ARCHITECTURAL DESIGN OF A RECREATIONAL CENTRE IN RAS BEIRUT WITH STRUCTURAL DESIGN OF THE BALCONY AND THE ROOF

MICHEL G. ATWEH

1949

ARCHITECTURAL DESIGN

OF A

RECREATIONAL CENTRE IN RAS-BEIRUT

WITH

STRUCTURAL DESIGN

OF THE

BALCONY AND ROOF SLAB

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INTRODUCTION

During the past three or four decades, a "city-going" movement spread all over the Lebanon. Villagers and farmers, left their farms and other property behind, and struggled to establish a foothold in the nearby cities. In no time practically, it was apparent that cities were overcrowded. The city developed into slum-like quarters which greatly contributed to the unhappiness and inefficiency of the working class. Especially is this fact noticeable in the city of Beirut.

Hence the need for proper recreational centers where a person could go and spend few hours during which he forgets about the rest of the world was fully realized by many. The demand for pleasure is evermore increasing in ratio to the increasing strenousness and complexity of modern life. It was only natural then, that many cinemas, cafés, and night clubs, be built in so short a time in order to meet the needs of the public. A noticeable characteristics about such places is the fact that they are purely professional and business-like in many respects. They contribute very little if any, to the welfare of the public. Being located in the center of the town, they augment the congestion in traffic, provide unhealthy surroundings for their clients and are always subject to noise. As a result they have partially or fully failed in their purpose.

As on my part, I have tried to solve such a problem from a totally different angle. All provisions and facilities that are within the limits of economy have, in so far as practicable, been included. Consequently such an attempt will be left to the public to judge the degree of success it has attained.

Perhaps also, the new science of community planning may offer something to the movie house. The movie house is a logical nucleus for an entertainment center that might offer many varieties of amusement and social activities. The theatre architect in his design will have to make use of all the arts and sciences that will add something to the quality of entertainment. Similarly, the theatre owner, will have to get over the idea that the function of the architect is to design a shell to cover so many seats. In fact he will need the architect as never before. This is especially true because the public has reached a stage where it can fully appreciate what is good and reject what is bad.

LOCATION AND PURPOSE

It will be found queer by many people to locate a project of this sort in a quarter such as Ras-Beirut, and on a street which is and has all the characteristics of a residential street. In fact, I had a definite plan and purpose in mind when such a step was taken.

In my opinion, the residents of Ras-Beirut are very different from the remaining population of our capital. Their education, behaviour, and outlook on life is unique in itself. This may be wholly or partially due to the location of the American University. Besides, it is very difficult on their part to mingle with people of other quarters. Like other human beings, they seek places for recreation in the hope of finding some pleasure; but it did not take them long before they realized that such was not their atmosphere or "milieu". They could not adapt themselves to it. That required a basic change in mentality and customs, which they could not afford. It was this very fact that lead me to the choice of this location, my purpose in that, being of course to preserve this uniqueness.

Poor English

Moreover the building is so located that it is easily reached from all Ras-Beirut district. Its nearness to the tram line adds another desirable characteristics. The street of Al-Hamra might develops into a business quarter due to the existence of the Tapline, or the probable erection of the Palace of Justice at the end of it. But, there are still all sorts of reasons to believe that very little noise will be produced if any, and a healthy atmosphere will be easily procured.

QUALITIES OF A RECREATIONAL CENTRE

It is easily noticeable that we no longer think too highly of seriously of our pleasures. Human beings came to realize that life itself is an art and neglect of it distresses or impoverishes us. Happily enough the tendancy to make the scenes of our lives, activities and pleasures, gay and cheerful is constantly growing. We no longer think of pomp and splendour, but rather in terms of light, colour, and air.

As a result, the building which is intended to provide our pleasure should be comfortable and amusing to sit in, and have nothing that is serious or sober about it. It should be refreshing and attractive in every respect.

One might argue that the picture going habit is responsible for the decay of homelife. Probably the reverse is nearer to the truth: that it is just because homelife has lost so much of its attractiveness that the cinema going habit continues to find fresh adherents.

As a building therefore, the cinema should be as informal, impersonal and free from all splendourly and glamarous pretentions. In my attempt I have tried to meet all the requirements of the building functioning as a cinema. The screen on the other hand conceals a properly equipped stage which is readily convertible into an ordinary theatre or concert hall. The screen is quite a different thing to a stage. The first requires only a very modest area; width and height without depth; while the second calls for considerable three-dimensional space, not to mention a platform and a roof provided with a certain amount of fixed equipment.

COMPARISON BETWEEN A THEATRE AND A CINEMA

The cinema, like a young and happy nation has no history. Its traditions are still in the embryonic stage. The cinema fills a need in our lives which no preceeding age has ever felt. This need, the theatre can never hope to answer. There is something formal and ceremonious about going to a theatre. It is an occasion, an event. It implies more careful consideration, if not an evening dress. We don't say casually, "Let's go to the theatre" as we say "Let's go to the pictures".

The cinema is primarily a sort of public lounge. One can go alone, with a friend, or with the whole family. Punctuality is of little or no consequence. One can drop, in and out at any time. In some countries smoking is allowed. One can chew sweets, or enjoy a little nap as easily as the luxury of a good laugh. In wet weather it is an escape from the rains, in winter a means of keeping warm. In short it is a pastime and a distraction.

Thus the cinema clearly requires a type of architectural expression utterly different from the theatre. The theatre has its traditions, and they are on the whole formal ones. The cinema is an essantially democratic institution. It is very much in harmony with the socially go-as you please age we live in. In fact it is a symbol of it.

TREATMENT OF THE FACADE

The cinema is a building which needs to state its business very plainly. The effect it produces is brought about by the artificial lighting system. This being the case, it is important for the façade to be elaborately detailed. The less of carving and moulding the better. Such work will not merely be out of place, it will be entirely wasted. Thus the first sensible economy which is a purely architectural one, is arrived at, which is rendered possible by new building material and plain surfaces. Hence the cinema façade should be designed for "fitness" of purpose and nothing else.

Actually, the cinema bears a striking resemblance to a factory for what is important about each goes on within and cannot be seen from without. As a manufacturing company will not fail to let the outside of its factory tell what is being manufactured inside, in the same manner, the exterior of a cinema ought to show that it is a cinema (neither more nor less) and what films are being shown inside.

Heavily carved columns, architraves, consoles, and other conventional ornaments do nothing to help the passer-by to realize that the building in question is a cinema and not a public library. The external lighting scheme ought to be as simple at it is practicable as the cinema depends wholly on the contrast between darkness and light, its façade should ignore the claims of sunshine and be interpreted in terms of night and not day architecture, because in darkness it can robe itself with a blaze of light, the hues of which are changeable at will.

HISTORY OF THE MOTION PICTURE*

a - Introduction

The motion picture is the latest machine tool in the service of expression. In the annals of history, man's efforts resulted in what is now known as language, the Arts, the stage music and lastly the screen. The motion picture camera brings action into graphic art.

b - Development

Several investigators made researches in the field of motion picture development, but none of them was of much importance until the coming of Edison. In 1887, Thomas A. Edison of New Jersey attacked the problem. His first motion picture machine recorded spirals of tiny picture on a cylinder, in the pattern of a phonograph groove. The pictures were given an intermittant motion, the results of which were inadequate, but Edison determined upon larger images to be handled on a tape or belt. He built a device for this purpose and experimented with various materials, but were unsatisfactory. Later, 1889, Edison bought a sample strip of a newly invented photographic films and tried it with success in his picture machine. The demonstration of the Edison kinetoscope at West Orange; N.J. on Oct. 6, 1889, with a strip of Eastman film, made the motion picture an accomplished fact.

* Summarized from the Encyclopedia Britanica.

Few other improvements were made in successive years. The machines made their first public appearance at a kinetoscope parlour at 1155 Broadway in New York City April 14, 1894. Thus began the commercial history of the motion picture. That Autumn several machines were exported. From these machines the English and European development of the motion picture sprang. Edison's invention was not patented abroad.

c - Production of Motion Pictures

The first story pictures, running only a few feet presented little more than simple incidents or records of events. Little or no attempt was made to capture true dramatic values. In 1907 David Griffith, a young American director, evolved a screen technique of far-reaching significance. He brought into first practical use such methods of pictorial and dramatic emphasis as the "close up" the "cut back", the "fade out" and the "dissolve", making possible the telling of more complex stories. Story pictures of this period were not more than one thousand feet in length the capacity of a single reel. The release of multireel pictures in the year 1910, made screen history.

From 1916, production steadily increased in volume and quality. Many new companies entered the field and large studies were constructed to accomodate the growing industry. Up to 1927 when sound recording and reproducing apparatus brought dialogue to the screen motion pictures were silent.

Among the more important studio departments which contribute to the production of modern pictures are : Architectural, Costume, Casting, Research, Story, Writing, Editorial, Laboratory, Electrical, Camera, and Sound.

STATISTICS

The following items of statistics concerning production and manufacture of motion picture are summarized from the Encyclopedia Britanica :

The motion picture industry in the United States continued to maintain world leadership in production and exhibition in the manufacture of equipment and in exportation, despite restrictive measures imposed in a number of foreign countries. In 1937, according to best estimates, there were 89,097 motion picture theatres throughout the world. Approximately 550 feature pictures were produced in the U.S. ~~and were~~ exibited to 88,000,000 weekly attendance paying over 1000,000,000 $ for the year in admissions at an average ticket cost of 22 3/4 cents.

Great Britain continued to be the most important outlet for American films.

Forty percent of the world's motion picture product was made in the United States but its value amounted to 75% of the world total.

PROJECTION

The development of screens having especially prepared surfaces added to distinctness and brilliancy. With the introduction of sound films, the controlling elements of the reproducing system were embodied in the projection machine and the rate of projection increased one half to meet the requirements of sound reprojection.

With early multireel pictures, the single projection machine necessitated a wait between reels. Two machines became standard in theatres. Fire hazards due to the inflammable nature of films were virtually diminished by fireproof projection booths.

The projection room, technically the most important part of any motion picture theatre, is a special fireproof room fitted with square or oblong port holes leading into the Auditorium, through which the light beams are thrown from the projectors to the screen. Two or more projection machines are nowadays installed in the projection room so that a long picture may be projected without interruption, a new machine being started just before each reel runs out. The projection is changed from one machine to the other so smoothly that those viewing the picture in the auditorium are not aware of the change.

AUDITORIUMS

From converted stores seatingless than one hundred persons, motion picture theatres kept pace with the development of projection. Auditoriums were designed for comfort and architectural beauty. The larger theatres reached capacities of several thousands. Since the introduction of sound, threatres have continued to improve in comfort, architectural design and spaciousness. The sound reproducing and amplifying equipment is installed in the projection and connected by means of wiring to the loud speakers behind the screen. The architectural phase of the auditorium as a housing for entertainment should not be of such a style that compete with the pictures on the screen. Here is a place for modern funcional design. Ample space for the corridors has been provided in order that possible congestion might be avoided. In addition, the seats have so arranged that they will command and interrupted view of the screen. They are easy to find even when the auditorium is darkened for the showing of the film, and the rows of seats are spaced far apart to allow an easy passage.

On the other hand, the roof is an element of almost paramount importance and calls for most skillful technical lighting.the curtain can be raised vertically and opened laterally.

The materials used in the interior of one of the most generally admired cinemas in Germany are: Metal plating, wood veneers, varnish, glass, paint, plaster, and LIGHT.

The last of these was the cheapest and most effective and at the same time the most difficult to use successfully. Too much light was as fatal to the ensemble of a well balanced composition as was too little. Few of the material orinarily employed in interior decoration are neutral to light. They either deaden, or absorb it or else reflect it in greater volume. Thus balance between reflecting and nonreflecting materials is very necessary.

The science of seeing tells us how violent are the lighting conditions in the typical auditoriums. Besides eye comfort, and therefore better illusion, better lighting would also improve convenience, simple safety and perhaps propriety in the theatre of today.

FOYERS

The entry into a cinema ought to prepare the spectator for the change from the outside world of everyday reality to the Hollywood world of the screen. Tactfully suggestive lighting is exceedingly important. The lighting of the foyer, has its own seperate problems. Some architects consider that transition from the atmosphere of the street to that of the screen ought to be as abrupt as possible in order that a violent contrast may be produced. Hence they abbreviate their foyers into mere gangways. Others, preferring that such a change of environment should be not only more gradual and ceremonious, but accompanied by decorative features and a softly lit lounge.

In my design, I have followed the second preferance and besides the ticket rooms, coat rooms, and a long passage way, there are two offices for the director and manager who will have to take care of the operation of the building as a whole.

LIGHTING AND DECORATION

The illumination of the foyer, auditorium etc., will be in three colours, the tints of which can be changed at will or their intensity modified. The stage lighting will be rendered perfect.

The design of the lighting scheme, considered as an integral part of the decoration, depends to a large extent on how swiftly can the spectators' interest be shiffted to the appreciation of the auditorium as a whole during intermission periods. But, on the other hand, it must not be allowed to distract his attention or become a rival to the screen. Such will, in most cases offer a notable example of resourceful economy of design.

It is easier to meet the visual requirements of continuious motion picture threatre lighting with incandescent lamp, than with fluorescent, as the extraordinary degree of control required is difficult with fluorescent. Furthermore, the incandescent equipment can be easily dimmed.

Fluorescent lighting can be used for the decorative and intermission lighting.

Marble is not much used for interior decoration, but facing with dark slabs of Travertine, or plain plats of copper, brass, aluminuim and chromium steel is very widely adopted. Ceramic, whether in plain colours or otherwise, and modernist Arabesque is also popular.

The auditorium walls will be left in so far as practicable, almost entirely undecorated to avoid competition with the screen image. But they will be carefully slanted and textured to reflect the brightness of the screen image into the auditorium itself. Secondary lighting will be cut down to a minimum.

ACOUSTICS

Acoustics is another major area for theatre improvement. As a matter of fact, I consider it of utmost importance such that I have tried to give as comprehensive a discussion of it as is possible with the limited space provided.

Most theatres, while having an adequate level of projected sound leave much to be desired as to quality, particularly as regards that "intimate" quality of sound which makes it seem to come from the screen. Here again the movie theatre might well profit from the science of auditorium acoustics which have been developed largely since movie houses were built.

In many respects the acoustical problems of motion picture and legitimate theatres are similar. Both should be properly insulated against noise, but in general a slightly greater noise level can be tolerated in motion picture theatres than in legitimate theatres because of the higher speech level.

Since the projection booth is a potential source of noise, all available interior surfaces should be heairly treated with fireproof acoustical material as a 2 - 3 inch universal wool blanket covered with perforated transite. Double panels of glass of different thicknesses should be employed in the portholes. The wall between the projection room and the auditorium should have a transmission loss of nearly all the sound.

The ceiling and walls should provide favourable reflections of sound especially for the seats far removed from the stage. In some instances the ceiling should also aid in the diffusion of sound. However, if adequate means of diffusion are furnished by the floor and wall surfaces, then the ceiling could be used to the utmost for the advantageous reflection of sound.

The shape of a room is one of the most important factors affecting its acoustical properties. Hence the determination of the most desirable shape is a problem that the architect should know how to solve - The optimum ratio of length to width for a room is not a fixed number, but varies with the size and shape of the seating area. For most rooms, ratios of length to width of between 2:1 and 1.2:1 have been found satisfactory. The audience constitutes a highly absorptive surface for sound waves. Hence it is good design in an auditorium from a standpoint of hearing as well as seeing to elevate the seats in order to provide a free flow of direct sound from the source to the listeners. In my case I have provided a slope of approximately 3% which is very comfortable and provides open lines of sight for the spectators.

Length greater than 150 ft. should be avoided in order to avoid a noticeable delay in the arrival of the sound to persons in the rear of the theatre. It requires about one seventh second for sound to travel 150 ft. The lack of synchronism between sight and sound, becomes quite annoying when the difference exceeds about one-seventh second.

The Motion Picture Research Council recommends for proper viewing and listening conditions that the first row of seats be at least 20 ft. from the screen, for screen widths not greater than 16 ft. For wider screens the first row of seats should be back an additional 15 in. for each foot of screen width over 16 ft.

In planing for good acoustics, the architect will avoid errors in design, if he sets up a check list of the necessary and sufficient measures to be taken. These steps, as recommended by Vern O. Kumdsen,* approximately in chronological order are as follows:

1) The selection of the site in the quietest surroundings consistent with other requirements.
2) A noise survey to determine how each sound insulation must be incorporated.
3) The arrangement of the rooms within the building.
4) The selection of the proper sound insulation constructions.
5) The control of the noise within the building, including solid-born noise.
6) The design of the shape and size of each room that will insure the mose advantageous flow of properly diffused sound to all auditors and that will enhance the esthetic qualities of speech and music.

* Prof. of Physics and Dean of the Graduate Division, University of California at Los Angelos.

7) The selection and the distribution of the absorptive and reflective materials and constructions that will provide the optimum conditions for the growth, the decay, and the steady-state distribution of sound in each room.

8) The supervision of the installation of the acoustical plaster, plastic absorbents, or other materials whose absorptivity is dependent on the manner of application.

9) The installation of sound amplification equipment under the supervision of a competent engineer, whenever such equipment is necessary.

10) The inspection of the finished building including tests to determine whether the required sound insulation, sound absorption and the other acoustical properties have been satisfactorily attained.

11) Maintenance instructions in writing to be left within the building manager.

AIR CONDITIONING AND FIRE PROOFING

Air conditioning, one of the major problems that will have to be properly dealt,with plays an important part in attracting the attention of the public. This fact is clearly demonstrated in existing movie houses. Especially is this fact true during the summer session. Many go to the movies in the afternoon just to avoid the heat or to have a nice and peaceful nap.

In my design I have provided a large basement under the stage that provides ample space for the machinery. Besides, an electric substation will allow of the maximum variations in the speed of scene shifting. Air conditioning will be of the forced system whereby the foul warm air is drawn down to the bottom, and fresh air is pumped through openings at the top. Ventilation will be such that every $ft.^3$ is renewed 8 times per hour. The air will be cooled in summer and warmed in winter to maintain constant temperature.

On the other hand, the measures taken to make the building fire-proof are complete. All woodwork is rendered incombustible. Fire alarms and extinguishers are installed to insure the maximum of safety. Exits are so designed and located that the building will be emptied in the minimum possible time. Rows of seats are so spaced that they offer no obstructions whatsoever. In addition the corridors are of considerable width such that they can offer a free and smooth passage way at times of crowding, for several persons at a time.

THE BUILDING AS A WHOLE

After reading what has abready been written in the previous pages, one might get the impression that the sole purpose of the building is to have it function as a cinema. Such is not the case. It is true that the auditorium containing so many seats is the most important unit in the project, and that is why it has been dealt with more exhaustively. But I still maintain the fact that without the addition of the other minor units, the importance of the auditorium would have been decreased considerably. At this point, I might mention that I have found out, it is absolutely unnecessary to enumerate the different units on the plans what are the dimensions of each, and how they are related to each other. As a matter of fact, such an attempt, will be a waste of time and utterly useless. It is not but a description of what is so clearly explained on the drawings.

On the other hand, I would like to point out how functional is the arrangement of the toilet rooms. They are more or less inconspicuously located and are easily reached. An additional desirable feature is the stair case arrangement that leads to the gallery. At its midheight, is a landing that leads to the restaurant, hence offering no interference with the traffic to the gallery. Moreover, two staircase rooms have been so located in order to provide free a access to the service quarter, but mainly to serve the two topmost flats which are exclusively made to function as business offices.

Now considering the building from another point of view, we can clearly see the facilities and the various means of entertainment that have been included. It is an ideal place, and hence easy and convenient for a man to go out with his family and spend a nice and pleasant evening, without even attending the film. The restaurant is of spacious dimensions and is equipped with the most modern means for quick service. After taking his dinner, one can spend sometime sipping some refreshments from the hearly soda fountain, at the same time having an open and direct view to the dancing floor. Music will be of course going on for the duration of the evening. A precaution have been met, so that in case the children do not like the atmosphere, they can go down, play some games, enjoy themselves and come back to join their parents. All this helps in creating nice cozy surroundings which attract the attention of new customers every day.

Finally, but of paramount importance is the parking place, the most desirable feature and requirement of modern design. This requirement, is rarely, if ever met. Such project should never be thought of before keeping the above precaution in mind. The strenuousness of modern life is continuously increasing due to the increased jamming or crowding of traffic thus causing delay and inefficiency. My parking area can take care of approximately 60 cars. During the time that the owner of the car is enjoying himself inside he might leave his car in the garage to be washed, cleaned, lubricated, and made ready for him. He does not have to worry about it. It will be taken care of by an appointed skillful manager, in return of which he will pay a small fee.

CONCLUSION

It is apparent from the previous discussion, that the need for properly built recreational centers is ever more increasing. I have attempted to point out in the previous analysis, the most important requirements of modern design, in so far as they are in harmony with economical considerations. I have full confidence that such a project will meet with the utmost of success and it only depends on how far do the capatilatists of our day appreciate the good of it. They will have to consider the welfare of the public as of primary importance and do away with the idea that such a center is built for profit and mere business-like transaction.

at end

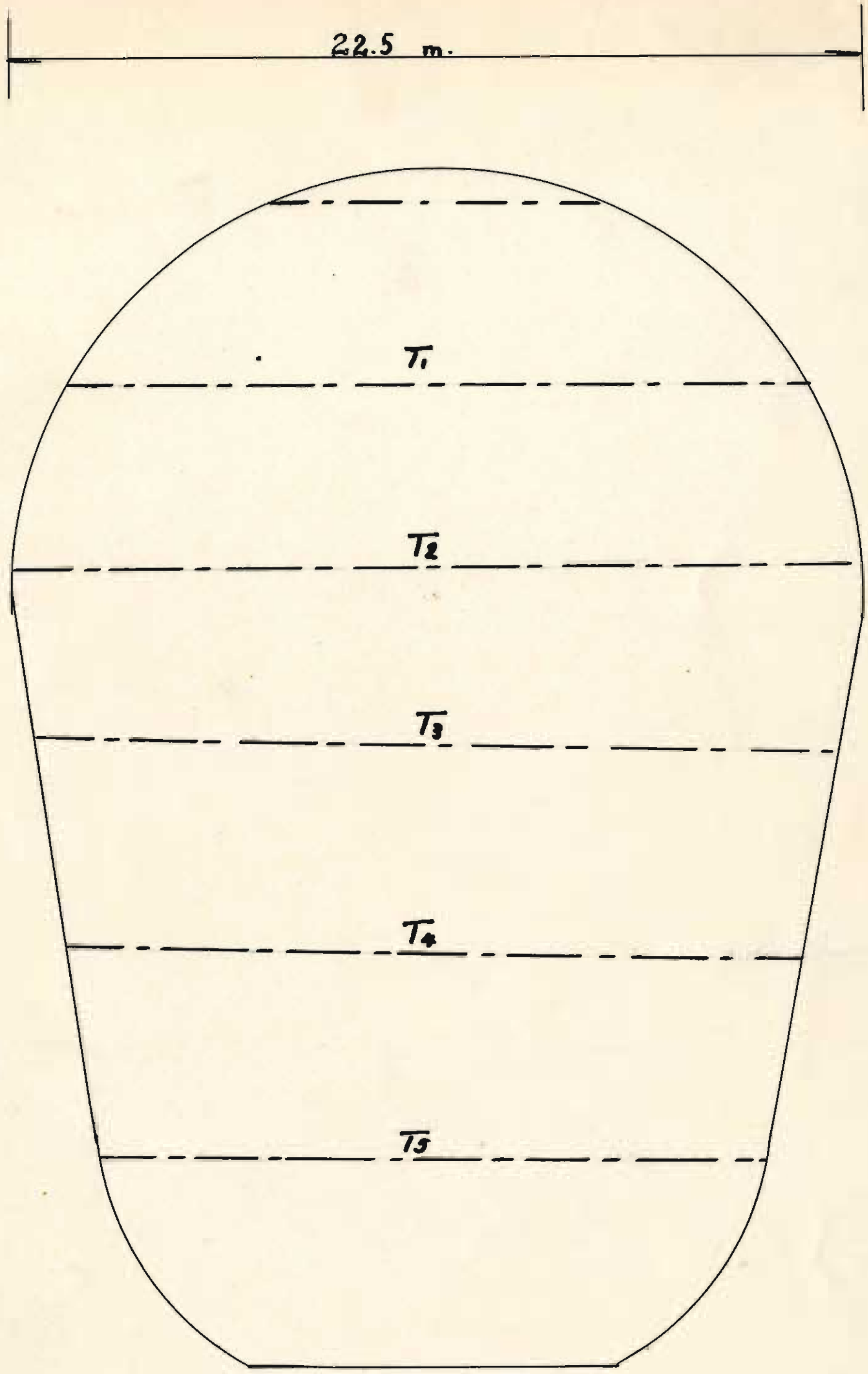
BIBLIOGRAPHY

1 - Modern Theatres and Cinemas - Shand

2 - Encyclopedia Britanica

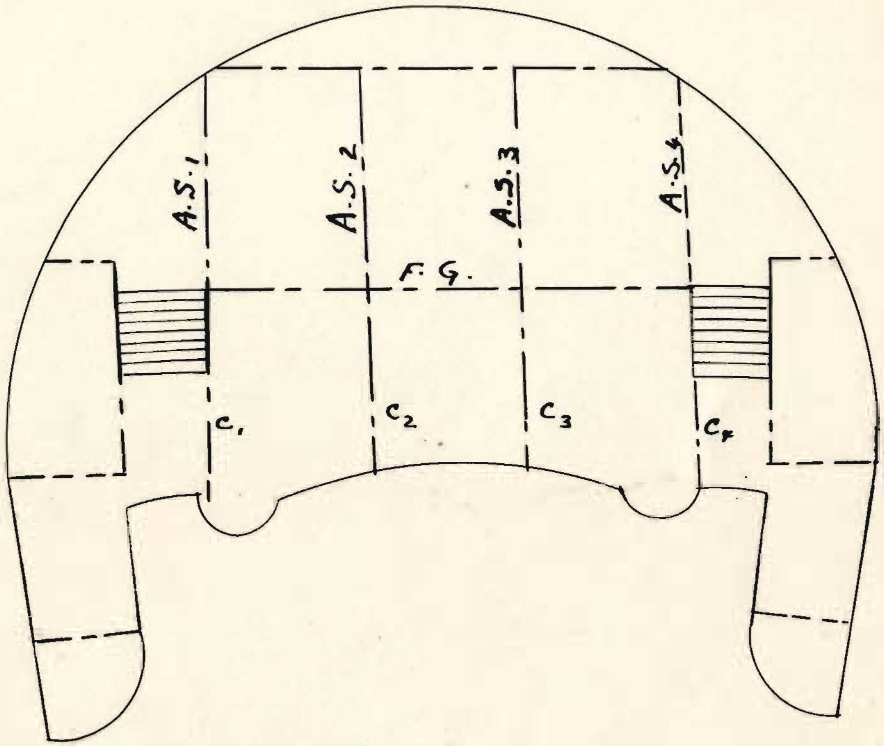
3 - Architectural Record - November 1948

C O N C R E T E   D E S I G N



ROOF PLAN

Scale 1:200



BALCONY PLAN

SCALE 1:200

NOTATION

F.G : FULCRUM GIRDER

A.S. : ANCHOR SPAN

C : CANTILEVER

SPECIFICATIONS

1.	Ultimate Stress in Concrete	2,000 p.s.i.
2.	Allowable Direct Stress in Concrete	800 p.s.i.
3.	Allowable Stress with Bending	630 p.s.i.
4.	Wt. of Concrete per cubic foot	150 lbs.
5.	Live Load for the roof	45 lbs./ft.^{2}
6.	Live Load for the Balcony	65 lbs./ft.^{2}
7.	K =	147
8.	k =	0.429
9.	j =	0.857
10.	Allowable Stress in bond =	80 p.s.i.
11.	Allowable shear in plain concrete =	40 p.s.i.

Design of Reinforced Concrete Slab and Truss

DESIGN OF SLAB:

L.L = 45 lbs. per sq. foot

D.L = 70 " " " " (assume)

Total 115 " " " "

Spacing of trusses = 16'-0"

$M = 1/10\ wl^2 = 1/10 \times 115 \times 16^2 \times 12 = 35,300$ in-lb.

$$d = \sqrt{\frac{M}{Kb}} = \sqrt{\frac{35,300}{12 \times 147}} = 4.45"$$

Using a d of 4.5" and 1 in. insulation the total weight of slab =

$\frac{5.5}{12} \times 150 = 70$ lbs. per sq. foot which checks with the assumed value.

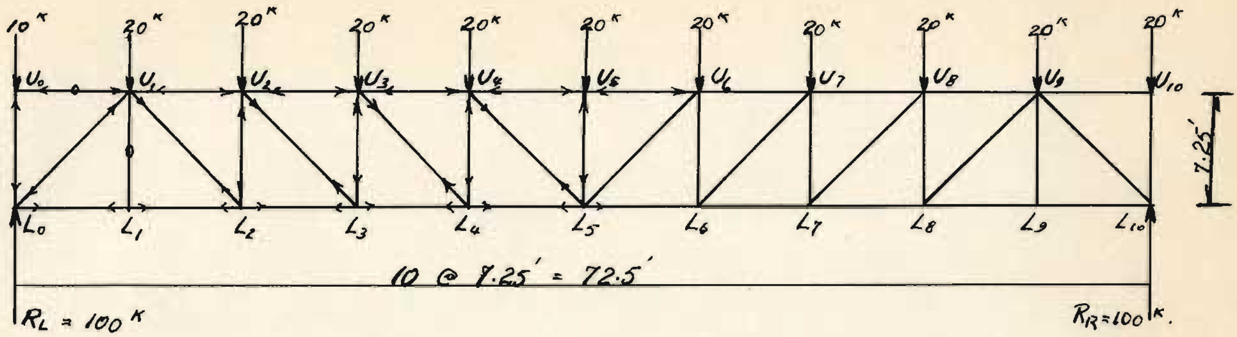
The area of steel for a 12 in. strip =

$$As = \frac{M}{f_s jd} = \frac{35,300}{16,000 \times 0.857 \times 4.5} = 0.570 \text{ in.}^2$$

This is furnished by 1/2" round bars 4" c. to c.

The moment is all assumed to act in the short direction. In the long direction a reinforcement of 1/4" bars at 6" c. to c. will be provided to take care of temperature and shrinkage stresses.

DESIGN OF TRUSS



Span =		72.5 ft.
Height =	1/10 h = 1/10 x 72.5 =	7.25 ft.
Panel length =		7.25 ft.

Length of members per panel = 32 ft.

Assume average section of members = 200 sq.in.

Wt./ft. of member = $\frac{200}{144}$ x 150 = 208 lbs./ft.

Wt./ft. of truss = $\frac{208 \times 32}{7.25}$ = 920 lbs./ft.

Wt. of slab coming to truss = 16 x 1 x 115 = 1840 lbs./ft.

Total wt./ft. of truss = 1840 + 920 = 2760 lbs.

Load / panel = 7.25 x 2760 = 20.00^k

REACTIONS

$R_l = R_r = 5 \times 20.00 = 100^k$

STRESSES

$U_0 U_1$ By inspection $U_0 U_1 = 0$

$U_0 L_0$ By inspection $U_0 L_0 = 10.0^k$ C

$U_1 L_0$ $\Sigma V = 0$

$100 - 10 = U_1 L_0 \times 0.707$

$U_1 L_0 = 127.00^k$ C

STRESSES (Cont.)

	$\Sigma H = 0$
$L_o L_1$	$L_o L_1 = 127 \times 0.707$
	$L_o L_1 = 90.00^k$ T
$L_1 L_2$	By inspection
	$L_1 L_2 = L_o L_1 = 90.00^k$ T
$U_1 L_1$	By inspection $U_1 L_1 = 0$
$U_1 L_2$	$\Sigma V = 0$
	$127 \times 0.707 - 20 = 0.707 \times U_1 L_2$
	$U_1 L_2 = 99.00^k$ T
$U_1 U_2$	$\Sigma H = 0$
	$127 \times 0.707 + 99 \times 0.707 = U_1 U_2$
	$U_1 U_2 = 160.00^k$ C
$U_2 L_2$	$U_2 L_2 = 99 \times 0.707 = 70.0^k$ C
$L_2 L_3$	$L_2 L_3 = 90 + 99 \times 0.707$
	$L_2 L_3 = 160.00^k$ T
$U_2 L_3$	$\Sigma V = 0$
	$U_2 L_3 \times 0.707 = 70 - 20$
	$U_2 L_3 = 70.0^k$ T
$U_2 U_3$	$\Sigma H = 0$
	$160 + 70 \times 0.707 = U_2 U_3$
	$U_2 U_3 = 210^k$ C

STRESSES (Cont.)

$U_3 L_3$ $\Sigma V = 70 \times 0.707 = U_3 L_3$

$U_3 L_3 = 50.00^k$ C

$L_3 L_4$ $160 + 70 \times 0.707 = L_3 L_4$

$L_3 L_4 = 210.00^k$ T

$U_3 L_4$ $50 - 20 = 0.707 \times U_3 L_4$

$U_3 L_4 = 42.50^k$ T

$U_3 U_4$ $210 + 42.50 \times 0.707 = U_3 U_4$

$U_3 U_4 = 240.00^k$ C

$U_4 L_4$ $U_4 L_4 = 42.50 \times 0.707 = 30.00^k$ C

$L_4 L_5$ $210 + 42.5 \times 0.707 = L_4 L_5$

$L_4 L_5 = 240.00^k$ T

$U_4 L_5$ $U_4 L_5 \times 0.707 = 30 - 20$

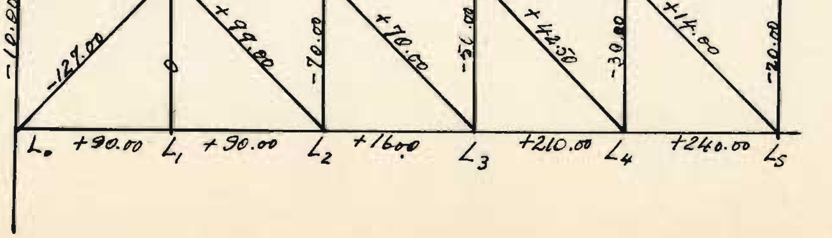
$U_4 L_5 = 14.00^k$ T

$U_4 U_5$ $240 + 14 \times 0.707 = U_4 U_5$

$U_4 U_5 = 250^k$ C

$U_5 L_5$ By inspection $U_5 L_5 = 20^k$ C

DESIGN STRESSES



PROCEDURE

In the following design, the area needed for the moment will be neglected on account of the fact that the section provided for direct stress will be more than enough to take care of moment. In other words, the reinforcement will be so placed that it is able to resist tension due to bending moments, to which the members may be subjected.

COMPRESSION MEMBERS

The top chord will be designed as columns with at least 0.5 percent steel of longitudinal reinforcement and uniformly spaced stirrups all through the chord. It will be poured monolithically with the roof slab. Compression web members are also designed as rectangular columns. However, the allowable stress will be so reduced as specified for combined stresses due to direct thrust and bending.

TENSION MEMBERS

In tension members all the tensile stresses are resisted by the reinforcement and the area of the concrete is made only sufficient to properly cover the bars.

JOINTS

The solid concrete at the joint which corresponds to the gusset plate in steel construction, must be of sufficient size to enable the concrete to transmit the stresses from any one member to the other members in the joint.

Each joint, in addition to the reinforcement of the members extending into it should be provided with special horizontal and vertical reinforcement in the shape of hoops or stirrups. These serve to take care of any secondary stresses and preserve the integrity of the joint.

END PANEL POINT

At the end panel points proper provision should be made for diagonal tension due to external shear. Reinforcement consisting of small bars, should be provided with hooks at the ends. If possible the tensile bars should hook up into the compression members. If not, they should hook around the reinforcement of the compression members.

DESIGN

Bottom Chord - Critical stress = 240^k

$L_3\ L_5$

$$A_s = \frac{S}{fs} = \frac{240{,}000}{16{,}000} = 15 \text{ in.}^2$$

Provide 12 - 1 1/8" sq. Bars = 15.19 in.^{2}

Concrete area = 12 x 16"

$L_2\ L_3$

$S = 160^k$

$$A_s = \frac{160{,}000}{16{,}000} = 10 \text{ in.}^2$$

Provide 8 - 1 1/8" sq. Bars = 10.12 in.^{2}

Concrete area is the same

$L_o L_2$

$S = 90^k$

$A_s = \frac{90,000}{16,000} = 5.62 \text{ in.}^2$

Provide 5 - 1 1/8 sq. Bars = 6.33 in.^{2}

Concrete area is the same

Top Chord

$U_3 U_5$

Critical stress = 250^k

Reduced allowable stress in concrete =

$0.315 f'_c = 0.315 \times 2,000 = 630$ p.s.i.

$A_c = \frac{250,000}{630} = 396 \text{ in.}^2$

Provide a section of 16 x 25 = 400 in.^{2}

$A_s = 400 \times 0.005 = 2 \text{ in.}^2$

Provide 8 - 1/2" sq. Bars = 2.00 in.^{2}

Stirrups are spaced 10" all through the chord

$U_2 U_3$

$S = 210^k$

$A_c = \frac{210,000}{630} = 334 \text{ in.}^2$

Provide same section as before with the same reinforcement.

$U_o U_2$

$S = 160^k$

$A_c = \frac{160,000}{630} = 256 \text{ in.}^2$

Provide a section of 12 x 25 = 300 in.^{2}

$A_s = 300 \times 0.005 = 1.5 \text{ in.}^2$

Provide 6 - 1/2" sq. Bars = 1.5 in.^{2}

Vertical Struts

Critical stress = 70^k

$A_c = \frac{70,000}{630} = 112 \text{ in.}^2$

Provide a section of 16 x 8 = 128 in.^{2}

$A_s = 128 \times 0.005 = 0.64$ in.^{2}

Provide 4 - 1/2" rd. Bars = 0.78 in.^{2}

Diagonals

$U_1 L_2$

$S = 99^k$

$A_s = \frac{99,000}{16,000} = 6.18$ in.^{2}

Provide 8 - 1" rd. Bars = 6.28 in.^{2}

Concrete section = 8 x 16

$U_2 L_3$

$S = 70^k$

$A_s = \frac{70,000}{16,000} = 4.38$ in.^{2}

Provide 6 - 1" rd. Bars = 4.71 in.^{2}

$U_3 L_4$
$U_4 L_5$

$S = 42^k$

$A_s \; \frac{42,000}{16,000} = 2.52$ in.^{2}

Provide 6 - 3/4" rd. Bars = 2.65 in.^{2}

$L_o U_1$

$S = 127^k$

$A_c = \frac{127,000}{630} = 202$ in.^{2}

Provide a section of 16 x 12

A_s = 6 - 1/2" rd. Bars = 1.18 in.^{2}

A knee brace, not considered in the design was added as a factor of safety.

Design of the Balcony

CANTILEVER

A slab of 5" thickness will be used all over the balcony.

D.L.(slab) =	$\frac{5}{12} \times 150$ =	65 lbs./ft.^{2}
L.L. =		65 lbs./ft.^{2}
Finish		5 " "
		135 " "

Spacing of cantilever = 13'

Cantilever arm = 16'

Anchor span = 19'

Uniformly distributed D.L.(own wt.) = 665 lbs/ft

Uniformly distributed D.L.(slab) = 13 x 70 = 910 lbs/ft

Uniformly distributed L.L. = 13 x 65 = 845 " "

Investigation for Uplift

Dead load reactions :

(Due to load on cantilever arm;)

At fulcrum girder, left = 25,200 lb.downward

" " " , right = 10,600 " "

At end support = 10,600 lb.upward

(Due to load on anchor span)

At fulcrum girder, right = 15,000 lbs. downward

At end support = 15,000 " "

The sum of the two reactions gives :

(Reaction due to dead load)

At fulcrum girder, left = 25,200 lbs. downward

" " " ,right =

15,000 + 10,600 = 25,600 " "

At end support =

15,000 - 10,600 = 4,400 lbs. downward

Live Load reactions, Cantilever arm only loaded

At fulcrum girder, left =	13,500 lbs. downward
" " " , right =	5,700 " "
At end support =	5,700 " upward

Uplift due to Live Load =	5,700 lbs.
Downward reaction due to Dead Load =	4,400 "
	1,300 "

If now, the L.L. on the cantilever is doubled or 2 x 5,700 = 11,400 lbs, the downward reaction due to dead load will remain the same. The net uplift for double L.L. on cantilever will amount to 11,400 - 4,400 = 7,000 lbs. To get a factor of safety of 2 against uplift, it is necessary to anchor the structure strongly enough to resist an upward pull of 7,000 lbs.

The above condition where only the cantilever arm is loaded produces maximum stress in the cantilever arm and also maximum negative bending moments in the anchor span. The uplift is also a maximum for this condition.

DESIGN

Uniformly distributed load = 910 + 845 + 665 = 2,420 lb/ft

End moment = $1/2\ wl^2 = 1/2 \times 2{,}420 \times 16^2 \times 12$ = 3,720,000"lbs

End shear = 16 x 2,420 = 38,800 lbs

Selecting a breadth of 16"

Depth as governed by moment

$$d = \sqrt{\frac{M}{K\,b}} = \sqrt{\frac{3{,}720{,}000}{16 \times 147}} = 39.6''$$

Depth as governed by shear

$$d = \frac{V}{vbj} = \frac{38{,}800}{120 \times 16 \times 0.857} = 23.5''$$

Depth by moment governs. Use a "d" = 40"

$$A_s = \frac{M}{f_s jd} = \frac{3{,}720{,}000}{16{,}000 \times 0.857 \times 40} = 6.77 \text{ in.}^2$$

$$\Sigma_o = \frac{V}{ujd} = \frac{38{,}800}{80 \times 7/8 \times 40} = 13.85 \text{ in.}$$

Reinforcement is governed by moment

Select 9 - 1" round bars = 7.07 in.^{2}

The amount of external shear that can be resisted by concrete

$$V_c = v_c bjd = 40 \times 16 \times 7/8 \times 40 = 22{,}400$$

Spacing of stirrups at support = $S = \dfrac{A_v f_v jd}{V - V_c}$

Selecting 3/8" round U stirrups

$$S = \frac{2 \times 0.1104 \times 16{,}000 \times 7/8 \times 40}{38{,}800 - 22{,}400} = 7.5''$$

A spacing of 7" will be used for the first third of the span and then a spacing of 10" will be used throughout the rest of the span. 3-3/4 round bars will be used in the compression area of the cantilever.

The depth of the cantilever arm must be the same on both sides of the fulcrum girder, so that the compression stresses on one side may be resisted by compression stresses on the other side of the girder. If the depth were different, torsion would be developed in the girder. Hence the anchor span will have the same depth as the cantilever at the girder and will be tapered towards the other support. Similarly the cantilever will be tapered towards its free end.

The reinforcement determined for the negative moment in the cantilever beam at the fulcrum girder must be extended on both sides. In the cantilever arm, at least one third of the bars should extend on the top for the full length of the arm. Some of the steel from the cantilever will be carried on the top for the full length of the anchor span

<u>FULCRUM GIRDER</u>

Span = 40' - 0"

Assuming that the anchor span has a depth of 30 inches

Its weight = $\frac{30 \times 16}{144} \times 150$ =	500 lbs/ft.
Slab	910 " "
L.L.	840 " "
	2,150 " "

Reaction of anchor span = $\frac{2,150 \times 19}{2}$	= 20,400 lbs.
Reaction of cantilever	34,600 "
Concentrated load at each of the one-third points	55,000 "

The maximum moment due to the concentrated load is

$M = 2/9 \times Pl = \frac{2}{9} \times 55,000 \times 40 \times 12 = 5,870,000$ in.lbs.

Assuming the weight of the girder as 1,150 lbs./ft.

Moment due to uniform load =

$1/10\ wl^2 = 1/10 \times 1{,}150 \times 40^2 \times 12 = 2{,}200{,}000$ in.-lbs.

Total maximum moment = 7,970,000 in.-lbs.

Total maximum shear = $55{,}000 + \frac{40}{2} \times 1{,}150 = 78{,}000$ lbs.

Assuming b' = 20"

Depth by moment = $\sqrt{\frac{M}{Kb}} = \sqrt{\frac{7{,}970{,}000}{147 \times 20}} = 52''$

Depth by shear = $\frac{V}{b'jv} = \frac{78{,}000}{20 \times 7/8 \times 120} = 37''$

Use a total height of H = 55"

$A_s = \frac{M}{f_s jd} = \frac{7{,}970{,}000}{16{,}000 \times 0.857 \times 52} = 11.15 \text{ in.}^2$

$\Sigma_o = \frac{V}{ujd} = \frac{78{,}000}{80 \times 7/8 \times 52} = 21.4$ in.

Reinforcement by moment governs

Provide 8 - 1 3/8" round bars = 11.88 in.^{2}

Amount of external shear that can be resisted by concrete.

$V_c = v_c bjd = 40 \times 20 \times 7/8 \times 52 = 36{,}500$

Spacing of stirrups at support

$S = \frac{A_v f_v jd}{V - V_c}$ With 7/16" - round U stirrups

$S = \frac{2 \times 0.1503 \times 16{,}000 \times 7/8 \times 52}{78{,}000 - 36{,}500} = 5.3$ in.

Use a spacing of 5" for the outer thirds and a spacing of 10" for the middle third.

The flange of the girder will be cast 40" wide in order not to exceed the allowable stresses in the concrete. Moreover, 4 - 3/4" round bars will be provided in the compression area to hold the stirrups. Half of the main reinforcement will be bent up as shown in the drawings.