Paper:129

TOWARDS LOW-COST BUILDINGS

By

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ABSTRACT

This paper is divided into two parts. First a prefabricated concrete system of building is described which requires no heavy equipment and which has been under continuous development since it was first produced as a response to the flood of 1973.

This structural skeleton includes foundations, columns, beams and roofing and is adaptable to many uses.

However a building is much more than its structural frame and there follows a consideration of some of the constituent parts of a building Techniques that have been used at the Christian Technical Training Centre with a view toward economy or building improvement are described.

Principal, Christian Technical Training Centre,
Gujranwala.

1. INTRODUCTION

We should face the problem of inexpensive housing and other accommodation at its problem area: the roof. Walls are rarely a problem and are capable of solution in many ways. They can be built of mud, brick in mud mortar, brick in lime, surki or cement mortar, sun dried brick, soil cement block, concrete block, precast concrete wall sections depending on circumstances.

The qualities that a roof is to provide are:

Protection against rain
Protection against heat
Protection against dust
Protection against wind
Protection against intruders
Durability and ridigity
Minimal maintenance
Maximum economy

2. ROOFS NORMAL PRACTICE

The usual solutions that have been tried for roofs, apart from kacha temporary roofs, are:

12" brock tiles on timber ballas on timber chat
12" brick tiles on 2" tee iron;
Reinforced brick(normally ½" bars at 9" centres
Small brick jack arches using RSJ longitudinal member;
Absbestos or GGI sheets on steel or timber trusses and purlin and
Reinforced concrete slabs or beams and slabs.

Most of these solutions have disadvantages, the major one is the extreme difficulty of quality control of work in country areas. The proposal that follows meets the need for quality control and provides a roof to meet the requirements outlined.

3. MATERIALS

In Pakistan there is a plentiful supply of certain building materials. Others, of a manufactured nature, are often in short supply. These materials are:

CLAY: It is available in abundance;

SAND: Sand of high concrete quality is in limited supply and location i.e. Lawrencepur in Punj and Bolari in Sindh. There is abundant pit and river sand which is poorly graded, being very fine grains.

CEMENT: Cement, although subject to shortage in distribution, is the principal high quality indigenous building product which can be made available in adequate quantity if priorities are arranged. The price moved up rapidly from 1974-1977.

STONE: Limestone of high quality is available in the Punjab from certain areas of the Potwar Plateau and, in Sindh, from areas around Hyderabad.

STEEL: Steel is available. It is originally all imported. Much locally available steel is made from scrap. The price has stabilis

rs;

A.C.SHEETS: Asbestos cement sheets, flat and corrugated are locally manufactured in Hyderabad. (The nalidar beam, approximately 16' x 3', is available from Karachi).

;

TIMBER: The country's supplies of timber are steadi diminishing. Prices continue to rise.

BRICKS: Bricks and burnt clay tiles are manufacture throughout the country in small kilns of 2 to 8 lacs capacity. Supply is adequate.

4. THE ARGUMENT

The structure that probably offers the mos economical solution with maximum use of local materials and minimum imported material is some form of high quality concrete that utilises the high strength of concrete in compression. To ensure high quality and

economy a central location is required for manufacture. Members must be portable and minimum section of structural members is essential. The basic design must be simple and its different members must be a minimum number. The design must be flexible to allow for changes in floor plan to accommodate varying site conditions and user requirements. It must be capable of construction by relatively unskilled men. It must not collapse in flood conditions and be robust. It should eliminate, as far as possible, any requirement for quality work in mortar or concrete at the erection site.

The proposed design (Fig.1) meets these requirements. With the addition of a cover of polythene sheet under 2" of lopai the roof meets the criteria that have been set down for roofs.

5. THE PROPOSAL

The proposal is the manufacture of a prefabricated framed reinforced concrete structure from foundation to roof under careful quality control. For a village dwelling, erection would be by a team of two trained men and eight labourers, taking one to two days. No mason would be needed. Walls would be of village manufacture of the occupants choice. Initially this would probably be mud. (In urban areas a wall of concrete slabs can be provided). Manufacture of the elements would be in a suitable geographic centre to the areas of need and related to main road access and rail (for cement deliveries). Concrete members would be constructed to close tolerance of measurement. While those could be stabilised when erected by horizontal and vertical diagonal steel ties, experience has indicated this would rarely be necessary. Foundation pads would be precast (Fig.2).

The structure is such that its parts can be used separately if needed and the roof can be utilised to rest on traditional walls of mud or brick.

There has been a rapid swing in comparative prices in recent years. Labour assumes an increasing proportion of costs (and problems). Skilled labour is less readily available. Timber has become relatively costly. Transportation costs have risen sharply. The price of cement has trebled.

The argument in favour of factory controlled quality concrete component and minimum site erection costs has been reinforced by the increasing difficulty in obtaining good site supervision as qualified and competent people go to the oil countries. The prefabricated structure proposed is already in use. Steel shuttering of simple and sturdy design ensures reduced shuttering cost per component.

Modular dimensions have been governed by the normal length of a truck body which is 14 feet. Tiles are 1'6" x 4'6", rafters are 9' and 13'6". Column heights are 10' and 13'6" with optional extension to 15' if required (Figs 3-10).

The maximum weight of the beam is 550 pounds. Workmen prefer to manhandle these into position rather than use a derrick post and chain block. For large scale use a fork lift truck would be desirable.

6. *MANUFACTURE*

This design, which is easily adaptable to both rural and urban use and which affords the basis of a low cost permanent structure finds multiple use. It is preferable that manufacture and erection be separated. Eventually the manufacture would handle and loan his concrete item with fork lift equipment to a controlled procedure in a carefully designed yard.

One truck can carry about 280 square
eet of frame structure. If rural areas are inaccessible
truck the load can be broken down into bullock cart
oads for the final stage. Experience has shown that
omponent breakage during transportation is negligible.

ERECTION

No particular difficulties have arisen
th site erection of frames. Erection routines have been
veloped. No mason is normally required since the system
intended to be demountable. It thus would have some
terest for the armed services or for construction
te or other buildings of a temporary nature

Erection can be by:

a) Specialist erection contractor who undertake, transportation and erection.

b) Public agencies which have their own transportation and labour force.

c) Communities or cooperatives that undertake their own erection using community labour and the services of an erection adviser.

d) Individuals erect their own structures.

e) A manufacturer's own subsidiary erection programme.

ITEM COSTS (March 1978)
(includes shuttering and supervision costs but not profit).

Foundation underpad	Rs. 42.50
Foundation pad	Rs. 79.00
Column 15'0"	Rs. 190.00
Column 13'6"	Rs. 118.00
Column 10'0"	Rs. 100.00

Beam 13'6"	Rs. 260.00	
Beam rafter + rafter support blocks	Rs. 230.00	
Rafter 9'0" + rafter support blocks	Rs. 122.00	
Tile 4'6"	Rs. 30.00	
Polythene sheet	Rs. 0.55	per sq.ft.
Locking pins	Rs. 5.00	
Rooflight edge beam 4'6"	Rs. 40.00	
Wall foundations 9"	Rs. 10.00	per ft.
Wall foundations 4½"	Rs. 6.80	per ft.
Lintels 4'6" x 9"	Rs. 44.00	
Lintels 4'6" x 4½"	Rs. 34.00	
Lintels 3'6" x 4½"	Rs. 29.00	
Seagull tile	Rs. 6.00	
Door frame 3'6" x 6'6" nominal	Rs. 100.00	
Door frame 3'0" x 6'6"	Rs. 96.00	
Door frame 2'6" x 6'6"	Rs. 92.00	
Window frame 4'2" x 3'2"	Rs. 80.00	
Window frame 3'2" x 2'2"	Rs. 68.00	
Shelves 2'5" x 2'0" x 1½"	Rs. 18.00	
Shelves 1'9"	Rs. 16.00	
Shelves 1'6"	Rs. 14.00	
Shelves 1'3"	Rs. 12.00	

9. USES

a) Roofs A primary need is roofs to rest on traditional solid walls. The regular beam rafter spans 12'6". On mud walls a wall beam laid flat and lightly reinforced spreads the roofing load and has proved effective. The flexible joints between tiles allow wall movement and settlement to occur without damage. The length of the room is unlimited.

Roof insulation is provided by 2" - 3" lepai on a layer of polythene sheet with suitable edge protection. The seagull tile described later in the paper may also be used. (Fig.11).

b) WALLS are not load bearing when the full frame is utilised. Normally such walls are mud or else brick laid in mud mortar. When urban use requires pucca walls an outer skin of 2" prefabricated wall panels or 3" brick prefabricated panels can be used and insulation is then provided by an inner skin of brick or mud. Where walls occur under beams or rafters the latter can be omitted if desired and the roof load is carried by the walls.

c) DWELLINGS: Many arrangements of dwelling are possible. The module is 13'6" square or 13'6" x 9". This permits flexible arrangement of walls which can permit changes in house plan whenever needed. Initially walls and floors may be of mud but at any time they can be replaced by more durable or suitable construction.

d) GRAIN STORES: It is not difficult to see that this form of structure can be readily adapted to provide small house grain stores of one or two tons capacity, village storage units (one bay 13'6" square can hold 20 tons) or even larger storage units by use of multiple bays.

10. SCHOOLS

The primary school layout is simple and practical. In the central room are kept floor mats, blackboards and easels, stools and other school materials.

There are four open sided classrooms at the four compass points. The covered area in each classroom is 360 square feet but can be increased to 900 square feet. Blackboard are on all walls and this gives flexibility in classroom use.

Extension of covered area can be provided bu adding more structural elements.

Similarly the upgrading of the school to a middle class school can be effected by the addition of further sections and, if necessary, a rearrangement of the non load bearing walls.

a) Traditional Schools

Various designs of schools utilising exterior walls are available, including a school to standard UNESCO dimension with a classroom dimension of 14'3" x 25'. Many other building designs have been developed.

11. THE CONSTITUENT PARTS OF A BUILDING

Let us now look at the constituent parts of a building as they are met in the course of normal construction.

1) Foundation: Exhaustive studies and practical .perience on low cost housing in the West Indies has shown that economies can be effected in foundations by the use of small short brick piers spanned by lightly reinforced brick courses just below ground level, as a substitute for traditional footings. Similarly the use of a lightly reinforced concrete ground beam spanning between column footings at ground level can effect economy and obviate the need for a damp proof course.

2 Damp roof Courses: Polythene sheet has become the universal vapour barrier and is now replacing or supplementing the traditional course of bitumen or bitumen/sand or concrete. Provided it is protected from ultra violet light, it seems to have an indefinite life. The polythese sheet that is commercially available is relatively thin and easily punctured. A large market awaits the plastic manufacturer who will produce and market a polythene vapour barrier of adequate thickness and

specification. Meanwhile two layers of the thickest available polythene sheet seems to provide the most suitable and economical DPC.

3) Flooring: There are many variations on flooring specifications. One question is how large can a 4" thick unreinforced concrete floor panel be. Some research stations in the Punjab area recommend a twenty square feet maximum.

Experience shows that it is possible to permit panels up to 150 square feet with a maximum side dimension of thirteen feet with joints staggered. The concrete may be 2½" of 1:2:4 brick concrete topped, while fresh, with a wearing coat of 1½" concrete made with the usual limestone aggregate. Cracks do not occur. A thin floor may here be mentioned of about 1¼' thickness that was laid about sixteen years ago and which is still performing satisfactorily. The floor was on new fill. This was levelled but not heavily compacted. Tapered holes on a 1'6" or 2' grid and about 1'6" deep were made by pushing in a 1" bar and rotating it. These holes were filled by adding concrete from a debra with a hole in the bottom. The lowest cost hessian (burlap) available was now stretched over the hole area and about 1¼" 1:2:4 concrete was placed on this and trowelled to a smooth finish. The fill gradually consolidated, opening up a small air gap between the floor and the fill which acted as a vapour barrier. In effect it is a floor slab supported on miniature pile foundations.

4) Walls: Research on optimum ceiling heights in hot climates reported from USA, India and Israwl all confirm this to be about 8'9". Pakistan building codes often require an 11' minimum on the ground floor and 10' on other floors. On multistorey buildings the permissible 8' on mezzanine floors can be utilised to reduce ceiling heights occasionally. There does appear desirable a review of the building codes in this matter for it could....

substantially reduce costs. Where ceiling fans are used a practical minimum would appear to be 9'.

One major problem in solid brick walling is the passage of water through the wall, particularly above slabs, lintels and shelves. The expedient of an external coat of cement is not always effective and requires continual maintenance.

Cavity wall construction has many advantages. It is certainly more expensive than solid wall construction but its benefits often justify its use. Apart from heat and damp insulation it permits the use of decorative panels of brickwork more readily. (The ties used at Gujranwala are manufactured from salvaged barbed wire, otherwise ¼" bar bent to shape is utilised).

Walls are frequently thicker than needed. Load bearing brickwork to twelve feet height needs usually be no thicker than one brick.

5) Door Frames The average 6'6" x 3'6" door chowkat requires 1.5 feet of 4" x 3" timber excluding wastage. It is unlikely to cost less than Rs. 150 and is likely to warp. Reinforced concrete door frames (c/s areas 14.75 sq. in). cast in the full rectangle to provide both sill and lintel, together with cast-in hinge plates, can be made for Rs. 100. They weigh 280 lbs. are free standing and are built in as work proceeds from DPC.

6) Doors Door leaves are an expensive component. Flush doors need tender loving care. Beds carried through to a courtyard can punch a hole in a flush door. Panel doors are satisfactory if designed to allow for shrinkage but are labour intensive. Steel doors at Rs. 350 or thereabout, although not as attractive as timber doors, are becoming competitive and popular.

Various designs of door leaf utilising unseasoned timber and requiring minimum labour are now under development.

7) Window Frames: Concrete window frames again provide both sill and lintel and may be used either vertically or horizontally. Steel window frames designed to make use of standard dimension of glass and to be thiefproof as well as flyproof are a complementary component than can eliminate the additional security 'jali'. Orientation affects building costs. If wall detailing is adequate there is no need for chajjas on the north side of a building. There is also little difficulty from the south in the summer since the latitude of Lahore is 32 degree. Adequate south windows permit ingress of the winter sun for comfort and economy to the user. The west wall has as few window as practicable.

8) Wall and roof panels The Central Building Research Institute, Roorkee has developed, and is extensively using roof and wall panels of 3" thick brickwork about 40" x 20" in area. These are laid flat, morter is poured in and they are lifted and placed after the mortar has set. They have proved strong, rapid and inexpensive to manufacture and needing minimal shuttering. Roof panels are reinforced with two nos ¼" bars.

Experiments are now being made with similar slabs 4'6" x 1'6" x 4¼" with facing concrete on both sides. These are made in precision steel moulds utilising freely available brickbats. They are cast one on top of the other to save casting yard space.

9) Roofing: One roofing/suspended flooring system which utilises precast thin shell arches 1½" thick and to 6' span has possibilities for low cost on-site work but is not suitable for off site transportation of shells since they are relatively fragile until placed in position and haunched with brick concrete. The shells are cast in a curved concrete 'dish' of suitable profile on the ground, the sides of the mould being

1½" angle iron bent to a curve. The shells are 6' x 1'4" and are reinforced with chicken mesh or 10 gauge wire. After placing on rafters and haunching a screed coat of 1½" concrete is added. The screed must be lightly reinforced to ensure watertightness.

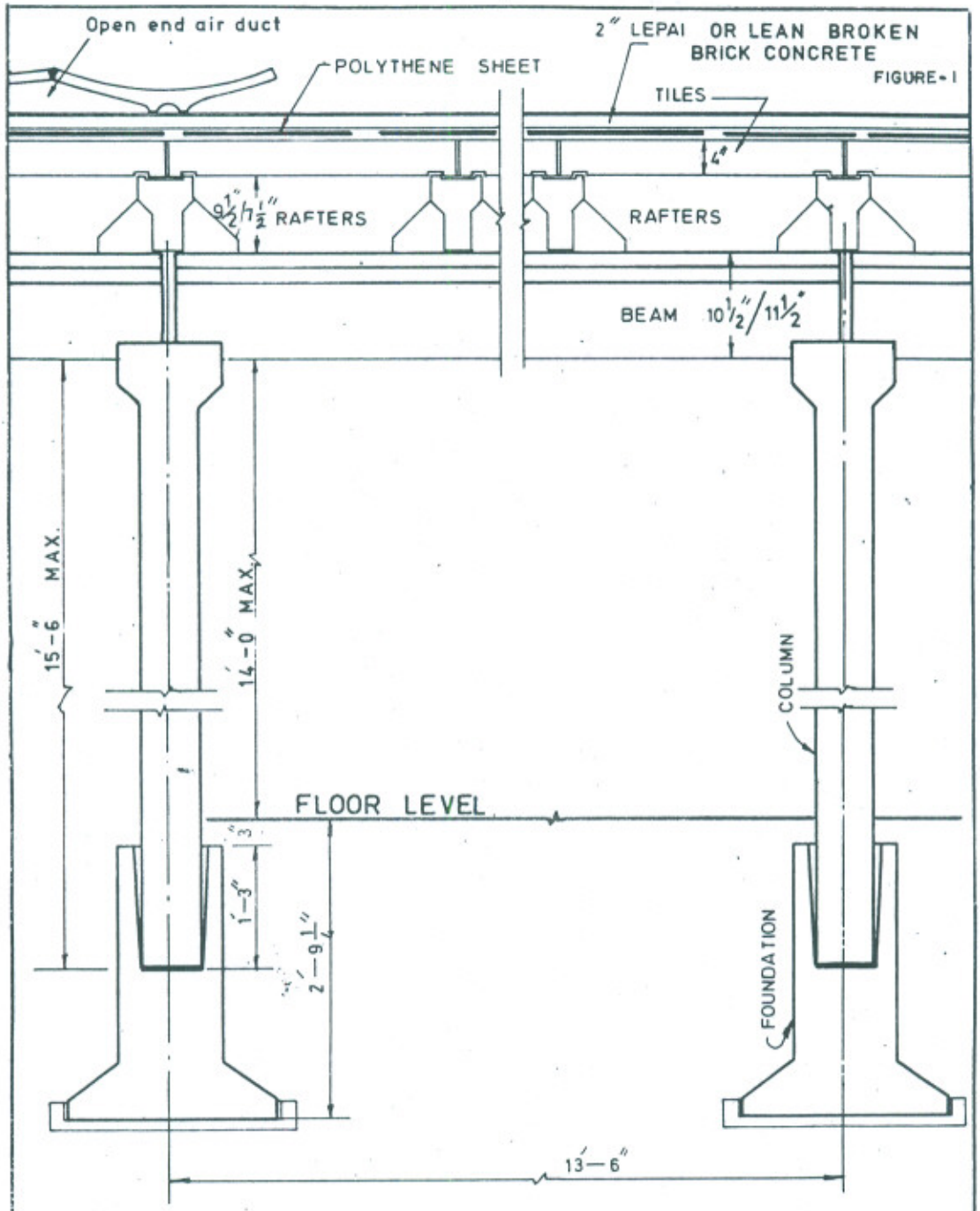
10) Roof Insulation : For insulation against rain it is normal to use the thickest available grade of polythene sheet protected by lepai or 2" low grade brick aggregate concrete. The edges of the polythene sheet must be carefully double overlapped or else heat sealed and the sheet must be laid on a smooth clean surface to avoid puncture of the sheet.

' Seagull ' tiles may be used for heat insulation and also as a first defence barrier against rain. These tiles, which resemble in profile a bird in flight, are 2'6" x 1' and are cast upside down on the ground on a suitably profiled concrete platform with wooden dividers. They require a minimum of labour and mortar for insulation and form a series of continuous small arches through which airflow occurs. They are very effective in reducing surface temperatures.

11) Sanitation: In closing the septic tank deserves brief mention. One manufactured from a steel oil drum and with a suitable precast concrete slab worked successfully for a long period. Precast concrete ones have not been made owing to the initial cost of the mould but there is no reason why they should not be successful and economical, discharging effluent to a borehole, soakpit or drain.

12) SUMMARY _ The minimising of building costs is a continuous process which must take into account the interplay of labour and material cost, supervision of construction, prcfit levels, job duration, climactic factors, population growth and its subsequent requirements, the 'rising' aspirations of society and many other factors.

The particular problem of low cost housing in Pakistan deserves as much attention from engineers as the much larger ' glamour ' projects that are visualised when development is discussed. Prefabricated concrete materials provide one of the basic low cost building techniques. The development of a strong prefabricated concrete building products industry merits active encouragement. It makes efficient use of a basic commodity, cement, which is in short supply. Such a stimulation of a relatively undeveloped basic industry might well be a subsidiary concern of of the cement manufacturing industry.

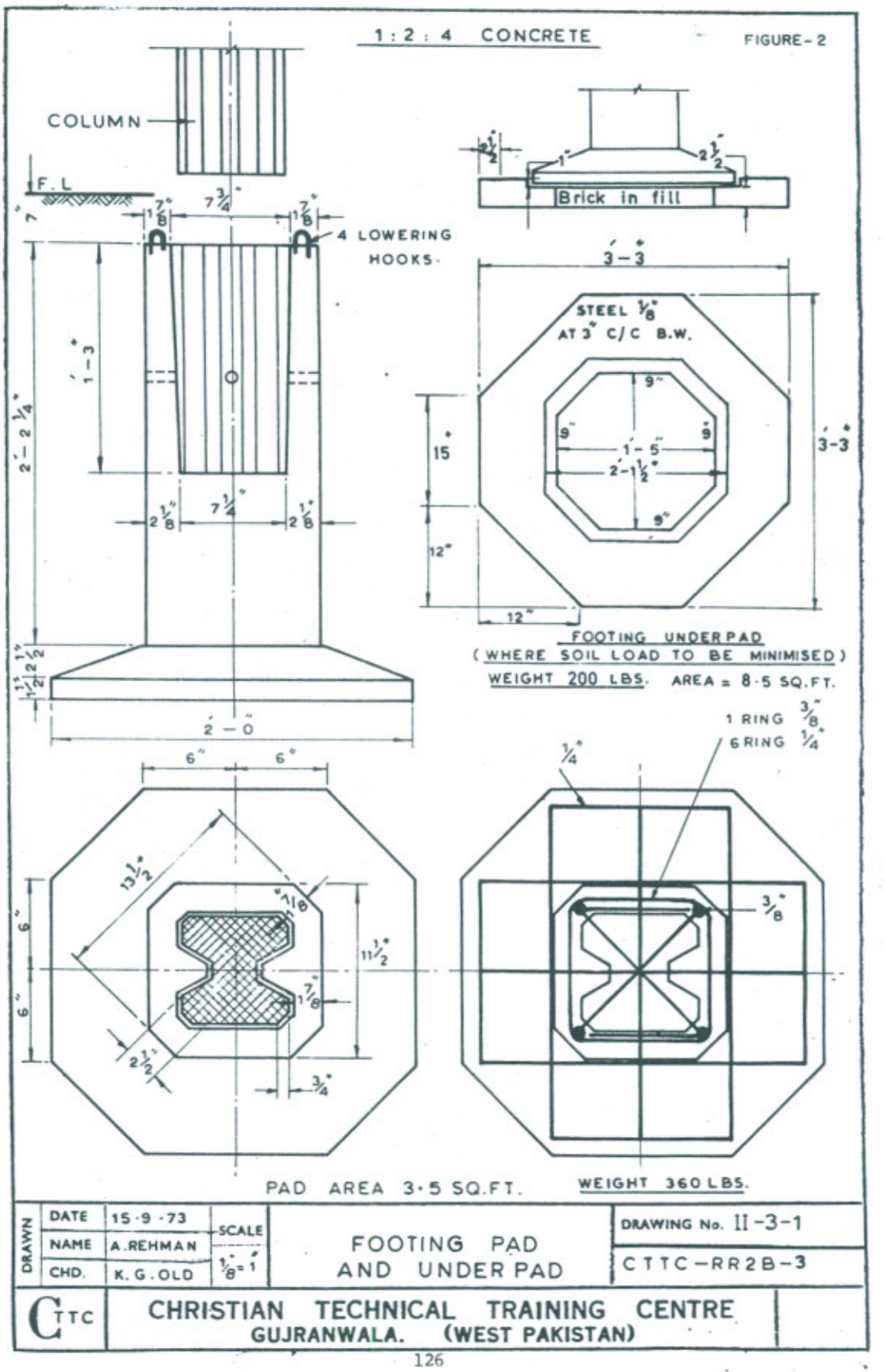


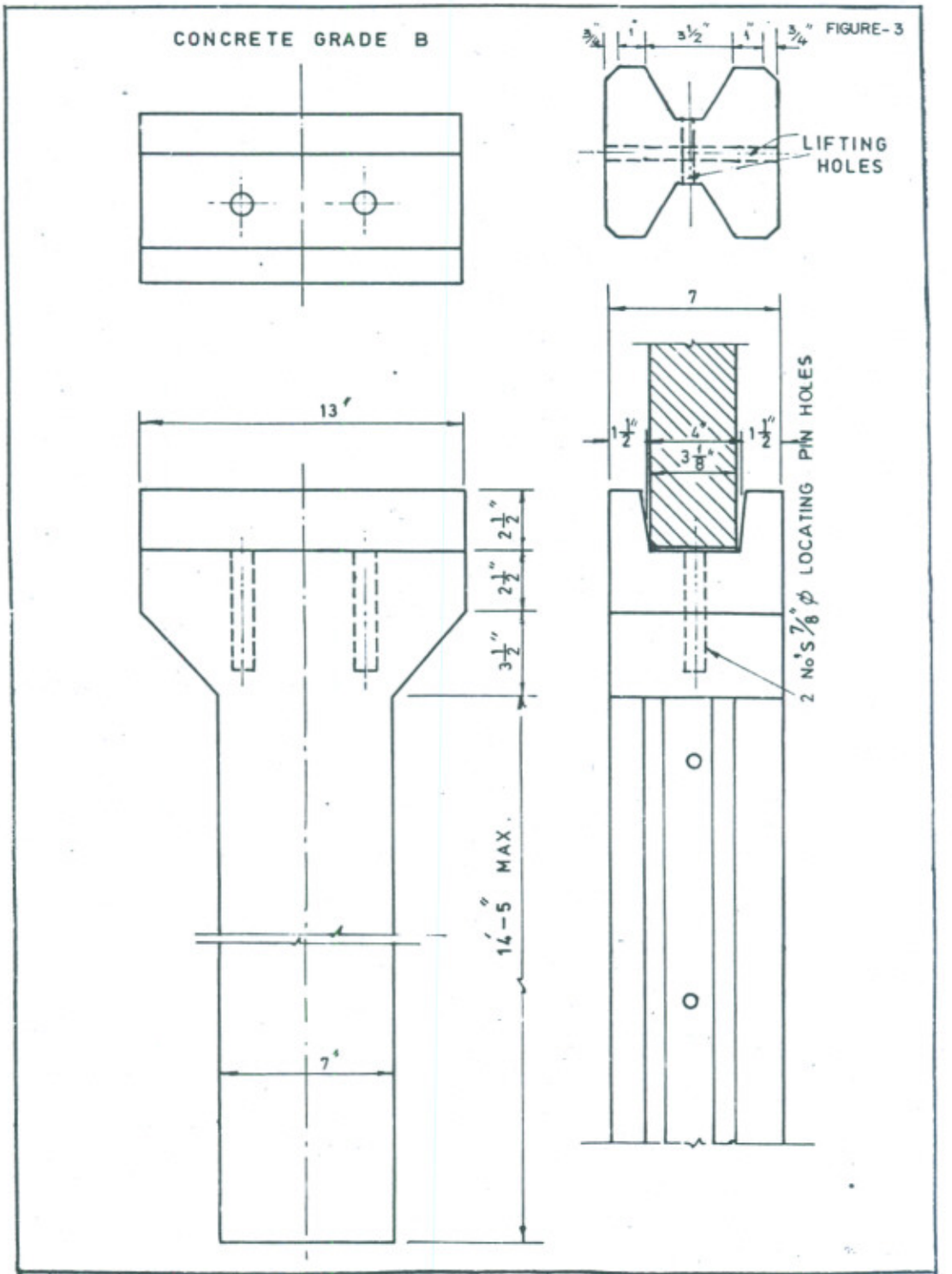
CROSS SECTION

DRAWN	DATE	19 · 7 · 76	SCALE	SECTION	PHASE II RRH
	NAME	A.R	¾"=1'-0"		CTTC – GS : II-2A
	CHD.				

CTTC **CHRISTIAN TECHNICAL TRAINING CENTRE**
GUJRANWALA. (PAKISTAN)

TRC. BY. NATHANIEL


1 : 2 : 4 CONCRETE
FIGURE-2
COLUMN
F.L
4 LOWERING HOOKS.
Brick in fill
STEEL 1/8" AT 3" C/C B.W.
FOOTING UNDER PAD
(WHERE SOIL LOAD TO BE MINIMISED)
WEIGHT 200 LBS. AREA = 8·5 SQ.FT.
1 RING 3/8"
6 RING 1/4"
PAD AREA 3·5 SQ.FT.
WEIGHT 360 LBS.
DRAWN
DATE 15·9·73
NAME A.REHMAN
CHD. K.G.OLD
SCALE 1/8" = 1'
FOOTING PAD AND UNDER PAD
DRAWING No. II-3-1
CTTC-RR2B-3
CTTC
CHRISTIAN TECHNICAL TRAINING CENTRE
GUJRANWALA. (WEST PAKISTAN)

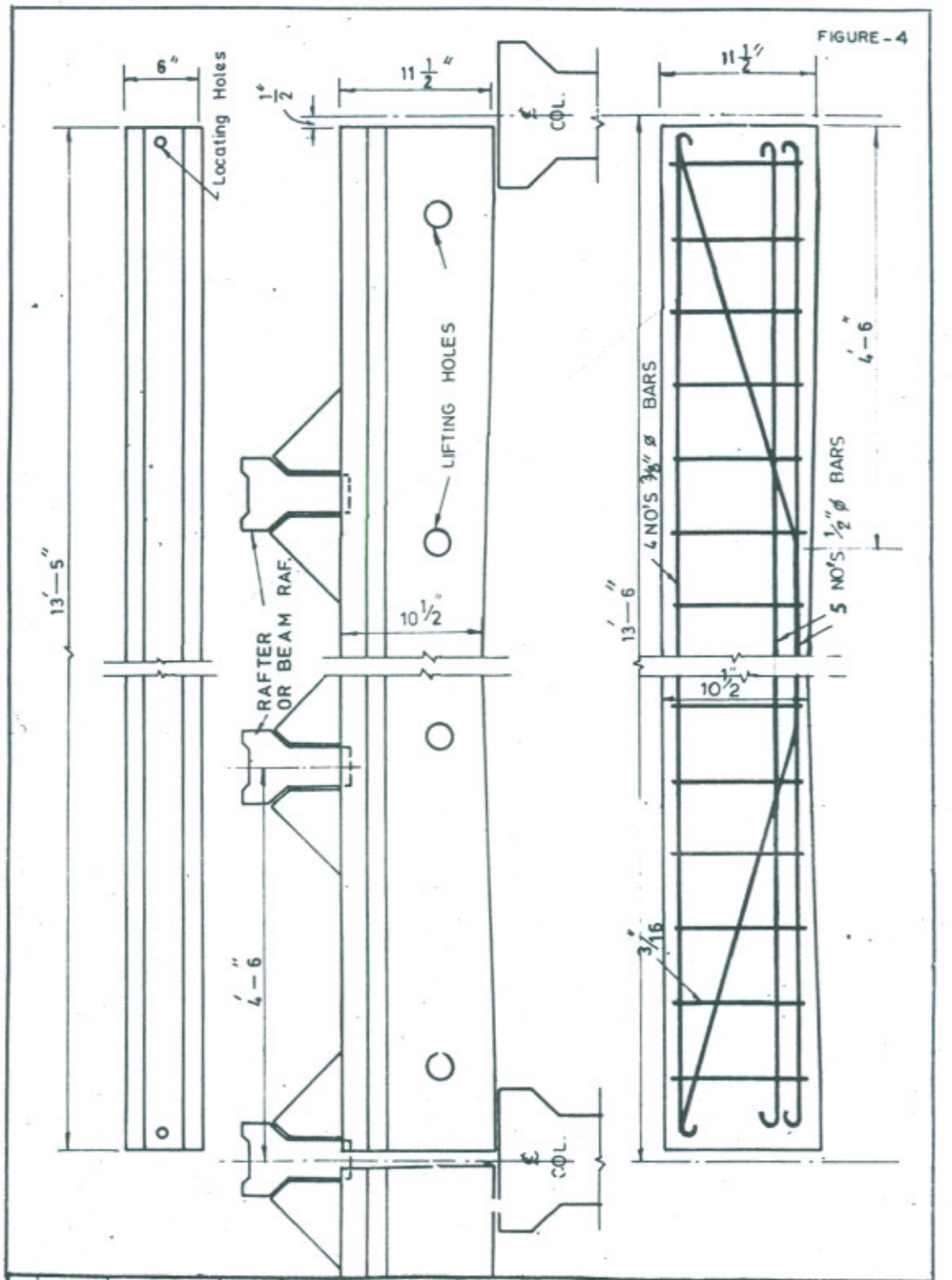


DRAWN	DATE	20-7-76	SCALE	COLUMN	RRH—II-3-3
	NAME	A.R	3/4"=1'		CTTC—GS:
	CHD.				

CTTC CHRISTIAN TECHNICAL TRAINING CENTRE
GUJRANWALA. (PAKISTAN)

TRC BY. NATHANIEL, 7-8-76

FIGURE - 4



DRAWN	DATE 31-7-76	SCALE 3/32" = 1'	BEAM . 13'—6"	R R H — II-3-4
	NAME A.R			CTTC — GS : 7A
	CHD.			

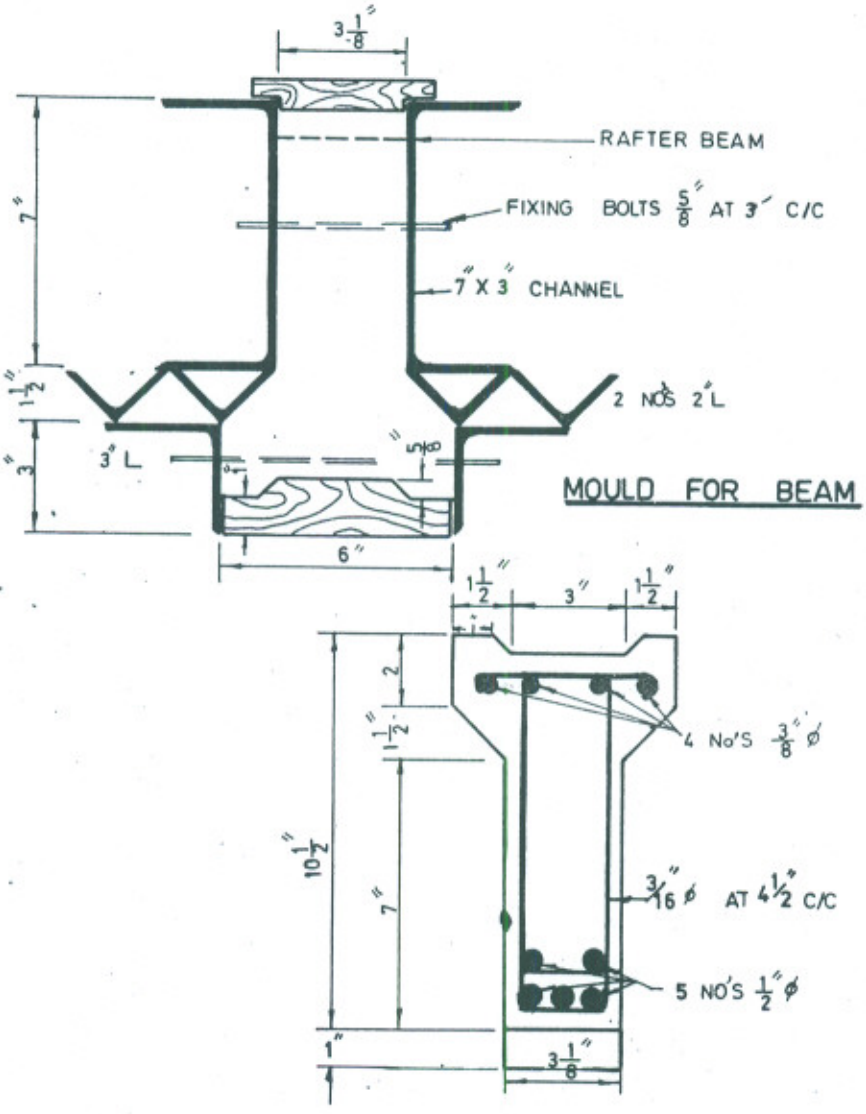
CTTC **CHRISTIAN TECHNICAL TRAINING CENTRE**
GUJRANWALA. (PAKISTAN)

TRC. NATHANIEL

FIGURE-5

WEIGHT PER FOOT 42.7 LBS.
WEIGHT OF 13'-6" BEAM 550 LBS.

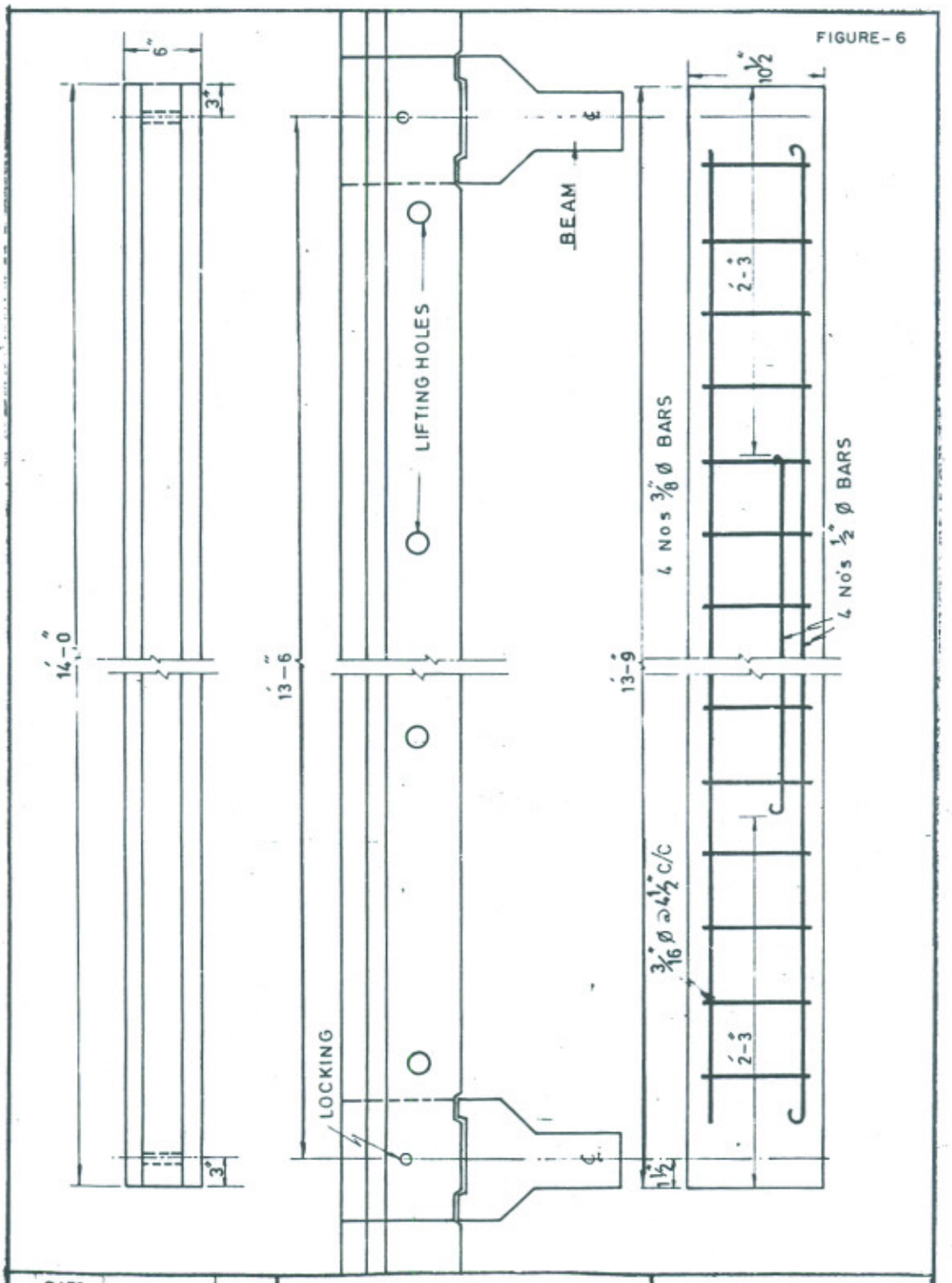
CONCRETE GRADE. B



DRAWN	DATE	19-7-76	SCALE	BEAM	RRH — II -3-4A
	NAME	A.R	1/4" = 1'		CTTC — GS : 6A
	CHD.	K.G.OLD			

CTTC CHRISTIAN TECHNICAL TRAINING CENTRE
GUJRANWALA. (PAKISTAN)

FIGURE-6

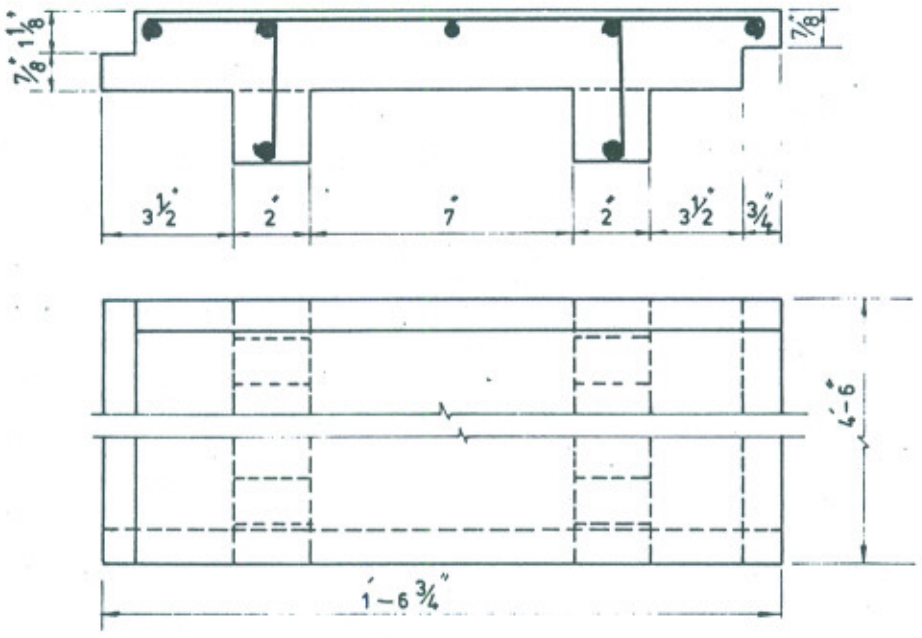


DRAWN	DATE 1·9·76	SCALE	BEAM RAFTER 13'-6"	RRH II-3-5
	NAME AREHMAN			
	CHD. K.G.OLD			

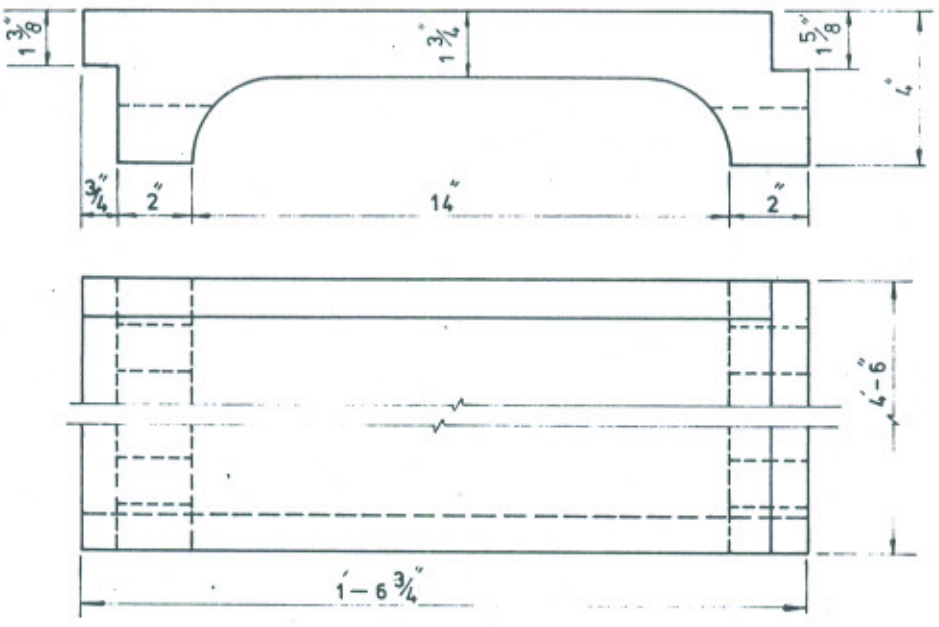
CTTC **CHRISTIAN TECHNICAL TRAINING CENTRE**
GUJRANWALA. (PAKISTAN)

FIGURE - 7

TILE - I



TILE - II



DRAWN	DATE	31-3-78	SCALE	TILES
	NAME	A.Rehman		
	CHD.	K.G.Old		R R H _ II

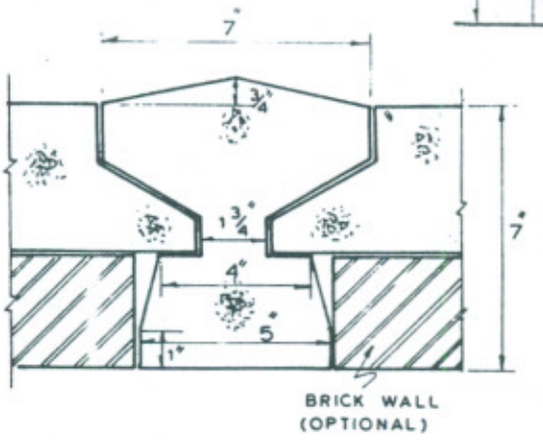
CTTC **CHRISTIAN TECHNICAL TRAINING CENTRE**
GUJRANWALA. (PAKISTAN)

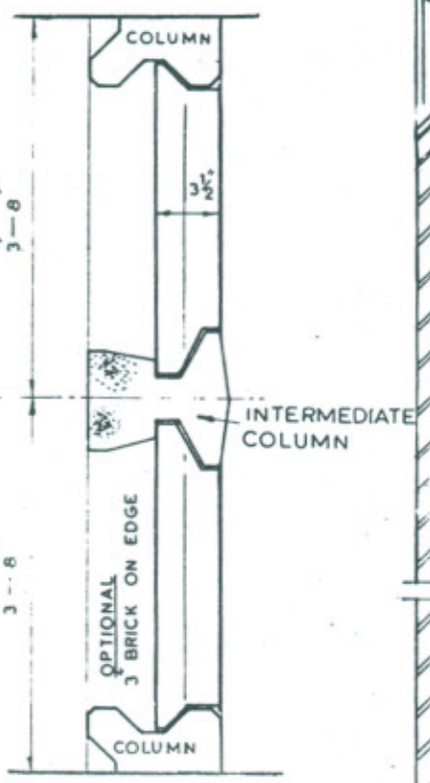
DRY JOINT EXTERIOR WALL FACING 1:2:4 CONCRETE FIGURE - 8

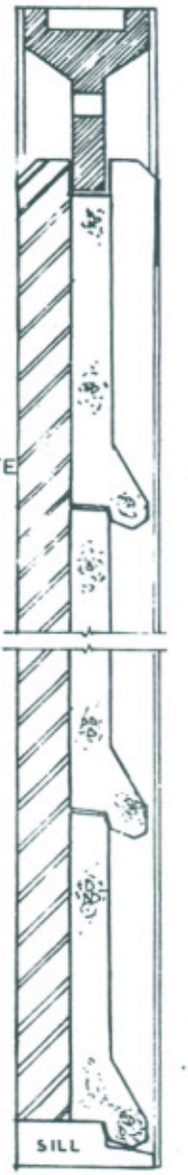
WEIGHT : 72 LBS.
LENGTH: 3 - 4 3/4"



DOOR FRAMES AND WINDOW FRAMES TO MODULAR WIDTH 3'-1".







DRY JOINT WALLING

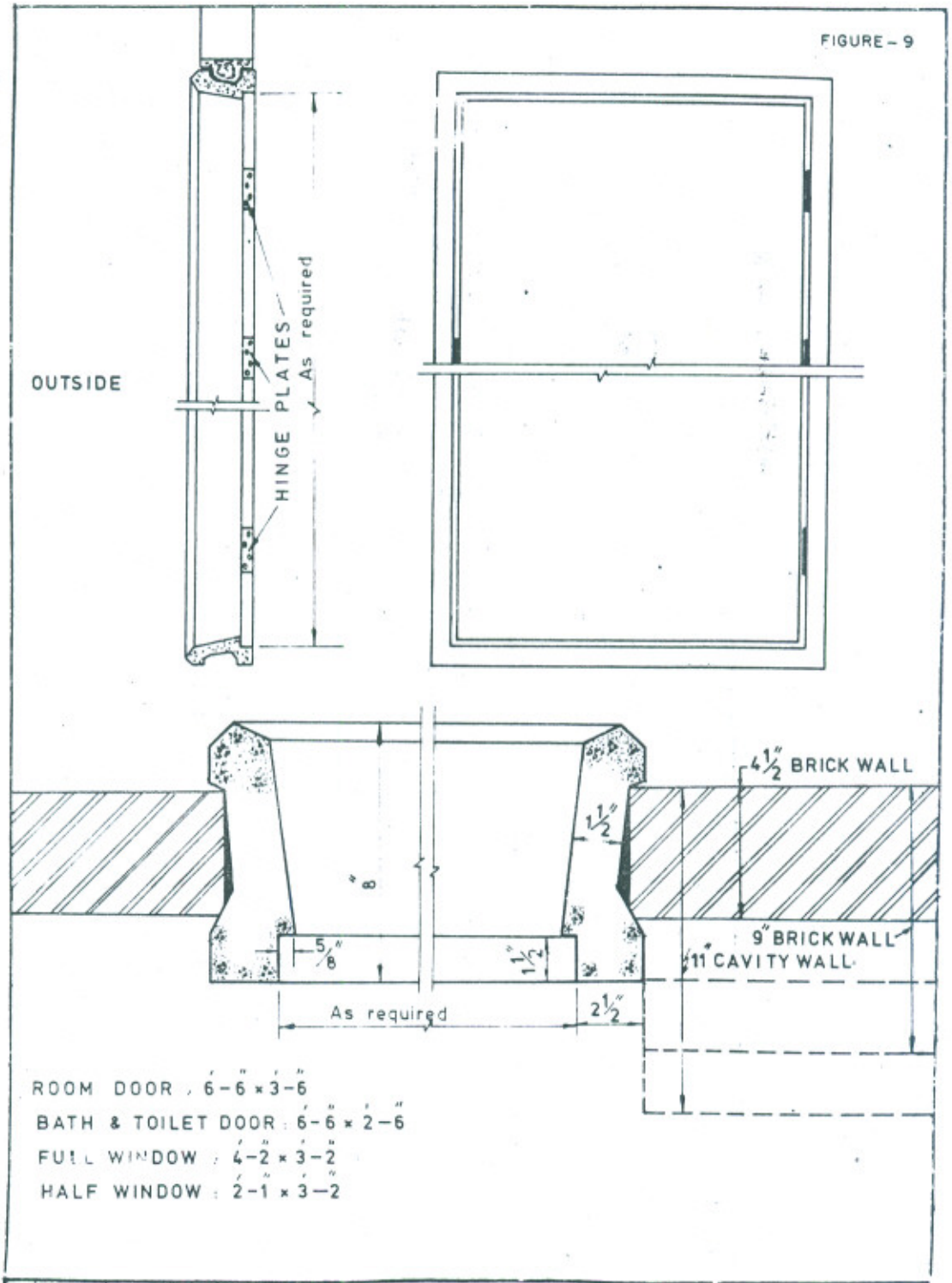
INTERMEDIATE COLUMN AT 3'-8" C/C.

Phase I

DRAWN	DATE	17.12.73	SCALE	WALLS FOR URBAN HOUSING	
	NAME	A.REHMAN			CTTC-RR-8
	HD.	K.G.OLD			

CTTC CHRISTIAN TECHNICAL TRAINING CENTRE
GUJRANWALA. (PAKISTAN)

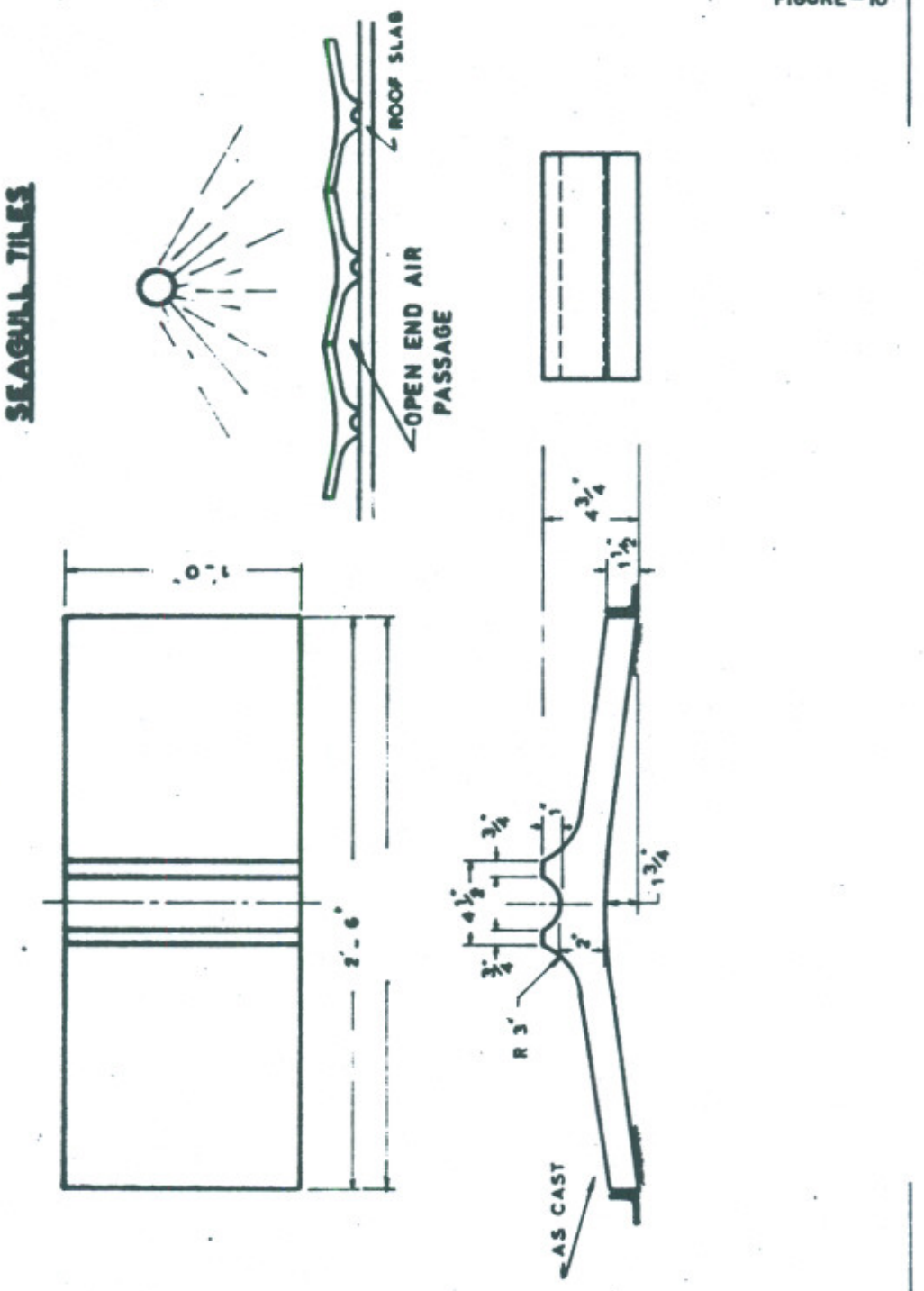
FIGURE – 9



ROOM DOOR : 6'-6" × 3'-6"
BATH & TOILET DOOR : 6'-6" × 2'-6"
FULL WINDOW : 4'-2" × 3'-2"
HALF WINDOW : 2'-1" × 3'-2"

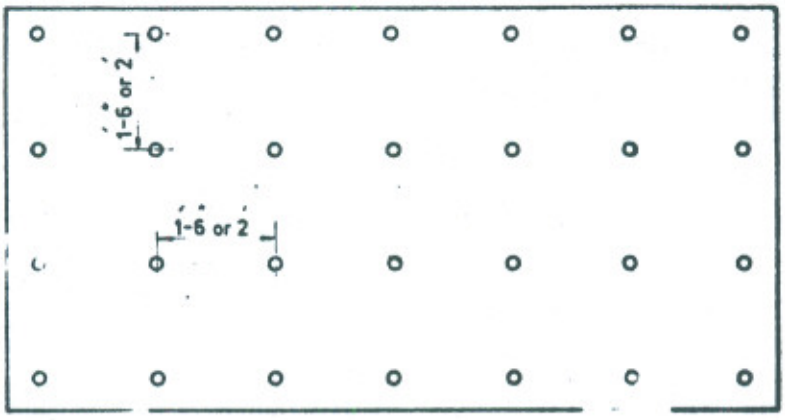
DRAWN	DATE	18-2-78	SCALE	DOOR & WINDOW FRAME	
	NAME	A.REHMAN			RRH II
	CHD.				
CTTC	CHRISTIAN TECHNICAL TRAINING CENTRE. GUJRANWALA. (PAKISTAN)				

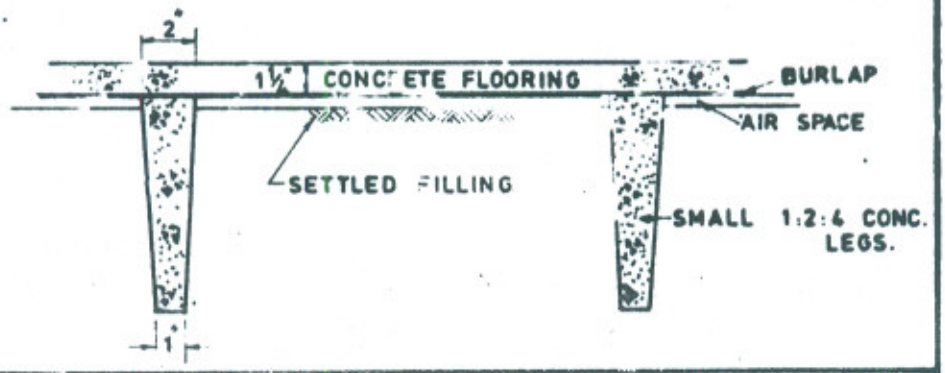
FIGURE – 10


SEAGULL TILES
ROOF SLAB
OPEN END AIR PASSAGE
1'-0"
2'-6"
4¾"
1½"
¾"
1"
1¾"
4½"
3¼"
2"
R 3"
AS CAST

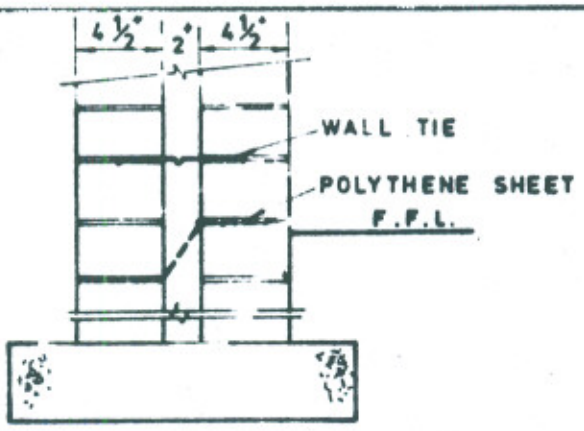
1¼ CONCRETE FLOORING

FIGURE – II





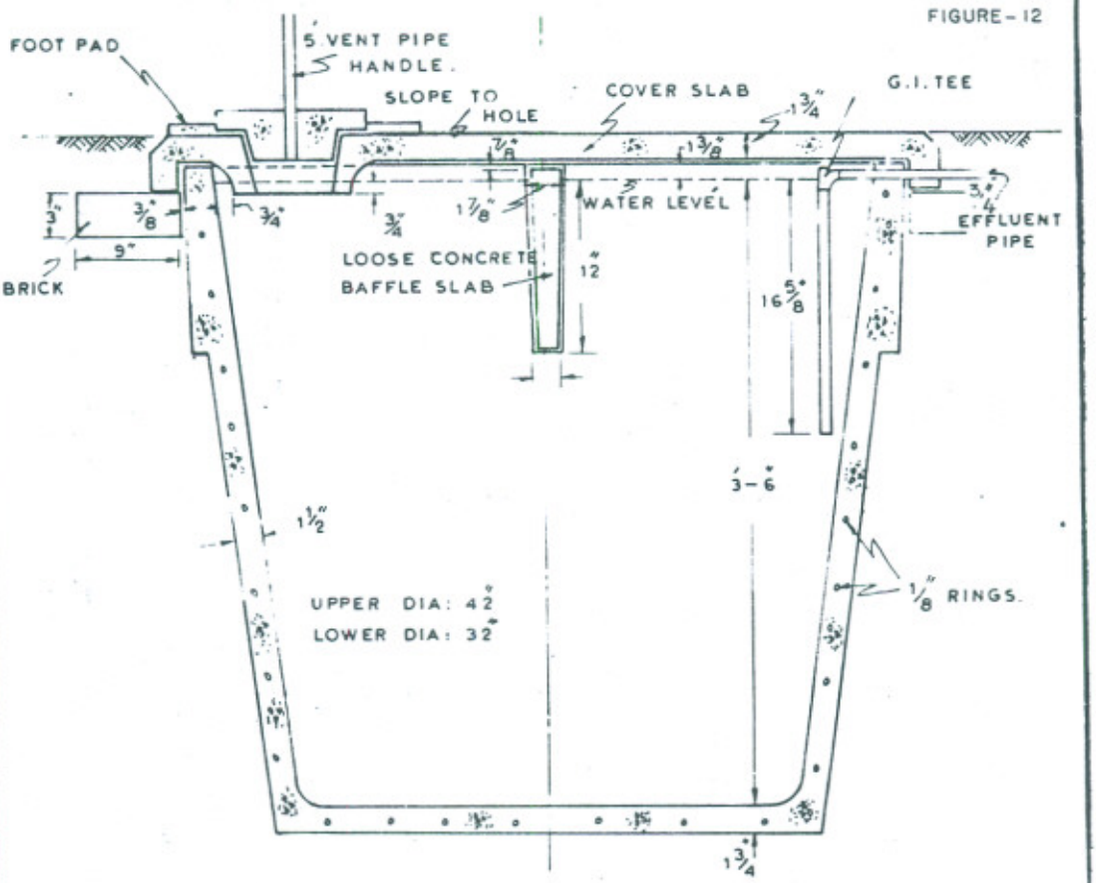
CAVITY WALLING

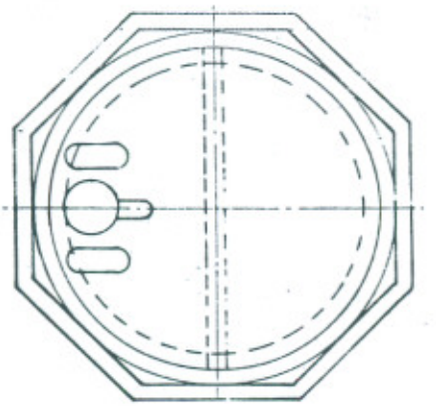


DRAWN	DATE 31-3-78	SCALE	CONCRETE FLOORING & CAVITY WALLING	R R H – II
	NAME A.Rehman			
	CHD. K.G.Old			

CTTC **CHRISTIAN TECHNICAL TRAINING CENTRE**
GUJRANWALA. (PAKISTAN)

FIGURE - 12







STACKING ARRANGEMENT

ASSUMPTION: DAILY INPUT WOULD NOT NORMALLY EXCEED FIFTEEN GALLONS.
FLUID CAPACITY OF TANK 170 GALLONS.
DISCHARGE TO EITHER 8" SEALED BOREHOLE OR A COVERED SOAKPIT.

DRAWN	DATE	23-11-73	SCALE	VILLAGE DOMESTIC LATRINE	DRAWING No. CTTC-RR-12
	NAME	A.REHMAN			
	CHD.	K:G.OLD			

CTTC CHRISTIAN TECHNICAL TRAINING CENTRE
GUJRANWALA. (WEST PAKISTAN)