REINFORCED CONCRETE.

MODULAR ROOF UNIT.

By

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B.Arch. Alexandria University, 1960.

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER IN ARCHITECTURE

AT THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JULY 1962.

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Signature of Thesis Supervisor
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Prof. Eduardo F. Catalano.

Signature of Head of Department,
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Prof. Lawrence B. Anderson.

July 27,1962.

Pietro Belluschi, Dean
School of Architecture and Planning
Massachusetts Institute of Technology
Cambridge 39, Massachusetts.

Dear Dean Belluschi :

In partial fulfillment of the requirements for the

degree of Master in Architecture, I hereby submit

this thesis entitled, " Reinforced Concrete Modular

Roof Unit."

Respectfully,

Shafik I. Rifaat.

ACKNOWLEDGEMENTS

I should like to thank the following
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the course of this study

Professor Eduardo F. Catalano
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and

Professor Howard Simpson
Professor Giulio Pizzetti
Professor A. G. Harris.

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REINFORCED CONCRETE MODULAR ROOF UNIT.

By

Shafik I. Rifaat.

Submitted in partial fulfillment of the requirements for the dgree of Master in Architecture in the Department of Architecture, on July 27,1962.

Program.

THE USE OF REINFORCED CONCRETE :

Project C. Design of a MODULAR ROOF UNIT for schools, shopping centers, or other one-story buildings.

Span : from 30 to 40 feet.

Space defined by a peripheral low horizontal area, and a central high area of varied forms. Natural and / or artificial light.

INTRODUCTION

Free education, to eradicate ignorance in the developing
countries, is a must. In Egypt, there is an urgent and
immediate need for primary schools. The number of students,
between the ages 6-12 years, in need of primary education,
who cannot find schools to accomodate them, are about
1,550,000 students. If we consider a primary school,
that has six stages of education, with three classrooms
per stage, and 35 students per classroom, then we will
need approximatly 2,460 primary schools, each consisting
of 18 classrooms, with a total number of 44,300 classrooms.

The aim of this thesis, is to direct the design and the
development, of a - modular roof unit, spanning from
9-12 meters, (30 - 40 feet), a space defined by a
peripheral low horizontal area and a central high one -
to form a classroom, self-contained, flexible within
itself, to allow and facilitate the teaching and other
activities to take place, and to form a system of growth,
of which this unit is the component.

OBJECTIVES

The unit should be designed to suit the Egyptian enviroment.
Both the simplicity of errection, and the lowering of the
total cost, without affecting the quality, are essential.
There should be maximum usage of natural resources, such
as day-light for lighting, and natural air movement for
cross-ventilation.

The following studies, have been a useful guide, to reach
the final architectonic expression of this unit :
1-   Structural system
2-   Quality of spaces
3-   Admittance of light
4-   Ventilation
5-   Acoustics
6-   Weather insulation
7-   Subdivision of space
8-   Construction.

1- STRUCTURAL SYSTEM

Structural analyses, based on logical assumptions, have been
studied, to attain maximum usage of the space enclosed,
and to obtain best performance of the material, Reinforced
Concrete. This is achieved through the geometrical
arrangement of the surfaces, and the system of supports.

Assumptions :

- The continuity of surfaces is essential; the low
horizontal area and the high one, should act together to
reduce the stresses in the structure.
- The structure should be carried on four supports, to
produce practical spans, and load distribution.
- The logical position of the four supports, is shown
in figure -C-, where the columns can support both, the
low horizontal area, and the high one, as well as reducing
the moments and shearing forces , (stresses) , in the
structure; as shown in the simple diagrams A, B, and C.
- The proportion of the cantilevers to the main span,
should not exceed 1:3:1; this gives equal positive and
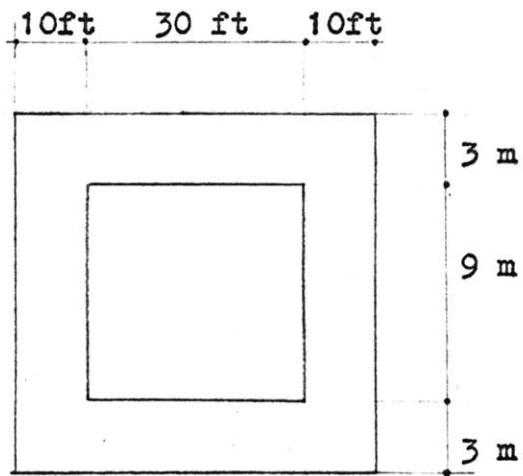negative moments under uniform distributed loading.
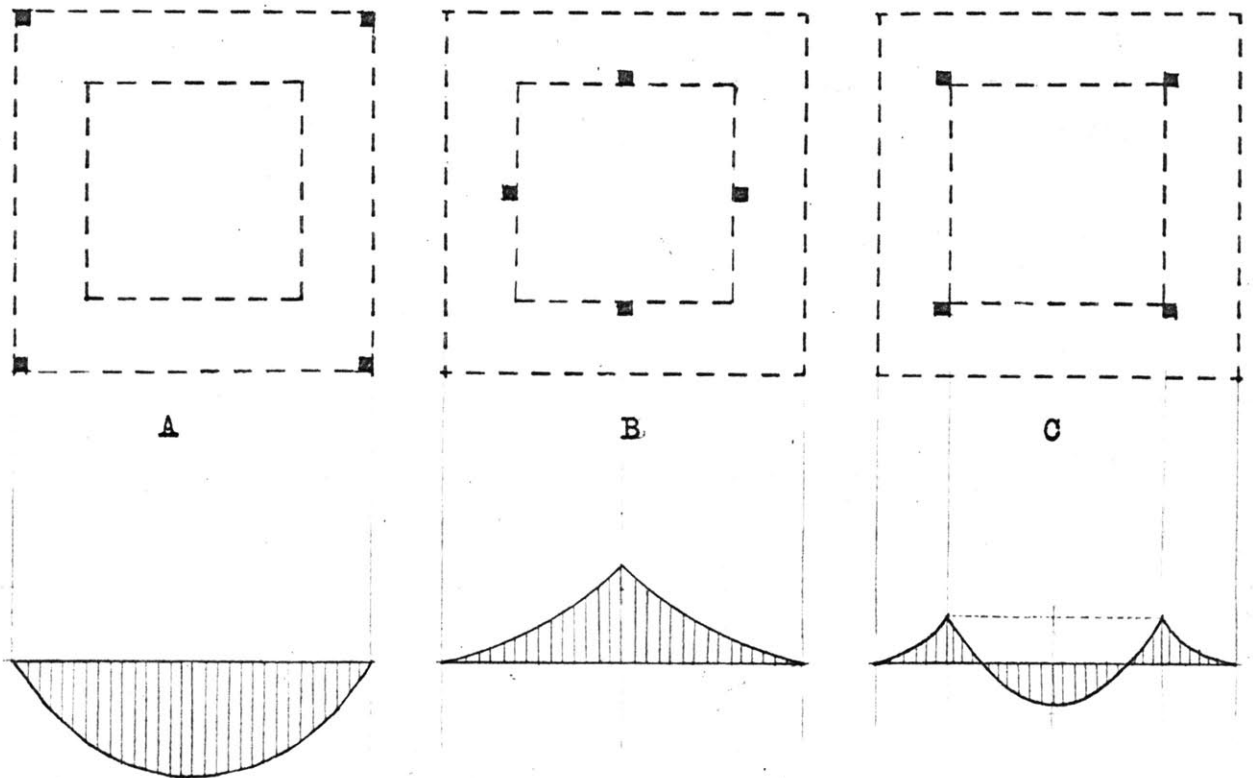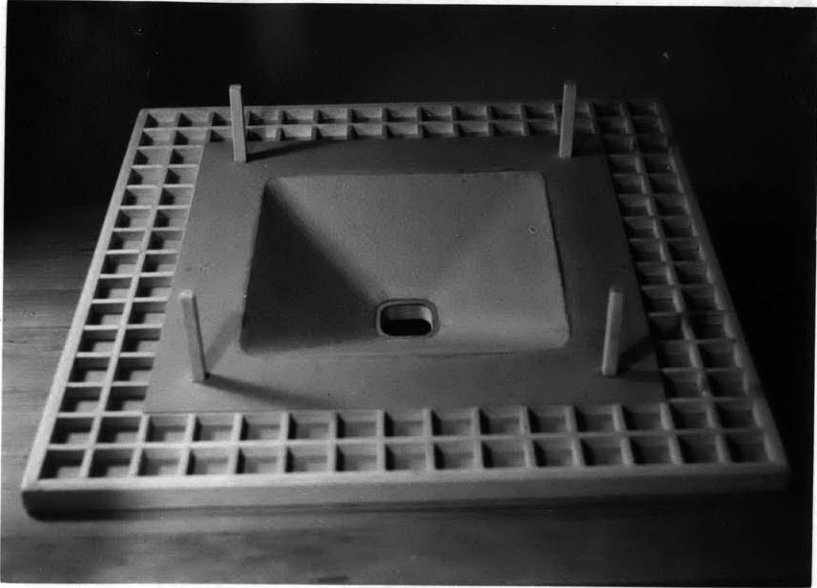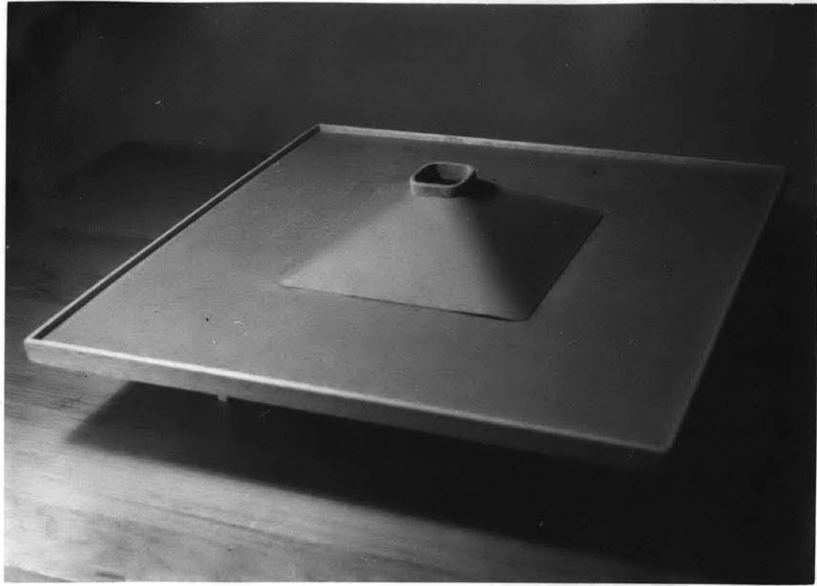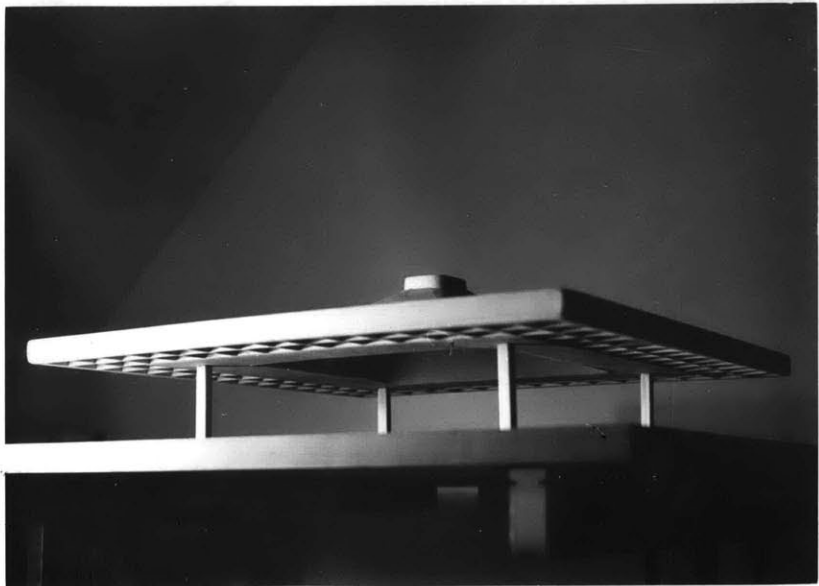(Figure 2 , page 5.)

Figure 1

Figure 2

STUDY MODEL

Final study

General description :

- A folded plate structure, with the horizontal plate

ABC and FGH forming the peripheral low area, and the

inclined plate CD and EF forming the pyramidal major space.

(As seen in section on page 11).

- Parts AB and GH form a waffle system, of 1 meter (3feet)

grid, with a depth of 25 centimeters (10 inches).

- Parts BC and FG are a solid slab, of 1.80 meter (6 feet)

in width, and 25 centimeters in depth(10 inches).

- The structure is supported on four columns, located

at a set-back of 80 centimeters,(2 feet 10 inches), from

the four corners of the pyramidal roof.

Structural behaviour :

The folded plate action will occur, as the pyramidal

slab CD will act as a deep beam, to resist the inclined

force F_1; the horizontal slab ABC will act as a tie ring

to resist the horizontal force F_h.

Both ABC and CD, as a folded plate will prevent the move-

ment of point C.in space.   (Figure 20 , page 20)

Load distribution :

Assumptions of load distribution between the low horizontal

area and the high one, have been calculated in previous' studies
to determine the behaviour of the structure under different
loading conditions.

The final load distribution is calculated in proportion to
the deflections at points of maximum moments.

The horizontal slab ABC is directly supported on the columns,
calculations of the deflections at points 1,2 and 3, are
made to determine the load distribution between parts AB
and BC. (diagram 3 page 11).

Beam A will transfer the load it receives from part AB,
to the columns, through the three cantilevers running
over the column, and carrying beam A itself.(diagram 13
page 18).

It is assumed here, that the solid slab (flat beam) BC,
will carry 35% of it's own weight, plus the load it
receives from part AB. This load is transferd directly
to the columns. At the same time, part BC will resist
the twisting moments of the cantilevers, hence reducing
the negative moments at the edge C.

The positive moments between the columns, occuring at part
BC due to 35% of the load, previously mentioned, will be
reduced by the over-hangs at both sides .(figure 15 on
page 18).

The remaining 65% of the load from part ABC, plus the

vertical component of load from the pyramidal roof, will

form reaction R at point C; this force R will be resisted

by the folded plate action of ABCand CD. (diagram 20 on

page 20)

The pyramidal roof slab has been designed, assuming that

it is fixed at the base and two sides, with the high edge

simply supported. The coefficient of load distribution

has been obtained from the American Reinforced Concrete

Codes.

The area of the cross-section of the column has been

increased, to allow for a drainage pipe, with a diameter

of 10 centimeters (4 inches).

A simple rectangular foundation is designed to function

in poor soil conditions.

Structural analysis:

(Mathematical calculations of the preceeding text.)

Dimensions submitted are by the metric system.

Loading is by the ton.

m = meter.   cm = centimeter.   t = ton.   kg = kilogram.

1 m^3 of reinforced concrete = 2.4 t.

Loading :

Assuming a 25 cms waffle slab for cantilever AB.

6 cms slab	= 0.06 x 1.00 x 2.4	= 0.144 t
12 x 20 cms beam	= 0.12 x 1.00 x 0.20 x 2.4	= 0.056 t
live load		= 0.050 t
insulating material		= 0.050 t
Total		= 0.300 t/m^2

Assuming a 25 cms solid slab for BC.

25 cms slab	= 0.25 x 1.00 x 2.4	= 0.600 t
insulatin material and live load		= 0.100 t
Total		= 0.700 t/m^2

Assuming an average thickness of 7.5 cms

for CD	= 0.075 x 1.00 x 2.4	= 0.180 t

Figure 4

| 3.00 | 9.00 | 3.00 |

2.50

| 2.00 | 1.8 | 7.4 | 1.8 | 2.00 |

0.50

60°

H G F E D C B A

.3 t/m .3 t/m .3 t/m .3 t/m

.7 t/m .7 t/m

Figure 3

15.00 m.

| 3.00 | 9.00 | 3.00 |

S

S

1.5

H G F E D C B A

3

2 1
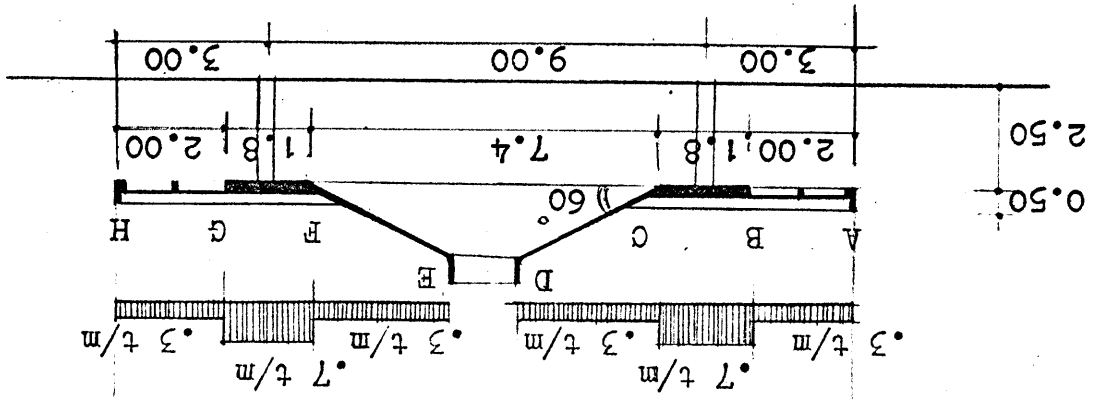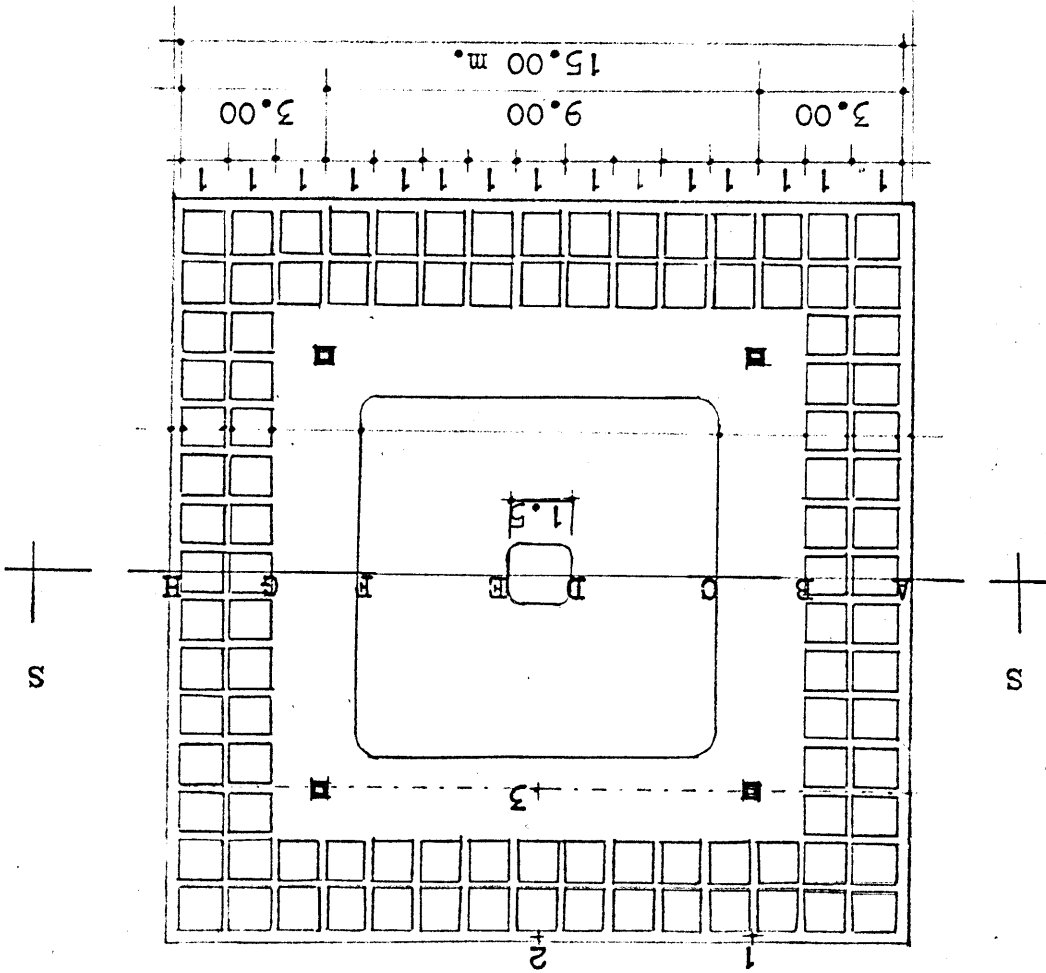
Insulating material and live load $\qquad$ = 0.100 t

Total $\qquad$ = 0.280 t/m^2

Horizontal projection $\qquad$ = 0.300 t/m^2

(figure 4 page 11).

Load distribution:

approximate distribution of load between A and BC, assuming

points 2 , 3 to have the same rigidity.

Load on point 2 $\qquad$ = 0.300 x 1.0 $\qquad$ = 0.3 t/m

Load on point 3 $\qquad$ = 0.300 + 1.4 x 0.700 $\qquad$ = 1.28 t/m

To calculate deflections at mid span of beams A and BC,

points 2,3

$$\delta \text{ at } 3 = \frac{5}{384} \times \frac{wl^4}{EI}$$

$$I \text{ at } 3 = 180 \times \frac{25^3}{12} = 235,000 \text{ cms}^4$$

$$\delta \text{ at } 3 = \frac{5}{384} \times \frac{1.28 \times 9^4 \times 10^4 \times 100}{235,000 \times E} = \frac{360}{E} \text{ cms.}$$

To get δ at point 2

Load on three cantilevers supporting beam A

$$= 0.300 \times \frac{9.00}{2} = 1.35 \text{ t}$$

Load on one cantilever $\qquad$ = 0.45 t

Deflection of end of cantilever at point 1

$$= \frac{0.45 \times 2^3}{3 \times EI}$$

$$I \text{ cantilever} = \frac{15 \times 25^3}{12} = 19{,}600 \text{ cms}^4$$

$$\delta \text{ at } 1 = \frac{0.45 \times 2^3 \times 10^4 \times 100}{3 \times 19{,}600} = \frac{61}{E} \text{ CMS}$$

$$I \text{ at } 2 = \frac{25 \times 25^3}{12} = 32{,}700 \text{ cms}^4$$

$$\delta \text{ at } 2 = \frac{61}{E} + \frac{0.3 \times 9^4 \times 10^4 \times 100}{32{,}700 \times E} = \frac{660}{E} \text{ cms.}$$

(figure   page   )

Approximate distribution of load between A & BC

$$\text{Beam A} = \frac{360}{(360+660)} \times 0.3 \times 2.00 = 0.21 \text{ t/m}$$

Assuming that beam BC will gain more rigidity , being

connected to rigid beam CD; then beam A will carry less load.

$$= 0.15 \text{ t/m}$$

Approximate distribution of load between BC & CD, assuming

beam BC will carry 35% of the load, while beam CD will

carry 65% of the load.

Load on beam BC $= 0.35(0.7 \times 1.8 + 0.3 \times 2 - 0.15) = 0.60 \text{ t/m}$

Load on Cd from cantilever roof $= 0.65 \times 1.71 = 1.11 \text{ t/m}$

Assuming distributed load on beam Bc to be triangular

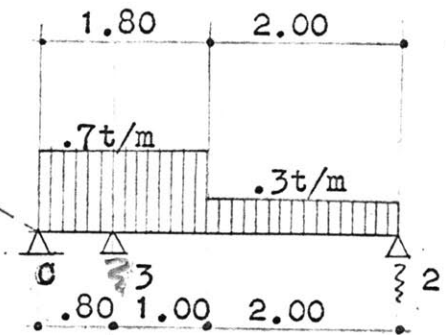$$P_{max} = \frac{0.60 \times 2}{1.8} = 0.66 \text{ t/m}$$

Design of different parts:

1- Design of cantilever slab: (figures page 14)

$$M_{x-x} = 0.3 \times 2 \times 2.8 + 0.7 \times \frac{1.8^2}{2}$$
$$-0.15 \times 4.8 - 0.66 \times \frac{1.8^2}{3}$$
$$= 1.68 + 1.15 - 0.72 - 0.71 = 1.4 \text{ mt}$$

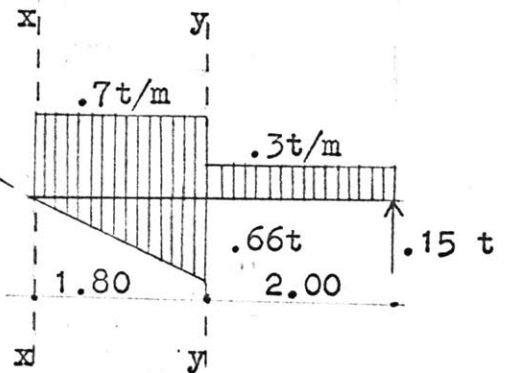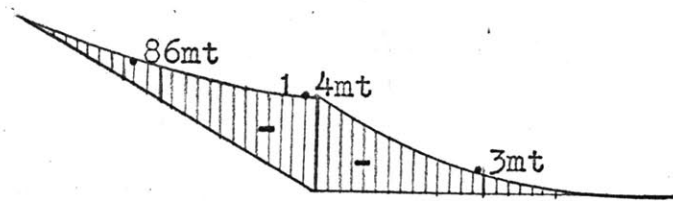# 1- Design of cantilever slab

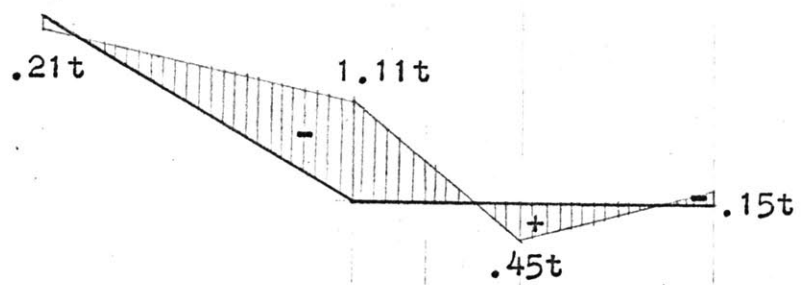Deflections at 3&2

Figure 5

Load distribution

Figure 6

B.M.D.

Figure 7

S.F.D.

Figure 8

$$\text{Shear}_{x-x} \qquad = 1.8 \times 0.7 + 0.6 - 0.15 - 0.6 \qquad = 1.11 \text{ t}$$

Design of section x-x

$$d \quad = 0.3 \sqrt{\frac{140000}{100}} \qquad = 11.2 \text{ cms}$$

t chosen 25 cms $\quad A_s = \dfrac{140000}{1250 \times 23} \qquad = 4.85 \text{ cms}^2$

Chosen 7 ϕ 3/8 " $\qquad\qquad\qquad = 4.97 \text{ cms}^2$

Check of shear $\qquad = \dfrac{1110}{100 \times 23 \times 0.87} \qquad = 0.555 \text{ Kg/cms}^2$

$$M_{y-y} \qquad = 0.3 \times \frac{2^2}{2} - 0.15 \times 2 \qquad = 0.30 \text{ mt}$$

$$\text{Shear}_{y-y} \qquad = 0.6 - 0.15 \qquad = 0.45 \text{ t}$$

Design of section y-y

$$d \qquad = 0.3 \sqrt{\frac{30000}{12}} \qquad = 15 \text{ cms.}$$

t chosen 25 cms.

$$A_s \qquad = \frac{30000}{1250 \times 23} \qquad = 1.04 \text{ cms}^2$$

Chosen 3 ϕ 5/16 $\qquad\qquad\qquad = 1.47 \text{ cms}^2$

or 2 ϕ 3/8 $\qquad\qquad\qquad = 1.42 \text{ cms}^2$

Check of shear $\qquad = \dfrac{450}{12 \times 23 \times 0.87} \qquad = 1.88 \text{ Kg/cms}^2$

2- Design of beam A: (Figures, page 16)

$$M_{-ve} \qquad = \frac{0.15 \times 2^2}{2} \qquad = 0.30 \text{ tm.}$$

$$M_{+ve} \qquad = 1.125 \times 4.5 - \frac{0.15 \times 7.5^2}{2} \qquad = 0.7 \text{ tm}$$
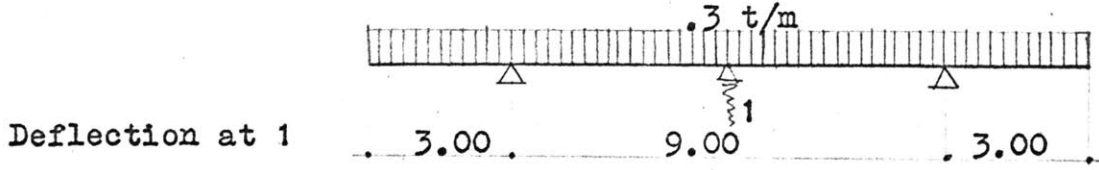
"2- Design of beam A.

Deflection at 1

.3 t/m

3.00   9.00   3.00
                 1

Figure 9

L. Distribution

.15 t/m

3.00   9.00 m   3.00
         1.125t   1.125t
2.00 1 1   7.00 m   1 1 2.00.
      .375t   .375t

Figure 10

B.M.D.

0.30tm   0.30tm
     -                     -
              +
         0.70tm

Figure 11

S.F.D.

0.675t
              0.45t
     -
              -
  +   +
0.45t
              0.675t
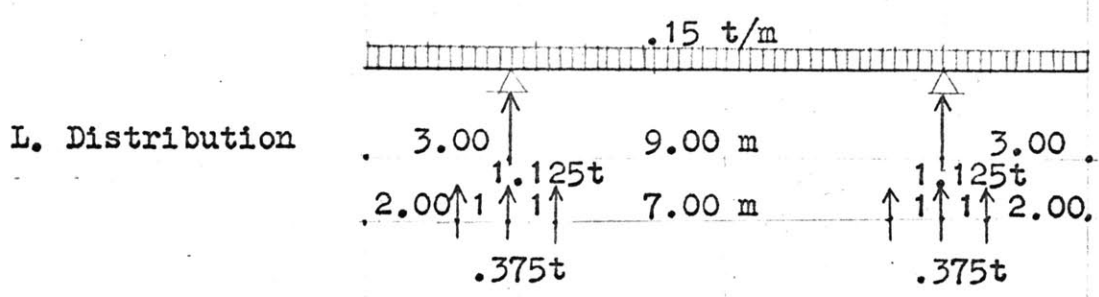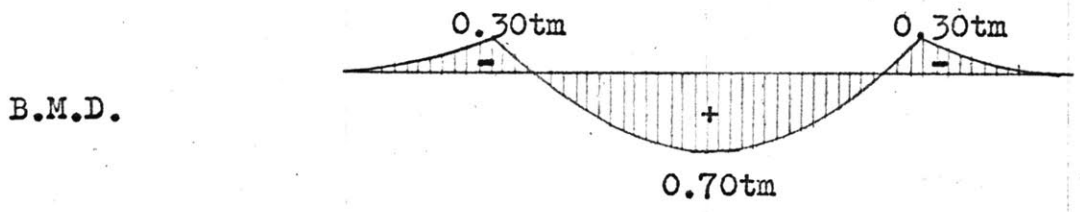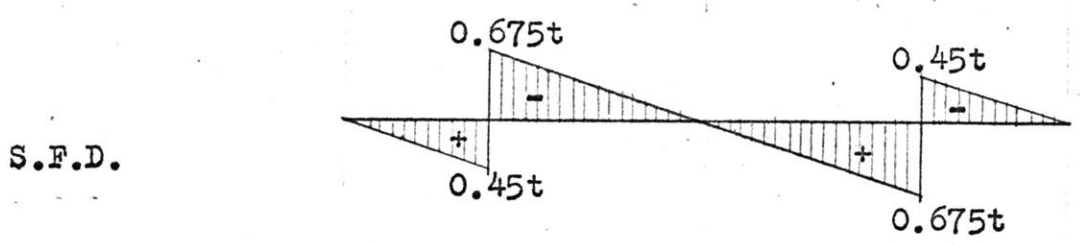
Figure 12

$$d = 0.3 \sqrt{\frac{70000}{25}} \qquad = 16 \text{cms.}$$

t chosen 25 cms

$$A_s = \frac{70000}{1250 \times 22} \qquad = 2.55 \text{ cms}^2$$

Chosen 2 ϕ 1/2" $\qquad = 2.54 \text{ cms}^2$

3- Design of three cantilevers supporting beam A:

(Figure 13, page 18)

$$M_{-ve} \qquad = 0.375 \times 2 \qquad = 0.75 \text{ tm}$$

$$d = 0.3 \sqrt{\frac{75000}{15}} \qquad = 21 \text{ cms}$$

t chosen 25 cms.

$$A_s = \frac{75000}{1250 \times 21} \qquad = 2.8 \text{ cms}^2$$

Chosen 2 ϕ 5/8" $\qquad = 3.94 \text{ cms}^2$

4- Design of beam BC: (figures , page 18)

$$M_{-ve} \qquad = 1.12 \times 2 \qquad = 2.25 \text{ tm}$$

$$M_{+ve} \qquad = -\frac{6.6 \times 5.5^2}{2} - 1.125 \times 7.5 + 4.45 \times 4.5$$

$$= -9 -8.5 +20 \qquad = 2.5 \text{ tm.}$$
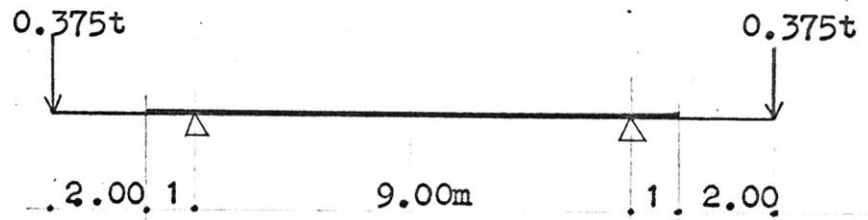
- 17 -

3- Design of the thre cantilevers supporting beam A.

0.375t   0.375t

.2.00 .1.   9.00m   .1. 2.00

Figure 13

4- Design of beam BC.

L. Distribution

1.125t   0.6 t/m   1.125t

4.425t   4.425t

2.00 .1.   9.00m   .1. 2.00

Figure 14

B.M.D.

2.25mt   2.25mt

−   −

+

2.5mt

Figure 15

S.F.D.

2.7t   1.725t

−   −
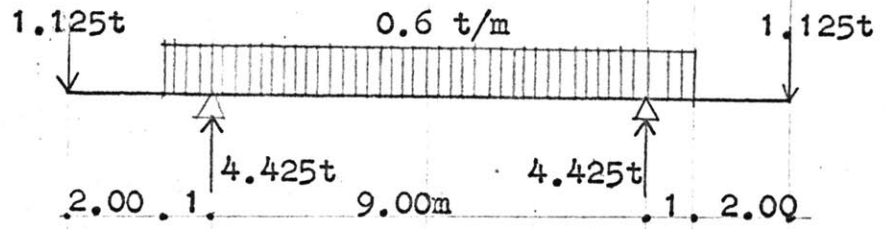
+   +
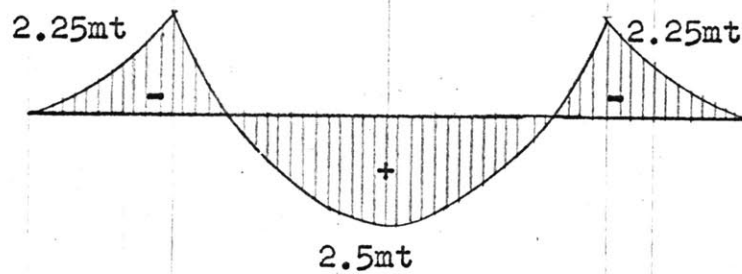
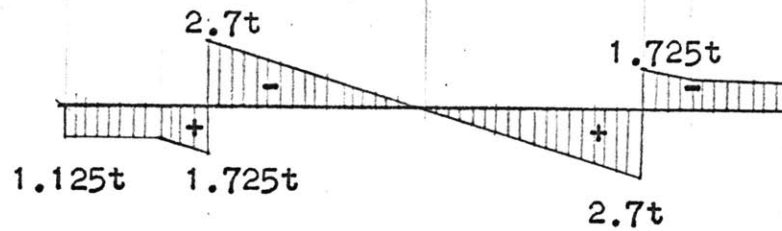1.125t   1.725t   2.7t

Figure 16

$$d = 0.3\sqrt{\dfrac{250000}{180}} \qquad = 11.3 \text{ cms}$$

t chosen 25 cms.

$$A_s = \dfrac{250000}{1250\times21} \qquad = 9.5 \text{ cms}^2$$

Chosen 8 ϕ 1/2"

5- Design of pyramidal roof : (figure 19 page 20)

$W_1'i$ $\qquad = 0.125 \times \left(\dfrac{1.5 + 7.4}{2}\right) \times \dfrac{3.35}{7.4} = 0.250$ t

W_2' $\qquad = \dfrac{0.25 \times 1.675}{2} \qquad = 0.210$ t

$W_2'i$ $\qquad = 2 \times 0.210 \qquad = 0.420$ t

$W_2'h$ $\qquad = 5 \times 0.210 \qquad = 0.470$ t

$V1$ $\qquad = 5 \times 1.11 \qquad = 2.475$ t

Vh $\qquad = 2 \times 1.11 \qquad = 2.220$ t

$F1$ $\qquad = 0.250 + 0.420 + 2.475 \qquad = 3.145$ t

Fh $\qquad = 0.470 + 2.220 \qquad = 2.690$ t

6- Design of CD, acting as a deep beam to resist F1:

(Figure 20, page 20)

- 19 -

4.54m

1.5m

3.35m

7.4 m

1.5m

7.4 m
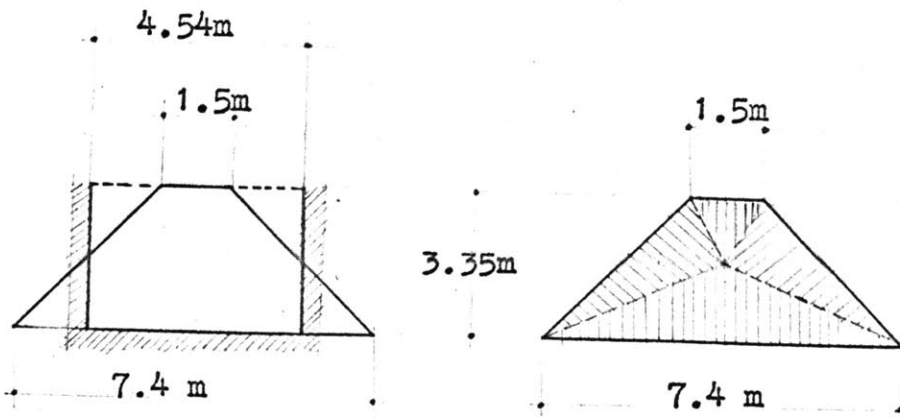
5- & 9- Design of pyramidal roof.

Figure 17   Figure 18

.28t

.25t

.125t

.42t

.21t

.47t

2.475t

2.22t

1.11t

F₁=3.145t

Fₕ=2.690t

R=1.11t

6- Design of OD.   Figure 19   Figure 20

1.80m

9.1 tm

18.2tm

3.7m

4.5m

7.40m

1.80m

9.2tm
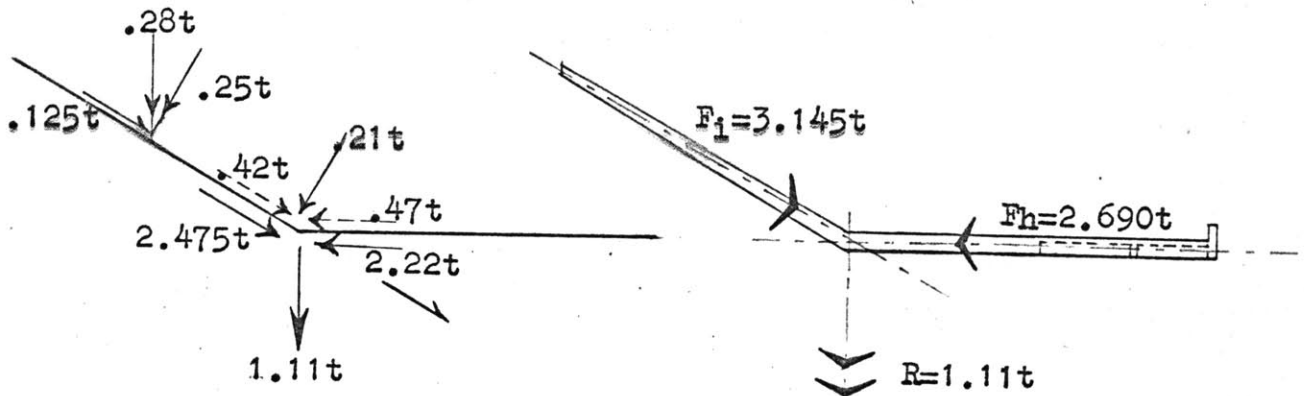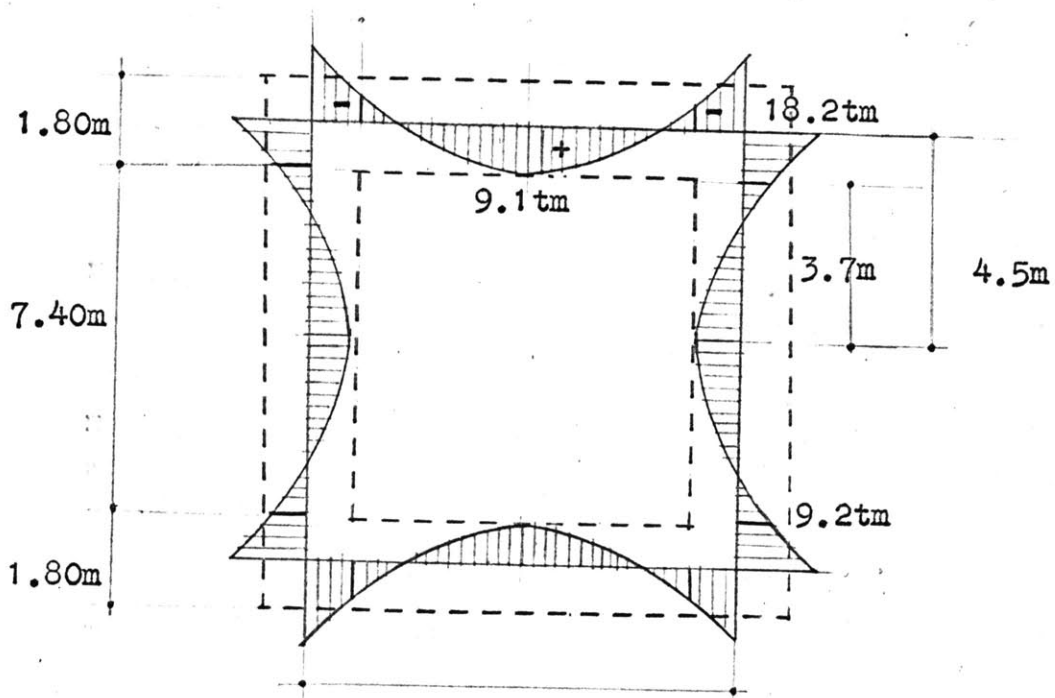
7- Design of tie beam BC.

Figure 21

$$M \qquad = 3.145 \times \frac{7.4^2}{8} \qquad = 21.5 \ \text{tm}$$

$$A_s \qquad = \frac{2150000}{1250 \times 0.87 \times 3.35} \qquad = 6.6 \ \text{cms}^2$$

Chosen 6 ϕ 1/2" $= 7.62 \ \text{cms}^2$

7- Design of tie beam BC : (Figure 21, page 20)

$$M_{+ve} \qquad = \frac{2.690 \times 9^2}{24} \qquad = 9.1 \ \text{tm}$$

$$M_{-ve} \qquad = \frac{2.690 \times 9^2}{12} \qquad = 18.2 \ \text{tm}$$

$$A_s +ve = \frac{910000}{1250 \times 170} \qquad = 4.25 \ \text{cms}^2$$

To get $A_s -ve$

$$M'-ve \qquad = \frac{3.7^2}{4.5} \times 27 - 9.1 \qquad = 9.2 \ \text{cms}^2$$

$$A_s -ve \quad = A_s +ve \qquad = \frac{920000}{1250 \times 170} \qquad = 4.25 \ \text{cms}^2$$

Chosen 4 ϕ 1/2" $= 5.08 \ \text{cms}^2$

8- Design of diagonal edges :

$$P \qquad = \frac{0.3 \times 7.4^2}{4} \qquad = 4.1 \ \text{t}$$

Taking one quarter of the load of the pyramidal slab.

$$M_x = M_y \qquad = \frac{4.1}{2} \times 0.8 \qquad = 1.64 \ \text{tm}$$

$$A_s = \frac{164000}{1250 \times 22} = 5.9 \text{ cms}^2$$

Chosen 3 ϕ 5/8" $= 5.94 \text{ cms}^2$

9- Design of pyramidal slab : (Figure 17 page 20)

$$A/B = \frac{3.35}{4.45} = 0.75$$

$$M_A\text{-ve} = 0.061 \times 250 \times 3.35^2 = 175 \text{ Kg.m}$$

$$M_B\text{-ve} = 0.036 \times 250 \times 4.45^2 = 180 \text{ Kg.m}$$

$$M_A\text{+ve} = 0.036 \times 250 \times 3.35^2 = 105 \text{ Kg.m}$$

$$M_B\text{+ve} = 0.013 \times 250 \times 4.5^2 = 65 \text{ Kg.m}$$

$$d \text{ for } M_{max} = 0.38 \sqrt{\frac{18000}{100}} = 5.5 \text{ cms}$$

$$A_s \text{ for } M_{max} = \frac{18000}{1250 \times 8.5} = 1.8 \text{ cms}^2$$

Chosen 5 ϕ 1/4"/m $= 1.6 \text{ cms}^2$

10- Design of column :

$$\text{Load per column} = \frac{1}{4} \quad 0.3 \times (15^2 - 11^2) + 0.7 \times (11^2 - 7.4^2) + 0.3 \times 7.4^2$$

$$= \frac{1}{4} \times 93.1 = 23.5 \text{ t}$$

$$P = f_c \times A_c \ (\ 1 + \text{Nxu} \ )$$

$$23500 = 45x \; A_c(1+15x0.008)$$

$$A_c \qquad = \frac{23500}{45} \qquad = 425 \; cms^2$$

Chosen 30 x 30 cms $\qquad = 900 \; cms^2$

To allow for a drainage pipe of 10 cms (4 ") diameter.

$$A_s \qquad = 435x0.004 \qquad = 1.74 \; cms^2$$

Chosen 4 ϕ 3/8 "

11- Design of foundation:

Net load on soil $\quad = 24.00$ t

$$f_{all.} \qquad = 0.8 \; Kg/ \; cms^2$$

i- Design of plane concrete :

$$A \qquad = \frac{24.00}{8.0} \qquad = 3.00 \; m^2$$

Chosen $\qquad$ 180 x 180 x 40 cms depth

ii- Design of reinforced concrete footing :

Dimensions: 100 x 100 x 30 cms depth

$$f \qquad = \frac{24}{1.0x1.0} \qquad = 24 \; tm$$

$$M \qquad = 24 \; x1.0x\frac{0.35^2}{2} \qquad = 1.5 \; tm$$

A_s $\qquad = \dfrac{1.5 \times 10^5}{1030 \times 30}$ $\qquad = 4.8 \text{ cms}^2$

Chosen 7 ϕ 3/8 $\qquad\qquad\qquad\qquad = 4.97 \text{ cms}^2$

Check of shear

Q $\qquad\qquad = 24 \times 1.0 \times 0.35$ $\qquad = 8.4 \text{ t}$

f $\qquad\qquad = \dfrac{8400}{100 \times 30}$ $\qquad = 2.8 \text{ Kg/cms}^2$

$\qquad\qquad\qquad\qquad\qquad$ (less than 4.0)

Check of bond

q_{bond} $\qquad = \dfrac{0.85 \times 8400}{30 \times 7 \times 3}$ $\qquad = 11.0 \text{ Kg/cms}^2$

$\qquad\qquad\qquad\qquad\qquad$ (less than 12.0)

2- QUALITY OF SPACES

The quality of the low horizontal space is different from
that of the high one, since they accomodate different activities.
The pyramidal high space - of 9 x 9 meters (30 x 30 feet),
is designed to house a major group activity, a class room
of 30 - 40 students. The introduction of matural top light
will allow the continuity of the low , and the high
surfaces, a major point affecting the design.
The horizontal low peripheral space - of three meters (10
feet) width - is designed on a one meter (3 feet) grid;
this will allow for the subdivision of the space,to house
the minor activities, related to the major space, such
as circulation, storage, offices, lavatory accomodations.

The low horizontal flat area, combines the pyramidal roof
and the grid system, in a harmonious transition of surfaces.

3- ADMITTANCE OF LIGHT

Natural light :
Top light : day light is admitted in the structure, through
a plastic dome, 1.5 x 1.5 meters (5 x 5 feet), to diffuse
the direct sun rays ; below it, is an aluminum grid, to
provide uniform intensity of light , over the student's
desks.

Side light : will be admitted only from two directions,
perpendicular to the plain of the black-board .

Artificial light:

The artificial light is integrated within the structure,
and is located in the same place where natural light is
admitted, to maintain the same qualities of the space.
The light will fall indirectly, either through the
aluminum grid, or reflected from the pyramidal slab,
as seen in section. The structure allows the use of
1.2 and 0.6 meter (4 feet and 2 feet) , fluorescent
lamps.

Number of lamps needed

$$K = \frac{h (l + w)}{2lw}$$

(h, l and w are the dimensions of the room.)

$$= \frac{10 \times 60}{2 \times 30 \times 30} = \frac{1}{3}$$

$f = 0.3348$

$$D = fg \ \frac{F_1}{A} \qquad \text{where } g = 0.60$$

$$50 = 0.3348 \times (0.60) \ \frac{F_1}{200}$$

$F_1 = 225,000$ lumens

14 lamps, of 200 watts each, will provide the required
intensity, of 50 lumens per foot square, on the student's
desks.

4- VENTILATION

The natural flow of air is organized, to ventilate the
space. The pyramidal roof will act as a hood, to collect
the hot air, full of carbon dioxide, to be sucked out
through the ventilating openings, in the uppermost central
part. Cold fresh air, is let into the space either ,
through the side windows, or through controlled louvers
at the floor level. This chimney action will speed up
the air flow; also a fan could be used to control it,
and to eliminate any undesirable thermal conditions, created
by the plastic dome. No heating systems are required,
on the contrary, heat insulation is needed.

5- ACOUSTICS

No sound treatment is needed, because of the small dimensions
of the room. Reverberation time is calculated for the
class room, when empty and when full, in both cases, it
is between the allowable limits of 0.6 and 1.4 seconds.

$$\text{Reverberation time} = \frac{0.49 \ V}{a}$$

Volume of room   = 11,160 cubic foot

Surfaces:

Brick walls   = 615 x 0.04   = 24.6

Reinforced concrete   = 1264 x 0.3   = 379.2

Glass   = 90 x 0.2   = 18.0

Wood   = 270 x 0.1   = 27.0

Cement floors   = 1170 x 0.02   = 23.4
                                              ————
                                              472.2

Chairs and tables   = 150 x 0.22   = 33

Chairs, tables and students = 150 x 0.7   = 105

Class room empty   = 505.2

Class room full   = 577.2

Reverberation time when class room is empty

$$= \frac{0.49 \times 11160}{505.2} \qquad = 1.08 \text{ sec}$$

Reverberation time when class room is full

$$= \frac{0.49 \times 11160}{577.2} \qquad = 0.98 \text{ sec}$$

Double walls with 15 centimeters (6 inches) , clearance,
are used between the lavatory accomodations and the class
rooms, to prevent any sound transmission.

6-   THERMAL INSULATION

Heat insulation will be the main concern, since the weather
is generally warm and sunny in Egypt most of the year round,
with rain occuring for two to three months during the winter,
and only in the northern part of the country.

Light weight aggregate, sand, white cement and gypsum are
used in different percentages, according to the climatic
conditions; more cement is to be used in wet weather,
while more gypsum is to be used in dry weather. Both
white cement and gypsum will form good reflecting surfaces,
they will increase the amount of reflected light, and will
decrease the amount of heat absorbed by the roof. This
layer of light-weight concrete, will act as a thermal
insulator, that protects the underlying reinforced concrete,
from extremes of temperature, thus prevent cracking and
leakage of water in cases of rain, also it provides a
sloping surface for water drainage.

7-   SUBDIVISION OF SPACE

Partitioning : The low peripheral horizontal area, is designed
on a one-meter grid. The beams to the interior measure
12.5 centimeters, to receive a 12 centimeter (5 inch),
half-brick wall. The beams to the exterior, measure 27 cms,
to receive a 25 centimeter (10 inch) one-brick wall, or
a 15 centimeter cavity-brick wall.
The one meter module of partitioning , is a reasonable
dimension for standard windows, doors, W.C.spacing, etc.

8-   CONSTRUCTION

Form work :

Durable materials are selected for the forms, to resist

the wear and tear. Forms are to be erected, steel placed

in position, concrete poured then left to dry, then the

forms are to be dismounted and reused. This will speed

the erection cycle, and will cut down the cost.

i- Waffle slab : Metal pans, 1 x 1 meter (3 x 3 foot),

20 centimeters deep (8 inches), are placed on wooden

joists, leaving in-between a cavity, to form wedged

beams of 12.5 centimeters (5 inches), at the bottom,

and 15 centimeters (6 inches) at the top. This will

facilitate pulling out of the metal pans after the setting

of the reinforced concrete.

ii- Pyramidal roof : Consists of four half-cylinder surfaces,

and four traperoidal plate, all made of 3 x 3/4 inch hard

wood boards, grooved and tongued, leaving a V shaped

chanel between the boards.

iii- Columns: Forms consist of square wooden shafts,

30 x 30 centimeters (12 x 12 inches)and 240 centimeters

(8 feet) in height, with a 4 inch drainage pipe in the

center.

iv- Footing : Simple rectangular wooden plated at four

sides, and the plane concrete foundation at the bottom,

will form a casing for the footing.

Flooring :

The floor consists of three layers, (from top to bottom):

i- 5 centimeter (2 inch) layer of cement, sand and fine
aggregates. A grid pattern , 1 x 1 meter (3 x 3 foot),
of grooves is made to prevent the cracking of cement.

ii- 2 centimeter Damp-Proof Course of asphalt.

iii- 15 - 20 centimeter (6 - 8 inch) plane concrete, of
cement, sand and aggregates.

CONCLUSION

A Reinforced Concrete structural system, can be developed,
to define an architectural expression, of enclosing diff-
erent spaces for useful occupancy.

The new techniques of construction, and mass production
systems, can be utilised to reduce the essential costs,
and to facilitate the erection processes.

This study deals with new possibilities, that have broad
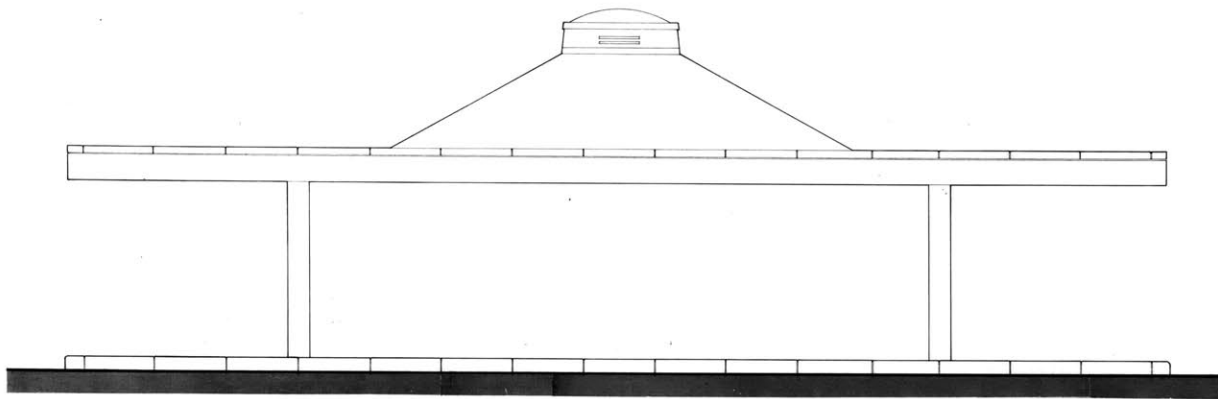applications, in the building industry in Egypt.
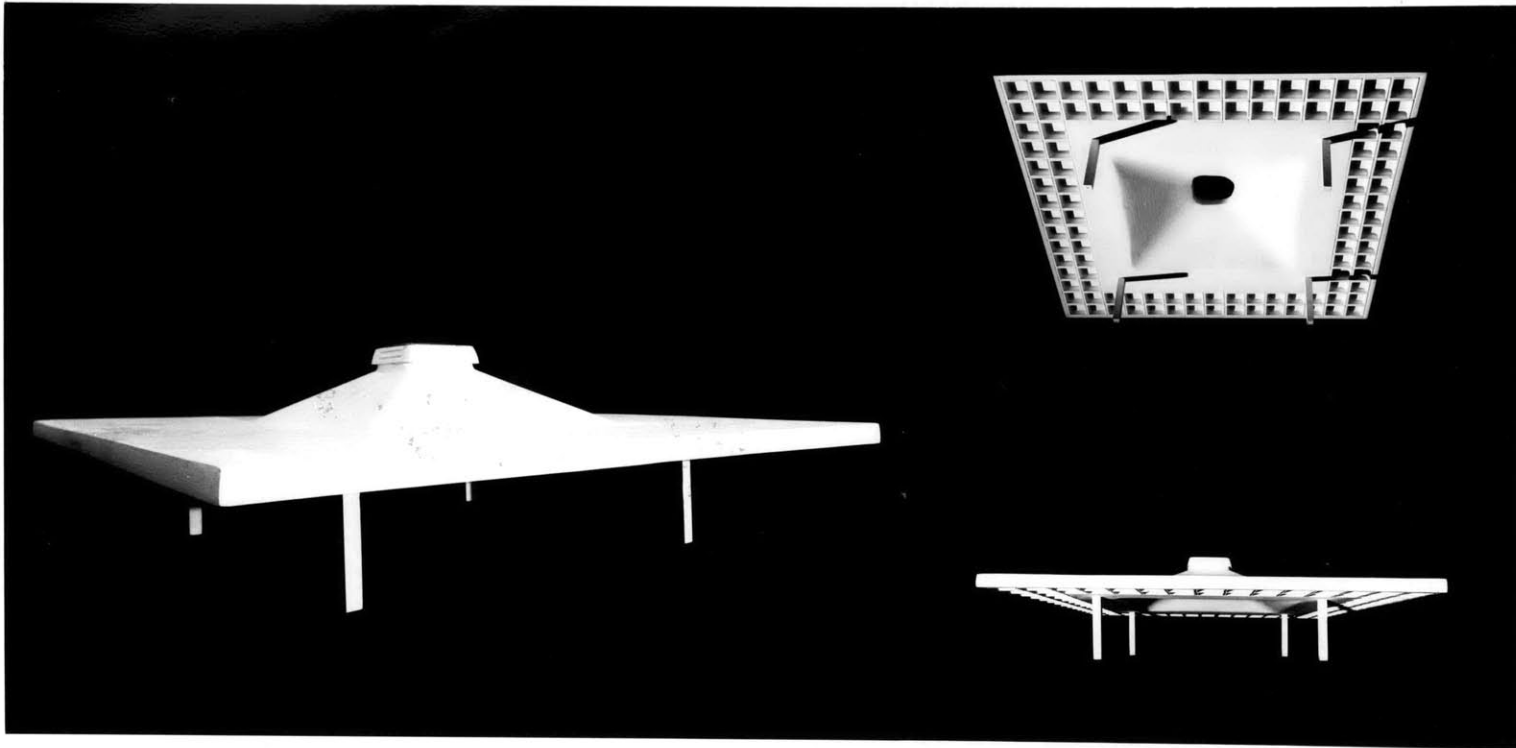
REINFORCED CONCRETE MODULAR ROOF UNIT

MASTER OF ARCHITECTURE THESIS

SHAFIK IBRAHIM RIFAAT   JULY 1962
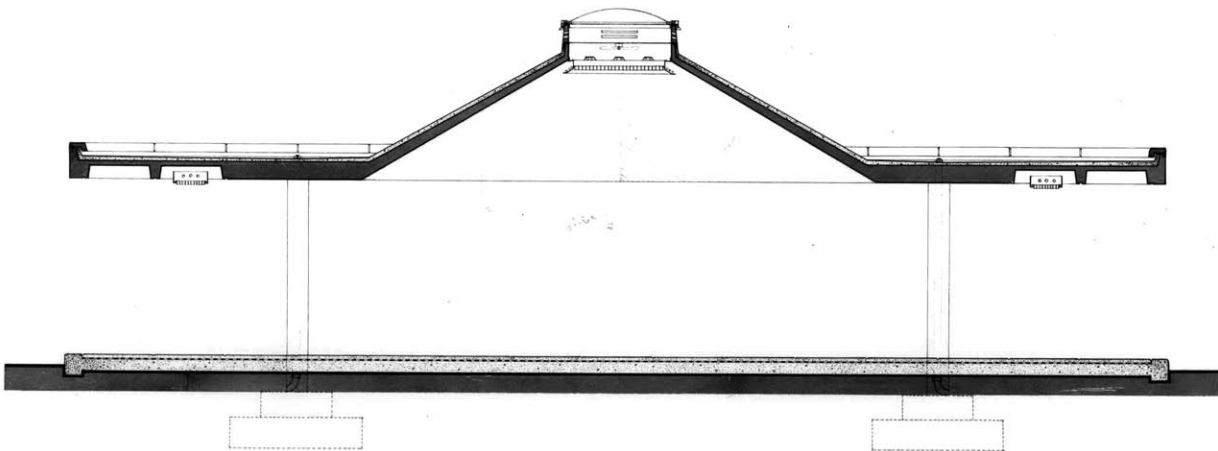
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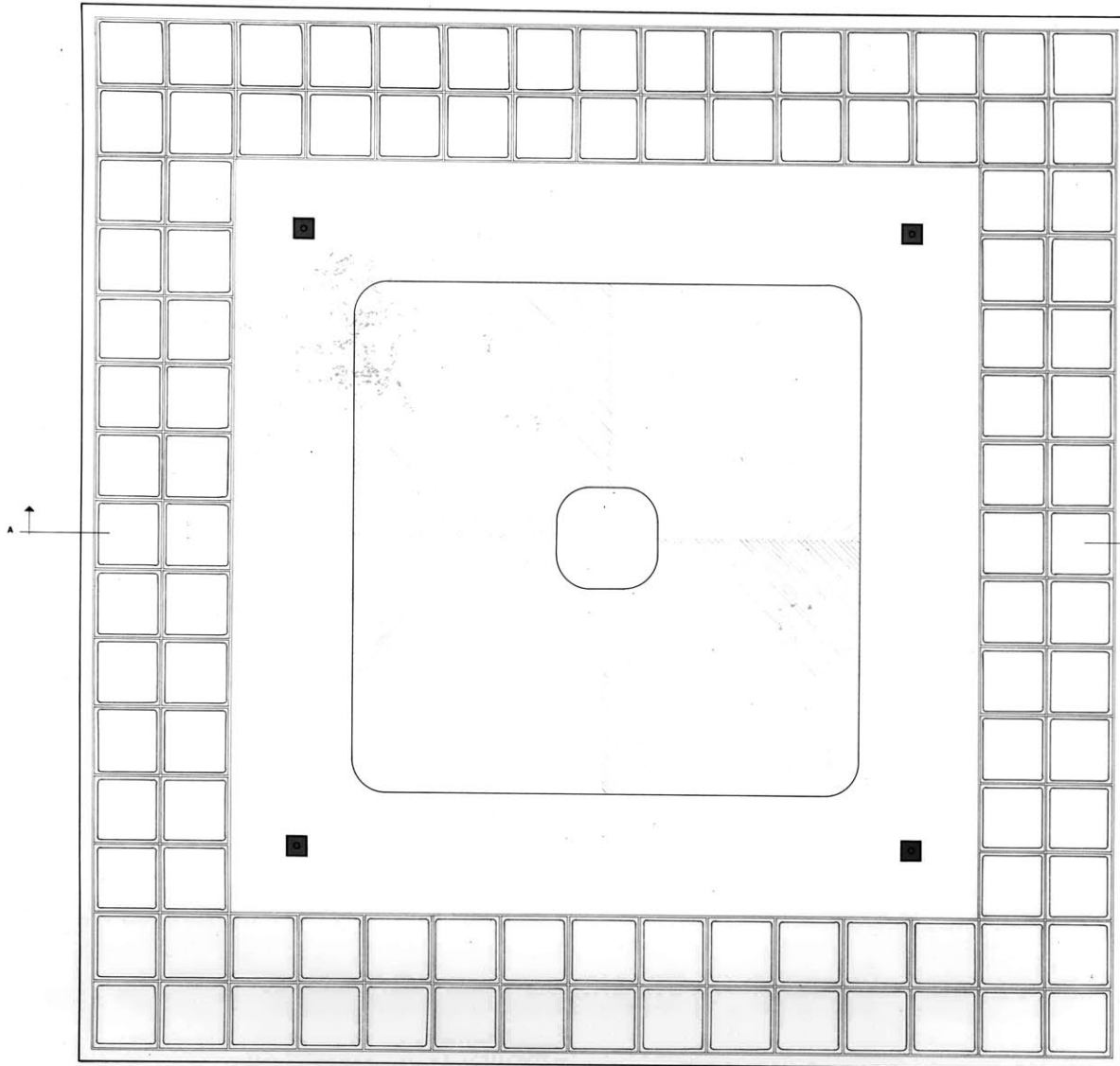
PLAN OF THE UNIT

REINFORCED CONCRETE MODULAR ROOF UNIT

MASTER OF ARCHITECTURE THESIS   SCALE   1 : 25.
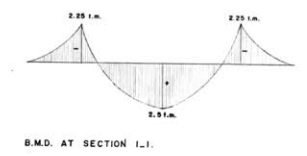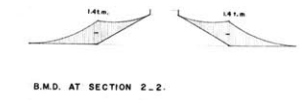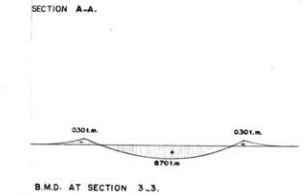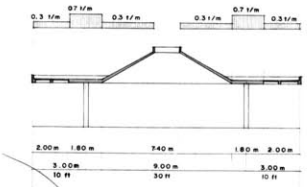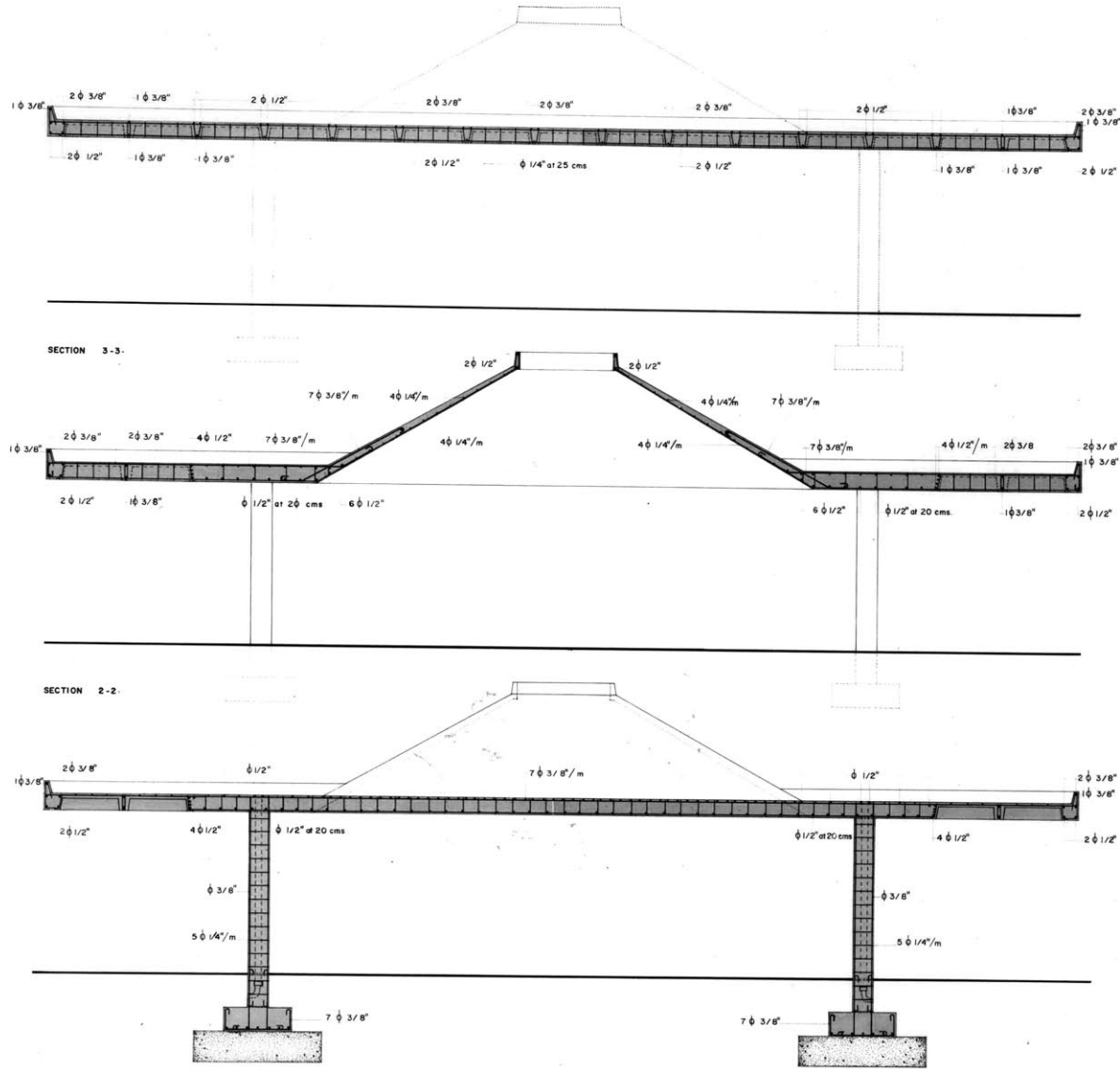
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ELEVATION.

SECTION A-A.

SECTION 3-3.

1φ 3/8" 2φ 3/8" 1φ 3/8" 2φ 1/2" 2φ 3/8" 2φ 3/8" 2φ 3/8" 2φ 1/2" 1φ 3/8" 2φ 3/8" 1φ 3/8"

2φ 1/2" 1φ 3/8" 1φ 3/8" 2φ 1/2" φ 1/4" at 25 cms 2φ 1/2" 1φ 3/8" 1φ 3/8" 2φ 1/2"

SECTION 2-2.

1φ 3/8" 2φ 3/8" 2φ 3/8" 4φ 1/2" 7φ 3/8"/m 2φ 1/2" 2φ 1/2" 4φ 1/4"/m 7φ 3/8"/m 4φ 1/2"/m 2φ 3/8 2φ 3/8" 1φ 3/8"

4φ 1/4"/m 4φ 1/4"/m

2φ 1/2" 1φ 3/8" φ 1/2" at 2φ cms 6φ 1/2" 6φ 1/2" φ 1/2" at 20 cms 1φ 3/8" 2φ 1/2"

SECTION 1-1.

1φ 3/8" 2φ 3/8" φ 1/2" 7φ 3/8"/m φ 1/2" 2φ 3/8" 1φ 3/8"

2φ 1/2" 4φ 1/2" φ 1/2" at 20 cms φ 1/2" at 20 cms 4φ 1/2" 2φ 1/2"

φ 3/8" φ 3/8"

5φ 1/4"/m 5φ 1/4"/m

7φ 3/8" 7φ 3/8"

0.3 t/m 0.7 t/m 0.3 t/m 0.31 t/m 0.71 t/m 0.31 t/m

2.00 m 1.80 m 7.40 m 1.80 m 2.00 m

3.00 m 9.00 m 3.00 m

10 ft 30 ft 10 ft

SECTION A-A.

0.30 t.m. 0.30 t.m.

0.70 t.m.

B.M.D. AT SECTION 3-3.

1.4 t.m. 1.4 t.m.

B.M.D. AT SECTION 2-2.

2.25 t.m. 2.25 t.m.

2.51 t.m.

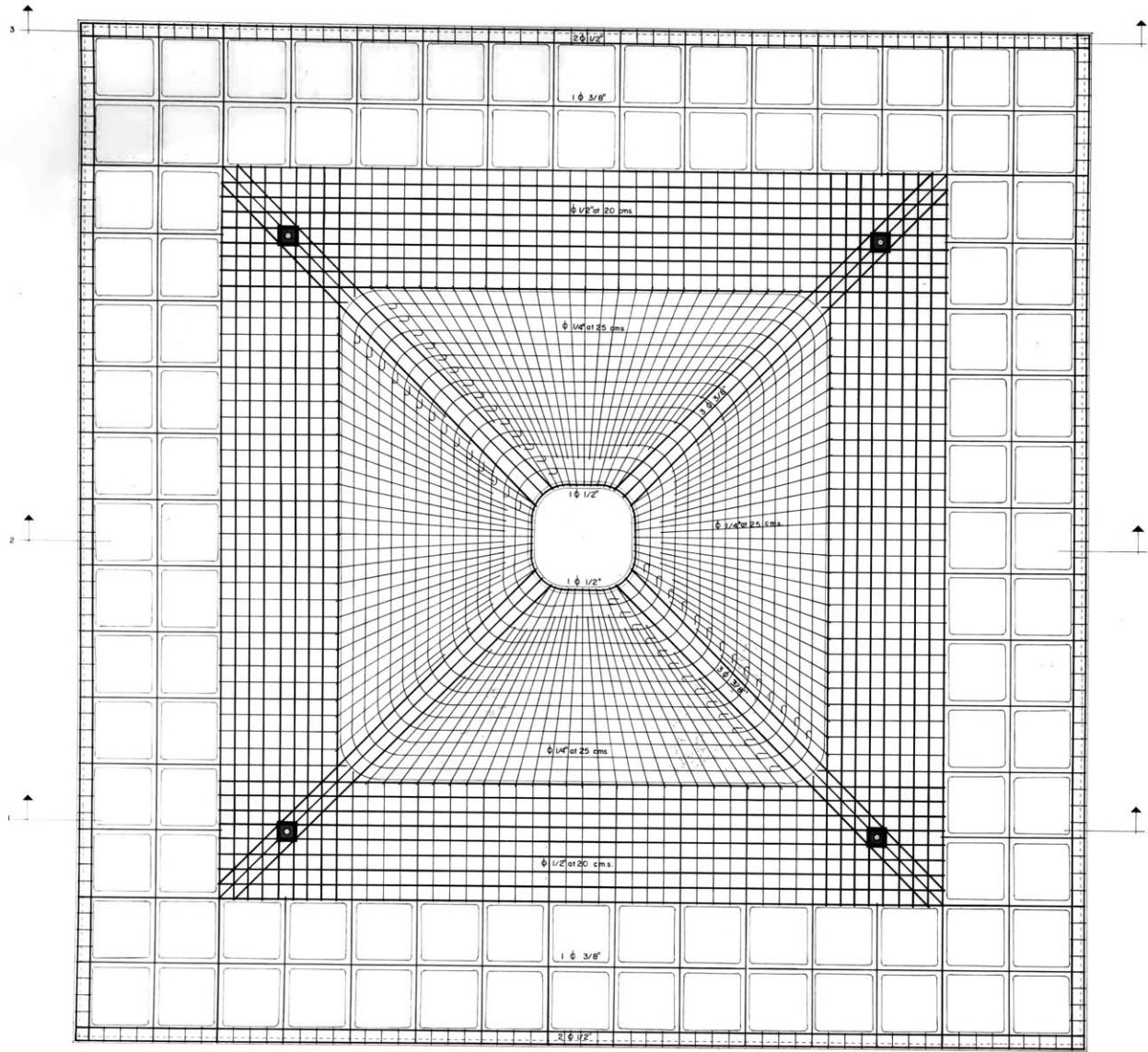B.M.D. AT SECTION 1-1.

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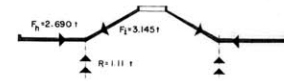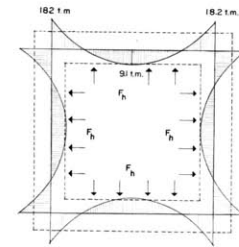
$F_h = 2.690\,t$ $F_1 = 3.145\,t$

$R = 1.11\,t$

FOLDED.PLATE ACTION TO RESIST FORCE R.

18.2 t.m.   18.2 t.m.

9.1 t.m.

F_h

F_h F_h

F_h

TIE BEAM ACTION TO RESIST HORIZONTAL FORCE F_h.

Plan labels:

2 φ 1/2"

1 φ 3/8"

φ 1/2" at 20 cms

φ 1/4" at 25 cms

1 φ 1/2"

1 φ 1/2"

φ 1/4" at 25 cms

φ 1/4" at 25 cms

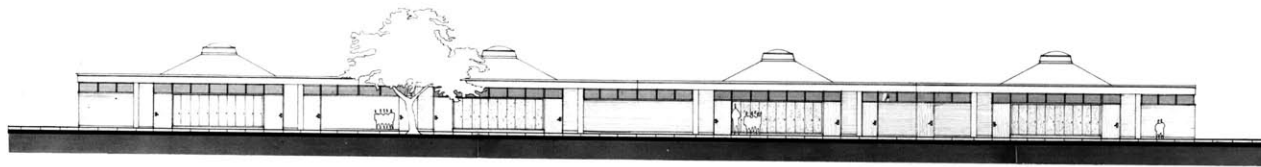φ 1/2" at 20 cms

1 φ 3/8"

2 φ 1/2"

PLAN OF CEILING

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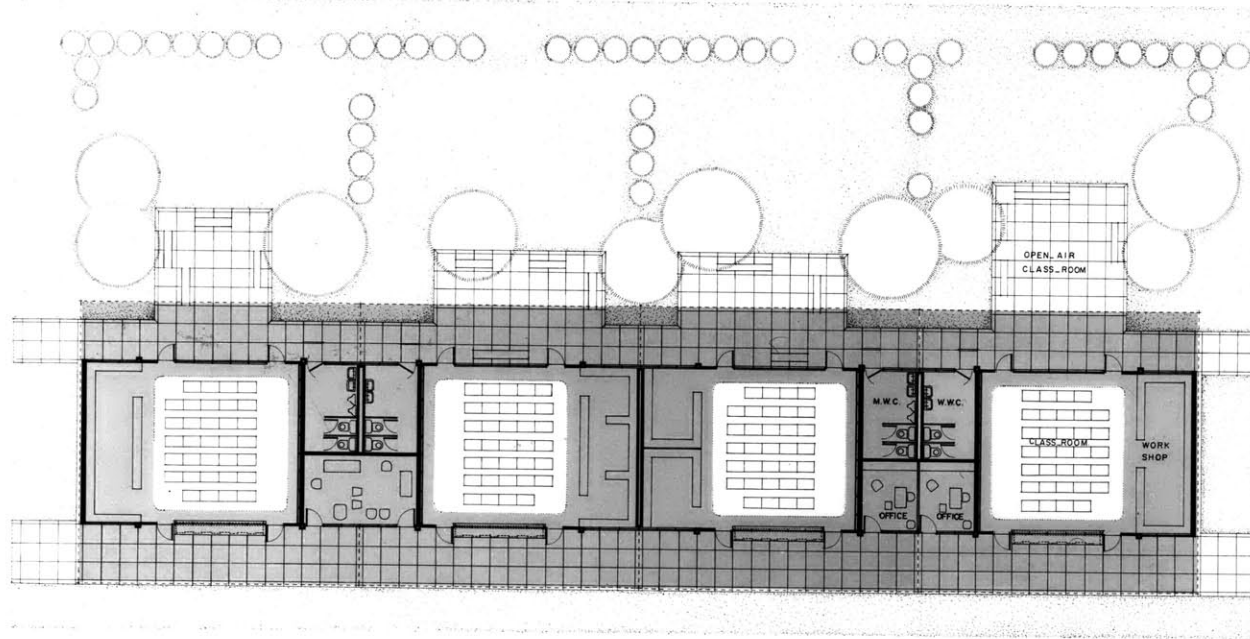
SHAFIK   IBRAHIM   RIFAAT   JULY   1962

PLAN OF ROOF

2 Ø 3/8"
4 Ø 1/4"/m
1 Ø 3/8"
2 Ø 1/2"
1 Ø 1/2"
2 Ø 1/2"
1 Ø 1/2"
2 Ø 1/2"
4 Ø 1/4"/m
2 Ø 3/8"
2 Ø 3/8"
2 Ø 3/8"
4 Ø 1/4"/m
2 Ø 3/8"
2 Ø 3/8"
2 Ø 1/2"
1 Ø 1/2"
2 Ø 1/2"
1 Ø 1/2"
2 Ø 1/2"
1 Ø 36
4 Ø 1/4"/m
2 Ø 3/8"

1 Ø 3/8"
4 Ø 1/4"/m
1 Ø 1/2"
4 Ø 1/4"/m
1 Ø 1/2"
4 Ø 1/4"/m
1 Ø 3/8"
7 Ø 3/8"/m
7 Ø 3/8"/m
7 Ø 3/8"/m

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MASTER OF ARCHITECTURE THESIS   SCALE 1 : 25
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ELEVATION

PLAN

OPEN AIR CLASS ROOM

M.W.C. W.W.C.

CLASS ROOM

WORK SHOP

OFFICE OFFICE
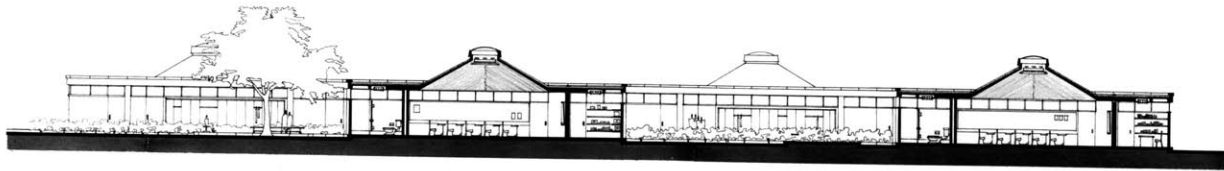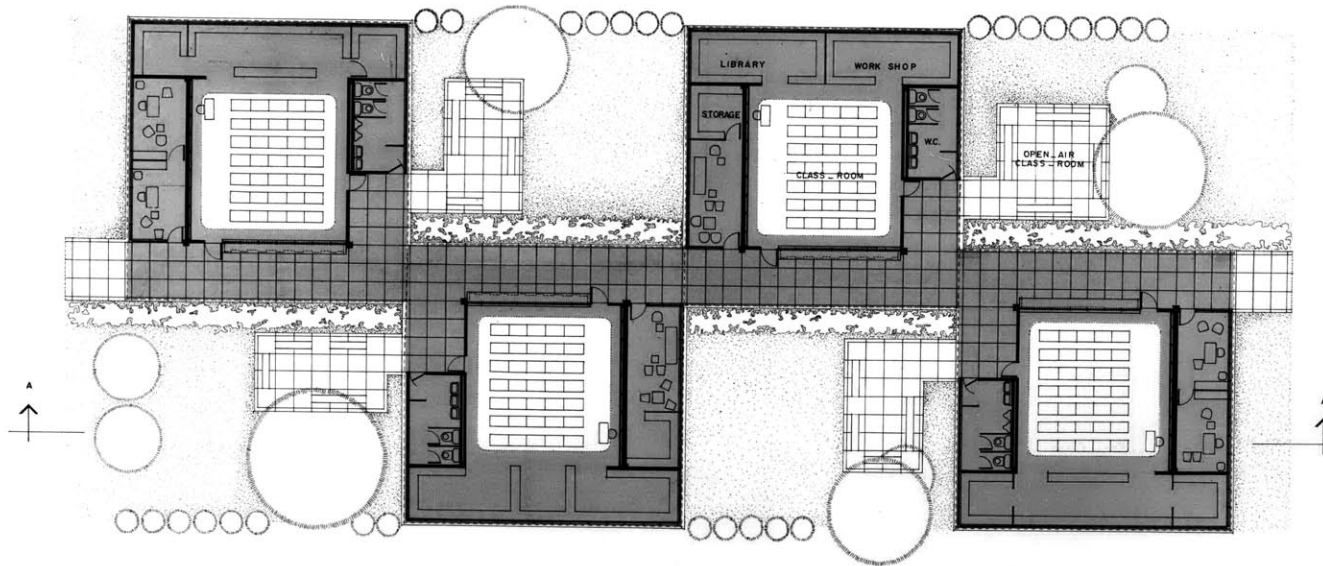
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MASTER OF ARCHITECTURE THESIS   SCALE 1:25

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SECTION A_A.

LIBRARY   WORK SHOP

STORAGE

OPEN AIR
CLASS-ROOM

CLASS-ROOM

W.C.

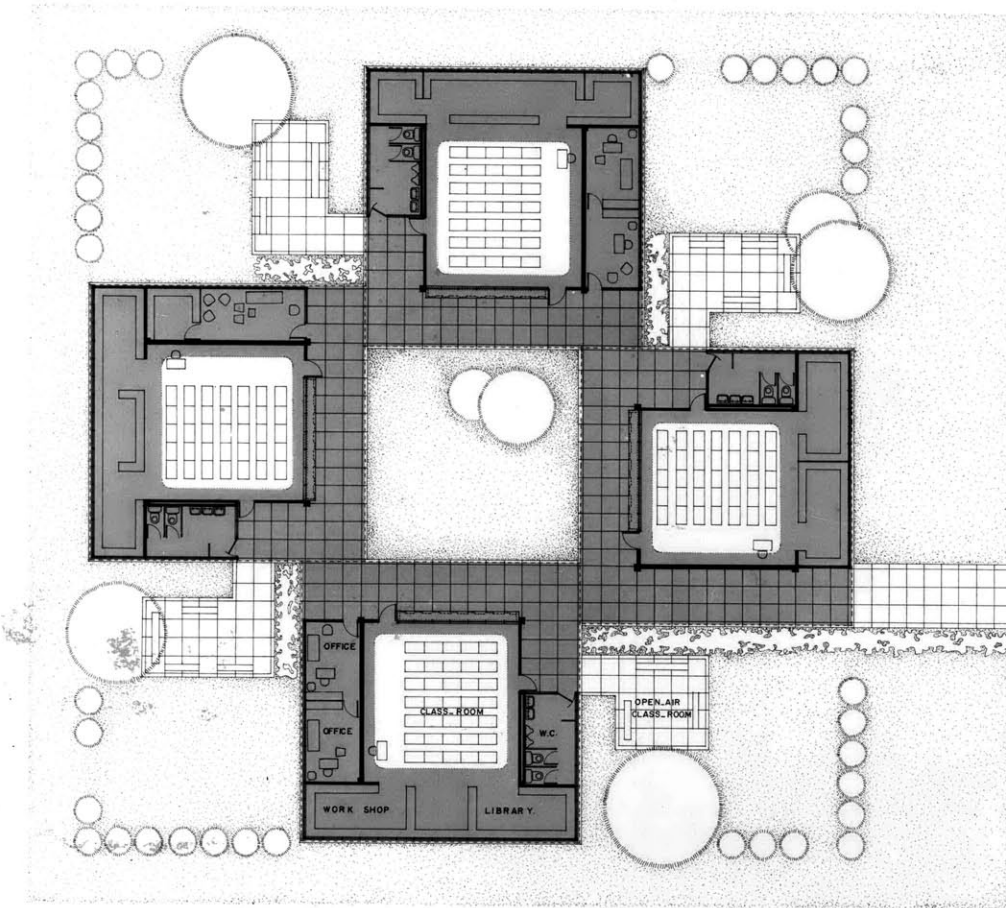A   A

PLAN

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MASTER OF ARCHITECTURE THESIS   SCALE 1 : 25.

SHAFIK   IBRAHIM   RIFAAT   JULY   1962.

PLAN

OFFICE

OFFICE

CLASS-ROOM

W.C.

OPEN-AIR
CLASS-ROOM

WORK SHOP

LIBRARY.