SULTANATE OF OMAN
Planning Committee for
Development and Environment
in the Southern Region

سلطنة عمان
لجنة التخطيط للتنمية والبيئة
بالمنطقة الجنوبية

DHOFAR KHAREEF STUDIES
FEASIBILITY OF FOG & RAIN WATER COLLECTION AND GUIDELINES FOR PILOT PROJECTS

REPORT No.1

COLLECTION SCREEN

DESIGN

JUNE 1990

COWIconsult
Consulting Engineers and Planners

كوي كونسلت
استشارات هندسية وتخطيط

CONTENT

1. INTRODUCTION

During the 1990 Khareef season, a comprehensive fog and rain water collection programme will be carried out by TS-PCDESR assisted by a team of consultants from Cowiconsult. The programme is a follow-up to the previous years experimental work, which was started in 1985. The 1989 research and development programme made it possible to draw a number of conclusions about the possibility of collecting significant amounts of water by appropriate siting of collecting screens. It was further demonstrated, that vegetation (trees) collect amounts of water which exceeds their consumptive use. The results and interpretations of the experiments done, fully justify a further development of the fog collection technique and testing of principles and designs at a full scale, and holds promise for a contribution to the development of the Jebel Qara area.

The present report deals with the design of collectors. The objectives of the design work are stated and requirements and design basis are outlined. Finally the designs of three sizes of collectors are described as regards the underlying principles and ideas as discussed and tentatively agreed with TS-PCDESR staff.

The report is an interim report. The contents may later be included in the final report on the activities and outcome of the project.

2.OBJECTIVES AND DESIGN REQUIREMENTS

The objectives behind the design work done are to test a number of different designs as to their applicability in terms of fog water collection in the Jebel Qara environment. This environment has the characteristic of moderate to strong winds during the Khareef season, while the Shamal wind can be considerably more fierce. It is however less frequent. As construction and operation and maintenance work will have to take into account the remoteness of collection sites a robust design is desirable. A summary of the main design considerations and requirements is given below.

2.1 Main design requirements.

Having studied the environment, discussed principles with relevant experts and drawing on experience from earlier experiments and projects in the Jebel and in Chile (ref.1), we have arrived at the following main requirements:

-Collection efficiency. In the design context (assuming a given suitable site) efficiency depends on mesh weave characteristics, mesh tension (avoiding ballooning) and gutter design. Loss of drops formed on the mesh must be avoided. Efficiency increases with wind speed, which means that the higher the mesh is positioned, the more water will be collected. A higher structure on the other hand, increases cost. This leads to the next point of cost-efficiency.

-Cost-efficiency. Cost criteria such as low cost per unit of water produced, leads to requirements for a simple structural solution using materials of standard dimensions and local well known manufacturing and construction methods.

-Suitability for local contracting. The local contracting will make it possible to keep cost levels reasonably low. Further, the local contractors will acquire the necessary skills and expertise required in possible later large-scale development.

-Suitability for application of local materials. This again will be important for keeping the costs down and would simplify any necessary replacements during the operation and maintenance.

-Long lifetime of permanent part of collector. As the permanent part of the structure represents a major cost item, it has been deemed important to use durable materials.

-Simple operation and infrequent, easy maintenance. These are important success parameters as we envisage that semi-skilled labor will be in charge of the O & M during a possible later large scale development.

-Easy dismantling after Khareef. In order to apply a reasonably low design criteria as regards wind speed and thus keep cost down lowering of the structure after the Khareef should be easy and removal of mesh should be possible.

-Easy transport. The accessability of potential sites may be difficult and require relatively small trucks. In addition transport on small trucks will be an important factor in keeping the costs down. Further, avoiding traffic by very heavy vehicles outside roads will be an advantage from an environmental point of view.

-Manageability. The general manageability in terms of handling of components during transport and at site has also been a requirement. Loading/unloading by hand and lowering and erection of the permanent structure without using special equipment has been emphasized.

In general a design wind speed of 50 m/s or 100 m.p.h. is recommended for structures in this area. This figure is believed to correspond to a 50 year return period and covers the whole year (including the Shamal winds). As the collectors shall only function during Khareef and as they will be lowered or screen panels dismantled after the Khareef, a value of less the above can be adopted, thus keeping construction cost down. It is also taken into account that a structural failure will not present a danger to human life and that any repair costs will be relatively small.

A design wind speed of 25 m/s has been adopted. Reliable long term measurements of wind speeds have not been made in the Jebel area. Qeiroon Heiritti data are influenced by the location of the anemometer on top of a building and does not allow a statistical analysis due to the relatively short record.
It is also taken into account that collector sites will be located where orographic effects create local high wind speeds, for instance the Fohen effect.
Local experience seem to suggest mean wind speeds during the Khareef of more than 10 m/s. We estimate a 5-year wind speed to be in the order of 15 to 20 m/s. Allowing for orographic effects and taking into account that the design should be potentially applicable at all points of the Jebel area we adopt 25 m/s as the design wind speed with an estimated recurrence interval of 5 years.

3. DESCRIPTION OF COLLECTOR DESIGN

3.1 General aspects

The collectors have generally been designed according to the design requirements as summarized in Section 2.1. The purpose of the designs is to test the applicability of various design options and at the same time gain experience on construction of such structures in the Jebel area. Various sizes of collectors have been selected to test the manageability. In addition these sizes allow a comparison of the collection efficiency of collectors with different ratios between height and width.

Thus we have designed three collectors of nominal sizes of 4 by 4 meters, 4 by 8 meters and 4 by 12 meters. The major design options concern alternative ways of fixing the columns to the base, alternative gutter shapes and material and alternative ways of attaching the mesh to the columns. The details of the design and the drawings are found at the end of the report for the three different sizes and types of collectors respectively.

3.2 Collector 1, four by four.

The collector is designed to test the suitability of attaching the mesh to the columns by rolling it around the column. The end of the mesh is initially attached by a tape or by placing it under a flat iron bent to shape and screwed on to the column. This arrangement allows the attaching of the net to be made in the workshop and an easy transport to site of two columns with the mesh rolled up. At site a round starter column (base) allows the screen to be tightened by rotating the top column. A swivel arrangement, where the stay wires are attached makes such rotation possible.

The gutter design is a PVC pipe from which a section of 90 degrees has been cut out. The pipe is attached to the lower net tension cable.

The screen to be used is a double layer of Tildenet PVC mesh with a coverage of 47%. This screen material has been tested in earlier experiments and has shown good collection efficiency.

An important feature of the design is the telescopic design of the base allowing for adjustments to be made according to variations in ground level at the site.

3.3 Collector 2, four by eight.

This collector is designed as a rigid frame with the screens arranged in removable panels. This design allows the main frame to be left in position over the whole year, while the panels are dismantled after the Khareef.

The individual panels are made with different frame designs. Four different designs have been made in order to test the practicability of transport and attachment to the main frame. One panel is made with a frame of plain steel 16 mm reinforcement bars and the mesh is sewn to the frame. The panel is hooked on to the main rigid frame. Another panel, which will be tested, is made of angle steel with netting attached by placing it between the steel angle and a 2 mm flat plate bolted to the angle. The panel is hooked on to the main rigid frame. These two panels will i.a. give experience on how easy it will be to handle panels of this weight and size.

A third panel design has a telescopic arrangement allowing it to be reduced to approximately half width during transport and handling. The mesh is sewn to the frame.and the panel can be hooked to the rigid main frame. The fourth panel is based on the principle of rolling the mesh around two iron bars. The mesh is either initially attached to the bar by tape or by placing it between the bar and a flat iron bent to shape and screwed to the bar. The bars are fixed to the rigid frame by hooking them on pegs welded to the main frame.

The gutter design is a 2/3mm steel plate bent to shape and attached to the lower member of the rigid main frame.

The screen to be used is a double layer of Tildenet PVC mesh with a coverage of 47%.

An adjustable design of the base allows for corrections according to ground level variations. Further, the design allows the frame to be lowered and erected by pivoting the columns around a bolt in the base structure.

3.4 Collector 3, four by twelve.

This collector is designed to test the suitability of attaching a large net to the columns by sewing or by using special clips. It is designed to test the manageability of the rather large dimension columns. It is further tested if the tension cables in combination with the method of mesh attachment will be able to keep the mesh from ballooning to a degree where collection efficiency is reduced. The base makes adjustments according to ground level variations possible and lowering and erection of the structure is done by pivoting of the columns around a bolt in the base structure.

The gutter design is a 2/3 mm steel plate bent to shape and cut in 2 m sections to allow for movement of the gutter to follow the curvature of the screen under the wind pressure.
The mesh type to be used is a double layer of Tildenet PVC mesh with a coverage of 47%.

The tension cables can be stretched by turnbuckles and are attached to the ground via the anchors of the stay cables.

4. MONITORING OF DESIGN SUITABILITY

4.1 General aspects

As one of the purposes of the design and construction exercise is to gain experience on the suitability of the design in relation to the requirements as summarized in Section 2.1, it is worthwhile considering how monitoring of compliance with these requirements will take place. The results of the monitoring process will be incorporated in the final report on the study and appropriate design modifications and recommendations will be made.

4.2 Monitoring and accumulation of experience

Below we go through the design requirements one by one and state which efforts we will make to monitor the performance in relation to these requirements.

-Collection efficiency. During the visits to the main site it should be checked to which degree ballooning takes place and if it results in loss of drops falling outside the gutter.Wind speed will be recorded during the observation. Tension of mesh may be increased, but a certain amount of ballooning will always take place under wind pressure. The visual monitoring may lead to changes in gutter design or improvement of possibilities for tensioning of the screen mesh (for instance by adding extra cables). The form ratio (height to width) is another efficiency parameter which will be assessed through the comparison of the three sizes of collectors. Due to the dynamic behavior of the wind there is not a directly proportional relation between the size of screen and the collection rate. In practical terms this means that increasing the screen width to the double will not double the collection rate.

-Cost-efficiency. The construction cost of the different sizes of collectors will be extracted from the contractors quotations and if necessary supplemented by own cost estimates to give a standardized picture of the cost of each size. By comparing cost per unit of water collected the most cost efficient size of collector can be identified.

-Suitability for local contracting. The designs prepared are assumed to be suitable for local contracting. The adequacy of the construction work will show to which degree this is true.

-Suitability for application of local materials. The design has not implied the use of materials which are not available locally. However, during construction any appliance of non local materials will be recorded and if appropriate, design and specifications will be amended.

-Long lifetime of permanent part of the structure. Compliance with this parameter cannot be checked fully under this consultancy. However, signs of wear and tear shall be noted during field visits.

-Simple operation and infrequent, easy maintenance. Compliance with this performance parameter will be checked during the visits to the main site for which a record of maintenance will be made.

-Easy dismantling after the Khareef. The dismantling and the ease with which it can be done will be tested using the contractors staff under the supervision of the consultant. The number of persons and the use of any equipment not normally available in the area will be noted for future reference and used to assess the suitability of the various designs.

-Easy transport. The vehicle sizes required for transport to the site will be recorded.

-Manageability. The use of any equipment in addition to manual labor for loading/unloading, erection, lowering, fitting of mesh, replacement of damaged mesh etc. shall be noted and taken into account during the preparation of recommendations of design.

5. COST ESTIMATES

The materials and workshop costs can be estimated to some degree of accuracy, but the cost of work to be done at site is considerably more difficult to assess. This is due to the uncertainties about how much a contractor would generally add for difficult working conditions, transport to site and unforeseen site conditions. Further, the competetive situation and the contractor's present portfolio of jobs would influence his price.However, a rough estimate of fabrication costs would be between 150 and 200 Rials per collector depending on size. We would assume fabrication cost to be in the range of 30% of total cost. The total construction cost for three collectors would be expected to be in the range of 1500 to 2000 Rials.
Contractor's quotations are at the moment of writing underway and a separate presentation of the offers will be made.

References:

1. Proyecto Camanchacas-Chile. Informe Final 1 Fase. Junio 1989 Waldo Canto Vera. Departamento Tecnico, Corporacion Nacional Forestal, 4.Region, Chile

GENERAL NOTES

GENERAL NOTE

STEEL

- All steel to be galvanized and painted (incl. bolts).
  Paint system: Primer plus 2 coats of coal tar epoxy, total dry film thickness 150 micron.

- Reinforcement bars for panels should be epoxy coated or painted as above.

  (Due to both time and cost restrictions, this year the above two procedures are going to be avoided when building the 3 large fog water collectors proposed in this report.)

FOUNDATIONS:

- All concrete for foundations to be 1:3:6 mix

- Foundations for columns to be as shown on drawings. If 0.5 m depth of excavations can not be obtained due to existence of rock, then rock anchors shall be used as specified in Schedule 1.

- Foundations in soil for cables/wires shall be as shown in Schedule 2.

- Foundations in rock for cables/wires shall be as shown in Schedule 3.

CABLES:

Type 1: For tying the net:
Min. breaking strength : 5 KN

Type 2: For stabilising 4 x 4 Collector and outer columns of 4 x 8 Collector.
Min. Breaking strength : 10 KN

Type 3: For stabilising outer columns of 4 x 12 Collector.
Min. breaking strength : 12 KN

Type 4: For stabilising middle column of 4 x 8 and 4 x 12 Collectors.
Min. breaking strength : 15 KN

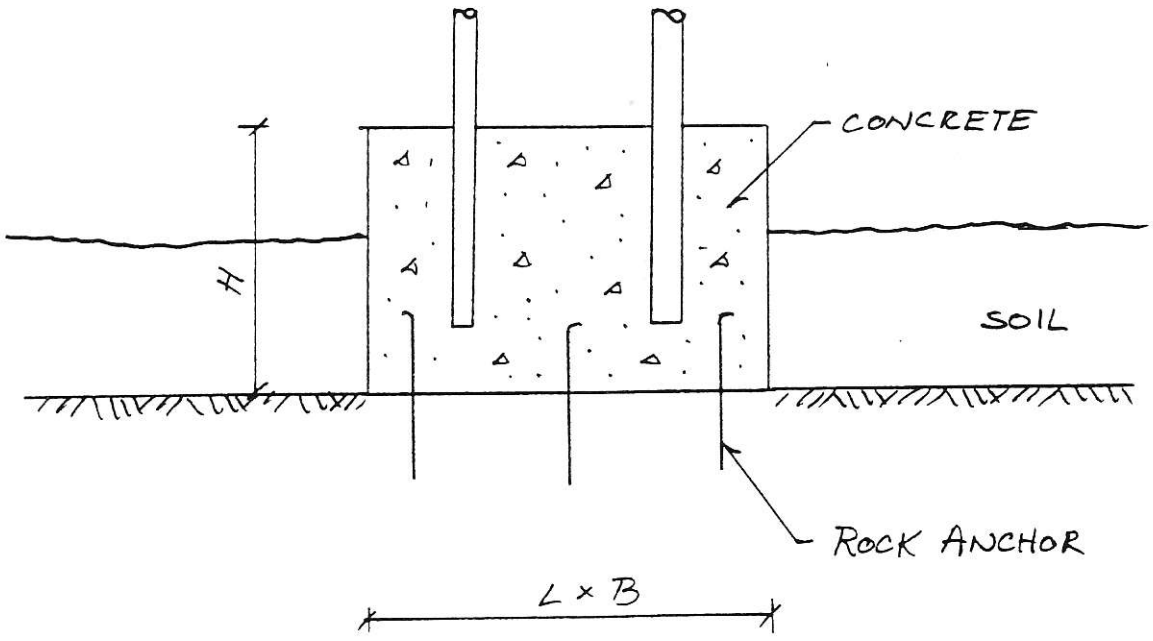
All cables/wires for stabilising columns shall be established under 45 deg. to horizontal.

SCHEDULE 1

Foundation for Columns in rock areas:

AT KN	Anchors Nos	l x b x h mm mm mm
0.5	3	800 x 800 x 500
1.0	2	800 x 800 x 400
1.5	2	800 x 800 x 300

Note: AT : Pull out strength of rock anchor.

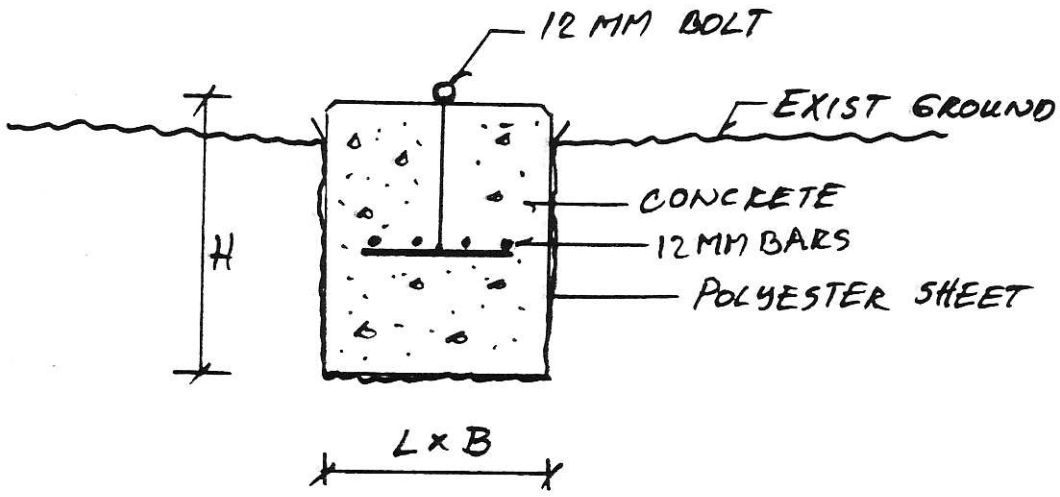


SCHEDULE 2

Foundation for cables/wires in soil.

Cable	Tmin	l mm	x	b mm	x	h mm
10	KN	700	x	700	x	1000
		800	x	800	x	800
		1000	x	1000	x	550
12	KN	700	x	700	x	1200
		800	x	800	x	1000
		1000	x	1000	x	650
15	KN	700	x	700	x	1400
		800	x	800	x	1150
		1000	x	1000	x	800

Note: Tmin = Min. strength of cable.

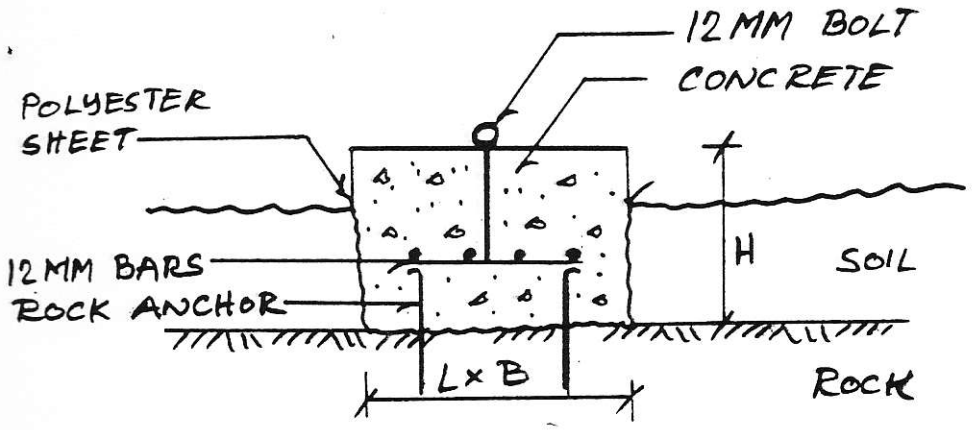


SCHEDULE 3

Foundation for cables/wires in rock

Cable Tmin KN	AT KN	Anchors Nos	l mm x b mm x h mm
10	0.5	2	950 x 950 x 400
	1.0	2	800 x 800 x 400
	1.5	2	700 x 700 x 400
12	0.5	3	950 x 950 x 400
	1.0	3	800 x 800 x 400
	1.5	3	700 x 700 x 400
15	0.5	4	950 x 950 x 400
	1.0	4	800 x 800 x 400
	1.5	4	700 x 700 x 400

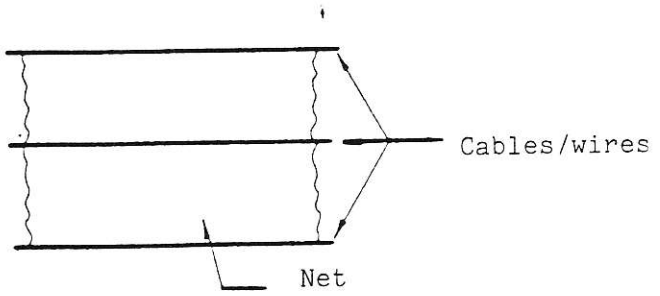
Note: AT = Pull out strength of rock anchor.
Tmin = Min. strength of cable.



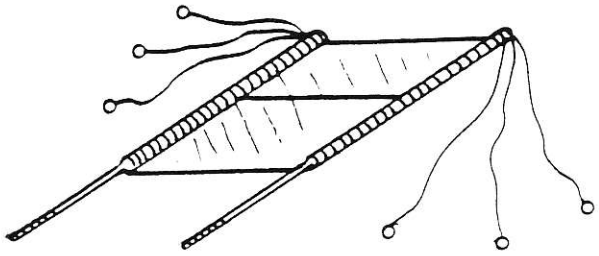
4 x 4 COLLECTOR

Workshop

1. Net prepared - cable/wire to be connected along top, middle and bottom.



- Cables/wire attached to columns via 3 holes, and net is rolled on tightly.



- Add cables to swivel ring so hanging loose

Site

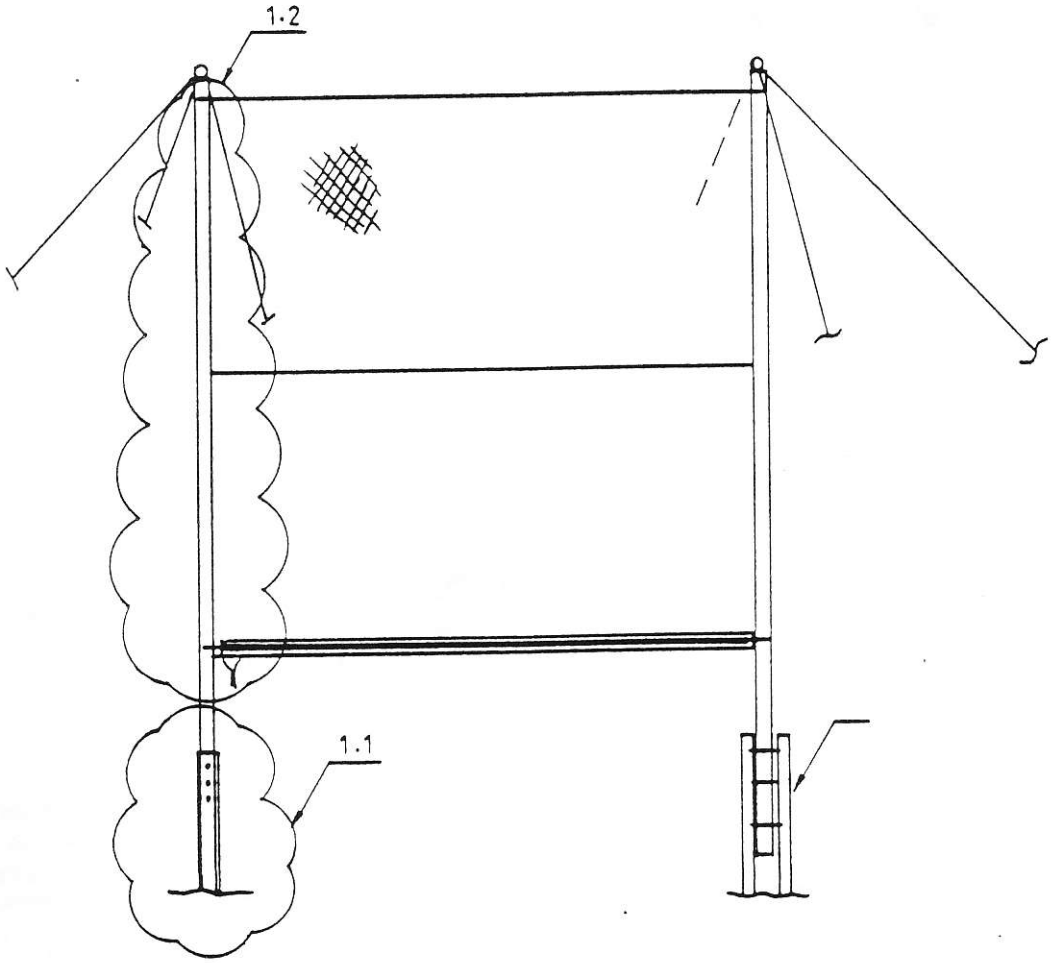
1. Cast in starter columns

2. Unroll netting so distance between columns equal distance between starter columns.

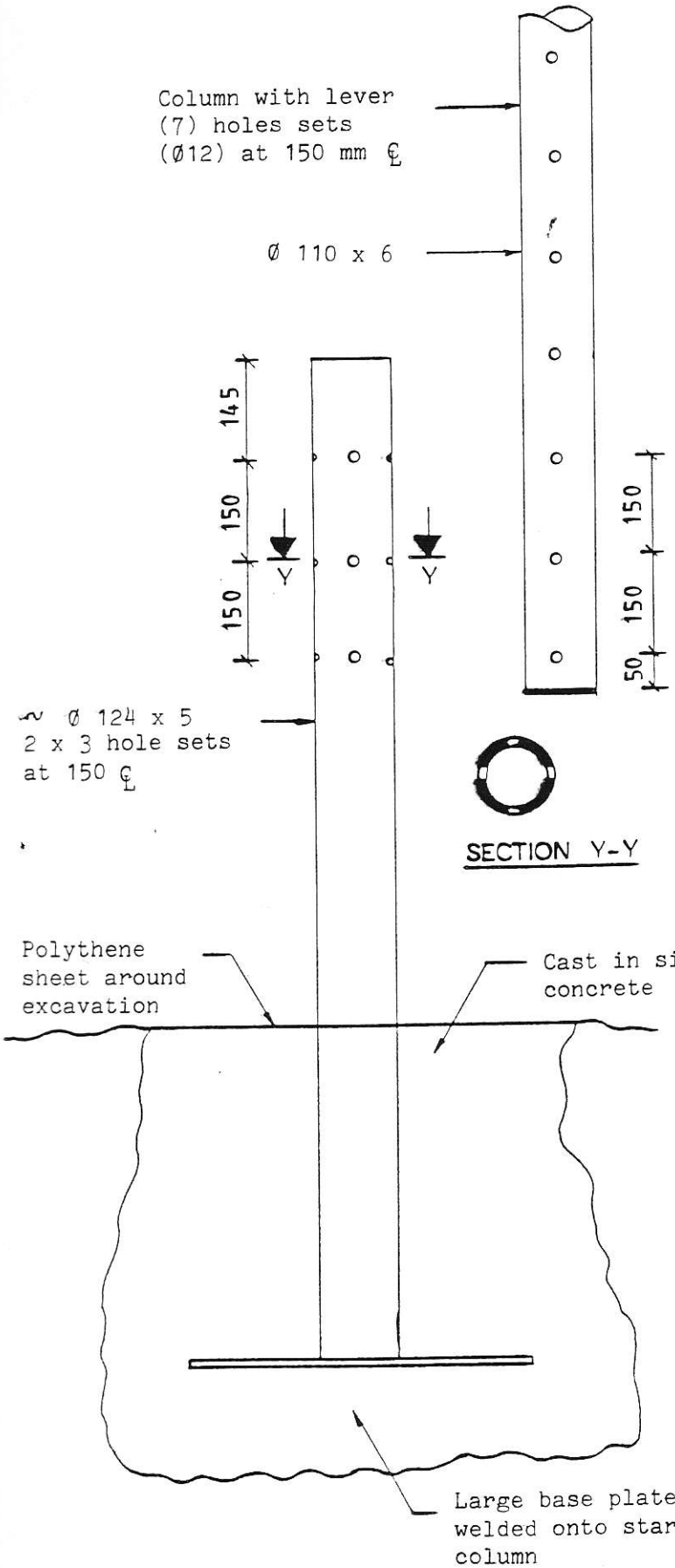
3. Place in starter columns.

4. By using a bar through one of the holes, as a lever, twin columns so netting tight.

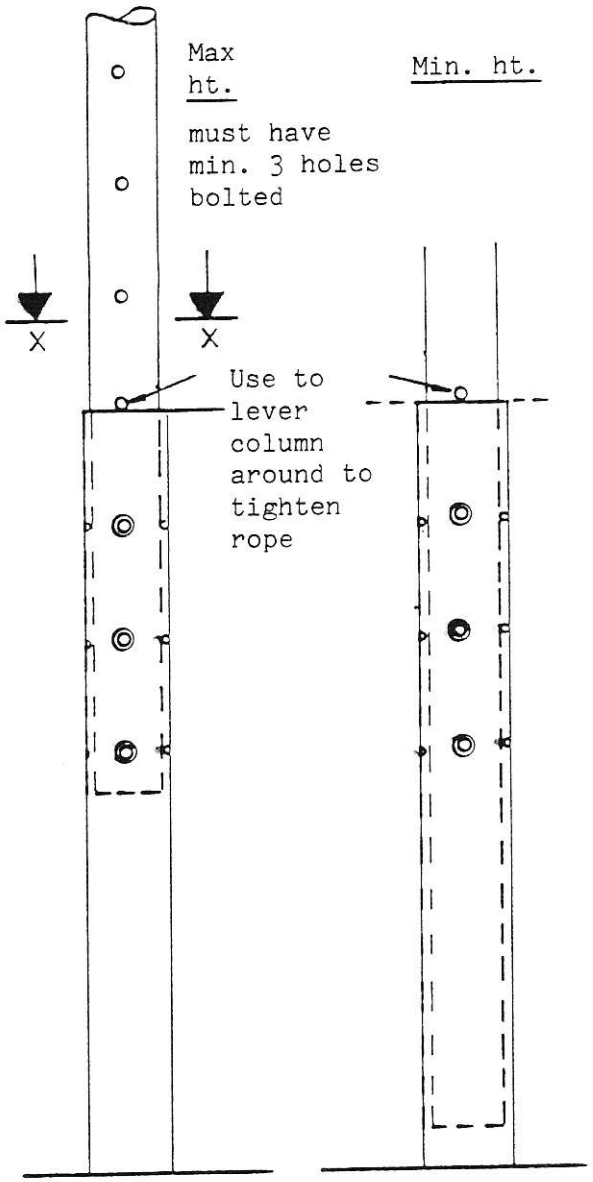
5. Connect/tighten cables to cast foundations, anchors so whole frame stable.

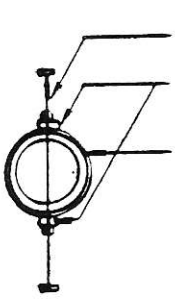

1.2
1.1

This solution enables the frame with the netting to be put into place and then tension added to the netting

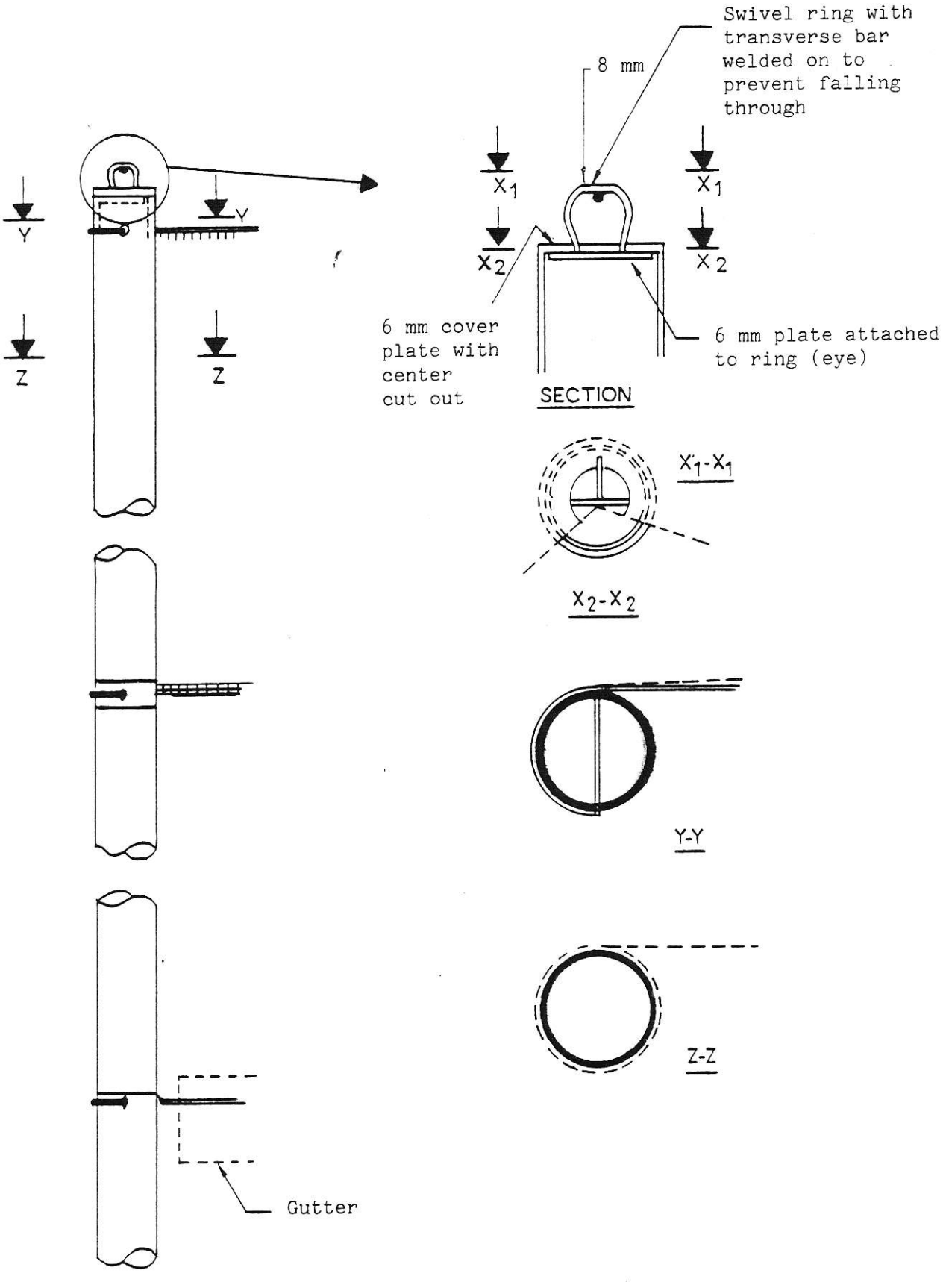


Possible to vary height of column by $\sim \frac{1}{2}$ m

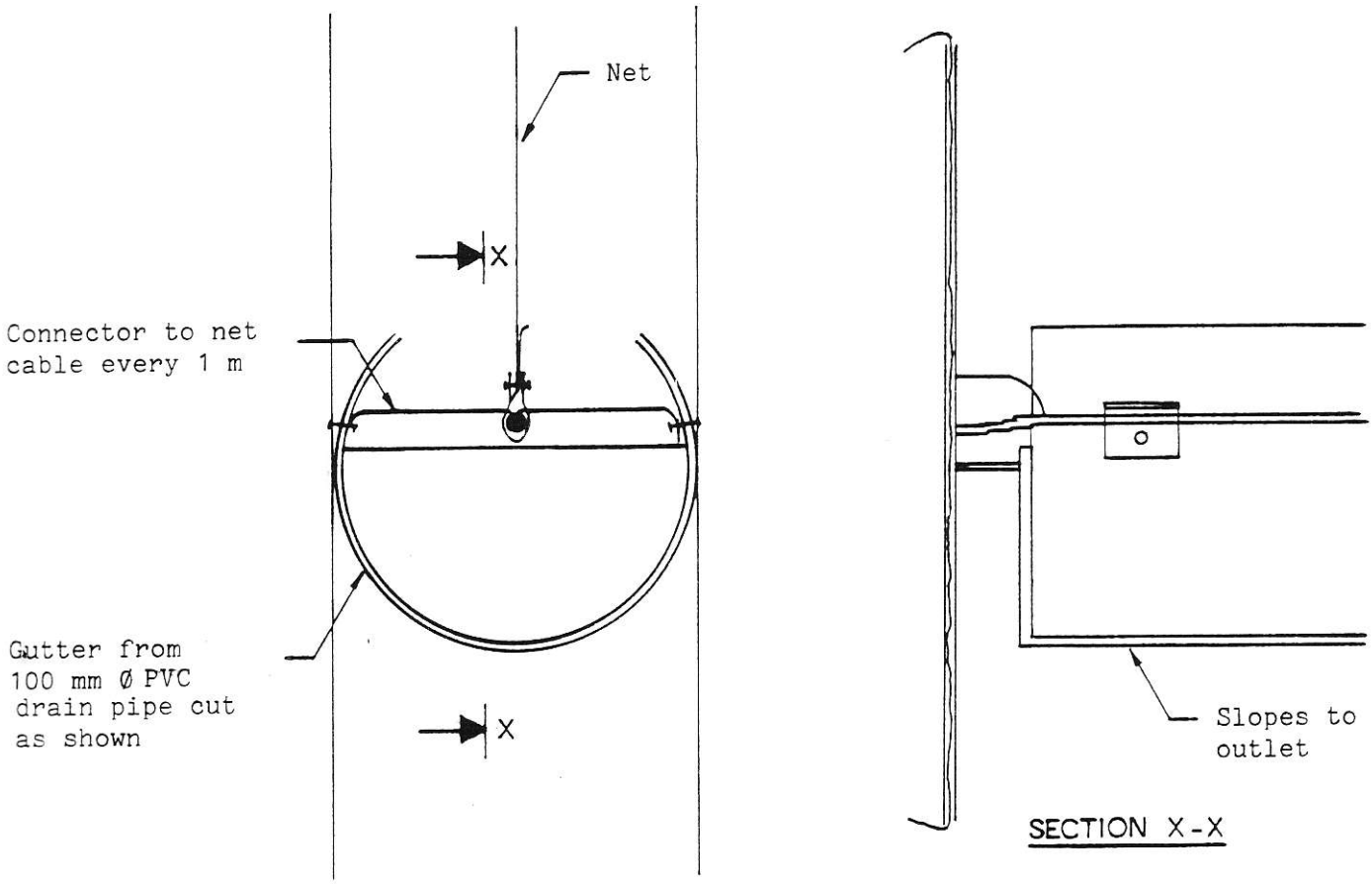




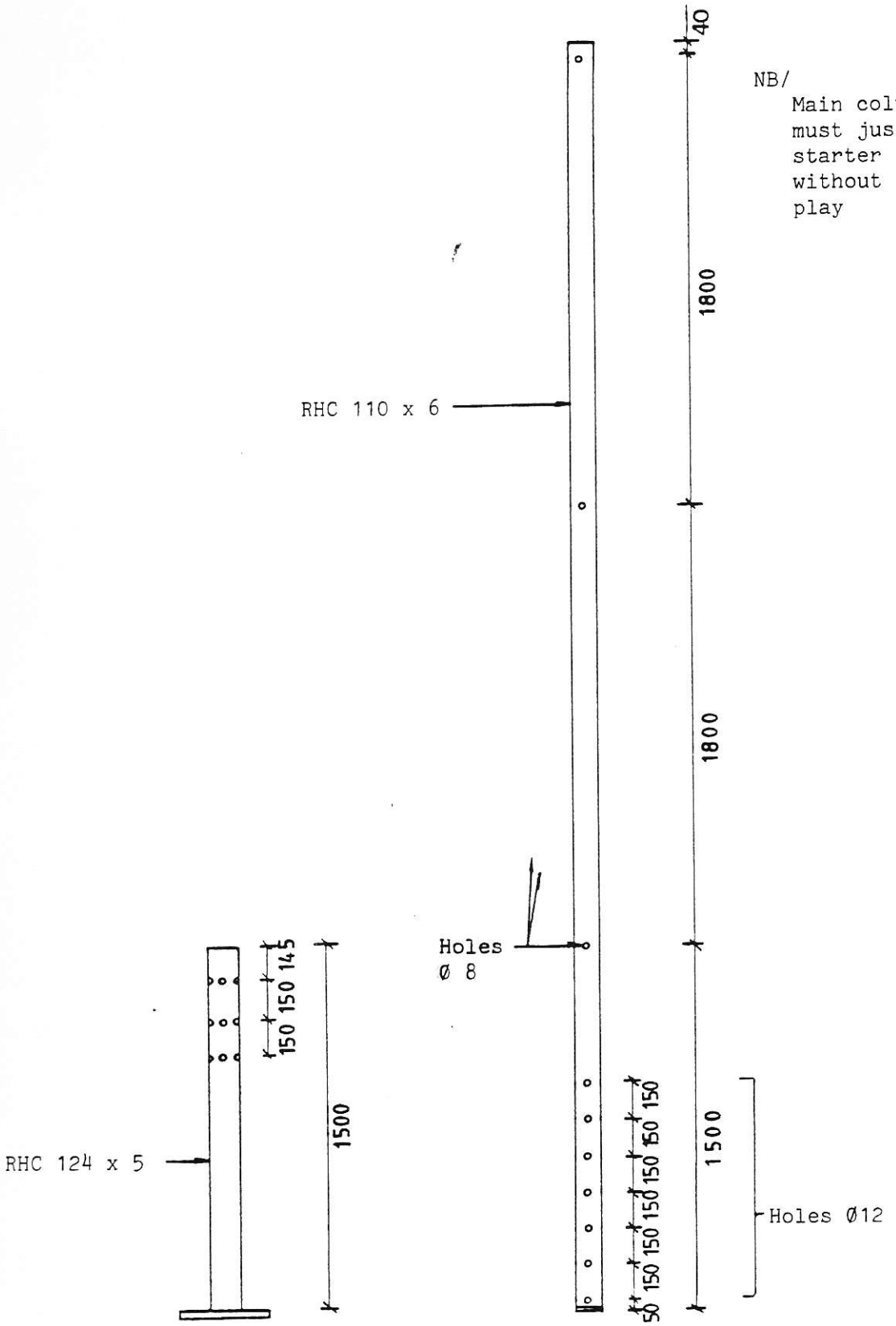
SECTION X-X



Cables for stabilizing not shown but to be attached to swivel ring/eye and pulled out.


Net
X
Connector to net cable every 1 m
Gutter from 100 mm Ø PVC drain pipe cut as shown
X
Slopes to outlet

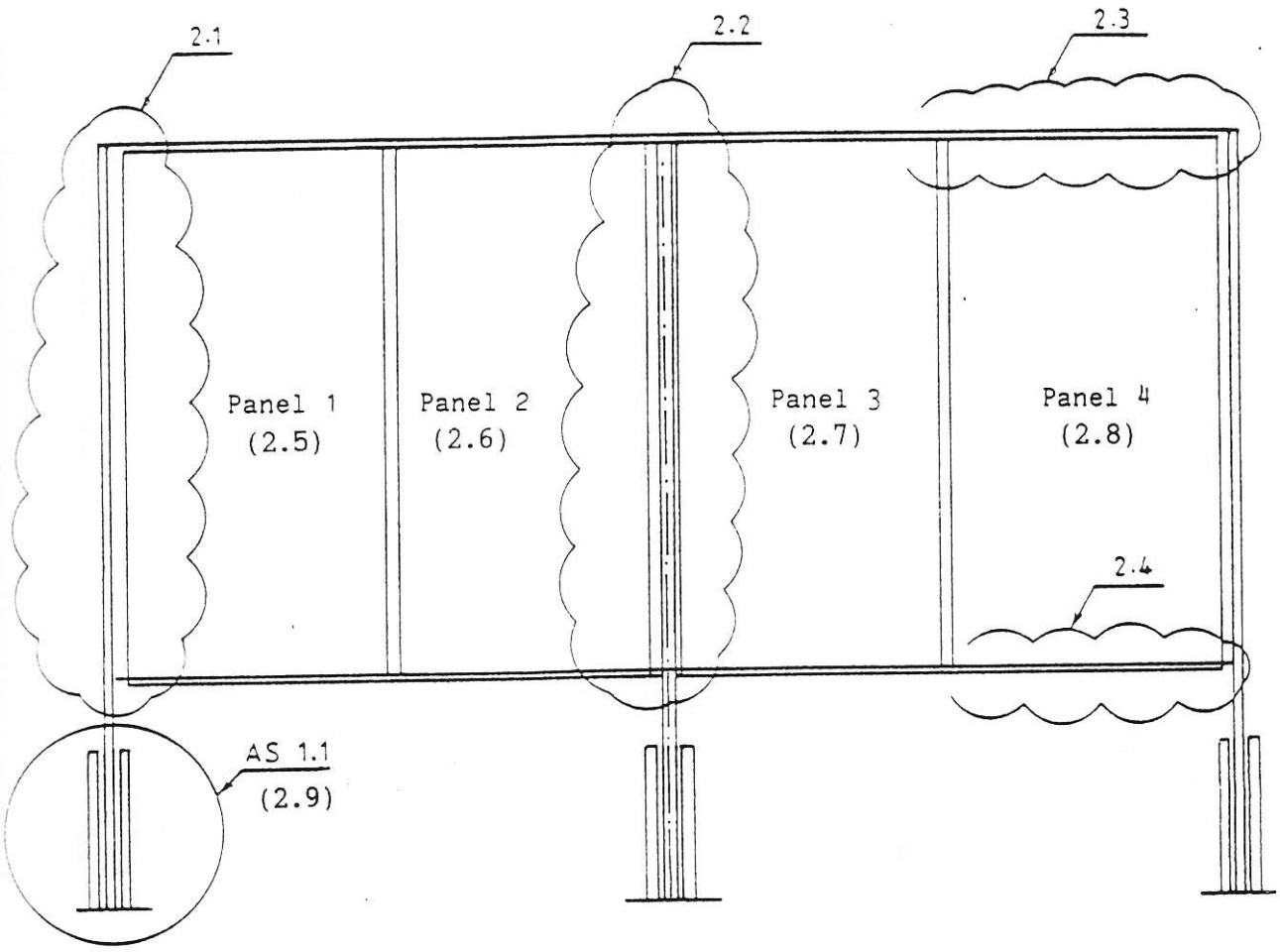
SECTION X-X

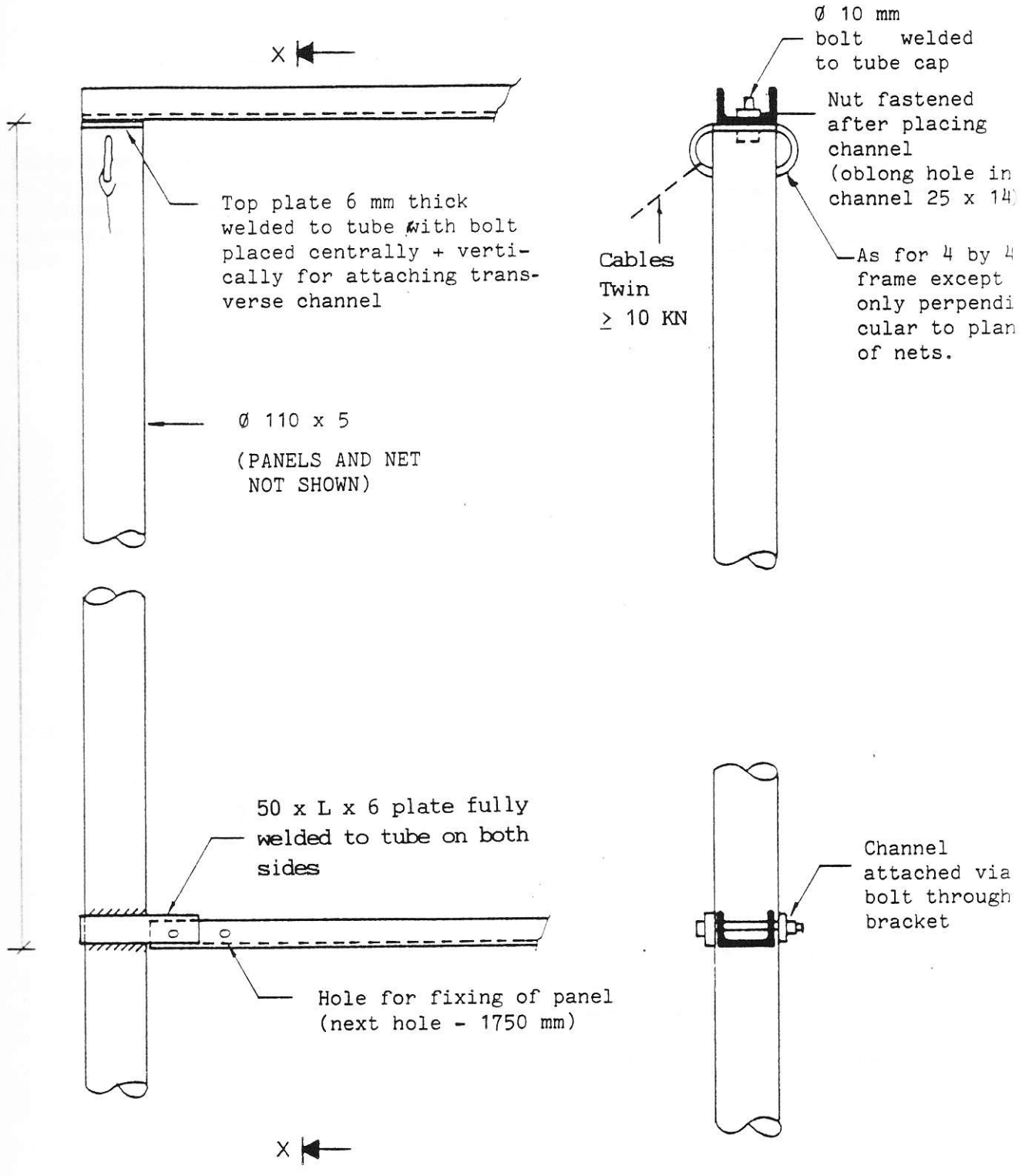


STARTER COLUMN - 1:25

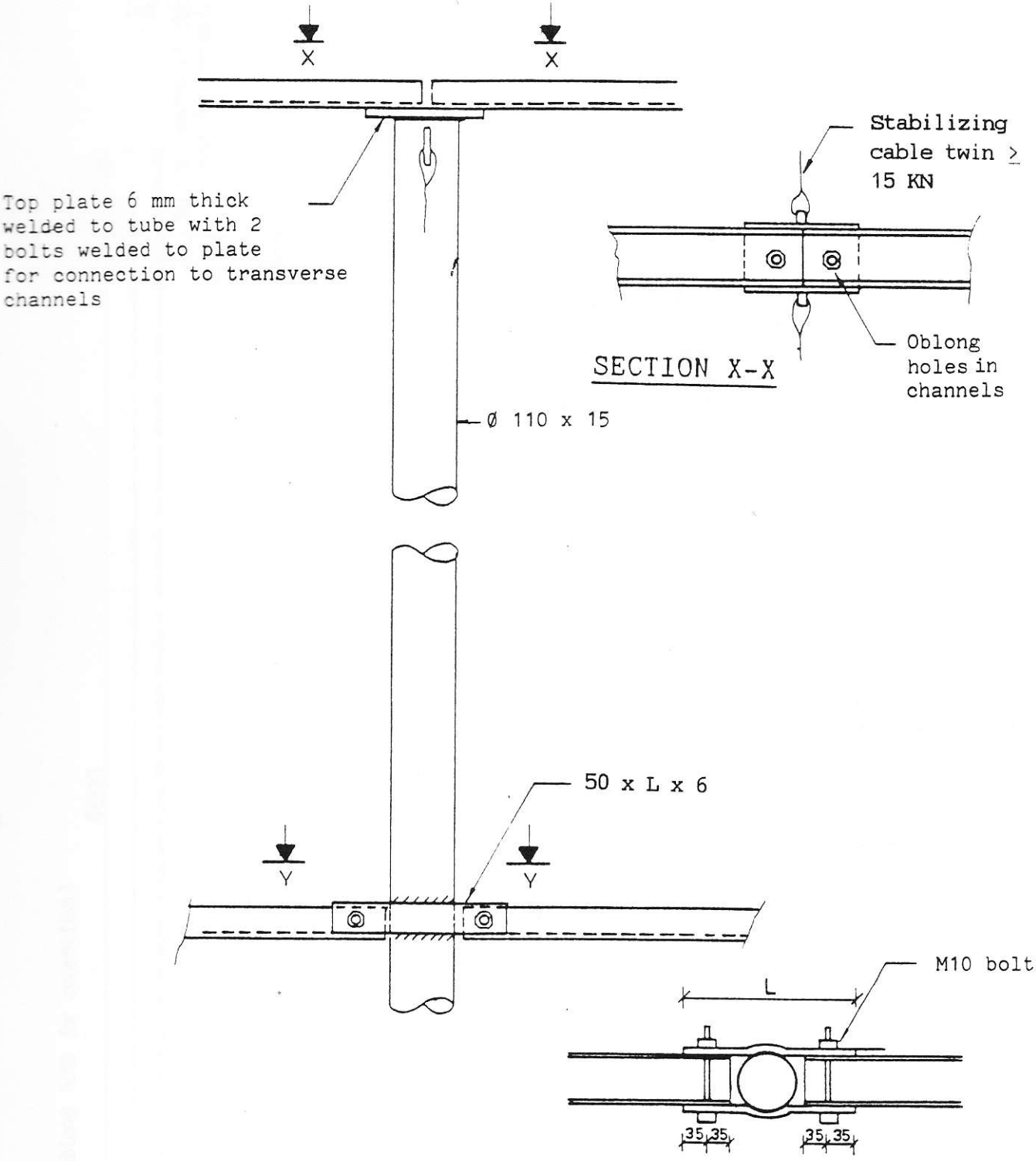
MAIN COLUMN - 1:25

4 x 8 COLLECTOR


2.1
2.2
2.3
Panel 1
(2.5)
Panel 2
(2.6)
Panel 3
(2.7)
Panel 4
(2.8)
2.4
AS 1.1
(2.9)

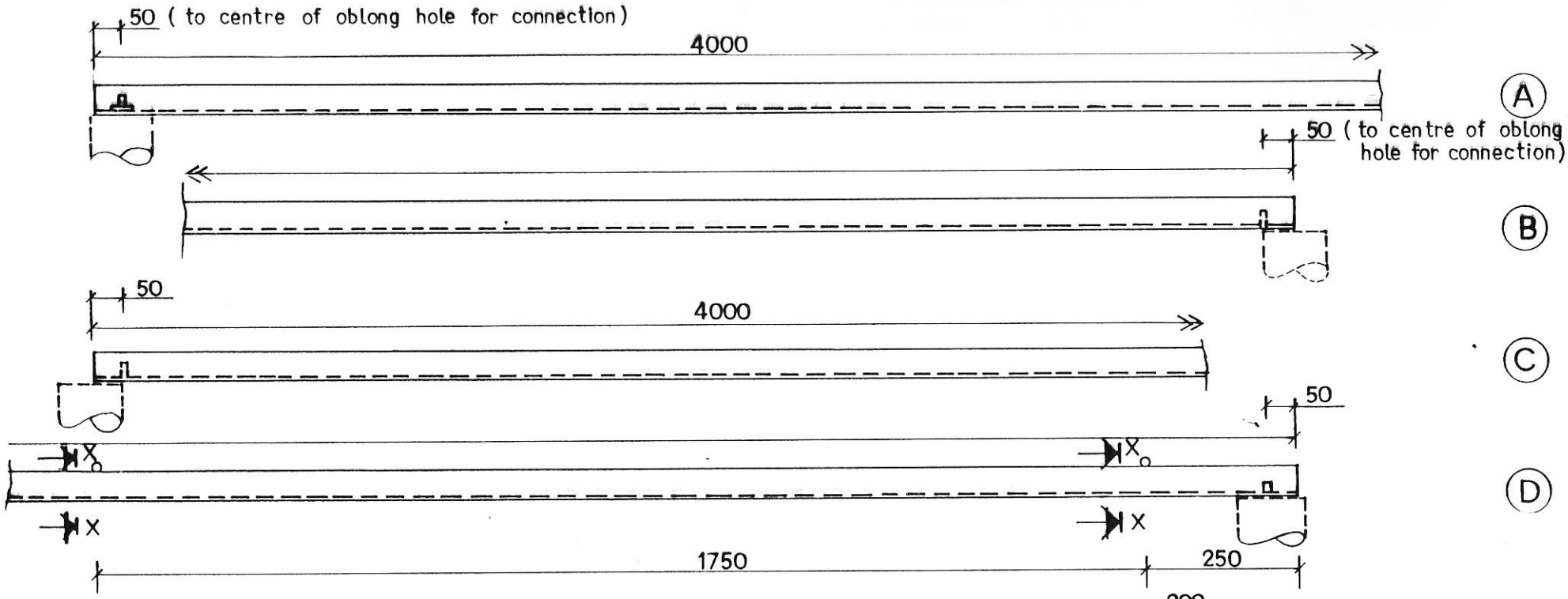

X
Top plate 6 mm thick welded to tube with bolt placed centrally + vertically for attaching transverse channel
Ø 110 x 5
(PANELS AND NET NOT SHOWN)
3500
50 x L x 6 plate fully welded to tube on both sides
Hole for fixing of panel (next hole - 1750 mm)
X
Ø 10 mm bolt welded to tube cap
Nut fastened after placing channel (oblong hole in channel 25 x 14)
Cables Twin ≥ 10 KN
As for 4 by 4 frame except only perpendicular to plan of nets.
Channel attached via bolt through bracket

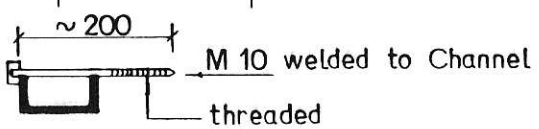
SECTION X-X



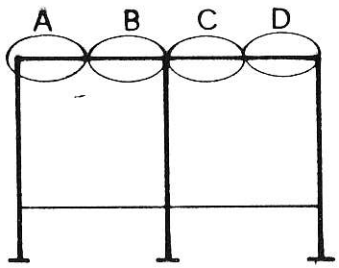
SECTION X-X

SECTION Y-Y



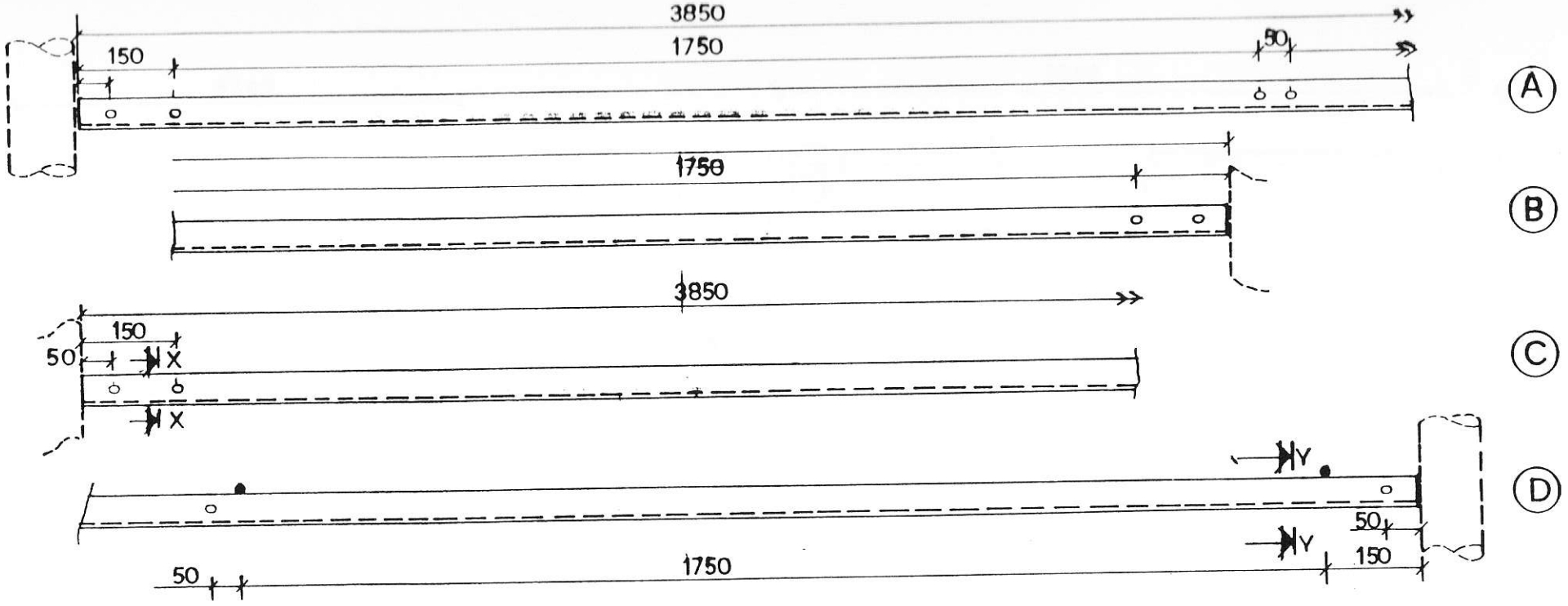


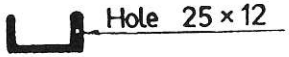
SECTION X-X



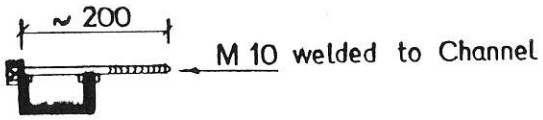
KEY

4×8 COLLECTOR



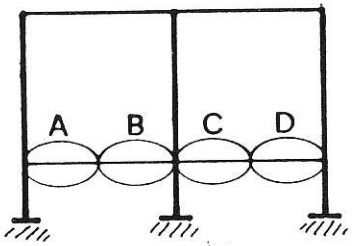


SECTION X - X



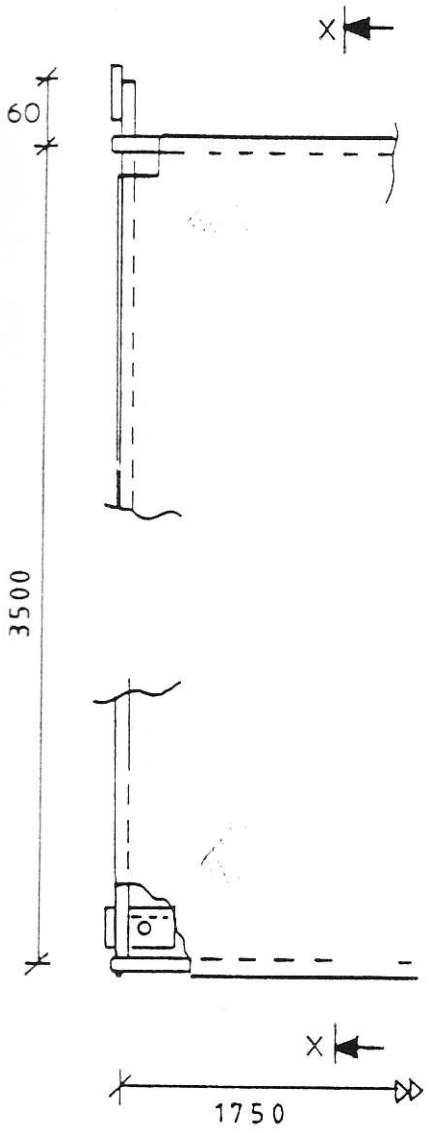
SECTION Y - Y

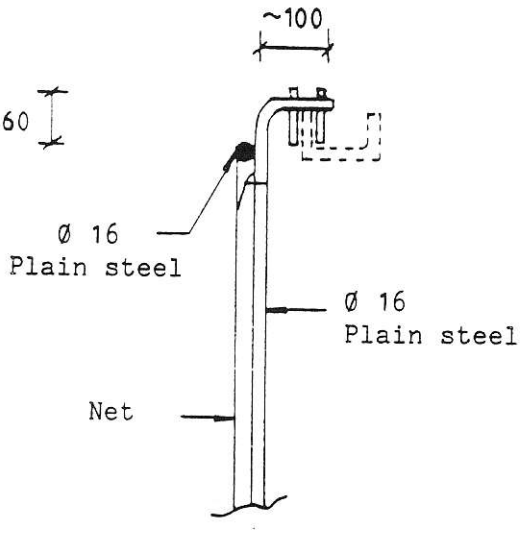
NB: Gutter fixing not shown
Only transverse members shown

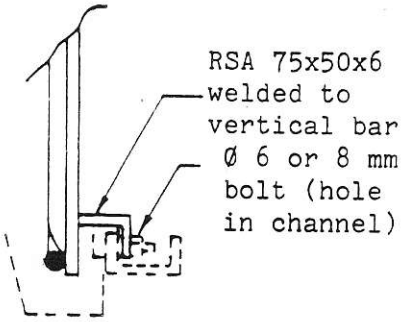


KEY

4×8 COLLECTOR

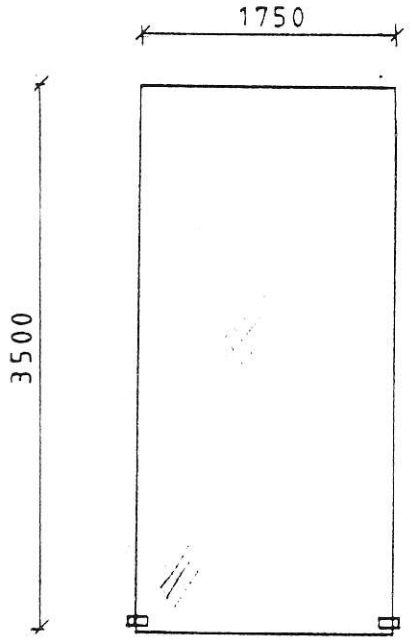




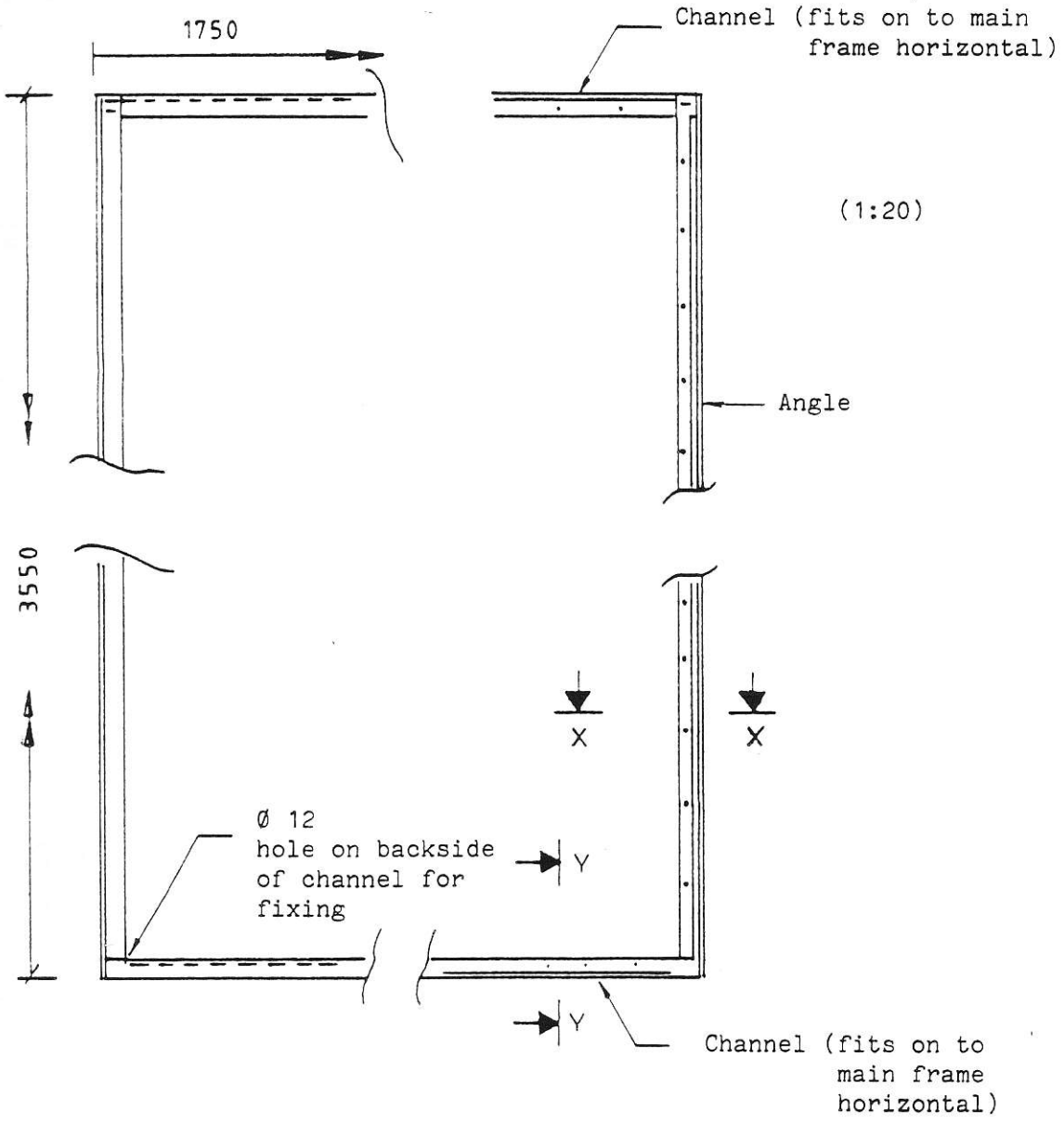


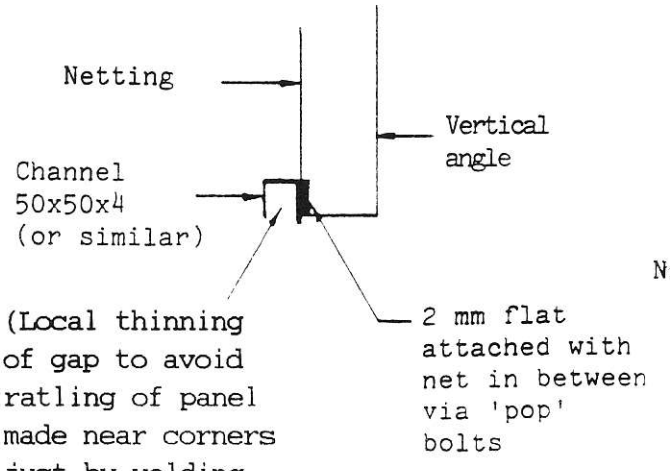
SECTION X - X

(1:10)



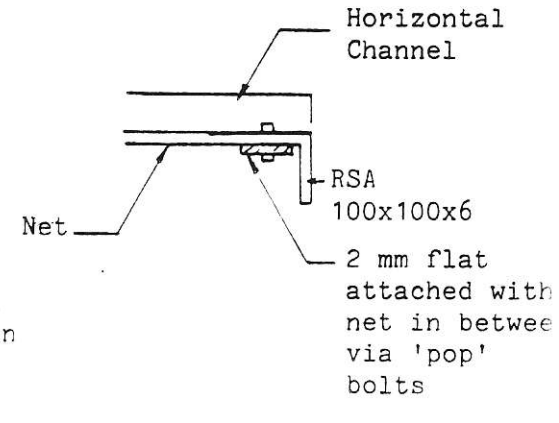
Frame (1:50)



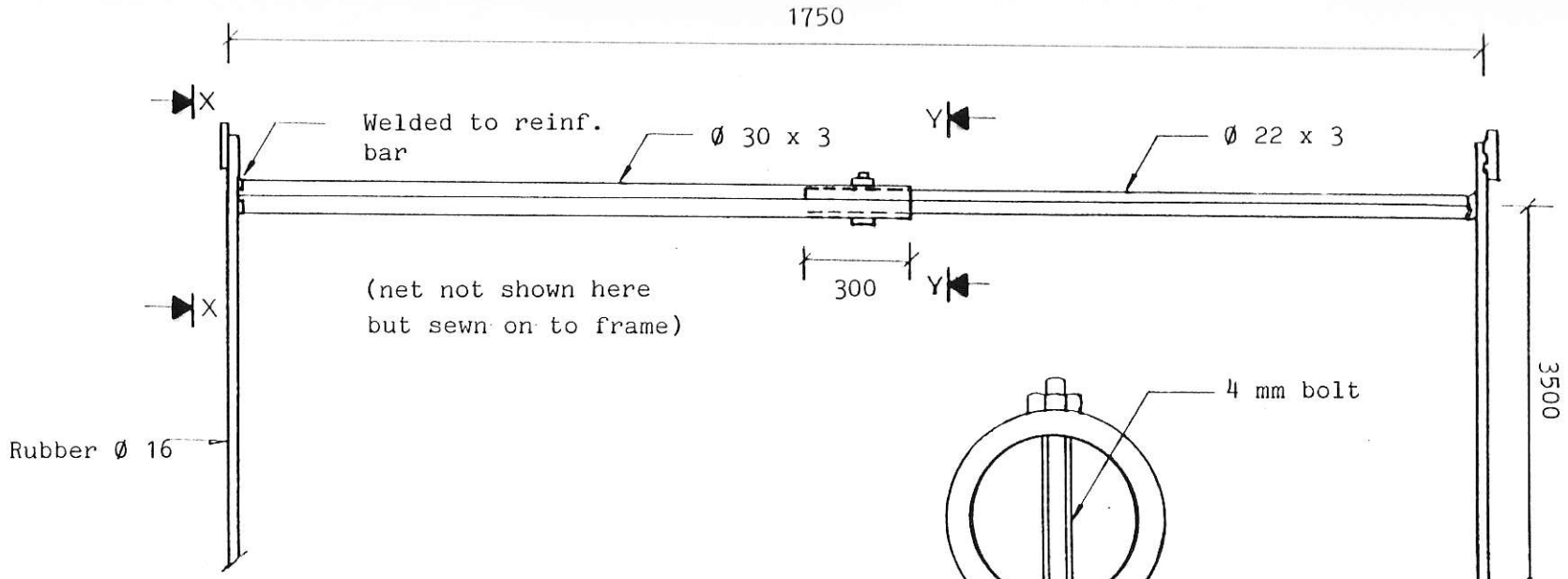


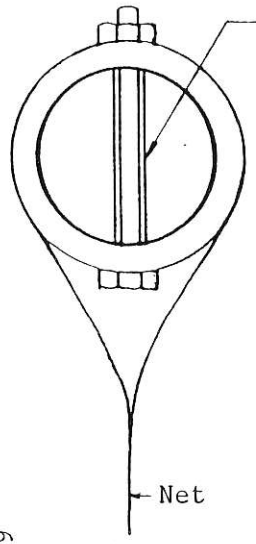
(Local thinning of gap to avoid ratling of panel made near corners just by welding two 16 mm 0 bars to each side top member only as bottom one is bolted)

SECTION Y-Y

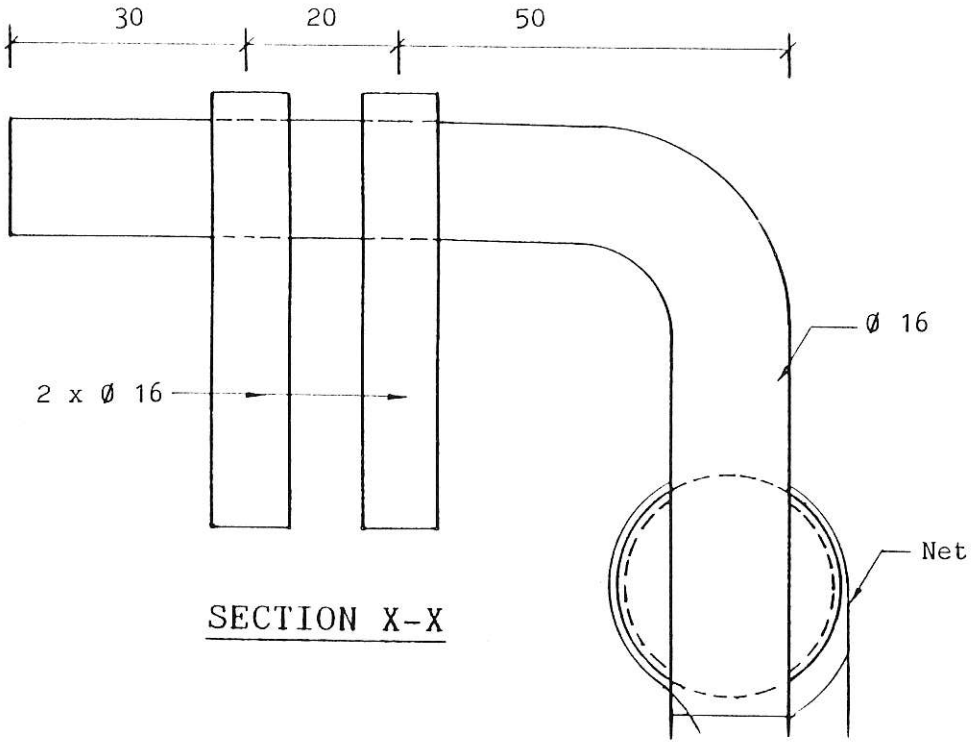


SECTION X-X

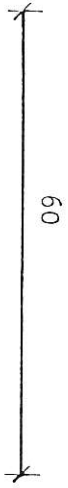




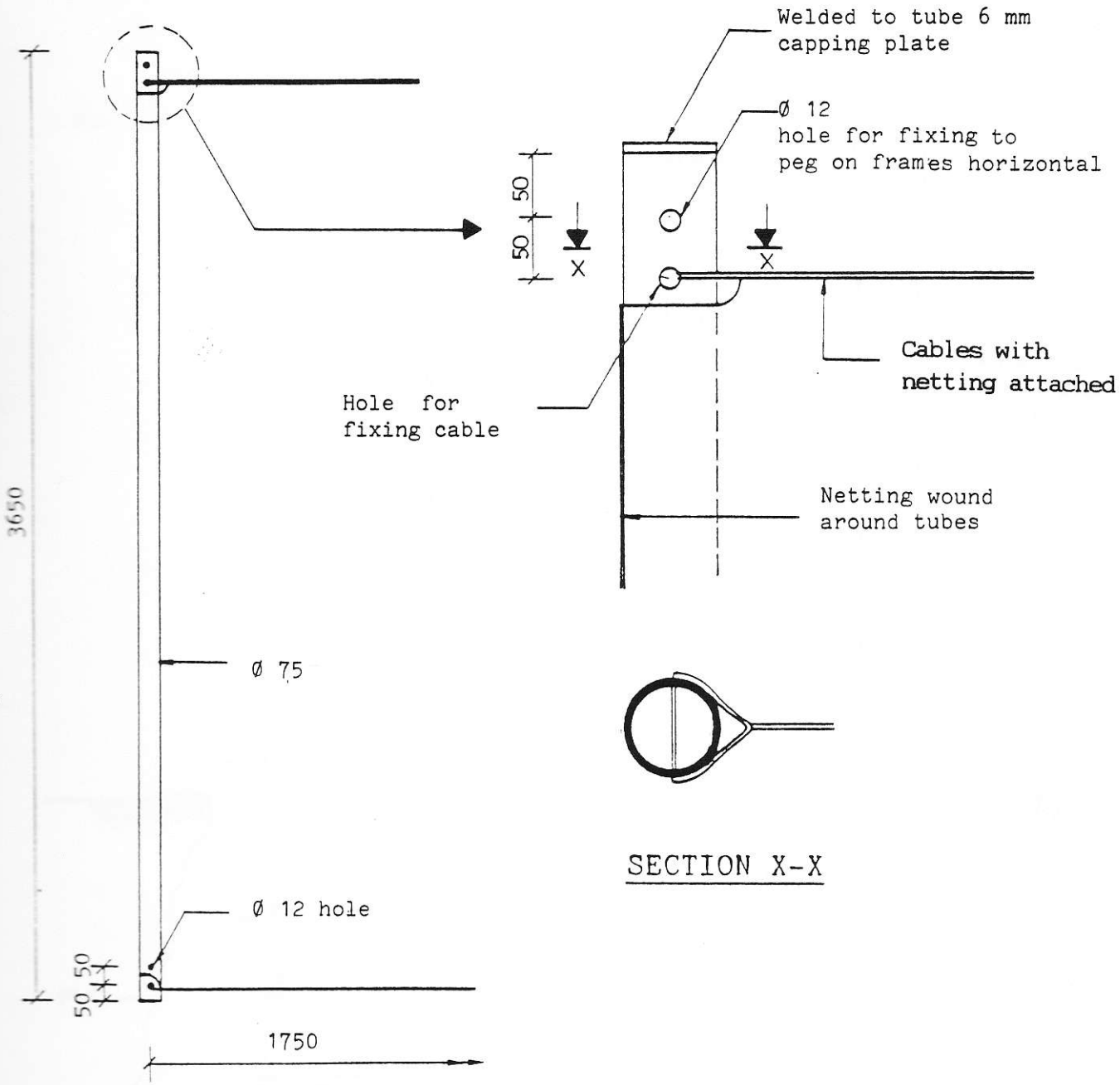
SECTION Y-Y



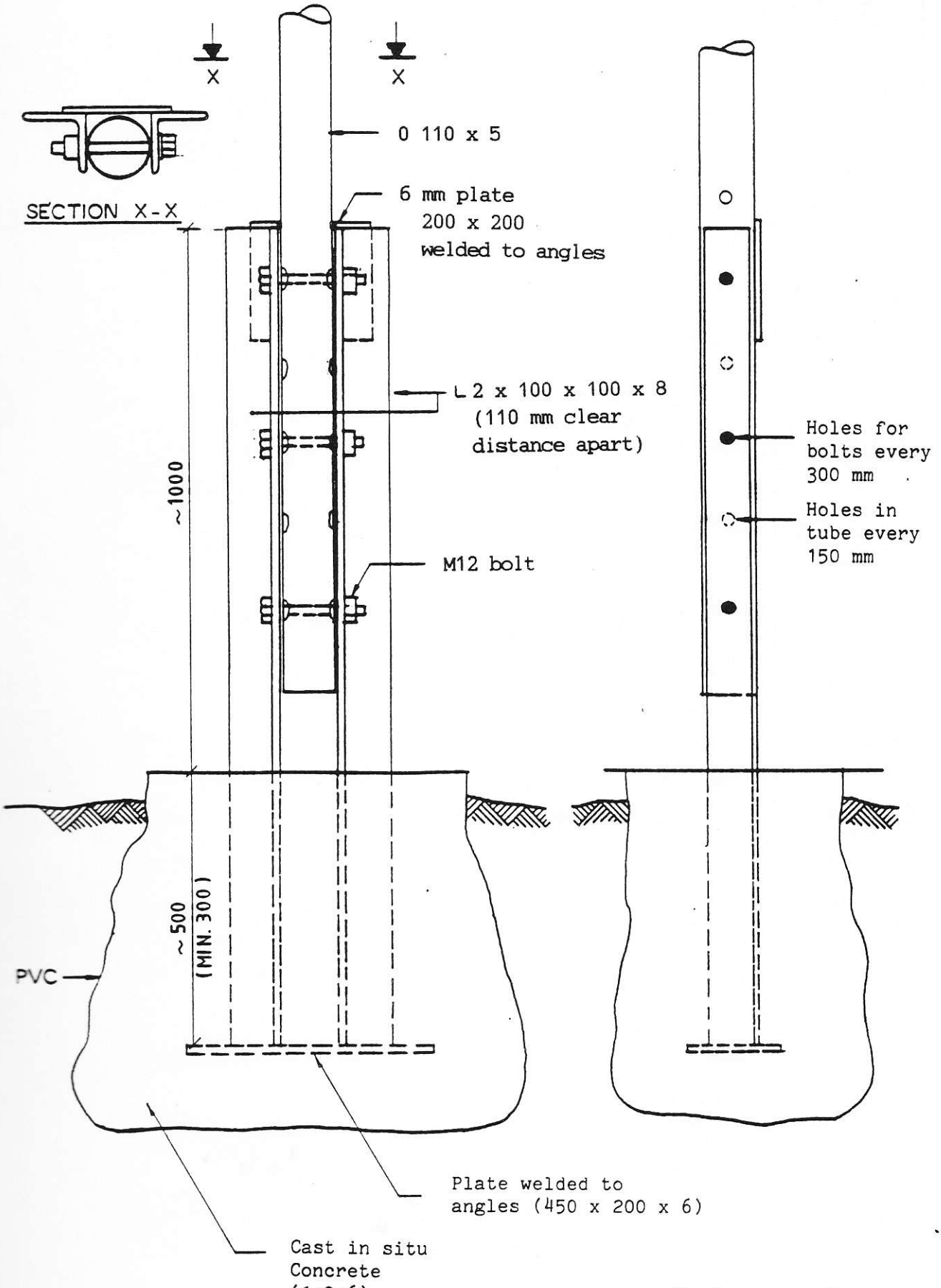
SECTION X-X



(1:20 and 1:1)

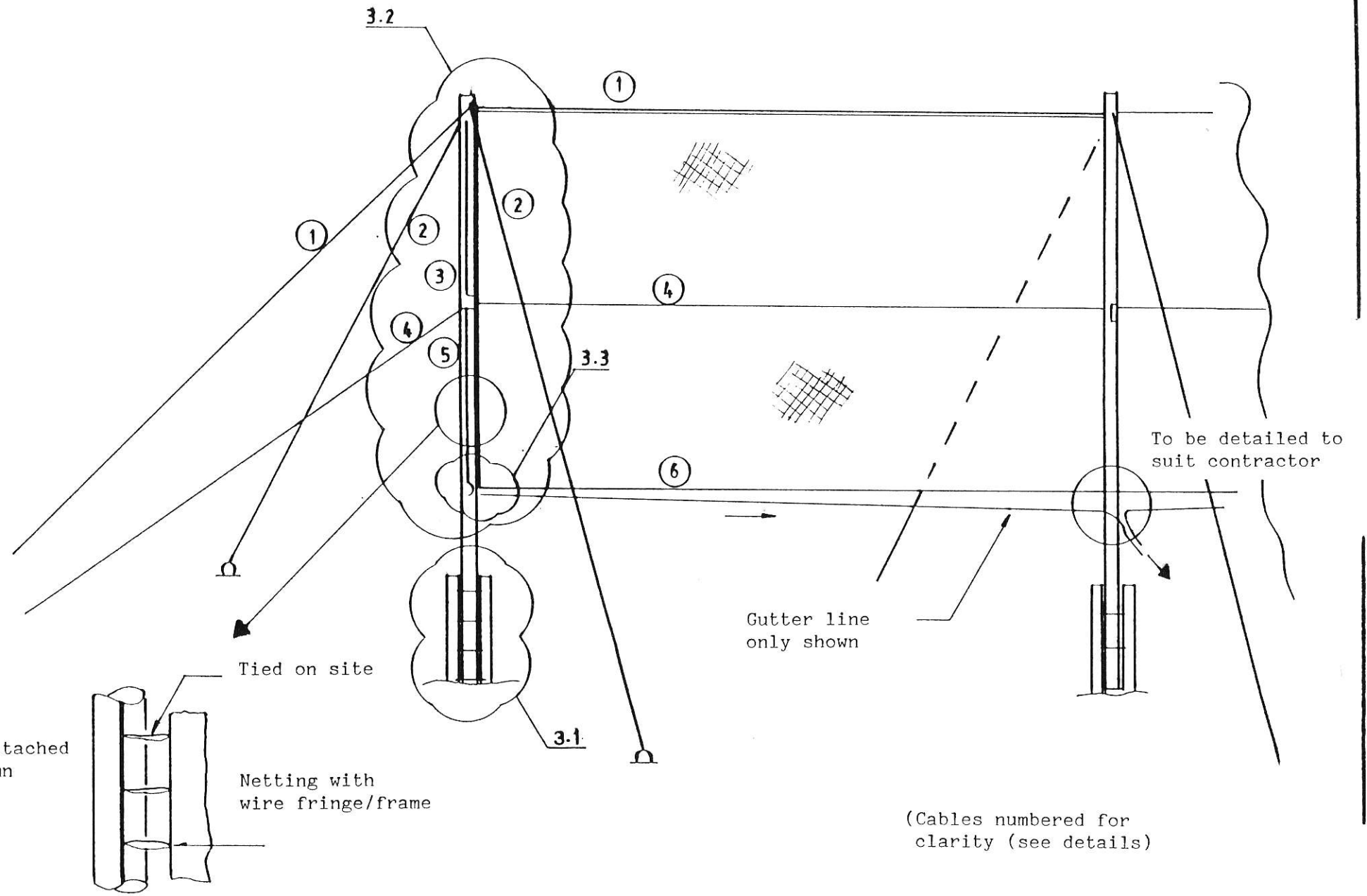

Welded to tube 6 mm
capping plate
Ø 12
hole for fixing to
peg on frames horizontal
50
50
X
X
Cables with
netting attached
Hole for
fixing cable
Netting wound
around tubes
3650
Ø 75
Ø 12 hole
50
50
1750

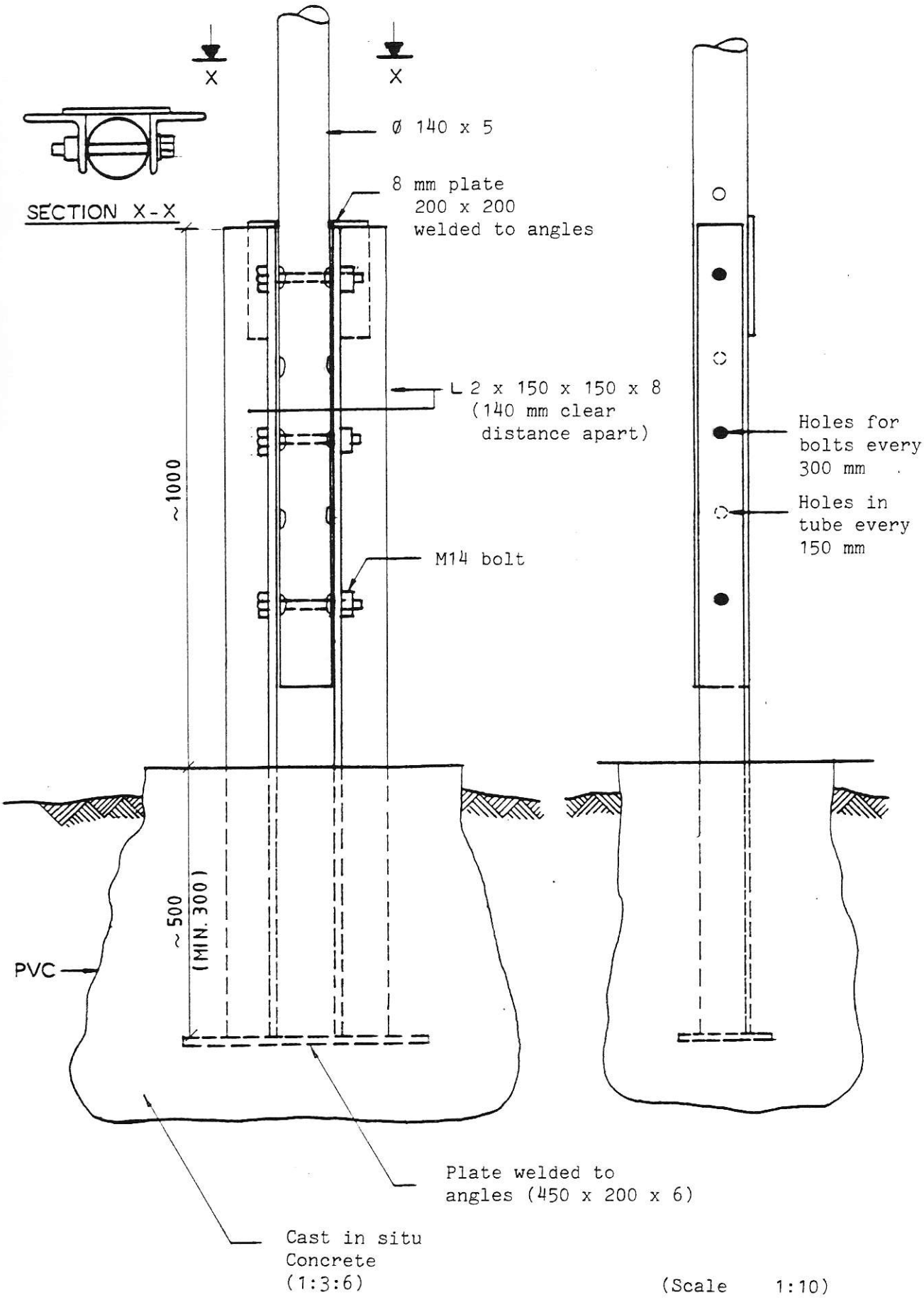
SECTION X-X


X
X
SECTION X-X
0 110 x 5
6 mm plate
200 x 200
welded to angles
L 2 x 100 x 100 x 8
(110 mm clear
distance apart)
~1000
M12 bolt
Holes for
bolts every
300 mm
Holes in
tube every
150 mm
~500
(MIN. 300)
PVC
Plate welded to
angles (450 x 200 x 6)
Cast in situ
Concrete
(1:3:6)

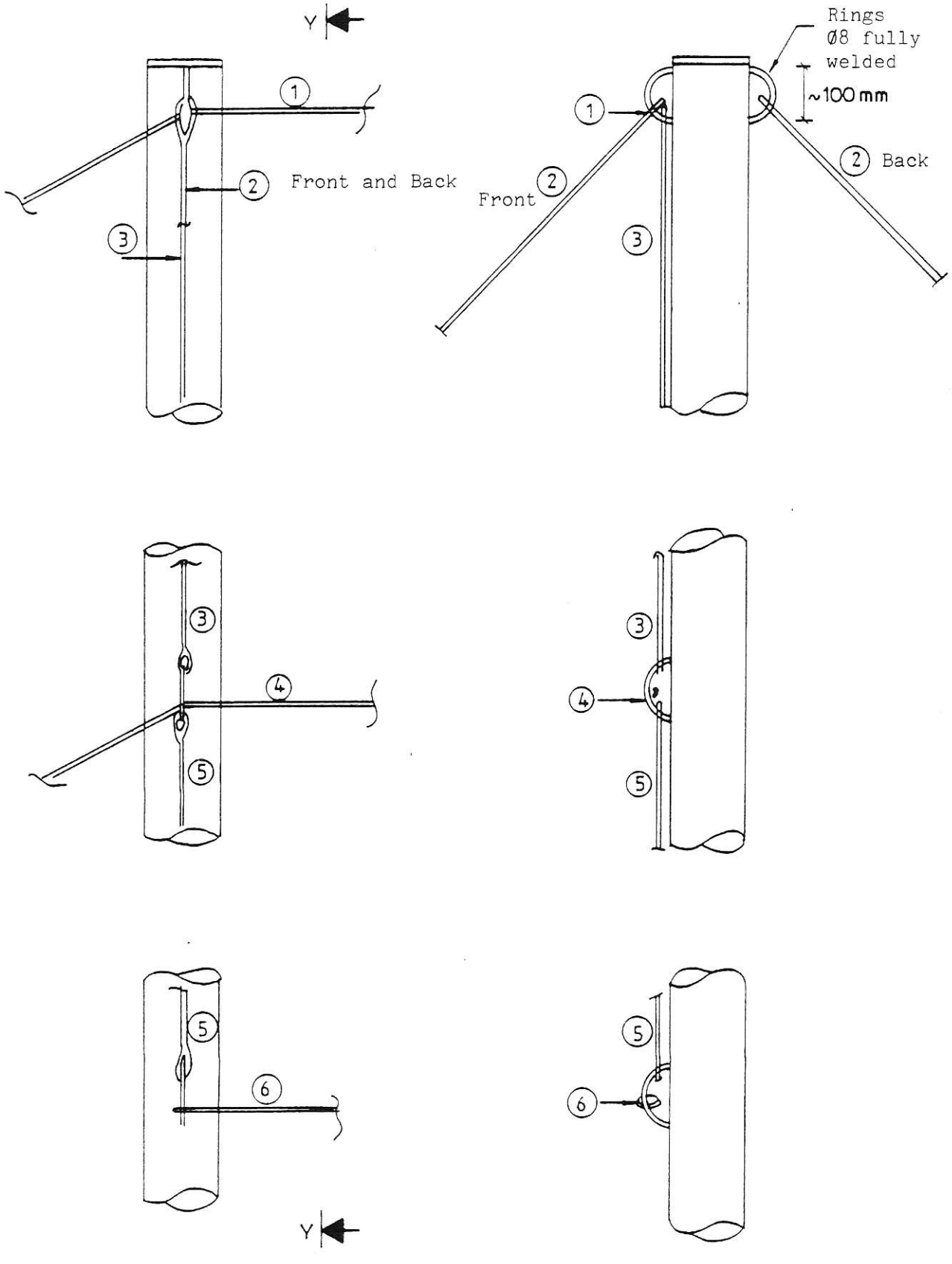
(Scale 1:10)

4 x 12 COLLECTOR


3.2
1
2
3
4
5
6
3.3
3.1
To be detailed to
suit contractor
Gutter line
only shown
Tied on site
Cable attached
to Column
Netting with
wire fringe/frame
(Cables numbered for
clarity (see details)

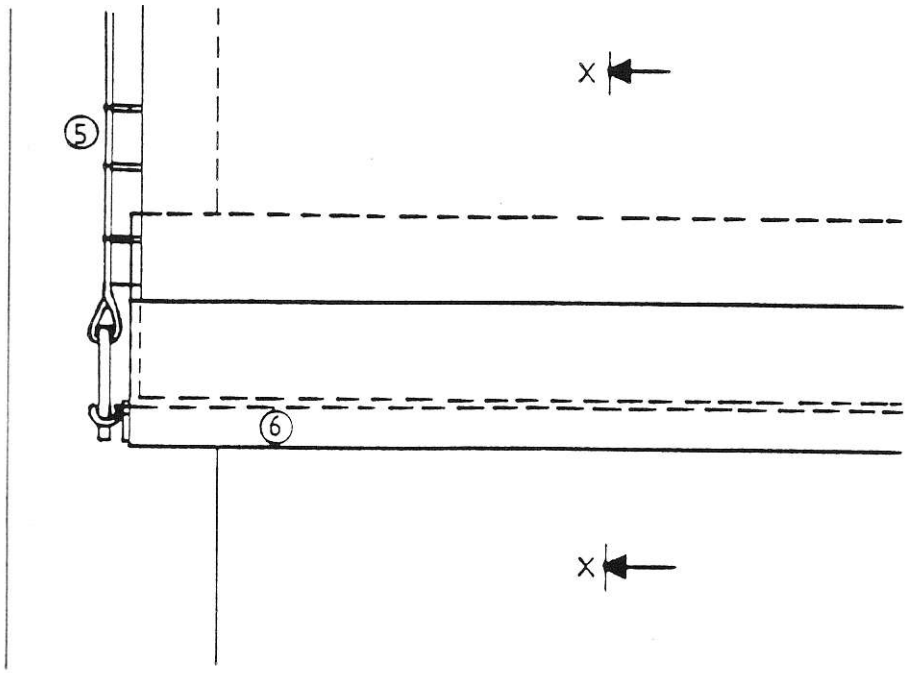

X
X
SECTION X-X
Ø 140 x 5
8 mm plate
200 x 200
welded to angles
L 2 x 150 x 150 x 8
(140 mm clear
distance apart)
M14 bolt
≈1000
Holes for
bolts every
300 mm
Holes in
tube every
150 mm
≈500
(MIN. 300)
PVC
Plate welded to
angles (450 x 200 x 6)
Cast in situ
Concrete
(1:3:6)

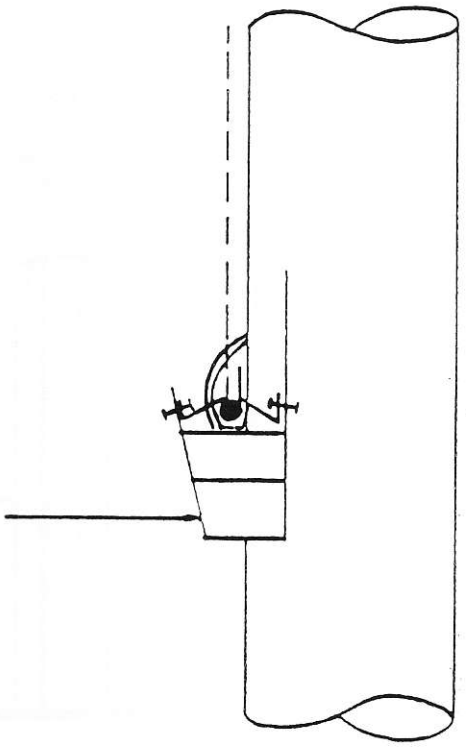
(Scale 1:10)



SECTION Y-Y

Netting not shown

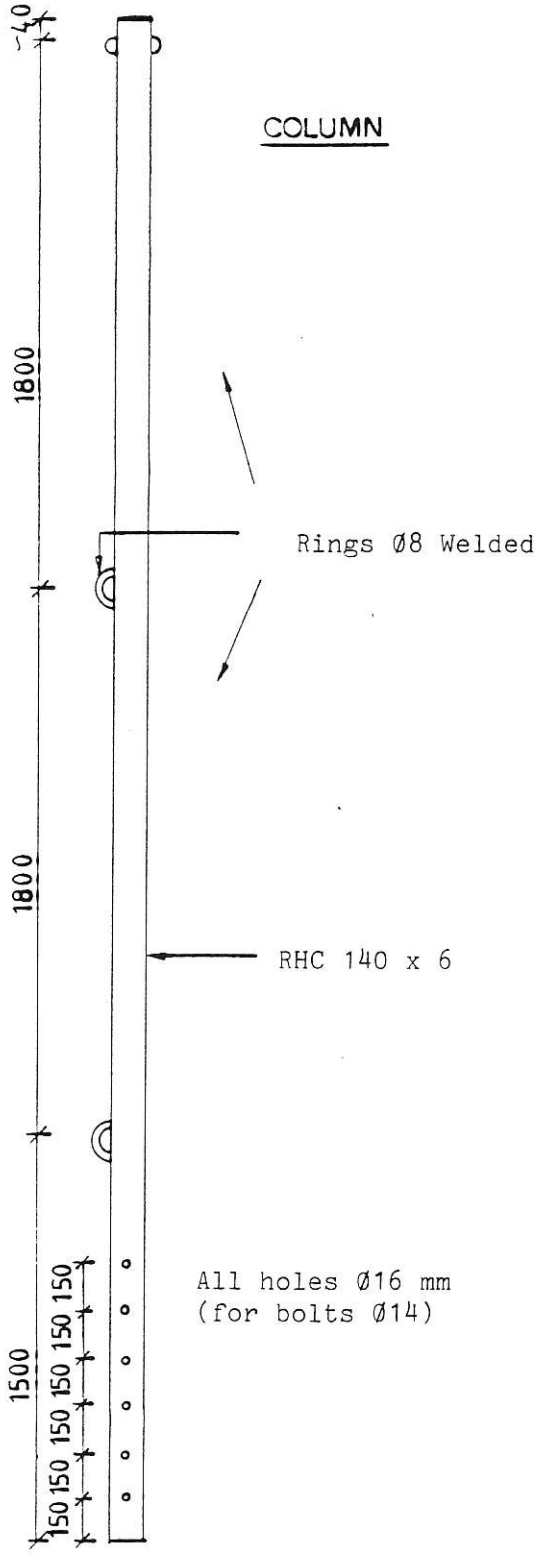




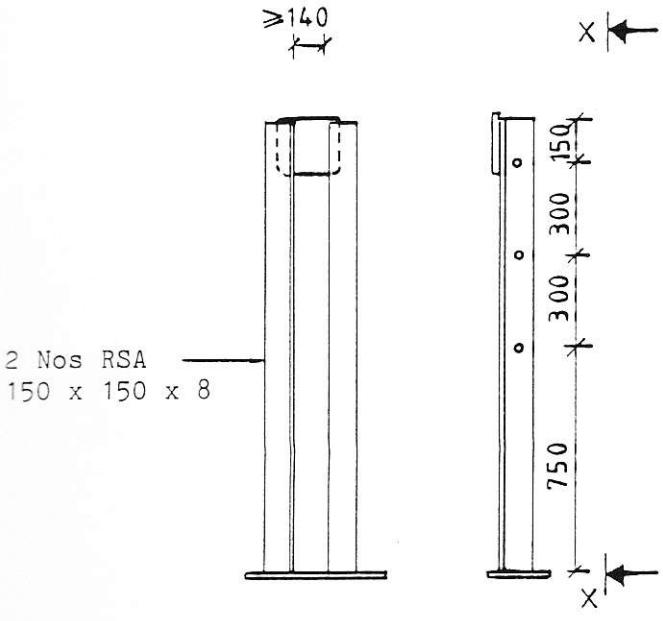
Galvanised steel gutter bent to shape connected so it slopes

SECTION X - X

2 Nos.



STARTER COLUMN



SECTION X-X