REINFORCED CONCRETE
STRUCTURAL ELEVATION
ITS APPLICATION ON SUN CONTROL
IN THE TROPICS.

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Submitted in partial fulfillment
of the requirements for the degree of
Master of Architecture at the
Massachusetts Institute of Technology

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July 26, 1962.

Dear Pietro Belluachi,
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Cambridge 39, Massachusetts.

Dear Sir:

A thesis entitled "Reinforced concrete structural elevation—Its application on suncontrol in the tropics" is hereby submitted in partial fulfillment of the requirements for the degree of Master of Architecture.

Respectfully submitted,

Hartono Poerbosapoetro
ABSTRACT

Solid and skeleton constructions have been in existence ever since man started to build, and not even the tremendous revolution of the technical age brought about any fundamental change.

New materials—steel, glass, and concrete have changed the appearance of buildings but the essence of their construction has always remained the same.

Since there are 2 types of spaces necessary in an air conditioned office building, the working spaces and the service core, a combination of the solid construction, the load bearing service core, and the load bearing periphery skeleton construction acting also as solar control devices to reduce sky glare and cooling load.

The problem of interrupting sunlight before it reaches the skin of the building and the idea to integrate the devices for this purpose into the structure, promises to create a series of pattern, visually as well as structurally.
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* * *
INTRODUCTION

The increased interest in the use of reinforced concrete which we have witnessed during the last few years, requires an awakening of the architect and structural engineer to the potentialities of this structural material.

Structural efficiency and architectural expression go side by side in reinforced concrete. Expressing the structure is actually expressing general basic truth, action and reaction, stability and the attempt of man to overcome earth gravity. There is nothing more worthy of being expressed than the structure, without which no building is possible. There are different concepts upon which the expression of these structure are based. There are different approaches to expression within each concept.

As a material going through a certain process of manufacture, reinforced concrete offers other paths of expression. The fact that reinforced concrete is cast in formwork on site or in factory, plays an important role in this type of expression.

One of the most valuable suggestions to come out of this thesis is that it is possible to create a beautiful
structural appearance in concrete if the architect is willing to collaborate with the engineer from the very beginning.

In the process of evolving solar control aspects, theoretical considerations yielded some interesting details and solutions. Existing solutions showed a great variety in fact, a new vocabulary of architectural expression.

The architectural appearance of the suncontrol is not an effect in itself—it is the result of several other developments. It is the direct consequence of the glass pane, which in turn was born from structural possibilities.

In 1938, in a plan for Algeria, the arrangement of solar control and construction is organically coupled by Le Corbusier. The brise-soleil unites with a clear system of construction as an incontestable element of architecture. The evaluation is molded into unity through the dramatic use of this element. For I.B.M. France's new research and development center at La Gaude, Nice, Architect Marcel Breuer created a deep shaded structural facade carried by muscular legs; the bright Mediterranean sun is brought under control by the 3 foot depth of the precast facade, cutting down on solar heat load and air-conditioning costs.
At a MacArthur Park in Los Angeles is a high rise office building designed by the Architects and Engineers Daniel, Mann, Johnson & Mendenhall, demonstrating a bearing grille tower providing an extremely rigid wall for the resistance of lateral loads.

The problem of integration of suncontrol into the structure will be studied and analysed in this thesis, using an office building as a study project and a humid tropical region Indonesia as a physical background, and finally a design proposal will be presented.

The approach is based on the belief that architectural expressions should grow from the ground of objective analyses and that the realm of feelings, the emotional content, should draw its synthesis beyond the technical and economical level. Then can architecture by fulfilling its dual role of satisfying emotional and physical needs—develop its true expression.
PART I. THE PROBLEM.

1. Preceeding approaches.

Architect Marcel Breuer created for IBM France's new research and development center at La Gaude, Nice, a double Y-plan, 550 feet long, provides all laboratories and offices with exterior daylight.

The bright Mediterranean sun is brought under control by the 3 foot depth of the precast facade, cutting down on solar heat load and air-conditioning costs.

The facade is structural, carried by muscular legs, and channels both horizontal and vertical runs for electric, gas, water, and other laboratory service lines, which are readily accessible through removable panels inside. Regular mechanical systems less subject to change—ductwork, lighting, telephone and power lines—are kept separate in the usual spaces between finish ceiling and floor. Despite heavy live loads of 125 pounds per square foot, the 40 foot width of typical floors is clear spanned, allowing partitions to be changed around at will.

To furnish flexible office space for the new headquarters for the American Cement Corporation on Wilshire Boulevard in Los Angeles, the present trend toward column-free interior space was adopted by the
Plate I. I.B.M. Office in La Gaude, France.
plate 2
Architects and Engineers Daniel, Mann, Johnson & Mendenhall. This was achieved in part by the use of exposed bearing grilles on the north and south sides of the structure.

The grille is used as a principal load bearing and shear-resisting element on the two exterior faces of the town. Grille members act in conjunction with precast floor beams, which span 33'-6" distance from the exterior faces of the building to the central core. Since it is also constructed of concrete, the core is also a load-bearing and shear-resisting element.

In the attempt to provide a maximum perimeter office space and an unobstructed floor area for an office building in Boston, Architect Marcel Breuer designed a tower with a service core rising through the center. Therefore its facilities are nearly equidistant from all points on the typical floor.

The walls surrounding fixed elements of the core, such as shafts, stairs, elevators, etc. replace columns as load supporting and laterally bracing structural members.

The structural system planned produces unobstructed floor areas 27'-6" in depth around the entire perimeter, and with additional depth at the two narrow ends of the office tower.
URBAN PROJECT BY MARCEL BREUER, ARCHITECT

HAMiLTON SMiTH, ASSOCiATE

plate 7.
The window partition module is set 5'-6" producing a two window office 11 feet in width. The architectural aims are to create an exterior bearing wall system where vertical and horizontal chases for air conditioning ducts and underwindow units and incidental plumbing and electrical connections are provided as an integral part of the structure.

Shading from the hottest sun is provided as an integral part of the structure, and no structural columns project from exterior walls into the interior space. Another dimension to the structure of the building is added by the plasticity and deep shadows of the facades. The transmission of the vertical loads by means of two trea columns at the north end is visually rather objectionable, although it is always possible to collect several loads and transmit it to ground by one element.

2. **Statement of the problem.**

The problem consists of the design of an office building for a humid tropical climate which is reasonably efficient, flexible in use, and taking the general condition of a developing country into account but applying the way of thought of modern technology, creating a reasonably contemporary appearance which will be feasible in the near future.
3. Basic approach.
The need for improvement of the administrative facilities of a town in a developing country requires both proper design and adequate understanding of the principles of modern technology. The aim of this thesis is to provide the proper design and justify it by the advantages of the introduced scheme in terms of economy of construction, efficiency, and better conditions or atmosphere for working.

PART II. DESIGN CRITERIA

1. The program.

Office space:
As an improved condition, a working space of 80 sq. ft. per person will be provided in the building. A module of 4'6" is thus suitable to meet this requirement since 4 modular area will give approximately 80 sq. ft.

Flexibility will be found not only in terms of arrangements but also the possibility to divide every floor into two or four small rental offices to serve community needs.

Core area:
A service area around 8% of the total area per floor is to be provided for toilet facilities, janitor room, vertical circulation, and duct shaft for air conditioning and electrical closets.
Lobby:
A lobby for the whole office building is to be provided with a flexible use as an exhibition room and lounge.

Cafeteria.
A dining room and buffet is to be provided to serve the needs of employers and customers.

Auxilliery spaces:
A mechanical room of around 7.5% of the gross area is needed for air conditioning in the tropics.

Adequate store room is necessary for a well planned office building for miscellaneous storage.

2. Space requirements:
I. lobby—exhibition room—lounge
   public toilets
   telephone exchange room
   call boxes
   information desk
II. office spaces
   toilet facilities
   janitor room.
III. Cafeteria
   Buffet and small kitchen
IV. Mechanical Room
   Store Rooms
3. **Materials and Methods**

The basic materials to be used for this project are wood and concrete. Wood will be used in the form of plywood or kiln-dry lumber for partition framing and fenestration. Special attention should be paid for the possibility of mass production and prefabrication of those elements, to reduce the building cost and to stimulate the wood industry.

Concrete will be cast-in-situ in wooden formwork since there is no weather hazard or problem of high labor cost. Fabrication of light weight precast elements can be introduced for speed of erection. It is advisable to cast the elements on the site to avoid transportation problems and handling difficulties.

Light weight metallic elements are of course necessary for air handling.

4. **Structural system.**

A system with load bearing core and load bearing periphery which have to support a light weight floor system with integrated structural, mechanical and electrical systems is to be introduced, to eliminate waste of space.

5. **Climatic requirements.**

Although the building will be completely air conditioned, solar control devices are to be provided to reduce cooling loads and minimize glare, while these devices are to be
integrated with the structure of the building. Since tropical climate means heavy rainfall, special attention should be given to drainage problems.

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PART III. THE SOLUTION

1. Plan.

The plan is basically a nuclear system with the service area as a core surrounded by working spaces. The core contains elements for vertical circulation of people as well as services necessary for the comfort of people. Logical radial distribution of these services from the core to the surrounding area could be achieved.

The deformation to a rectangular plan gives orientation possibility to minimize sun exposure of the elevations. The lobby which has the function as a buffer space between the surrounding and the building is arcaded on all four sides, providing a covered exterior space for people and continuous sun protection for the lobby glass wall.

The cafeteria is located on the top floor for a good view of the surrounding scene. The mechanical room is in the basement, accessible from the ramped service drive behind the building.

Necessary outdoor air conditioning equipments are located in the penthouse.
2. **Vertical circulation.**

All elements for vertical circulation are placed in the core of approximately 600 sq. ft. Completely enclosed fire stairs are accessible within a maximum distance of around 100 ft. Two elevators serving as passenger and freight cars are provided although the calculation shows that 5 cars are needed to serve this building (using the standard of the U.S.); this situation is acceptable since the interval is still less than 60 seconds or one minute.

Spaces for ducts in the core are calculated in the air conditioning section.

**Preliminary Selection of Elevators**

- **type of building**: office
- **number of floors**: 5 (above ground floor)
- **floor to floor height**: 12 ft.
- **total population**: 1150 persons
- **max interval**: 30 sec.

**total travel** = 5 x 12 = 60 ft.

**required passenger - carrying capacity** = 13% pop.

= 0.13 x 1150 = 150 persons/5 min.

**recommended speed** = 200 ft/min.

**elevator capacity** = 2000 lbs.

**round-trip time** = 95 sec.

**passengers per trip** = 10 (normal peak)
passenger cap. per car. 5 min. = \( \frac{60 \times 5 \times \text{pass per trip}}{\text{round trip time (sec)}} \)

\[ = \frac{60 \times 5 \times 10}{95} = 31.5 \text{ p/5 min.} \]

required number of cars = \( \frac{150}{31.5} = 5 \) cars

\[ \text{interval} = \frac{\text{round trip time}}{\text{number of cars in bank}} = \frac{95}{5} = 19.0 \text{ sec.} \]

\[ \text{min. interval} = 12 \text{ sec.} \]

3. REINFORCED CONCRETE STRUCTURE

Basic considerations

Considering local conditions and availability of local materials, the structure of the project in question will be carried out in reinforced concrete cast-in-situ with several minor elements in precast concrete.

The structure is to be designed as such that the use of more cement is preferable than more reinforcing. The lower the cement content the cheaper the concrete but, other factors being equal, the lower is the strength and durability of the concrete. Taking compressive strength and cost into account; a concrete rich in cement is more economical than a leaner concrete. In beams and slabs, however, where much of the concrete is in tension and therefore neglected in the calculations, a lean
concrete is cheaper than a rich one. A medium strength concrete of 3000 psi is to be used for those elements of the structure. In columns, where the concrete is compression, the use of rich concrete is more economical, since besides the concrete being more efficient, there is a saving in formwork consequent upon the reduction in size of the columns. The use of 5000 psi concrete is to be proposed for the columns.

For equal weights combined material and labor costs for reinforcement bars of small diameter are greater than those for large bars, and within wide limits long bars are cheaper than those for large bars, if there is sufficient weight to justify special transport charges and handling facilities. Since labor cost is not a problem for this particular project, the use of bars with smaller diameter for equal weights is preferable, because it also gives greater construction depth in beams to resist bending.

The use of steel in compression is always uneconomical when the cost of a single member is being considered, but advantages resulting from decreasing the depths of beams especially at the supports with great negative moments may offset the extra cost of formwork.
Economy generally results from the use of simple formwork even if this requires more concrete compared with more complex and more expensive formwork. Formwork is obviously cheaper if angles are right angles, if surfaces are plane, and if there is some repetition of use. Since wood will be used for the formwork in this project, those principles will be followed, although the repetition of use is quite limited.

When the cost of formwork is considered in conjunction with the cost of concrete and steel, the introduction of complications in the formwork may lead to more economical construction. Large continuous beams are more economical if they are haunced at the supports. This consideration occurs for the bottom beams carrying concentrated loads from the load bearing sunshades.

**Structural concept.**

The structure of the building consists of a load bearing core and a load bearing periphery consisting of structural sun shades, both types of elements have to support a waffle floor, a two-directional ribbed slab. The structural sunshades again, are supported by bottom beams along the periphery of the building, and to provide a continuous flow of space from the surrounding to the
public hall on the groundfloor, the bottom beams are supported by a minimum number of columns.

To give a flexibility of arrangement of offices a ribbed floor is introduced in which the partitions can be attached directly to the exposed ribs. Besides, the ribbed floor has less dead load in order to have a maximum span.

Using a 4'-6" module for the spacing of the ribs in two directions, a square bay span of 40'-6" is proposed for maximum of flexibility of space arrangement and less disturbance by the columns.

The presence of the 4 columns in the office space is a sacrifice in order to gain a maximum of efficiency, in terms of the ratio of core area to the office spaces.

In relation with the approximate calculation of the structure, several assumptions have been made to simplify the computation, which are quite close to the actual behavior of the structure and still within the limits of safety requirements.

The triangular loads on both sides of the edge beams of 2 square bays is assumed to be supported by 3 beams which are supported by the structural sunshades and
FIG. 1 LOADING SCHEME FLOOR SLAB
the drop-panel around the column. (joists 1, 2, 3). The remaining joists is calculated as one way joists supported by the primary joists or the structural sunshades on one side and the core on the other.

The function of the drop panel is not only to resist shear along the periphery of it but also to provide built-in haunches to increase the compression zone of the primary joists. To avoid an excessive amount of compression reinforcing, the joists of the waffle slab are considered to be simply supported by the structural sunshades on one side, and those which are supported by the drop-panels are considered as fixed on the other end.

The section of the waffle slab is determined as such to ease the removal of the wooden formwork and to provide increasing widths of the ribs to be able to put more reinforcing in one row either for tension or compression.

Calculations

waffle floorslab:

- $t_1 = 24''$
- $t = 3''$
- $W_L = 50$ psf. life load
- $f_{c}^{1} = 3000$ psi.
- $f_s = 20000$ psi.
- $f_g = 1350$ psi.
- $v = 240$ psi.
dead load:
slab \[ = 40.5^2 \times 2 \times 150 \text{ lb.} = 482,500 \text{ lb.} \]
air floor \[ = 36^2 \times 0.25 \times 50 \text{ lb.} = 16,200 \text{ lb.} \]
\( \frac{1}{2} \)" linoleum \[ = 36^2 \times 1 \text{ lb.} = 1,300 \text{ lb.} \]

\[ = 500,000 \text{ lb.} \]

less 81 - 4 = 77 domes:
77 \times 1.75 \times \sqrt{0.5 \times (3.85 \times 3.25)} \times 150 = 255,000 \text{ lb.} \]

\[ \text{dead load per square bay} \quad W = 245,000 \text{ lb.} \]
unit dead load \[ W = \frac{245,000}{40.5^2} = 150 \text{ psf.} \]
life load \[ W_L = 50 \text{ psf.} \]

\[ \text{unit design load} \quad W_{\text{tot}} = 200 \text{ psf.} \]

joists 1:
The total load to be supported by 3 joists No. 1 is the area of 2 triangle load times the unit design load =
\[ 2 \times 0.5 \times 40.5^2 \times 200 \text{ lb} = 328,500 \text{ lb.} = 328.5 \text{ kip.} \]
This load is assumed to be carried by 3 joists No. 1, each one carrying \( \frac{228.5}{3} = 109.5 \) kip. This load for each joist No. 1 is assumed to be equally distributed to the joist with a unit load of: \( w = \frac{109.5}{40.5} \) kip/ft = 2.7 kip/ft

Joists 1 are simply supported on one end and fixed on the other, hence a positive moment of \( \frac{9}{128} wL^2 \) occurs at a distance of \( \frac{3}{8} l \) from the hinged end (see fig. 3) and a negative moment of \( \frac{wL}{6} \) in the fixed end.

\[
M_{\text{pos}} = \frac{9}{128} wL^2 = \frac{9 \times 2.7 \times 39.5^2}{128} \text{ kips. ft.} \\
= 296.5 \text{ kips. ft.}
\]

39.5 ft. is the actual space of the joists No. 1 that is the distance between the axes of the column and the structural sunshades. Using the CRSI design handbook we find for \( f_c = 3000 \) psi and \( f_s = 20000 \) psi.

\( k = 0.403 \)

\( d = 24 \) --protection--stirrup diameter--bar diameter

\( \text{--min. bar distance--bar diameter--1/2 min.} \)

bar distance (4 layers of reinforcing)

\( = 24 - 1.5 - \frac{3}{8} - 1 - 1 - 1 - 1/2 = 18.625 \text{ in.} \)
$kd = 0.403 \times 18.625 = 7.25 \, \text{in} \rightarrow \text{T-beam}$

$jd = d - 2t = \frac{t(3kd - 2t)}{3(2kd - t)}$

$= 18.625 - \frac{3(3 \times 0.403 \times 18.625 - 2 \times 3)}{3(2 \times 0.403 \times 18.625 - 3)}$

$= 18.625 - 1.375 = 17.25 \, \text{in.}$

The required area of positive moment reinforcing is

$A_s = \frac{M}{f_{sb} \, jd} = \frac{296,500 \times 12}{20,000 \times 17.15} \, \text{in}^2 = 10.4 \, \text{in}^2.$

Selected reinforcing:

2 # 6 = 0.88 \, \text{in}^2
4 # 8 = 3.62

Stirrups #3

4 # 8 = 3.62
3 # 8 = 2.37

$\text{total} = 10.49 \, \text{in}^2$

Note: the $d$ in the calculation above for $A_s$ is for 4 layers of reinforcing #8. The required steel reinforcing is less than 4 layers #8, hence the $d$ is greater. The working stress in the provided reinforcing will be thus smaller than the allowable $f_{sb}$.

Check working stress in concrete:

$f_c = \frac{Mkd.}{bt \left(\frac{kd - t}{2}\right) \, jd}$

(CRSHI design handbook pg. 24)

$d = 19.625$

$kd = \frac{2nA_s + bt^2}{2nA_s + 2bt} = \frac{2 \times 10 \times 19.625 \times 10.49 \, 4.5 \times 12 \times 3^2}{2 \times 10 \times 10.49 \, 2 \times 4.5 \times 12 \times 3} = 8.6 \, \text{in.}$
\[ k = \frac{8.6}{19.625} = 0.437 \]
\[ p = \frac{A_g}{bd} = \frac{10.49}{4.5 \times 12 \times 19.625} = 0.0099 \]
\[ j = \frac{6-6}{\left(\frac{3}{19.625}\right)} + 2 \left(\frac{3}{19.625}\right)^2 + \left(\frac{3}{19.625}\right)^3 = 0.928 \]
\[ f'_c = \frac{296 \times 500 \times 12 \times 0.437 \times 19.625}{4.5 \times 12 \times 3 \left(\frac{6-6}{2}\right) 0.928 \times 19.625} = 1460 \text{ psi} \]

The negative moment is:
\[ \frac{wL^2}{8} = \frac{2.7 \times 39.5^2}{8} \text{ kip ft.} \]
\[ = 512 \text{ kip ft.} \]

3 layers of #8 reinforcing, \( d = 24 - 1 \frac{5}{8} - \frac{3}{8} - 1 - 1 \frac{1}{8} \]
\[ = 19.625 \]

\[ A_B = \frac{M}{f'_c \frac{Jd}{k}} = \frac{512 \times 1000 \times 12}{20 \times 000 \times 0.8657 \times 19.625} \text{ in}^2 = 18.16 \text{ in}^2 \]

Selected:
\[ 8\#8 = 6.32 \text{ in}^2 \]
\[ 8\#8 = 6.32 \]

Stirrups #3, #8 = 5.52 \text{ in}^2.

Working stress in concrete:
\[ f'_c = \frac{2M}{k \sqrt{bd^2}} = \frac{2 \times 512 \times 1000 \times 12}{0.403 \times 0.8657 \times 180 \times 19.625^2} = 502 \text{ psi} \]
FIG. 4  HORIZONTAL HAUNCHING IN DROP PANEL
Shear reinforcement.

The shear force beyond the free support is $\frac{3}{8} \cdot \frac{w}{l}$ (see fig. 3) = $3 \times 2.7 \times 39.5 = 4 \text{ kip.}$

$$v = \frac{V}{bd} = \frac{4000}{14 \times 0.8657 \times 19.625} = 168 \text{ psi} < 240 \quad (\text{ACI code pg. 927})$$

#3 stirrups only for mounting

$v$ beyond the fixed end $= \frac{16.3 \times 4}{15.2} = 4.3 \text{ kip.}$

$$v = \frac{V}{bd} = \frac{4300}{14 \times 0.8657 \times 19.625} = 180 \text{ psi} < 240.$$  

$$b' = \frac{20 + 8}{2} = 14 \text{ in.}$$

No shear reinforcing is necessary for joists No. 1. average shear:

$V_{\text{tot}} = 272.5 \text{ kip.},$ carried by 20 joists.

$V_{\text{per Joist}} = \frac{272.5}{20} = 13.625 \text{ kip.}$

$$v = \frac{13.625}{14 \times 0.8657 \times 19.625} = 57 \text{ psi} < 100 \text{ psi.}$$
Load Bearing Sunshades:

\[ A_g = \text{gross area of column.} \]

\[ = 8 \times 36 = 287.5 \text{ in}^2 . \]

\[ f_c = 3000 \text{ psi} \quad f_y = 20000 \text{ psi} \]

\[ n = 10 \]

\[ h = 9 \text{ ft.} = 108 \text{ in} \quad l_o = 80 \text{ in}. \]

\[ t = 8 \text{ in.} \]

part I = between 1st floor and 3rd floor:

own weight column = \[ 63 \times 3 \times 0.33 \times 150 = 9350 \text{ lb.} \]

4 floor loads = \[ 4 \times 4 \text{ kips} = 16000 \text{ lb.} \]

roof load \[ = 3 \times 2.5 \times 39.5 \quad = 3700 \text{ lb.} \]

\[ \text{Axial load } N = 29050 \text{ lb.} \]

check dimension of the column:

\[ A_g = 287.5 \text{ in}^2 \]

steel ratio \[ f_y = 0.04 \]

\[ P = 0.80 A_g \left( 0.225 \frac{f_c}{f_y} + f_y \frac{P_g}{f_y} \right) \quad \text{(ACI code pg. 968-971)} \]

\[ A_g = \left( \frac{p(1.3 - 0.03 h/t)}{0.80(0.225 f_c + f_y P_g)} \right) = 0.895p \]

\[ = \frac{29050 (1.3 - 0.03 \times 108/8)}{0.80(0.225 \times 3000 + 2000 \times 0.04)} \text{ in}^2 = 22 \text{ in}^2 \]

provided \[ 287.5 \text{ in}^2 \geq 22 \text{ in}^2 . \]
\[ A_g = \frac{0.895P}{0.8(0.225 f_c - f_s p_g)} \]

\[ 0.8x0.225 f_a A_g \quad A_g f_s p_g = 0.895P. \]

\[ A = \frac{P_g A_g}{f_s} = \frac{0.895P - 0.8x0.225 f_a A_g}{f_s} \]

\[ = \frac{0.895x29000 - 0.8x0.225x3000x287.5}{20000} \]

\[ A_{\text{g}} = \text{negative} \]

provided min reinforcing 0.01 x 0.5 x \( A_g \) (ACI pg 971)

\[ = 0.01x0.5x287.5 = 1.44 \text{ in}^2. \]

\#1 tie 8\text{"} apart. 6\#5 = 1.06 \text{ in}^2.

check excentric loading:

excentricity \( e = 14\text{"} \quad 2/3t \quad 2/3x36 \)

\[ M = 4000x14 = 56000 \text{ lb. in.} \]

\[ d = 36-2-0.3125 = 33.6875 \text{ in.} \]

\[ k = 0.403. \]

\[ J = 0.8657. \]

\[ A_g = \frac{M}{f_s J a} = \frac{56000}{20000x0.8657x33.6875} = 0.96 \text{ in}^2. \]

\[ 3\#5 = 0.93 \text{ in}^2. \]

Final structural shade reinforcing = 8\#5 = 2.48 \text{ in}^2

\#1 tie 8\text{"} apart.
This reinforcement is continuous over the whole length of the sunshades which have to support primary joists No. 1 and No. 3.

The remaining sunshades are to be provided with minimum reinforcing = 6#5
#1 tie 8" apart.

BOTTOM SPANDREL BEAM.
Consider that part with both fixed ends.
This beam has to support its own weight and the concentrated loads of the structural shades supporting the waffle floors.

own weight = 4x3x150 lb/ft$^1$ = 1800 lb/ft$^1$.

$P_{1} \text{tot} = 5 \text{ floor loads} = 5x4 \text{ kip} = 20 \text{ kip}.$

\[
\begin{align*}
\text{own weight sunshade} & = 9.35 \\
\text{roof load} & = 3.70 \\
\hline
\text{P}_1 \text{ tot} & = 33.00 \text{ kip.}
\end{align*}
\]

$P_{4} \text{ tot} = \text{own weight sunshade} = 9.35 \text{ kip}.$

5 floor loads =

\[
\begin{align*}
5x1/2x0,2x4.5x40.5 & = 91.00. \\
\text{roof load} & = 3.70. \\
\hline
\text{P}_4 \text{ tot} & = 104.00 \text{ kip.}
\end{align*}
\]
FIG. 5. BOTTOM SPANDREL BEAM.
SHEAR DUE TO CONCENTRATED LOADS

SHEAR DUE TO OWN WEIGHT
BOTTOM SPANDREL BEAM

FIG. 6. BOTTOM SPANDREL BEAM
SHEAR STRESSES DUE TO CONCENTRATED LOADS & OWN WEIGHT BEAM

FIG. 7. BOTTOM SPANDREL BEAM
due to the concentrated loads, both ends simply supported =

\[ R_A = R_B = P_1 \text{ tot} + 3x P_4 \text{ tot.} \]

\[ = 33 + 3x10^4 = 345 \text{ kip.} \]

\[ M_1 = 345 \times 4.5 = 1550 \text{ kip ft.} \]
\[ M_2 = 345 \times 9 - 33 \times 4.5 = 29 \text{ kip ft.} \]
\[ M_3 = 345 \times 13.5 - 33 \times 104 \times 4.5 = 3884 \text{ kip ft.} \]
\[ M_4 = 345 \times 18 - 33 \times 13.5 - 104 \times 9 - 104 \times 4.5 = 4351 \text{ kip ft.} \]

Negative moments at the fixed supports due to concentrated loads: (CRSI pg. 62)
due to \( P_1 \text{ tot} = M = 1/2a (1-a) WL. \)
\[ M_A = M_B = \frac{1}{2}x \frac{1}{9} (1-\frac{1}{9}) x 2x33x40.5 \]
\[ = 132 \text{ kip ft.} \]
due to \( P_2 \text{ tot} = \)
\[ M_A = M_B = 1/2x2/9 (1-2/9) x 2x104x40.5 \]
\[ = 730 \text{ kip ft.} \]
due to \( P_3 \text{ tot} = \)
\[ M_A = M_B = 1/2x1/3 (1-1/3)x2x104x40.5 \]
\[ = 935 \text{ kip ft.} \]
due to \( P_4 \text{ tot}: \)
\[ M_A = M_B = 1/2x4/9 (1-4/9)x2x104x40.5. \]
\[ = 1040 \text{ kip ft.} \]
Total fixed end moment = 132 kip. ft.

730

935

1040

2837 kip. ft.

CRSI pg 62:

fixed end moment due to own weight 1.8 kip/ft^1.

\[ M_A = M_B = \frac{1}{12} \times 1.8 \times 40.5^2 = 246 \text{ kip. ft.} \]

\[ M_{\text{pos}} = (\frac{1}{8} - \frac{1}{12}) \times 1.8 \times 40.5^2 = 123 \text{ kip. ft.} \]

Design fixed end moment = 2837 246 = 3083 kip. ft.

positive moment = 1514 123 = 1637 kip. ft.

d = 48 - 2 - 3/8 -1/2 = 43.125 in.

j = 0.8657.

\[ A_s = \frac{M}{f_{\text{bd}}} = \frac{1337 \times 12}{20 \times 0.000 \times 0.8657 \times 43.125} = 26.3 \text{ in}^2. \]

selected: 2#8 = 1.58 in^2.

16#8 = 12.65

stirrups #3
\( M_{\text{neg}} = 3083 \text{ kip. ft.} \)
\( J = 0.8657 \)
\( k = 0.403 \)

\[
d = \frac{\sqrt{\frac{M}{1/2fc kjb}}}{12}
\]

\[
= \frac{\sqrt{3083 \times 000 \times 12}}{0.5 \times 1350 \times 0.403 \times 0.8657 \times 36}
\]

By haunching to 88 inches, 20° slope = provided = 88-2-8/3-1-1-1/2 = 82.125 in.

\( J = 0.8657 \quad f_s = 20 \text{ 000 psi} \)

\[
A_s = \frac{M}{f_s Jd} = \frac{3083 \times 000 \times 12}{20 \times 000 \times 0.8657 \times 82.125} = \text{26 in}^2.
\]

stirrups #3. selected 2#8 = 1.58 in\(^2\)

\[
16#8 = 12.65
\]

\[
16#8 = 12.65
\]

\[
26.88 \text{ in}^2.
\]

Shear Reinforcement:

Shear force at A due to own weight = 1/2 \(wl\)

\[
V_A = V_B = \frac{1}{2} x 1.8 \times 40.5 = 36.25 \text{ kip.}
\]

From the diagram for shear stresses shown in fig. 7, we can see that in the haunched parts as well as in the constant cross section area, except beyond section 2,
The calculated shear stresses are always less than the allowable 240 psi (ACI code pg. 927).
Theoretically there is no shear reinforcement necessary. The stirrups #3 will keep the longitudinal reinforcement on its place.

Shear Stresses in Bottom Spanorel beam:

\[ V_A = V = \frac{381.25}{36 \times 0.8657 \times 82.125} = 149 \text{ psi}. \]

\[ V_1 = \frac{373.25}{36 \times 0.8657 \times 62.125} = 192 \text{ psi}. \]

\[ V_{1L} = \frac{340.25}{36 \times 0.8657 \times 62.125} = 176 \text{ psi}. \]

\[ V_2 = \frac{332.20}{36 \times 0.8657 \times 42.125} = 252 \text{ psi}. \]

\[ V_{2L} = \frac{228.20}{36 \times 0.8657 \times 42.125} = 173 \text{ psi}. \]
\[ \begin{align*}
V_3 &= 220.2 \text{ kip.} \\
V_3 &= \frac{220200}{1310} = 168 \text{ psi} \\
V_3 &= 116.2 \text{ kip.} \\
V_3 &= \frac{116200}{1310} = 89 \text{ psi} \\
V_4 &= 108.06 \text{ kip.} \\
V_4 &= \frac{108060}{1310} = 82.5 \text{ psi} \\
V_4 &= 4.06 \text{ kip.} \\
V_4 &= \frac{4060}{1310} = 3.1 \text{ psi.}
\end{align*} \]

The excess shear beyond section 2 will be taken care of by the stirrups or bent up bars.

**PERIPHERY COLUMN:**

The total load for this column is

\[ \begin{align*}
33 + 2 \times 381.25 &= 795.5 \text{ kip.} \\
\text{own weight} &= 2 \times 3 \times 17 \times 150 = 16.8 \\
\hline
N &= 812.3 \text{ kip.}
\end{align*} \]

\[ A_g = \text{gross area of column} \]
\[ = 2' \times 3' = 24 \times 36 = 865 \text{ in}^2 \]
\[ f_{\text{eff}} = 3000 \text{ psi} \]
\[ f_B = 20000 \text{ psi} \]
\[ n = 10 \]
\[ t = 24 \text{ in.} \]
\[ h = 17 \text{ ft} = 17 \times 12 < 10 \text{ t} = 240 \text{ in.} \]

Check dimensions of the column =

Steel ratio \( \rho_g = 0.04 \)

\[ P = 0.80 A_g (0.225 f_{\text{eff}} + f_B) \]  \text{(ACI code pg. 968-971)
\[ A_g = \frac{P}{0.8(0.225 f_c + f_y p_y)} \]

\[ = \frac{812 \times 300}{0.8(0.225 \times 3000 + 20 \times 000 \times 0.04)} = 690 \text{ in}^2. \]

provided: \(865 \text{ in}^2 \geq 690 \text{ in}^2.\)

\[ P = 0.80 A_g (0.225 f_c + f_y p_y). \]

\[ P = 0.80 \times 0.225 A_g f_c \quad 0.80 A_g f_y p_y. \]

\[ A_g = p_y A_g = \frac{P - 0.80 \times 0.225 A_g f_c}{0.8 f_y} \]

\[ = \frac{812 \times 300 - 0.80 \times 0.225 \times 865 \times 3000}{0.8 \times 20 \times 000} = 21.5 \text{ in}^2. \]

Minimum reinforcing = \(0.01 A_g = 8.65 \text{ in}^2.\)

Maximum reinforcing = \(0.04 A_g = 34.5 \text{ in}^2.\)

selected column reinforcement = \#8

\[ = 22.08 \text{ in}^2. \]

ties: bar \#3

**INTERIOR COLUMN:**

\[ A_g = 2' \times 2' = 24 \times 24 = 576 \text{ in}^2. \]

total load for the column:

\[ 40.5 \times 33.75 \times 200 \times 5 = 1365 \text{ kip.} \]

\[ 16 \times 5 \times 1.75 \times 0.5(3.85 + 3.25)/2 \times 150 = 265 \]

own weight = \(2 \times 2 \times 19 \times 150 = 11.40 \)

\[ 1.66^2 \times 18 \times 150 = 7.45 \]

\[ 1.33^2 \times 27 \times 150 = 7.20 \]

roof = \(50.5 \times 3.75 \times 150 = 22.75 \)

\[ \frac{16 \times 1.75 \times 0.5(3.85 + 3.25)/2 \times 150}{N = 170230 \text{ kip}} = 23.50. \]
check dimensions of the column:

steel ratio \( p = 0.04 \).

\[
P = 0.80 \frac{A_g}{(0.225 f^r + f_s f_g)}
\]

\[
A_g = \frac{P}{0.80 (0.225 f^r + f_s f_g)}
\]

\[
= \frac{1702}{0.80(0.225 \times 5000 + 2000 \times 0.04)} = 1100 \text{ in}^2.
\]

The column section is too small.

Increase the dimensions of the interior columns:

- groundfloor = 2.7' x 2.7'
- 1st 2nd floor = 2.3' x 2.3'
- 2nd top floor = 2' x 2'.

total load for the column:

5 floors = 1365 kip.

drop panels = 265

roof = 23.50

own weight:

\[
\begin{align*}
2.7^2 \times 19 \times 150 & = 20.75 \\
2.3^2 \times 18 \times 150 & = 14.30 \\
2^2 \times 27 \times 150 & = 16.20 \\
\end{align*}
\]

\[ N = 1704.75 \text{ kip.} \]
\[ A_{\text{gc}} = \frac{P}{0.80 \left( 0.225 \times f_{c}^{0.8} \times f_{y} \right)} \]

\[ = \frac{1704 \times 750}{0.8(0.225 \times 5000 \times 20 \times 200 \times 0.04)} = 1100 \text{ in}^2. \]

provided \( A_{\text{gc}} = 1050 \text{ in}^2. \)

\[ A = \frac{P \times A_{\text{gc}}}{0.8 \times f_{y}} = \frac{P - 0.8 \times 0.225 \times A_{\text{gc}}}{0.8 \times f_{y}} \]

\[ = \frac{1704 \times 750 - 0.8 \times 0.225 \times 1050 \times 5000}{0.8 \times 20 \times 000} \text{ in}^2 = 48 \text{ in}^2. \]

\[ \frac{60 \#8}{60 \#8} = 47.5 \text{ in}^2. \]

Check Shear Around the Column:

\[ V = \frac{V}{b \times d} \]

\[ V = 1 \text{ floor load} = 272.5 \text{ kip.} \]

\[ b = 4 \times 2.7 \times 12 = 130 \text{ in.} \]

\[ d = 24 \text{ in.} \]

\[ V = \frac{272 \times 500}{130 \times 0.8657 \times 24} = 100 \text{ psi}. \text{ Q.k.} \]
4. Solar control.

As it has been stated before that solar control devices are necessary to minimize the cooling load for the building, and since these devices are to be integrated in the structure, the spacing of it is thus governed by the module adopted for the building. The depth is then determined by the ultimate sun angles to give adequate protection to the glass area behind them.

By means of the sun path diagram for the area in question thus 7° south latitude the horizontal and vertical angles could be found, provided that sunshine between 9 a.m. and 5 p.m. should be eliminated.

Exterior devices may conduct heat into a structure on windless hot days. This can be avoided if the devices are insulated from the building. The simplest solution to achieve this is, not to connect the device along its entire length with the glass wall, leaving an open air space in between serving as an escape hatch for banked up warm air.

The problem of maintenance is always present, with or without shading devices; its solution would seem to lie in the quality of architectural design which
will encompass not only the shading problem but also that of maintenance as well. The solution shown in the design proposal gives not only adequate sun protection but also sufficient space for window cleaners, since the cleaning does not occur by mechanical means.

Design of shading devices:
The time when shading is needed is between 9 a.m.—5 p.m. throughout the year. To determine the position of the sun when the shading is needed can be done with the use of the sun path diagram, which shows the sky vault projected on to the horizon plane. On the diagram the horizon line appears as a circle at the outside edge and the sun paths as curved lines. These lines designating days and months of the year represent the sun's path on the dates shown. Connecting lines indicate the hours. The sun's position can be determined at any time with the use of this diagram:

The horizontal angle can be found on the outer circle after connecting the center with the point of intersection of the hour line and sun path curve. The concentric circle passing through this point of intersection indicates the vertical angle.
The relation between the spacing and the depth of the shading devices is thus determined by these ultimate angles.

5. Air Conditioning.
Parallel with the introduced design scheme for the office building, installation of air conditioning equipment is a necessity for the comfort of employees or tenants, which is considered a sufficient justification for the expense involved. The advantages are likely to justify the extra expenses for the following reasons:
1. Comfortable conditions in parts of the building used by the public are a valuable asset to business.
2. Street noises are greatly reduced with constantly closed and locked windows.
3. Dust (originally disagreeably prevalent on the lower floors of buildings) can be kept out of the building.
4. Number of employees can be greater in a given number of square feet of floor space, without causing bad air conditions.
5. Constant control of temperature and humidity increases the efficiency of the employees because of constant comfort temperature and humidity.

To cool a building costs possibly three times as much as to heat it volume for volume. In equatorial climates the system will be operating throughout the year. Air-conditioning is therefore expensive. The cooling load should be kept down by shading and insulation and in a humid climate, by a vapour barrier.

Sources of heat and moisture within the conditioned space should be treated at source. Building volume should be kept to a minimum and plans compact.

The design of the air conditioning plant should be such that the proportion of fresh air may be increased to take advantage of those periods when the outside is at such a condition that it can be used direct to do cooling, thus reducing the period of use of the refrigeration plant.

Before the kind of air conditioning system to be used can be considered, a study of the basic load patterns of a building must be made. Every building
can be divided into two main zones—exterior and interior. The interior zone is the area in the center of the building which is not influenced by the sun on widely fluctuating outdoor temperatures. The exterior zone is the area around the periphery of the building which extends from the outside wall toward the interior to the first partition line, or in open areas, a distance of 12 to 18 ft.

For flexibility of operation, it is desirable to divide the air conditioning for this building into four zones, each of which may be operated independently of the others.

---

External design conditions.
Dry bulb temp. = 95°F
rel. humidity = 75%
solar radiation Nov. 300 Btu/ft²/hr
Sept. 265 Btu. (dust reduces the solar intensity).
Internal Design Conditions:
Continuous occupancy 75°F
trancient occupancy 80°F
relative himidity 60%
supply air temp. 12-20°F lower
fresh air 10% total circulated air.
min. required for breathing 1200 cf/person/hour.

Calculations:
A. Interior Zone

The interior zone is relatively easy to air condition because the loads are always positive, requiring cooling all the times. This area is not influenced by the widely fluctuating load of the exterior but is limited to the heat gain from people, lights and business machines.

Total area = \(4 \times \sqrt{19 \times 4.5 \times 35 \times 4.5 - 9 \times 4.5 \times 15 \times 4.5} \) ft\(^2\).
= 4 \times 10400 = 41,500 \text{ ft}^2.

Total persons (80 ft \(^2/p\)) = 520 persons.

The heat to be absorbed by the cooled air per hour:
1. heat from 520 occupants (400 Btu /person/hour) = 207,500 Btu.

heat from lights (4 watts/sq. ft floor area) = 13.6 Btu/sq.ft/hr.
41,500 \times 13.6 = 565,000 Btu.
Total sensible heat to be absorbed
per hour = 772,500 Btu

heat in moisture from occupants =
520 \times 0.1 = 52 \text{ lb./hr (1050 Btu/lb)} = 547,500 \text{ Btu.}

total heat to be removed = 827,250 \text{ Btu/hr.}

The latent heat of water vapor $L$ in Btu per pound calculated for temperatures between 40–150°F

$$L = 1092 - 0.56t \quad (t \text{ in } ^\circ\text{F})$$

(Moyer & Fittz p.15)

$L = 1072 - 0.56 \times 75 = 1050 \text{ Btu/lb.}$

Conditioned air is to be introduced into the office spaces at a dry bulb temperature of 60°F to allow a temperature rise in the rooms of 15°F, the approximate quantity $Q$ of cooled air in cubic feet per minute to be supplied =

$$H_S = \text{total sensible heat to be absorbed in Btu/hr.}$$

$d$ = temperature difference between leaving and entering air in degrees Fahrenheit.

$s$ = heat capacity of air, 0.018 Btu per cubic foot per degree Fahrenheit. It is the product of the specific heat of air (0.24) per pound and its density (0.075 lb.) at ordinary room temperatures.
Q = \frac{H_b}{60 \times dxs}

= \frac{827.250}{60 \times 15 \times 0.018} = 51,000 \text{ cf/min.}

Of this amount, at least 5000 cu ft. min should be fresh air (10%), and the remainder 46,000 cu. ft. per min. should be recirculated.

2. Main lobby (ground floor) transient occupancy:
   total area = 10,400 sq. ft.
   total persons = 10,400 = 100 persons

heat from 100 p. = 100 \times 400 \text{ Btu/p/hr.} = 40,000 \text{ Btu}

heat from lights = 10,400 \times 13.6 \text{ Btu/sq.ft} = 142,500

heat in moisture = 100 \times 0.1 \times 1047 = 10,470

\[
\text{total heat gain} = 194,000 \text{ Btu}
\]

Note:
\[ L = 1092 - 0.56.80 = \log - 44.75 = 1047 \text{ Btu/lb.} \]

internal design condition 80°F; supply air 65°F.

heat transmission through glass walls =

North = 2675 \times 19.85 = 53,000 \text{ Btuh}
South = 2675 \times 12.65 = 33,750
East = 1450 \times 87.25 = 126,500
West = 1450 \times 31.25 = 45,250

\[
\text{total heat gain} = 452,500 \text{ Btuh}
\]
B. Exterior Zone.

The exterior zone of a building presents an extremely complicated problem. The basic load of lights and people that make up the interior zone load are also the steady load of the exterior zone. However, to complicate matters, the variable loads of transmission through the outside walls and windows plus the fluctuating sun load are superimposed upon it.

The effect of sun radiation is an important factor in determining cooling requirements that a system must provide.

If the sun is not shining, cooling will be required until a point is reached when the heat loss from the space due to transmission is equal to the heat from lights and people.

In order to use the large areas of glass without substantially increasing the cost of the air conditioning,
sun shades which in this project have a structural function, have been used to reduce the sun load.

Area per floor $= 8 \times 4.5 \times 3.40.5 = 4350$ sq. ft.

$6 \times 4.5 \times 35 \times 4.5 = 4250$ sq. ft.

$\frac{4250}{8600} = 0.5$ sq. ft.

4 floors $= 4 \times 8600 = 34400$ sq. ft.

total person $(80 \text{ ft}^2/p) = \frac{34400}{430} = 80$ p.

Heat from lights $(13.6 \text{ Btu/ft}^2/hr)$

$34400 \times 13.6 = 468000$ Btu a)

Heat from 430 occupants $(400 \text{ Btu/p/hr})$

$430 \times 400 = 1720$ b)

Heat transmission through windows and walls based on 20°F difference $(95-75)$ =

$Q = u(A)(t_1-t_2)$.

$Q = \text{heat flow rate in Btu/h.}$

$U = \text{an overall coefficient of heat transfer; the units for this coefficient are in terms of the number of Btu's that will pass in one hour through a surface one square foot in area which has a difference in air temperature of 1°F on its two sides, commonly referred to as the U value for a wall or ceiling or window.}$
The temperature difference of the air on the two sides of the surface in deg. F.

\[ (t_1 - t_2) \]

A = wall area in square feet.

\[
\begin{align*}
\text{North} &= 4 \times 1350 \times 24.85 = 132,000 \text{ Btuh.} \\
\text{South} &= 4 \times 1350 \times 17.65 = 95,500 \\
\text{East} &= 4 \times 785 \times 92.25 = 290,000 \\
\text{West} &= 4 \times 785 \times 36.25 = 114,000 \\
\end{align*}
\]

\[
\begin{align*}
17200 \\
\end{align*}
\]

Total heat gain = 1,116,700 Btuh.

\[ Q = \frac{1116700}{60 \times 15 \times 0.018} \text{ cfm} = 72000 \text{ cfm.} \]

Fresh air 10% = 7000 cfm.

Recirculation = 65000 cfm.

C. Topfloor:

Total area = 19,775 sq. ft.

Total persons = 245.

Taking approximate identical values from ASHRAE guide =

Total instantaneous heat gain through regular plate glass shaded =
\[ q_N = 0.87 \times 10.5 \times 1.0 \times 9.5 = 24.85 \text{ btuh/sq.ft.} \]
\[ q_S = 0.87 \times 16 \times 1.0 \times 8 = 17.65 \text{ btuh/sq.ft.} \]
\[ q_E = 0.87 \times 90 \times 1.0 \times 8.5 = 92.25 \text{ btuh/ft}^2 \]
\[ q_W = 0.87 \times 15 \times 1.0 \times 10.5 = 36.25 \text{ btuh/ft}^2 \]

Present concrete wall \( u = 0.18 \)
Concrete roof insulated \( u = 0.26 \).

Heat from lights = \[ 19775 \times 13.6 = 268500 \text{ Btuh} \]
Heat from 245 occupants = \[ 245 \times 400 = 98000 \]
Heat gain through windows =
\[ N = 1350 \times 24.85 = 33600 \]
\[ S = 1350 \times 17.65 = 24000 \]
\[ E = 785 \times 92.25 = 72500 \]
\[ W = 785 \times 36.25 = 28500 \]
Concrete walls \[ 1225 \times 0.18 \times 20 = 4400 \]
Concrete roof \[ 19775 \times 0.26 \times 20 = 103000 \]

Total heat gain = \[ 632500 \text{ Btuh} \]

\[ Q = \frac{632500}{60 \times 15 \times 0.018} = 39000 \text{ cfm.} \]
Fresh air 10% = \[ 4000 \text{ cfm.} \]
Recirculated = \[ 35000 \text{ cfm.} \]
### Duct Space:

<table>
<thead>
<tr>
<th>Zone</th>
<th>Supply</th>
<th>Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Interior</td>
<td>57 000 cfm.</td>
<td>46 000 cfm.</td>
</tr>
<tr>
<td>B. Buffer</td>
<td>28 000</td>
<td>25 000</td>
</tr>
<tr>
<td>C. Exterior</td>
<td>72 000</td>
<td>65 000</td>
</tr>
<tr>
<td>D. Topfloor</td>
<td>39 000</td>
<td>35 000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>190 000 cfm.</strong></td>
<td><strong>171 000 cfm.</strong></td>
</tr>
</tbody>
</table>

Supply duct area = \( \frac{190 000 \text{ ft}^2}{1200} \) = 158 sq. ft.

Return duct area = \( \frac{171 000}{1200} \) = 142 sq. ft.

Total duct area = 300 sq. ft.

= 1.5%

### Proposal for Air Conditioning System:

All air-low velocity—single duct distribution.

Peripheral distribution occurs through a series of 3/8 in metal vaults carries cold air to the registers; the vaults are embedded in a light weight concrete poured on top of the waffle slab. This fill contains electrical and telephonic raceways.

Floor to floor heights are, by means of such construction, held to a minimum.
6. Drainage:

Since tropical climate means heavy rainfall of
2.5 mm/ft²/hr. = 0.1 in./sq. ft./hr. sincere attention should be paid on the drainage especially of the roof and the overhangs.

The main drainage pipes are best located along the periphery of the building in order not to be too eye catching; they are to be built in the columns.

Approximate Calculation:

roof drainage: \(40.2 \times 3 \times 5 \times 12 \times 0.1 \text{ in}^3/\text{hr.} \)

\[\frac{24 \times 30 \times 12 \times A}{24 \times 80 \times 12} = 367,500 \text{ in}^3/\text{hr.}\]

A = cross section are drainage pipe.

\[A = \frac{367,500}{24 \times 80 \times 12} \text{ in}^2.\]

\[= \frac{16 \text{ in}^2.}{d = \sqrt[4]{\frac{16 \times 4}{\pi}} = 4.5 \text{ in. pipe diameter.}}\]

7. Illumination.

Considerable study was devoted to integrating the structural, lighting, mechanical and electrical systems within the fabric of the building. The waffle slabs (4′-6″ squares) provide lighting troughs for recessed fluorescent light fixtures of 2′8″.
8. Acoustics.

Use of air conditioning closes the windows to outside noise.

The chief absorber of sound in the office area is the acoustical treatment of the waffle slab with soft board adhesively bonded to the concrete. Other absorption being contributed to a minor extent by the double pane plywood partitions and furniture, and to a greater extent by the linoleum floor.

PART IV. PRACTICAL CONSIDERATIONS.

1. Method of erection.

The general sequence of the construction work would be the erection of the core parallel with the casting of the supporting elements and waffle floor slab, while at the same time precast components should be placed with connections embedded in the poured in place concrete.

All wooden fenestrations would be installed after the concrete skeleton is completed. Therefore special attention should be paid on the detailing of the connection system with the concrete frame—
work as well as the interconnection of the wooden framing.

An insert system is introduced for connection of the wooden fenestration as well as the wooden partitions for flexibility of arrangement.

2. Formwork

There is one best way to build any form, and that way is to use the timber available to the best advantage, having each member of the structure correctly proportioned to carry its part of the load with no waste of material, at the same time giving attention to a few construction details that will facilitate erection and stripping of forms. Economy in stripping is very important. However well a form may be built, its ultimate success depends upon the speed and ease with which it can be stripped. The economy of being able to use the timber over and over again is obvious. This means unit or panel construction.

A unit formwork made of plywood is introduced for the casting of the waffle slab. All forms coming in contact with concrete, since the concrete is not to be plastered, would be well oiled or greased to allow easy stripping and to prevent concrete adhering to and
coming away with the forms. Soft soap and water is satisfactory for this purpose.

Most of the concrete work will be left exposed in this project. Since casting occurs part by part of the structure, it would be honest to show the joints of the successive phases of concreting as well as the joints of the wooden formwork, which will contribute to the characteristic appearance of an exposed poured in place concrete structure.
PART V. CONCLUDING REMARKS.

This project is an attempt to propose a prototype office building for a tropical climate. If air conditioning will not be provided, it is still possible to have a reasonable convenient working condition in the office spaces by providing only mechanical ventilation, since the perimeter glass wall is sufficiently shaded and banked up warm air is avoided by locating the glass wall on a certain distance from the structural solar control devices.

Of course special fenestration should be designed in which the windows could be opened to allow breeze passing through the rooms and cooled the bodies of the occupants by evaporation. Besides, the mechanical ventilation could be regulated as such that a certain air velocity could be achieved which is still within the limits of comfort zone.
# LIST OF ILLUSTRATIONS

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<td>I.B.M. office in La Gaude, France.</td>
<td>2.</td>
</tr>
<tr>
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GROUND FLOOR PLAN - SCALE 1/8"=1'-0"
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