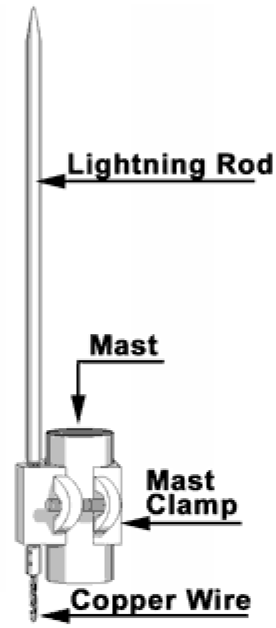
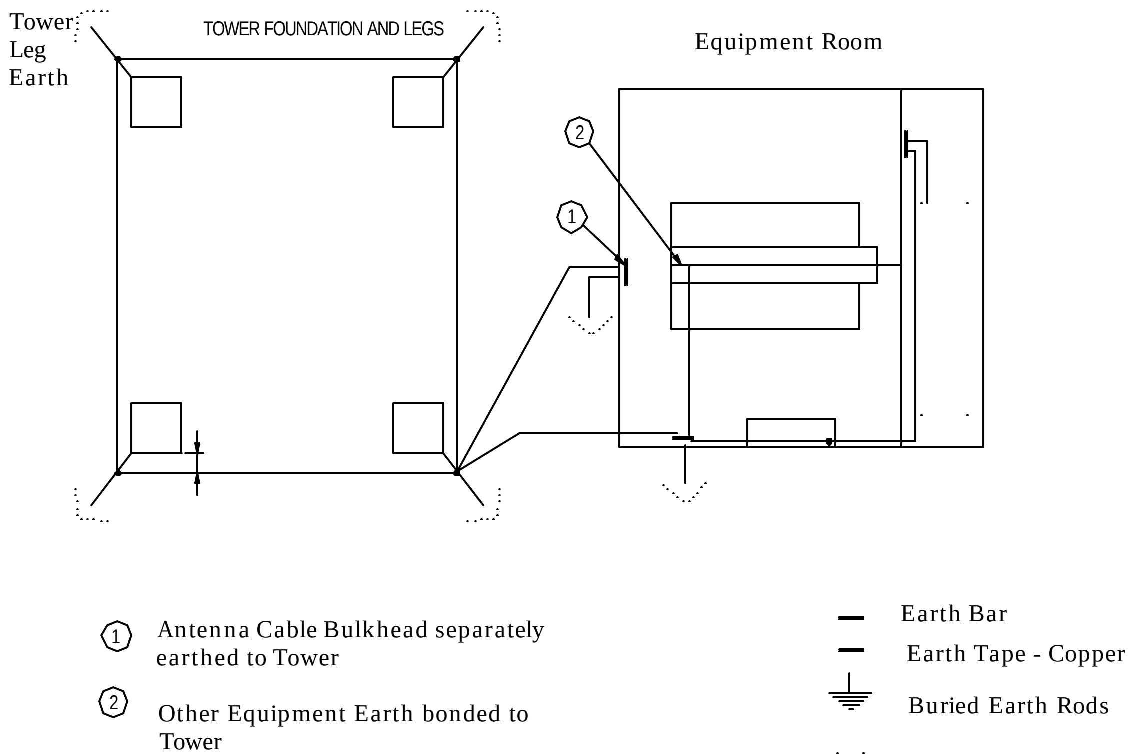


Figure 2.33



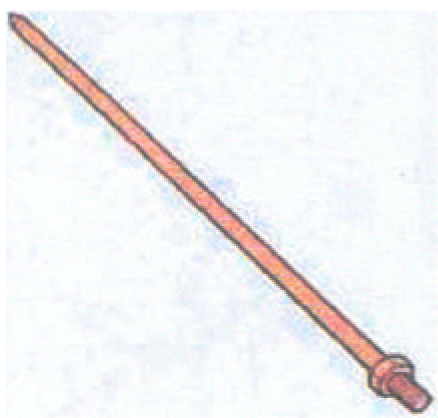
TOWER EARTHING DESIGN - TYPICAL

Figure 2.34

Soil	Resistivity, ohm, cm
Marshy Ground	200 – 270
Loam and Clay	400 – 15,000
Chalk	6,000 – 40,000
Sand	9,000 – 800,000
Peat	20,000
Sandy Gravel	30,000 – 50,000
Rock	100,000

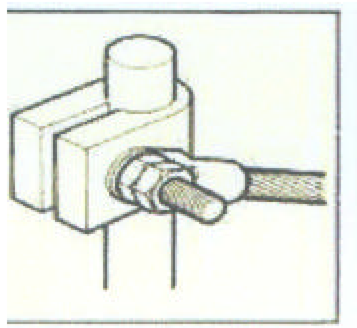
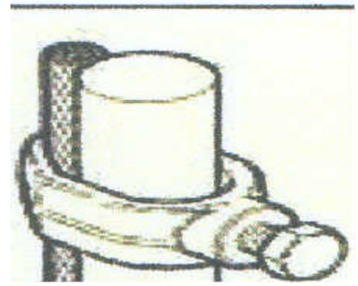
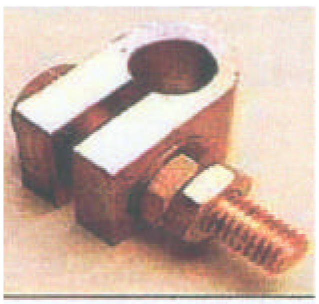
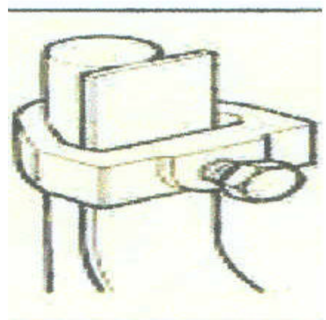
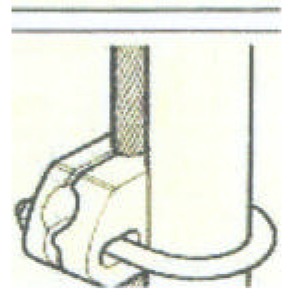
Table 2.14 – Resistivity Values for different Soil Types

Table 2.14 gives typical values, which can be used for computation but shall not serve as a substitute for actual measured values.



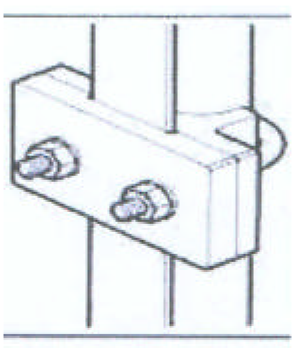
Air Terminal- Lighting spike
Figure 2.35

Earthing Clamps

Typical clamps for installation of earth tapes

<u>U-Bolts</u>



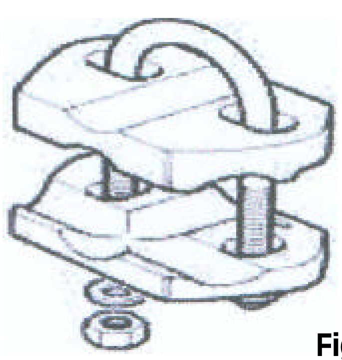
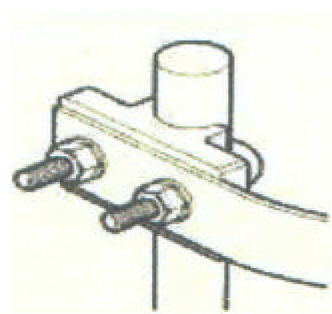
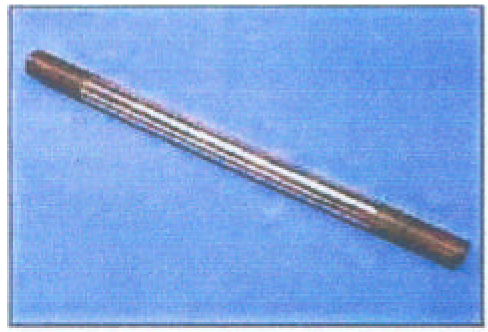




Figure 3.1

Multi-Point Air terminal Elevation Rods Mounting
Brackets



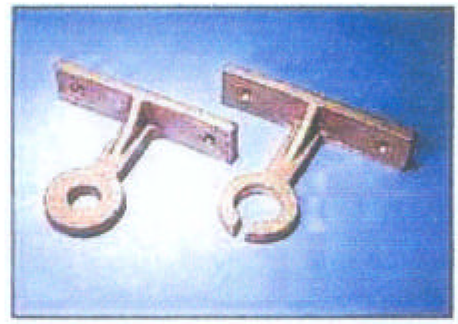
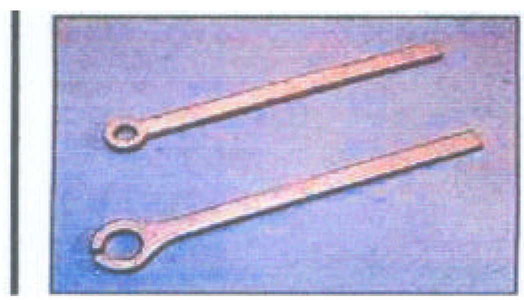
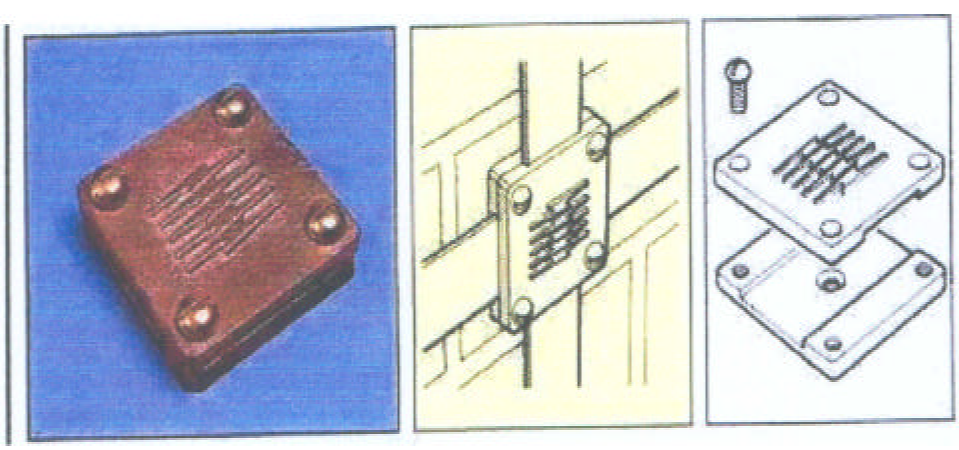


Figure 3.2
Earth and lightning protection materials

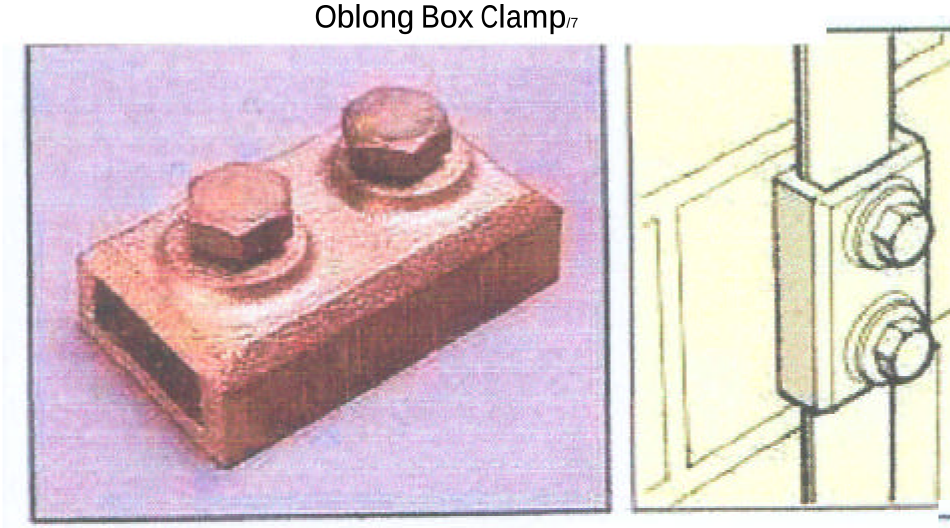
Rod to Tape Coupling Building in Rod Holdfasts



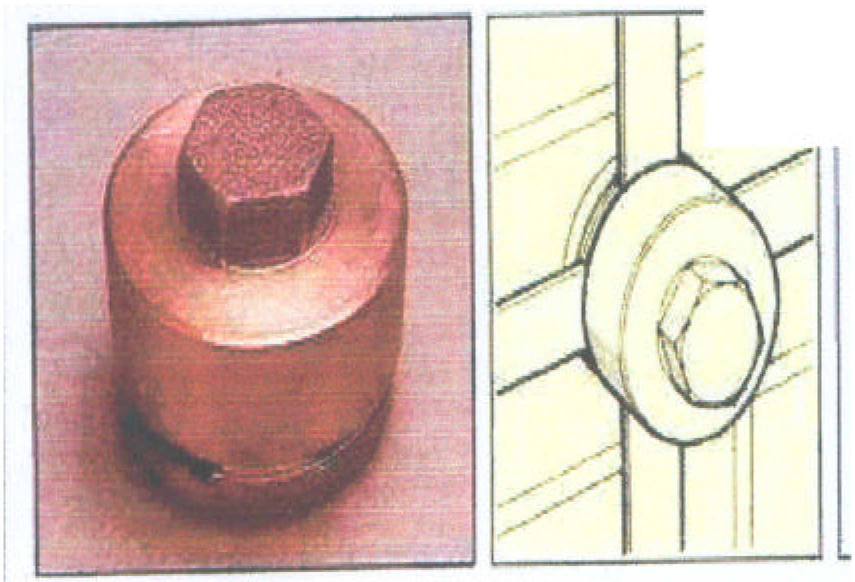
Connector Clamps
Square Tape Clamp



Oblong Box Clamp/7



Screw down Clamp



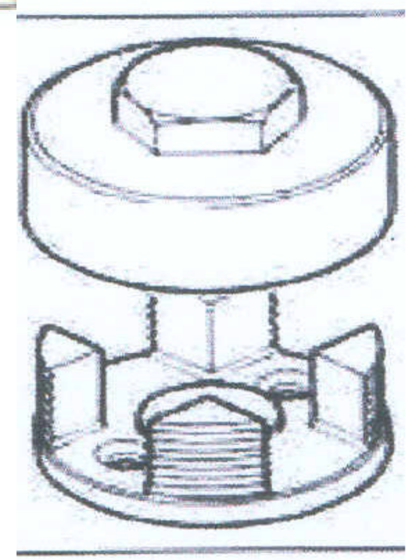
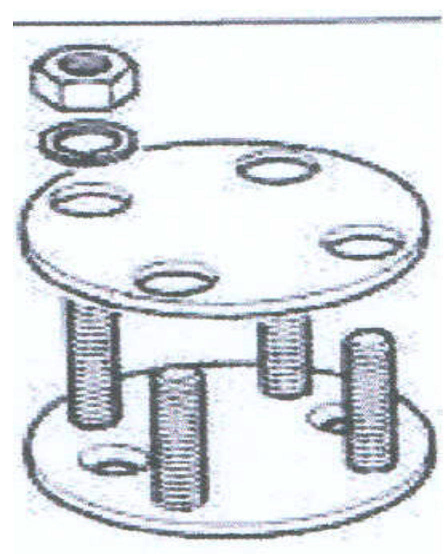


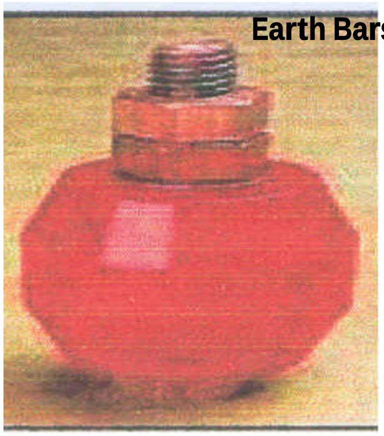
Plate Type Clamp

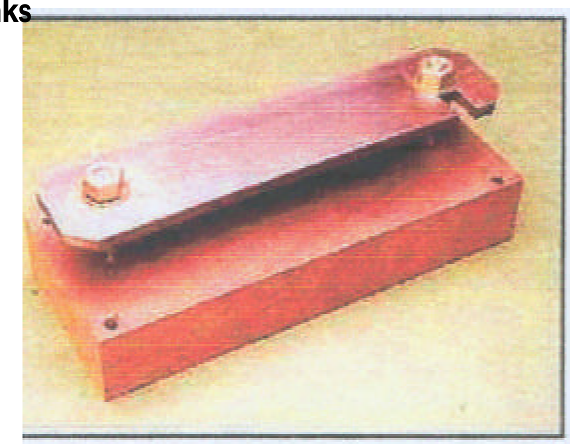


Installation Materials – Earthing and lightning protection

Figure 3.3

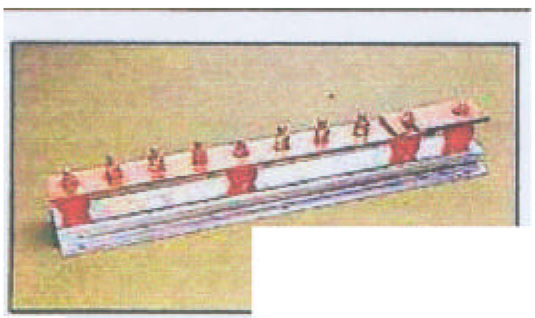
Earth Bars and Disconnecting Links



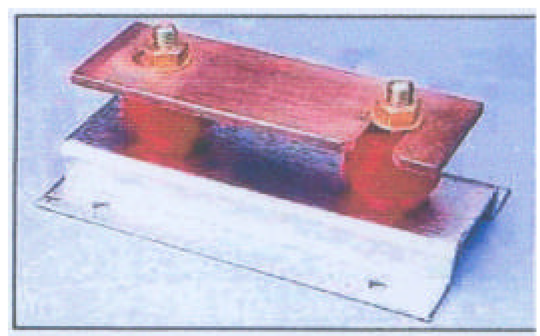


Insulator

Wooden base disconnecting link



6-way disconnecting link



Disconnecting link channel Iron base

Inspection Housing

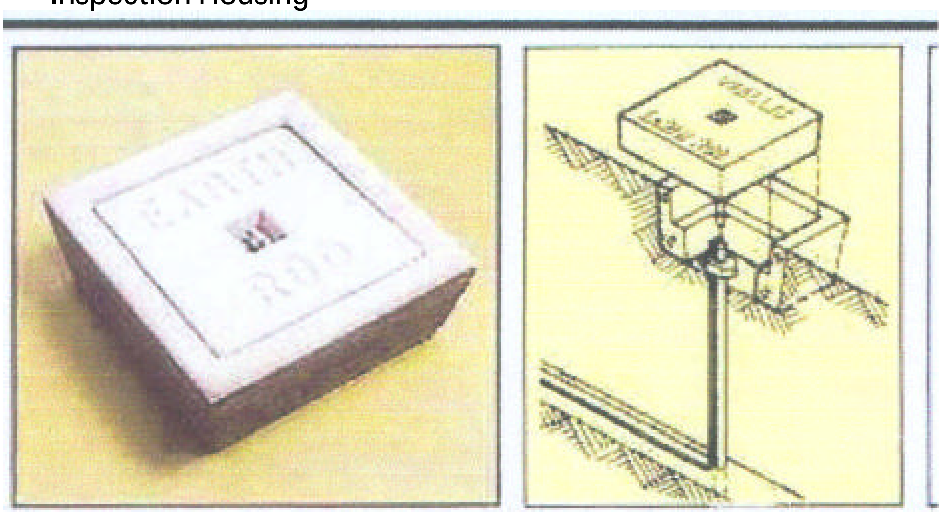


Figure 3.4
These materials are used for earthing installation to make testing easy

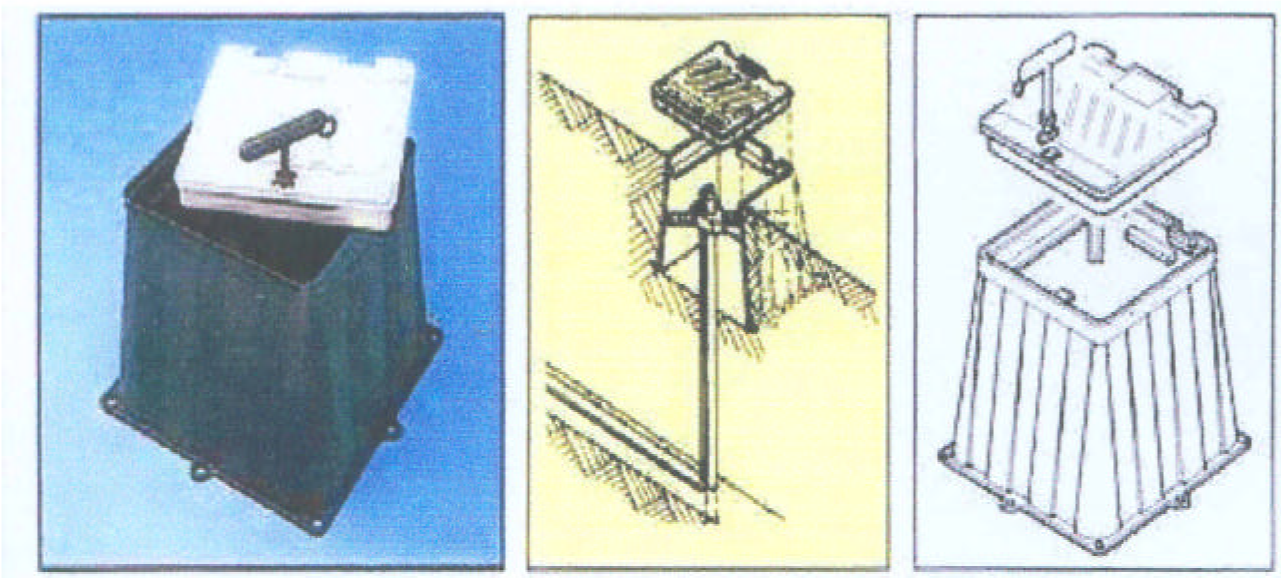


Figure 3.5
These materials are used for earthing installation to make testing easy

Notes

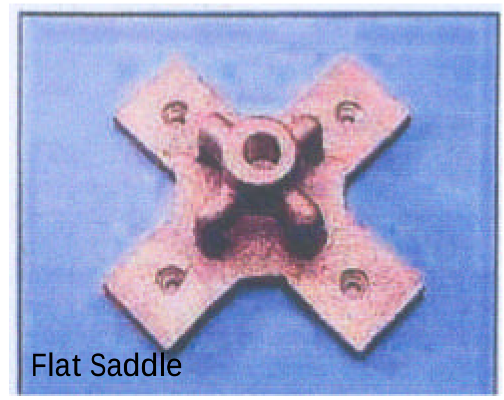
i) *Conductor inspection housing shall be installed at test points to protect the earth rod and earth connections and make them available for testing.*

ii) *It shall be made from high grade, heavy-duty polypropylene and ultra violet stabilized to prevent degradation by sunlight.*

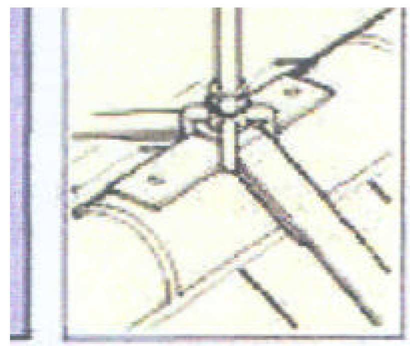
iii) *It shall be non-brittle.*

Lightning Arrestor Installation Materials

Pointed Air Rod



Flat Saddle



Light Duty Saddle

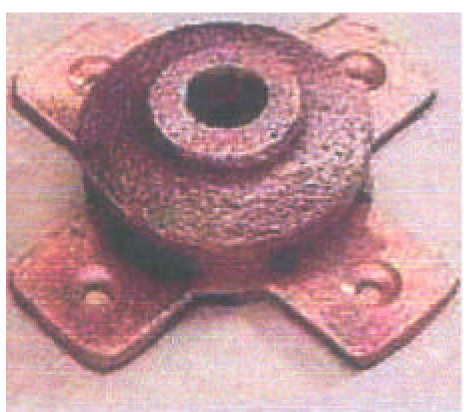
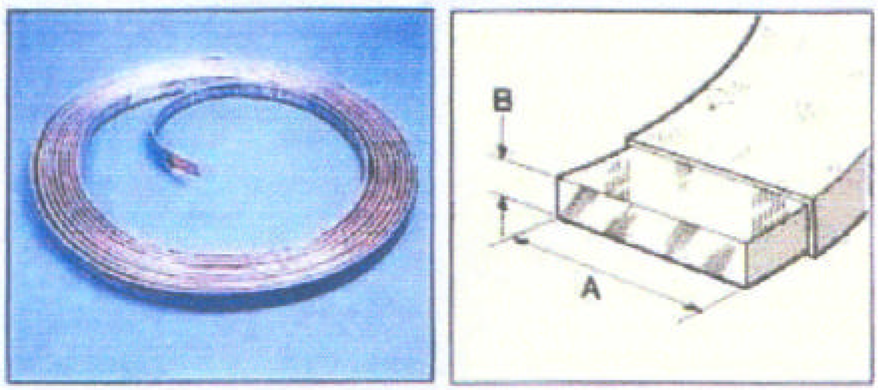


Figure 3.6

Pointed Air rod and installation saddle

Copper Tapes – Can be Tin or lead covered

Copper Tape



Flexible Copper braid

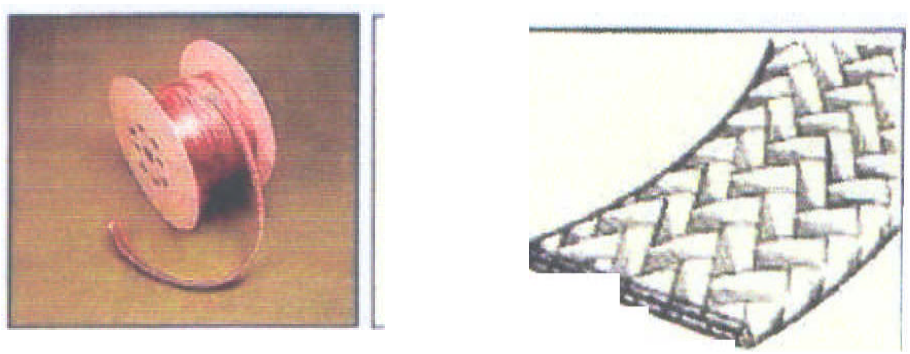
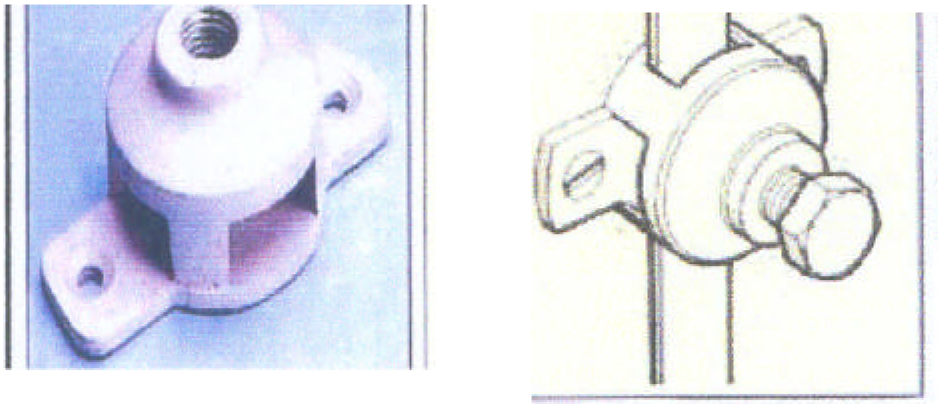


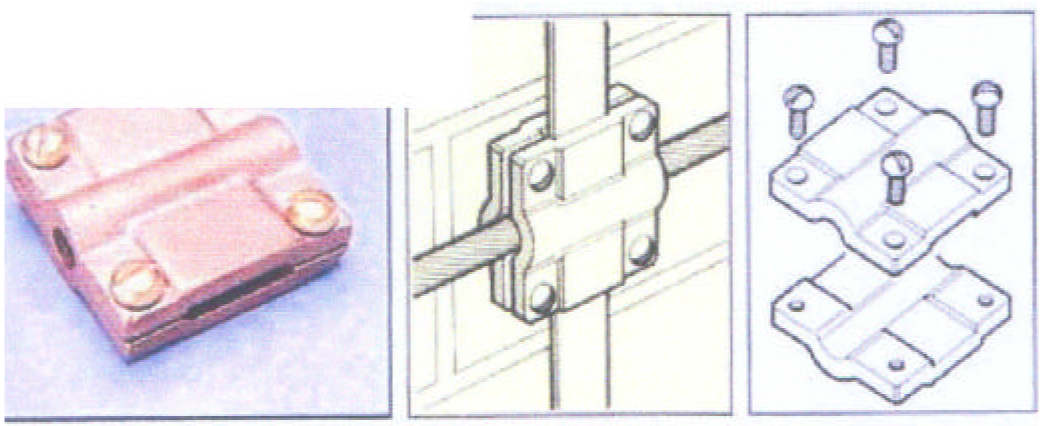
Figure 3.7
Flat Copper Tape and Flexible Copper Braid

Connectors

Circular cable connector



Cable to Tape Junction Clamp



Cable To Cable Test Clamp

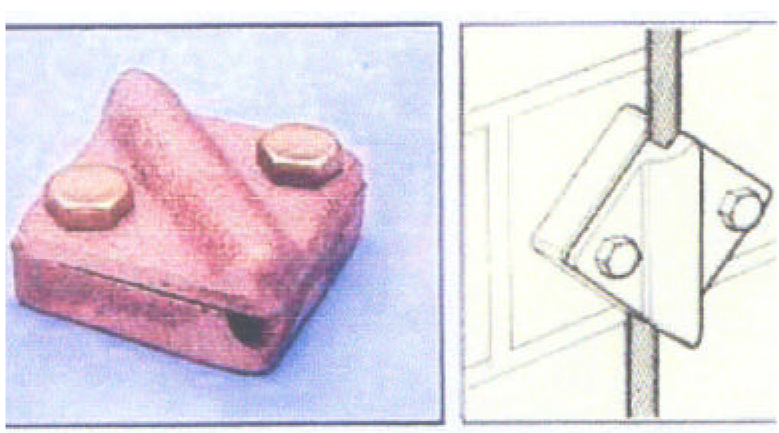
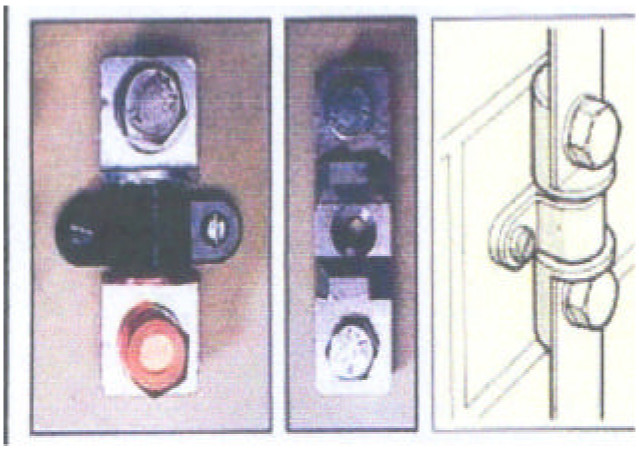
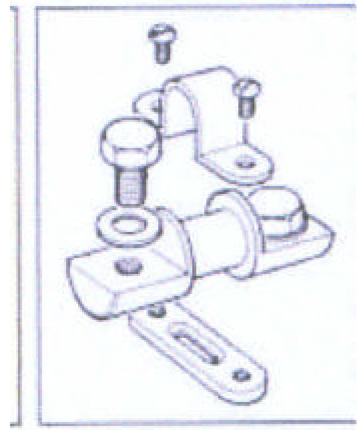


Figure 3.8

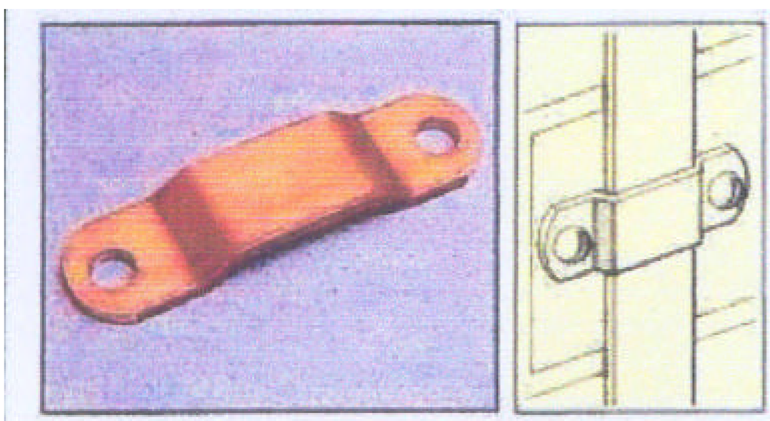
Cable connectors

Bi-Metallic Connectors

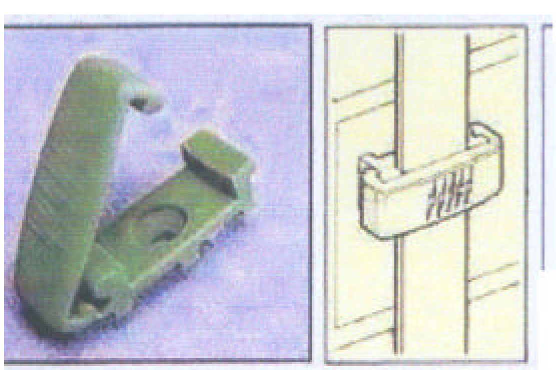




Metal Tape Clip



Non-Metallic Clips



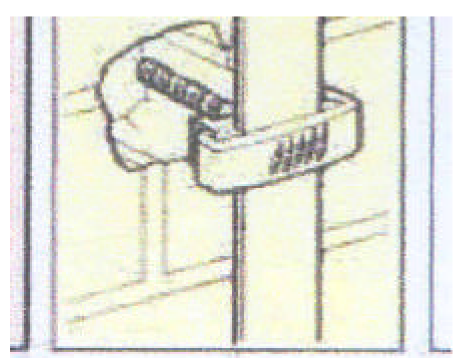
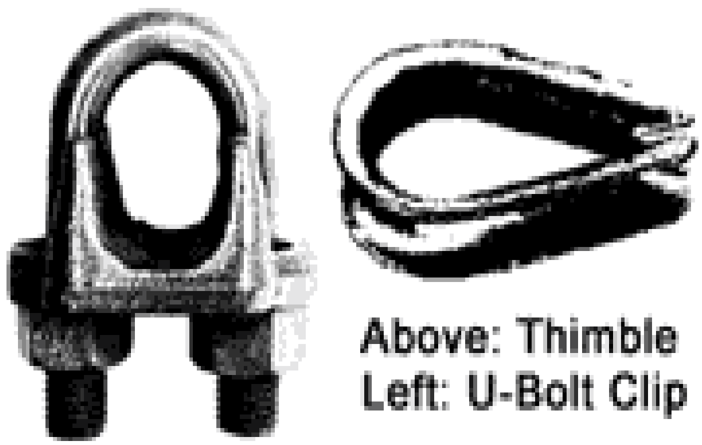


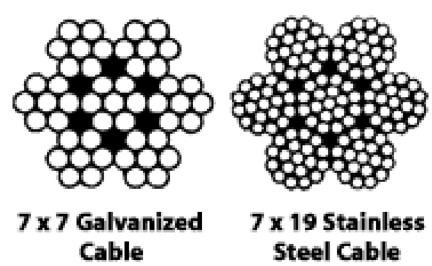
Figure 3.9
Cable and Tape clips

Guy System Materials



Earth Screw Anchor

Turnbuckle



Guy Wire

Figure 3.10

Guy materials

Guying materials shall conform to the sizes, mechanical strengths and capacities shown below in Tables 3.1 (1-4)

Size & Grade	Working Load	Break Strength	Wt. / 100 strands
3.5mm x 7 x 7 Galvanised Steel	154 Kg	771 Kg	1.27 Kg
10mm x 7 x 19 Galvanised Steel	1306 Kg	6532 Kg	1.10 Kg
8mm x 7 x 19 Stainless Steel(304)	245 Kg	1089 Kg	2.27 Kg
5mm x 7 x 19 304 Stainless Steel(304)	336 Kg	1678 Kg	4.10 Kg
6.5mm x 7 x 19 Stainless Steel(304)	581 Kg	2903 Kg	5.00 Kg

Table 3.1 Guying Cable

Working Load (Kg)	Diameter & Take Up	Unit Wt. (Kg)
750	10mm X 15cm	0.45
1,000	12.5mm X 22cm	0.9
1,500	15mm X 30cm	1.8

Table 3.2 Turnbuckles

Turnbuckles shall be made from drop forged steel, be of hot dip galvanized Finish and have Eye and eye construction

Overall Length	Rod Dial. In.	Helix Diameter	Holding Power in Normal Soil	Unit Wt(Kg)
75 cm	12.5 mm	10 cm	1,135 Kg.	3.2
120 cm	16 mm	15 cm	1,815 Kg.	5.5
173 cm	17.5 mm	20 cm	5,000 Kg.	12
12.5mm Link from earth anchor to turnbuckle. Hot dip galvanized finish.				

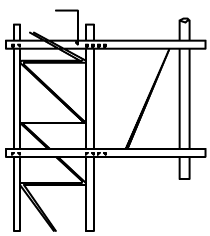
Table 3.3 Earth Screw Anchors

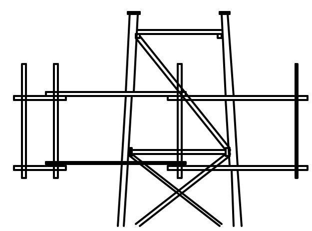
Description	Kgs. Per 100
3mm Galvanized Steel U-Bolt Clip	4.54
8mm Galvanized Steel U-Bolt Clip	8.16
6.5mm Galvanized Steel U-Bolt Clip	8.16
8mm Galvanized Steel U-Bolt Clip	13.6
10mm Galvanized Steel U-Bolt Clip	21.8
6.5mm Galvanized Heavy Duty Thimble	4.54
8mm Galvanized Heavy Duty Thimble	6.35
10mm Galvanized Heavy Duty Thimble	11.34

Table 3.4 U-Bolt Clips and Thimbles

Some basic designs

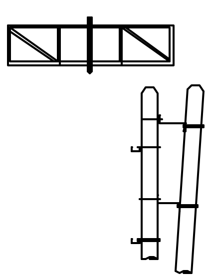
Tower structure

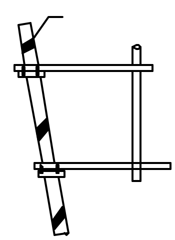




Antenna Mount on Self-Support Tower

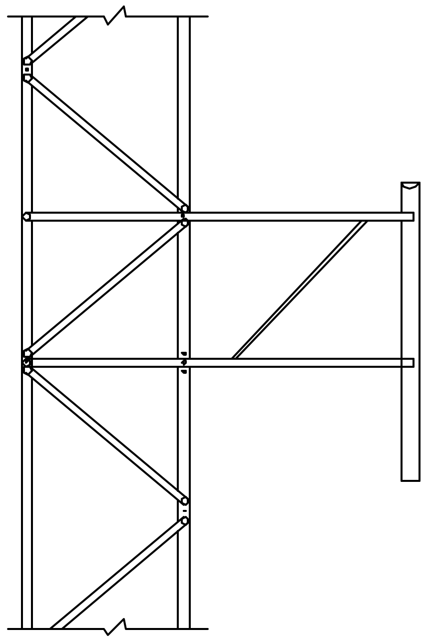
Side Antenna Mount





Figures 3.11

Side Antenna Mount



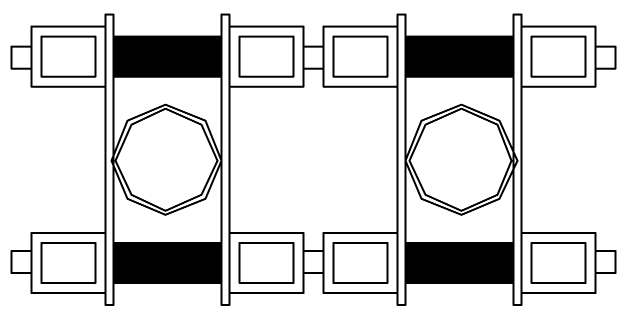
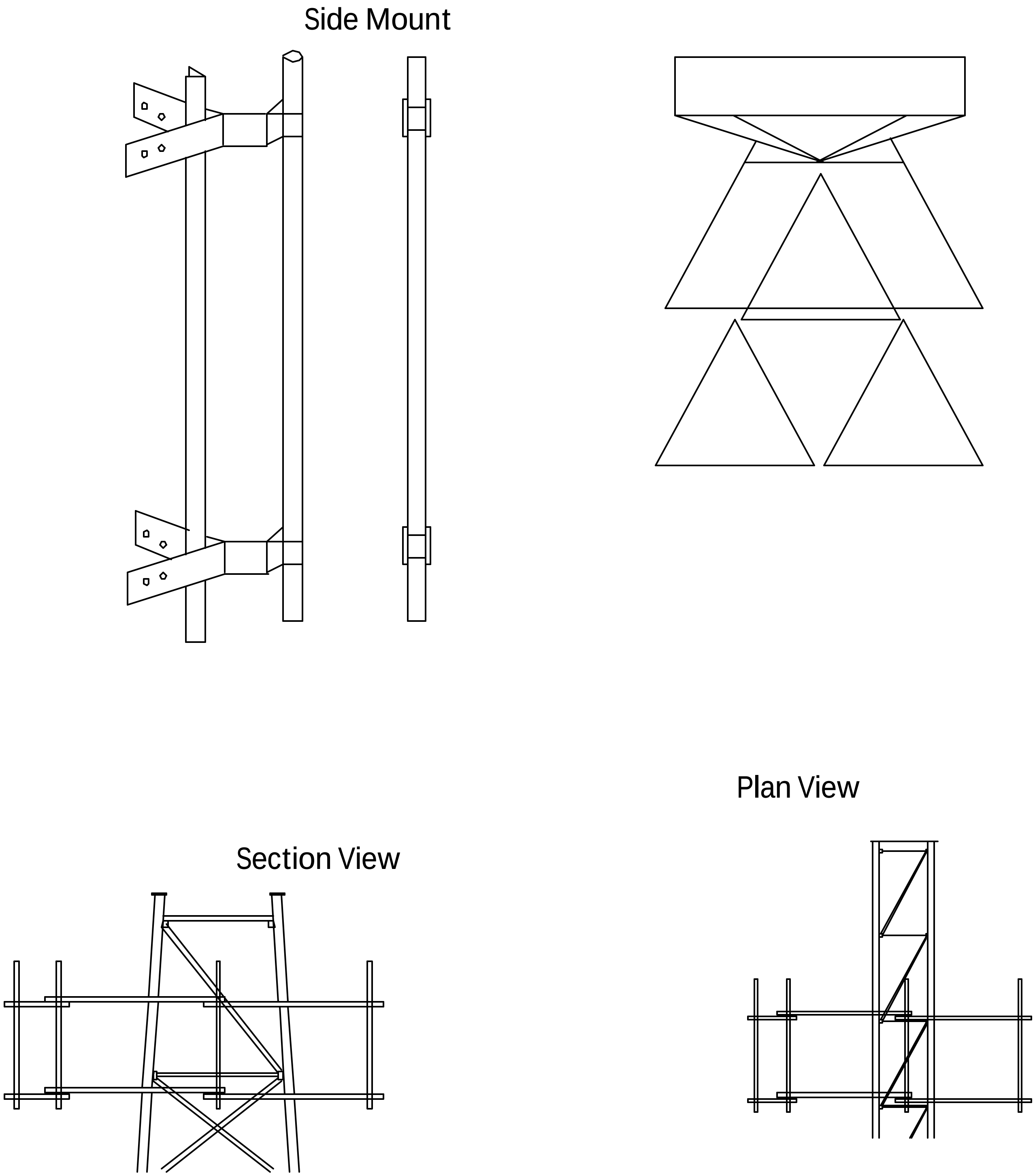


Figure 3.12

SADDLE- BRACKET



Antenna Mount on Self-Support Tower

Figure 3.13

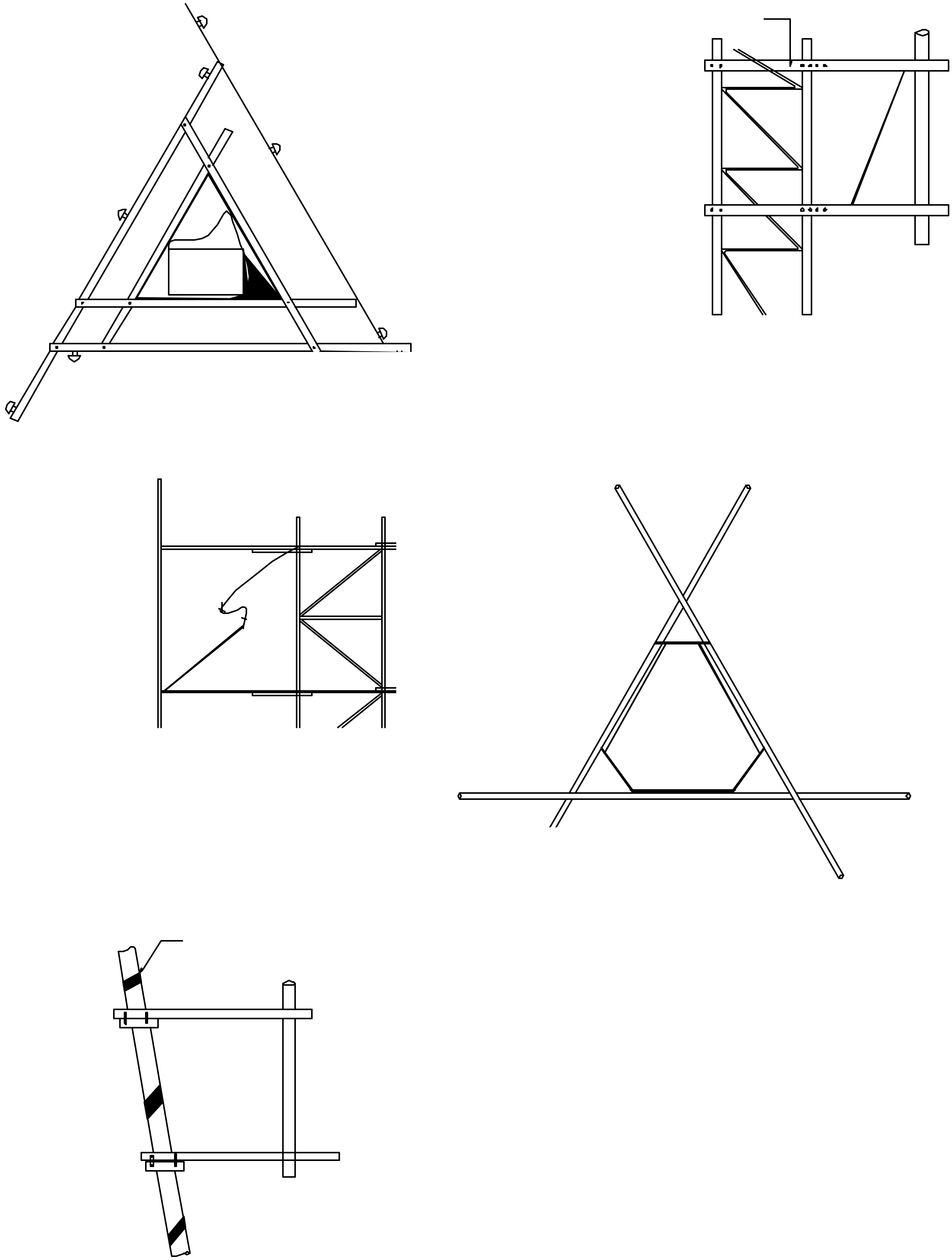


Figure 3.14

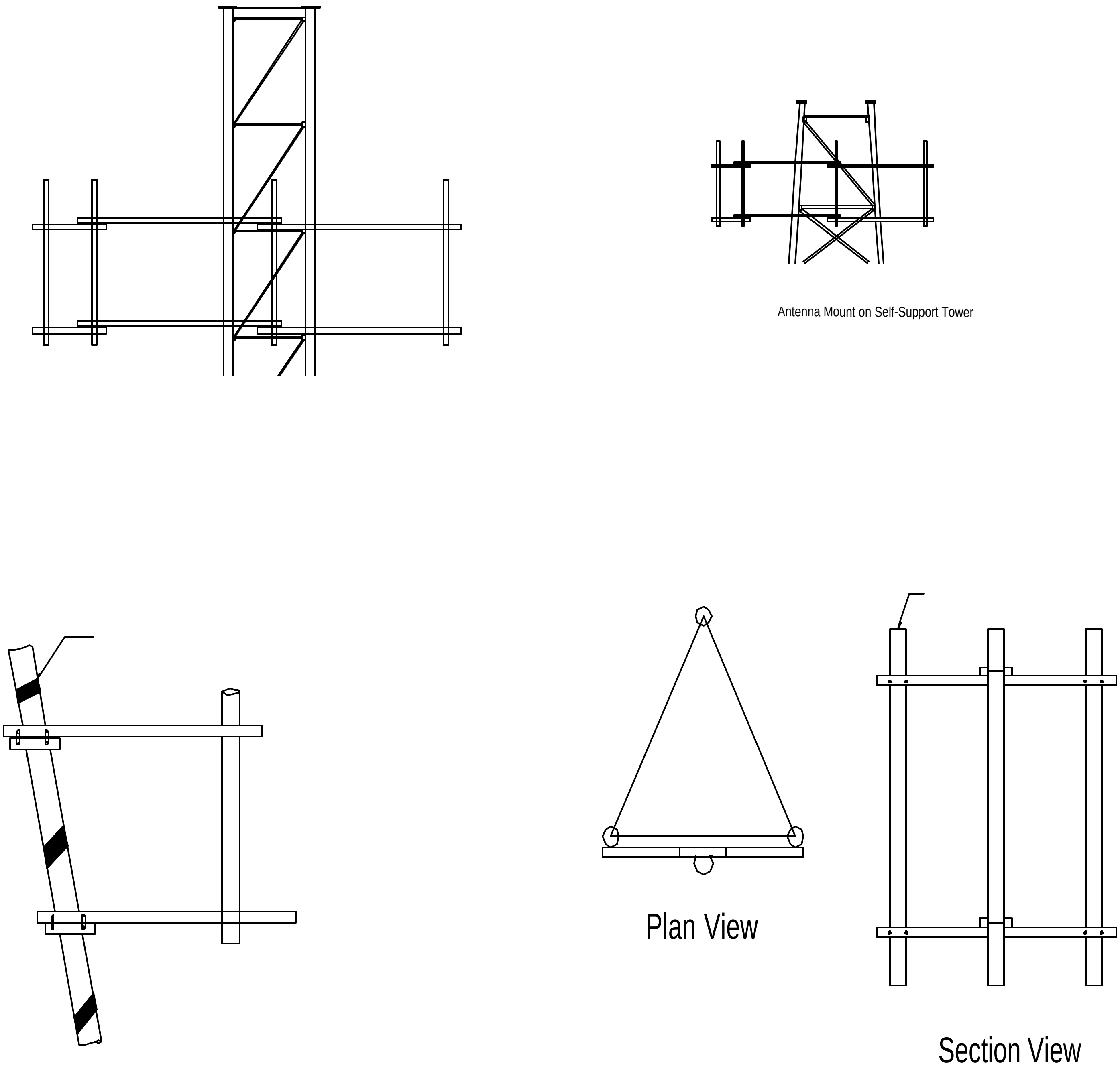


Figure 3.15

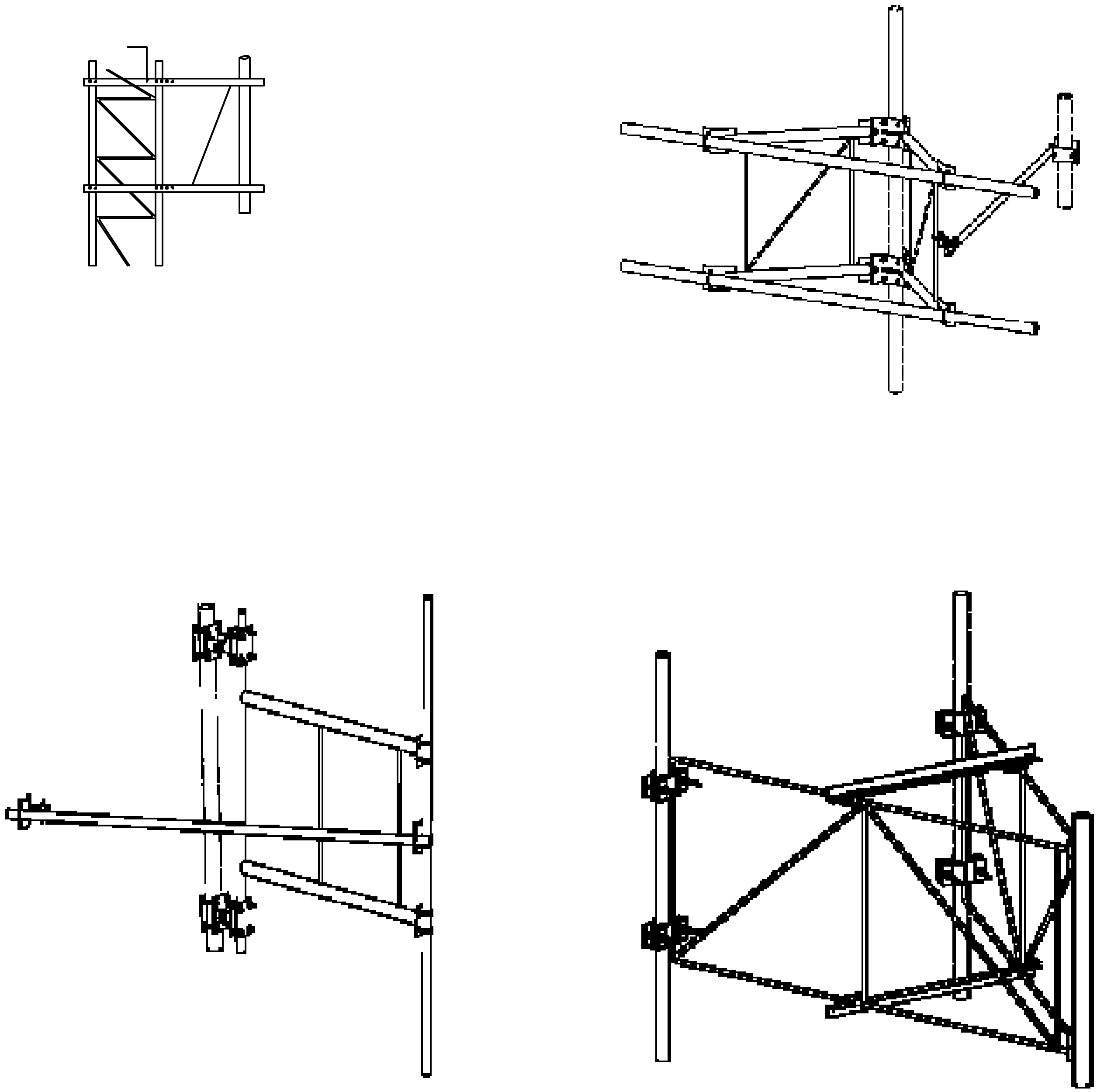


Figure 3.16

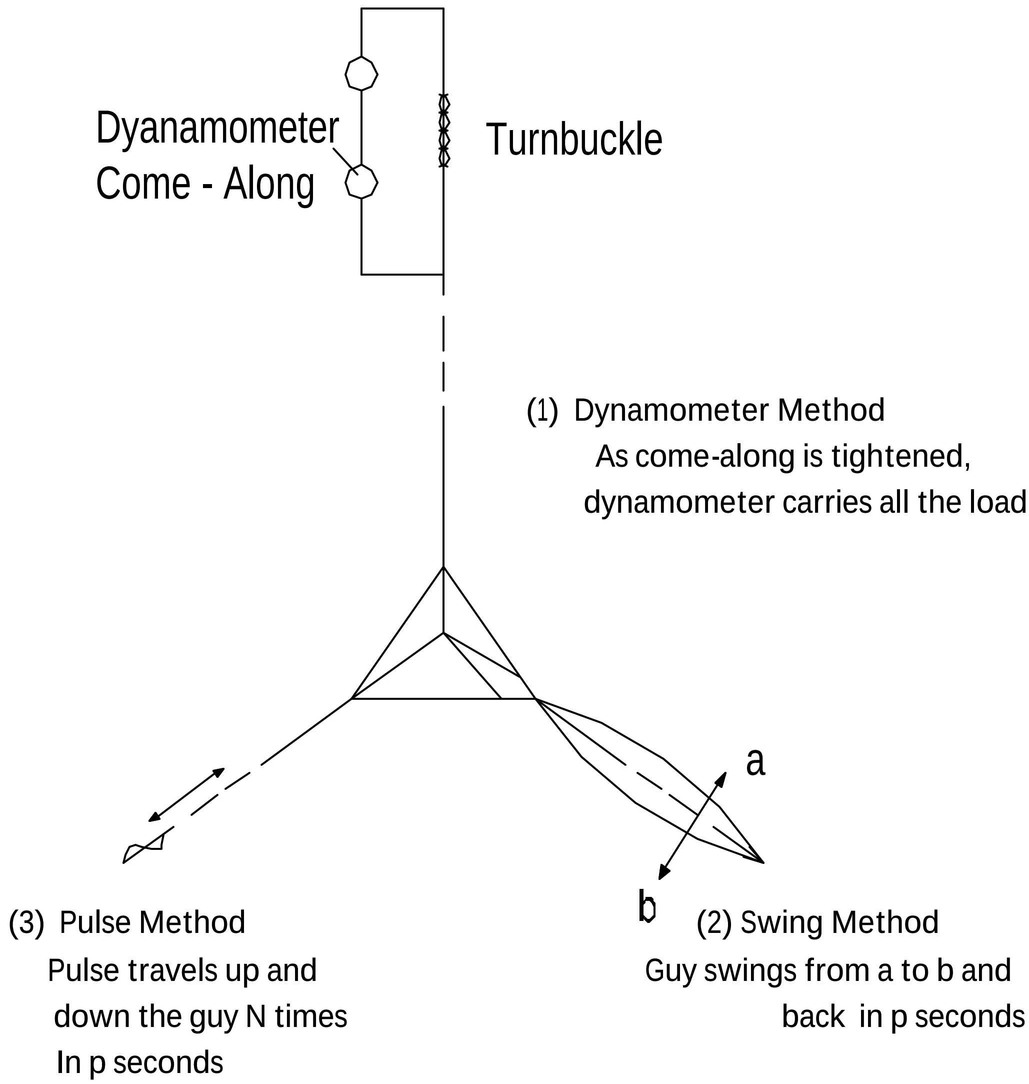


Figure 4.1

Measurement of Tension of Guy

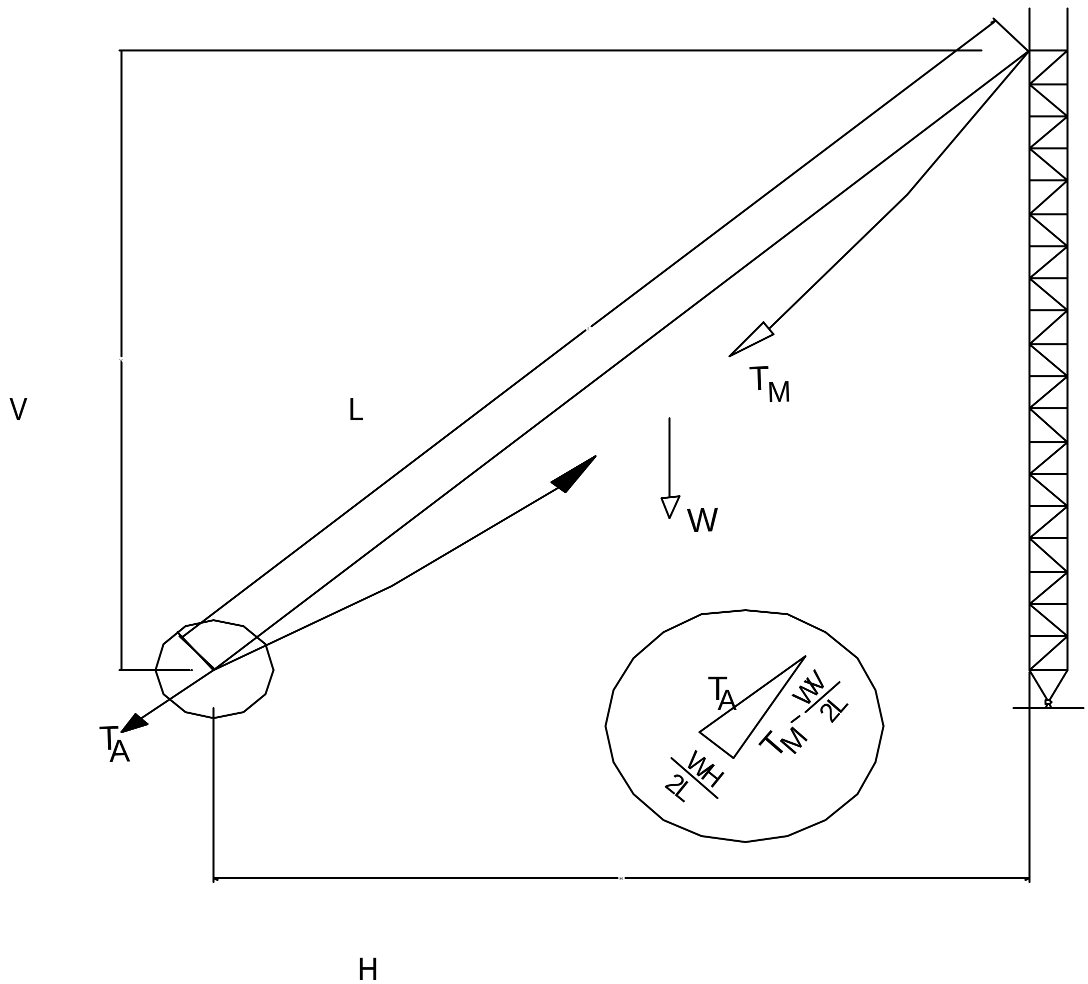


Figure 4.2

Relationship between Guy Tension at Anchor and at Mid-Guy

The Tangent Intercept Method

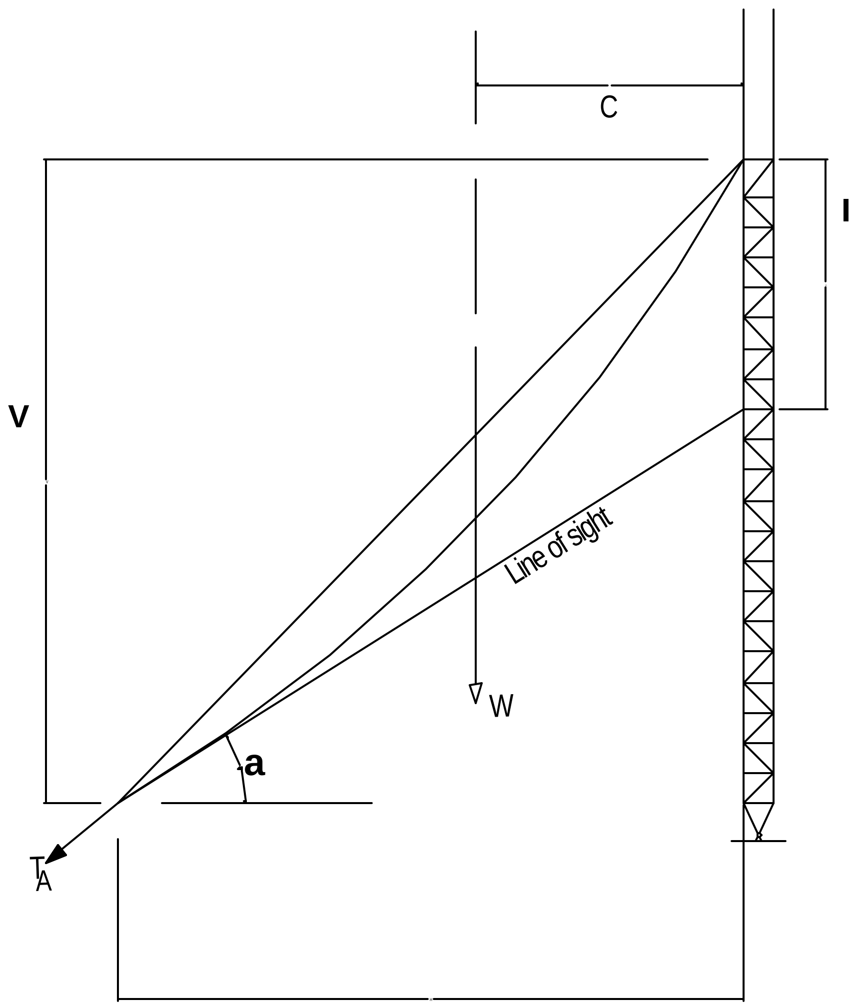


Figure 4.3

Table 6.1: Radiation level in mW/cm2 of body weight

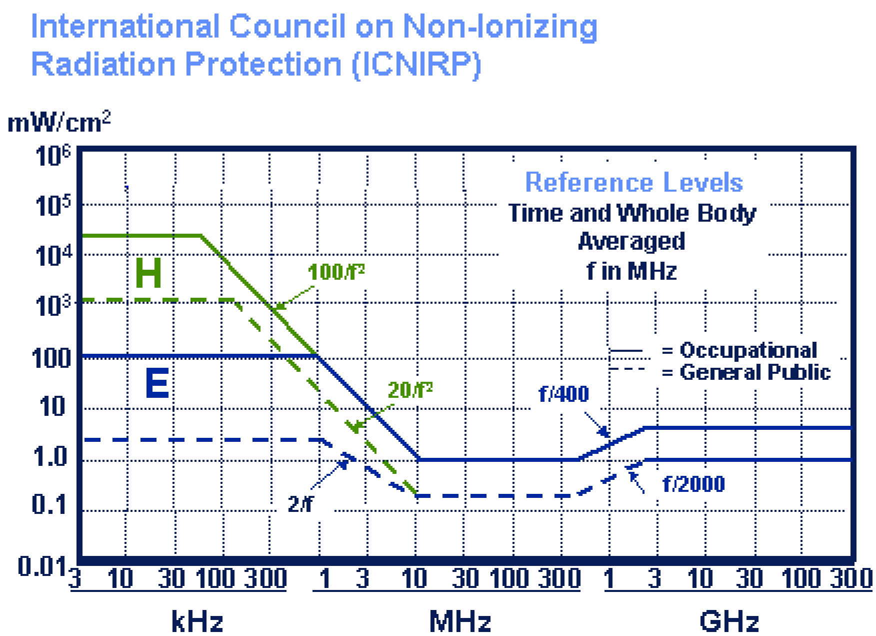


Table 6.2: Radiation level in E, H and S for Occupational Staff on site

Frequency Range (f)	Electric Field (E)	Magnetic Field (H)	Power Density (S) (E;H Fields)
	(V/m)	(A/m)	(mW/cm^2)
<1 Hz	—	163 x 10^3	—
1 - 8 Hz	20,000	163 x $10^3/f^2$	—
8 - 25 Hz	20,000	2.0 x $10^4/f$	—
0.025 - 0.82 kHz	500/f	20/f	—
0.82 - 65 kHz	610	24.4	100; 22,445
0.065 - 1 MHz	610	1.6/f	100; $100/f^2$
1 - 10	610/f	1.6/f	$100/f^2$
10 - 400 MHz	61	0.16	1.0
400 - 2,000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	f/400
2 - 300 GHz	137	0.36	5.0

Table 6.3: Radiation level in E, H and S for General Public

Frequency Range (f)	Electric Field (E)	Magnetic Field (H)	Power Density (S) (E,H Fields)
	(V/m)	(A/m)	(mW/cm^2)
<1 Hz	—	3.2×10^4	—
1 - 8 Hz	10,000	$3.2 \times 10^4/f^2$	—
8 - 25 Hz	10,000	4000/f	—
0.025 - 0.8 kHz	250/f	4/f	—
0.8 - 3 kHz	250/f	5	—
3 -150 kHz	87	5	2.0; 995
0.15 - 1 MHz	87	0.73/f	2.0; $20/f^2$
1 - 10	$87/f^{1/2}$	0.73/f	2.0/f; $20/f^2$
10 - 400 MHz	28	0.073	0.2
400 - 2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	f/2000
2 - 300 GHz	61	0.16	1.0

Frequency Range	Maximum Current (ma)	
	Occupational	General Public
<2.5 kHz	1.0	0.5
2.5 - 100 kHz	0.4f	0.2/f
100 kHz - 110 MHz	40	20

Frequency Range	Maximum Current (ma)	
	Occupational	General Public
10 - 110 MHz	100	45