THESIS

REDESIGN OF ROOF
AND SIXTH FLOOR
OF BIJOU BLOCK
IN REINFORCED CONCRETE

W. N. MOSS D. L. BOYD

1909

Building Details

This thesis was contributed by

Mr. W. N. Moss

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MICHIGAN AGRICULTURAL COLLEGE

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-oO/1909/Oo-

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by

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THESIS

REDESIGN OF ROOF AND SIXTH FLOOR OF BIJOU BLOCK IN REINFORCED CONCRETE

The purpose of this thesis is to redesign the roof and the sixth floor of the Bijou Block, a six-story brick building, containing business offices and a theatre, which now stands on the corner of Capitol and Michigan avenues in the city of Lansing, and in the new design to replace the brick pilasters and wooden floors as now constructed, with reinforced concrete columns, beams and floors such as to form a fire proof building and retain the original dimensions of the offices and theatre as nearly as possible.. It was our first intention to redesign the whole building, but so much time was spent in determining the best methods of design as followed in actual practice that we were able only to complete the design and drawings for the roof and sixth floor.

The original plans and specifications of the building were obtained from Mr. E. A. Bowd, Architect, and the new system of framing was made to conform as nearly as possible to that of these plans, so that the architects arrangement of offices, etc. should be carried out in the new design.

The "Kahn System of Reinforcing Concrete" was used throughout the redesign, as it is said to be one of the best methods of reinforcing concrete for use in construction of fire proof buildings.. The formulae we have used are those given in the hand book "Kahn System Standards". These formulae we have checked with those from Monolith Hand Book and also those given by the American Correspondence School in Vol. 10 Cyclopedia of C. E. and find them to be correct.

As it is not our purpose to investigate the theory of concrete reinforcing, but to actually design the parts mentioned by the most practical methods, we have copied the explanation of the Action of reinforced concrete from the "Kahn System Standards" as we believe this clear put concise explaination will add interest to our design.

Reinforced concrete is exactly what the name implies. It is concrete in which steel has been imbedded to give additional strength and elasticity. Plain concrete when used in the form of pillars or posts, is capable of carrying heavy direct loads through its great compressive strength. But when subjected to a direct pull, that is to tensil strains, it is weak. For example, if a plain concrete beam is subjected to a load it will break at the bottom just as a piece of chalk would break under like conditions, being unable to resist the tension in the lower portions of the beam (Fig. 1). In order to overcome this, reinforcing steel is used to give proper tensile strength and elasticity. The concrete in the top of the beam takes care of the compression. A properly reinforced beam has, therefore, the strength of stone in resisting compression united with the tensile resisting power of steel (Kahn System Standards).

The development of the strength of the steel when imbedded in concrete is due to the peculiar adhesion or bond

formed when cement hardens about the metal. The bond between concrete and a plain bar has been determined experimentally and is set by most authorities at 50 pounds per square inch of surface for plain bars and 75 pounds per square inch for Cup Bars.

The coefficient of expansion of concrete and steel is very nearly the same as shown by the following data (Prof. W. D. Pence, Purdue).

Concrete

1 Part cement, 2 parts sand, 4 parts broken stone.

No. of tests, 7.

Has an average coefficient of expansion - - - .0000055

Coefficient of expansion of steel- - - - - - - - - .0000067

Or for the same length, a change of temperature of 70° F. will only produce a difference of .0000084 of this length between the expanded steel and expanded concrete, therefore, the bond will not be destroyed by difference in expansion of the two materials.

When a beam is loaded and supported at the two ends, it will have a tendency to deflect. To illustrate, assume that a beam is made up of a series of flat plates, or in other words, like a pad of paper, the difference being that in the pad of paper the leaves are not in any way connected to each other, whereas in a beam the adhesion of the various particles of the material ties the imaginary plates together. Now, when the supported beam starts to deflect one of two things will happen. Either the various plates separate, as when a pad of paper is bent, and in separating slide by one another, or, if the plates be held together and sliding is prevented, the particles in the upper plates compress and in the lower plates elongate.

It is seen that in addition to the compression and tensile stresses of equal importance against which the concrete must also be reinforced. To accomplish this it is necessary that there shall be diagonal steel reinforcement extending well up into the mass of the concrete. This latter reinforcement should be attached to the steel at the bottom of the beam in order that the steel may act together with the concrete in forming a properly reinforced beam. (Kahn System Standards)

There is also the same tendency to vertical shearing as in any other type of beam, but this is amply cared for by allowing the reinforcement to project over on the supporting beam or column, except in a few cases where a concentrated load acts on the beam near the support.

The forces resisting this shear are as follows:

Area of section of beam (sq. in.)(50)- - - - - - - - - --

" " diagonals of Kahn bars (sq. in.)(sine 45°)16000

" " cup bars (sq. in.)(sine 30°)16000- - - - - - - --

Total shear resistance- - - --

When beams are built so as to form part of a floor construction, the floor slab will act with and may be considered part of the same when the concrete of the beam and the slab is placed continously so that the two will be perfectly united.

In the design of T beams there are four considerations which govern the width of the floor slab that may be considered as acting as the compressive flange of the beam.

1. Shear along the plane mn.

2. Shear along the planes mo & np.

3. Span of beam as affecting width of T.

4. Strength in compression.

To cover these considerations the following results have been arrived at by good authority and are instituted in various Municipal Building Codes.

1. In order that the beam shall be safe in shearing along the plane mn, b' must not be greater than 5b.

2. b' must not be greater than b + 10d.

3. b' must not be greater than 1/3 of the span of the beam.

4. The width of flang necessary for compression is dependent on the ratio of the area of the tensile reinforcement in the bottom of the beam to the rectangular area of concrete bd.

Equation (2) $\frac{c}{f} = \frac{x}{m(1-x)}$ X c = (750# per sq.in.) f = 16000#/□" m = 15

Solving- - - - - - - --x = .413

The stress at lower edge of slab = $\frac{x-t}{x}c$

Total compressive stress = $\frac{1}{2}cbxd + \frac{1}{2}(b'-b)\frac{(2x-t)}{x}ctd$.

Total tensile stress = 16000ptd.

Equating and solving for $\frac{b'}{b}$.

$$\frac{b'}{b} = 1 + \frac{32{,}000(p-cx)}{\frac{2x-t}{x}ct}$$ Substitute for c and x.

$$\frac{b'}{b} = 1 + \frac{32000p-310}{(.826-t1816t)}$$

When the lower edge of the slab falls below the neutral axis the analysis of the beam is the same as for a simple beam of width b' and depth d.

Theory of Reinforced "Kahn System Standards"

d = distance from extreme com. fiber to center of steel.

xd = distance from extreme comp. fiber to the neutral axis.

x = ratio of the depth of neutral axis to depth (d) of steel.

kd = distance from center of com. of concrete to center of steel.

k = ratio of this distance to depth of beam (d).

b = breadth of beam.

$m = \frac{E_s}{E_c} = \frac{\text{modulus of elasticity of steel}}{\text{modulus of elasticity of concrete}}$

A_s = area of steel reinforcement.

P = ratio of area of steel to area of concrete = $\frac{A_s}{A_c}$

C = compressive stress in extreme fiber of concrete.

f = tensile stress in steel.

RM = moment of resistance of beam.

BM = bending moment.

This theory is based on the following assumptions.

1. A section plane before bending remains plane after bending; that is, the stress on any fibre is directly proportional to its distance from the neutral axis or what is commonly called the straight line formula.

2. The tensile strength of the concrete is entirely neglected.

3. There are no initial strains in the beam.

4. All shearing strain is cared for and there is no slipping between the concrete and the steel.

5. The modulus of elasticity of concrete in compression is constant.

The total compression in the beam must equal the total tension. Equating these forces.

$\frac{1}{2}cxd$(area of comp.)$b = A_s f = Pbdf$

$\frac{1}{2}cx = pf$ (1)

According to the first assumption.

$$\frac{C}{f} = \frac{xd}{d(1-x)} \times \frac{E}{E} = \frac{x}{m(1-x)} \quad (2)$$

Combining (1) and (2)

$$\frac{1}{2}x^2 = m(1-x)P$$

$$X = -Pm + \sqrt{(PM)^2 + 2PM} \quad (3)$$

Or again combinining (1) and (2)

$$P = \frac{1}{2}\frac{C^2M}{f(f+CM)} \quad (4)$$

The strain stress curve being a straight line the center of compression is located 2/3xd above the neutral plane.

Taking moments about the neutral axis.

$$RM = (1/3Cx^2 + Pf(1-x))bd^2 \quad (5)$$

$$RM = \frac{Cxbd^2}{2}(1-\frac{x}{3}) = K\frac{Cxbd^2}{2} \quad (6)$$

Taking moments about the center of compression in the concrete..

$$RM = (1-\frac{x}{3})dA_sf = KdA_sf \quad (7)$$

From equation (7) it is at once evident that the moment of resistance of a concrete beam is dependent only on the factor (K) the area of reinforvement, the depth of the beam, and the allowable stress in the steel, with this important proviso-- THAT THE ALLOWABLE COMPRESSIVE STRESS IN THE CONCRETE IS NOT EXCEEDED.. This allowable stress will not be exceeded if the

percentage of steel is kept below the value determined by equation (4). It will be seen from equation (4) that if we assume a value for (f) equal to 16,000# per sq. in. and also values for (m) =12 that curves can be plotted showing the relation between the percentage of the metal and the compressive stress in the concrete.

From such curves it will be seen that if the percentage of steel does not exceed 1% of the rock cement there is no danger of the concrete failing by compression.

The factor (k) in equation (7) is the distance between the center of compression of the concrete and the center of the steel. It depends entirely for its value on the position of the neutral axis. From equation (3) it is seen that the position of the neutral axis is dependent entirely on the percentage of the reinforcement and the values of (m)

Again assuming (m) = 12 we plot curves for equation (3) and find the position of the neutral axis for various percentages of metal. An inspection of these curves show that for all ordinary practical percentages of reinforcement, this factor (k) does not vary appreciably. It reduces to a value equal to .86 when the percentage of metal equals 1%. For all lower per cent of metal its value is greater. It is therefore, a very safe assumption to reduce equation (7) to the following simple formula.

R.M. = $.86dA_sf$ or for f = 16,000# per sq.in. = $13.76dA_s$

B.M. (uniformly loaded) = $\frac{1}{8}Wl$.

W = loading per linear foot $\frac{1}{8}Wl = 13.760dA_s$

l = length of beam in inches $\quad A_s = \frac{Wl}{8 \times 13760d}$

Constants

Ultimate tensile strength of steel - - -70,000# per sq. in.

Factor of safety - - - - - - - - - - - - - - - - - 4

Safe tensile strength of steel - - - - -16,000# per sq. in.

Safe compressive " " concrete - - - - -750# per sq. in.

" shearing " " " - - - - --- 50# " " "

Tensile strength of concrete neglected.

Wt. of brickwork (Common and Paving) - - - 120# per cu. ft.

Wt. of concrete - - - - - - - - - - - - - - - - - 1# " " in.

Snow load - 30# per sq. ft.

Live load on floors - - - - - - - - - - - - - - 75# per sq. ft.

Weight of tile partitions neglected as live load is sufficient to cover.

Bond plain bar 50# per sq. in. of surface

" cuf " 75# " " " " "

Filling, 6" ash concrete, 22# per sq. foot.

Plastering - - - - - - - - 7# " " "

Design of a Typical Floor Slab

In the cross section of the roof as shown in Figure (10) it is seen that the space between the rows of tile, when filled with concrete, forms a small beam or joist, each joist having its steel bar to take tension and concrete to take compression. These joists carry all the load while the tile serves merely as a filler to reduce dead weight and save the cost of making forms for each individual joist.

The block thus formed by the tile and steel imbedded in concrete and lying between beams is called a slab. By a beam is meant a beam which is not formed between tile alone but must have a special and larger form made for it when it is cast.

It is not practical to make the length of joist in a slab over twenty feet in length and then only in extreme cases, for the depth of the slab will be so great in order to support its own weight, that it would be much cheaper to frame the slab with a small beam cutting these joist at the center and have this beam in turn frame into other beams or columns. Therefore, the first thing to do in the redesign from a system of mill construction is to so frame the beams and columns as to, first, keep short floor spans, and second, to keep these beams and columns hidden by partitions, etc. as much as possible.

It has also been found that either 16" or 17""center to center" is the best spacing of joist to use in floors of ordinary loading and span, for a less distance between joist would necessitate the use of smaller bars than can be easily handled or else thinner floors which is not economical for the total amount of steel used would be greatly increased, as an impractical formula it is usually taken that the floor slabs should have a thickness at least equal to 1/30 clear span. If a greater distance than 17" between centers was used for the same load and span we would have the depth of the slab increased for the depth of the joist would necessarily have to be increased to hold the extra steel put in each, therefore, and unnecessary addition to the dead load.

A uniform spacing is carried throughout a floor where two or more slabs are continuous over a beam or beams, in order that top reinforcement may be placed in such a manner as to extend across the beam, and along a joist of the slab on each side. This top reinforcement due to the monolithic construction, will take a part of the load from one slab and carry it to the slab on the opposite side of the beam and thus prevent the floor cracking just above the beam due to the deflection of the floor and it also enables us to decrease the weight of steel necessary for a floor as will be shown later.

In order to produce the proper continuous action, top reinforcement must be provided over each of the supports equal in area to one-eight of the area of the bars in the floor. This area of top reinforcement may be subtracted from the area of steel necessary at the center of the span as explained.

In the case of floors reinforced with ½ x 1½"bars the construction of joist and tile is covered with a 1" coat of concrete and the floor with ¾" x 2 3/16" bars with a 2" coat. This is in order to provide sufficient compressive area.

These thicknesses may be increased if the conditions warrant it.

In our design we found that by using 17" c.c. spacing and varying the thickness of the slab from 4" tile + 1" concrete to 4" tile + 2" concrete and 6" tile + 1" concrete that all the loads could be economically carried by using ½" x 1½" and ¾" x 2 3/16" Kahn Bars.

As the design of the roof varies from a floor slab only in that the load on the roof is all "dead load" while on the floor slabs we have a live load. The formula and method of handling floor slabs is identical with those used in the design of a roof slab, the amount of load being the only quantity which varies, therefore, I will give the details for the design of roof slab No. II.

In the sketch attached (b) is a coat of 1" concrete trowled on for water proofing, (c) is a filling of ash concrete varying from 2" to 8" in depth. This placed quite dry and tampped to a gradual slope to the down spoute so that the water will drain off, (d) is a coat of concrete varying from 1" to 2" according as the conditions warrant it, covering the tile and pourd at the same time as the joist, (e) is the tile filler, (f) is the Kahn Bar lying along the bottom of the joist and the diagonals projecting up to near the surface (d). This bar is raised so that there is ¾" of concrete underneath it to prevent the heat of a fire from heating the bar so that it would stretch. (g) is the plaster coat, and (a) is top reinforcing bar, diagonals turned down.

Load on Roof Slabs

(Data from Kidders Hand Book)

Snow load per sq. ft. - - - - - - - -	30 lbs.
Average ash covering 6" deept- - - --	22 "
1" concrete top dressing- - - - -- --	12 "
Plaster on under side- - - - - - - -- -	7 "
Total weight on slab- - -	71 lbs. sq. ft. area

Load on Floor Slabs.

Live load- - - - - - - - -- - - - - -- - 75 lbs. sq. ft. area

This is sufficient to cover weight of tile partitions for live load does not come closer than 10" on each side of the partition.

Reduction of Formulae

Standard formulae -- R.M. $= .86 d A_s f$ BM $= \frac{1}{8} Wl$

where R.M. = resistance moment

d = depth of center of steel below surface of slab

A_s = area of steel

f = tensile stress safe for steel = 16000# per sq."

B.M. = bending moment due to uniform loading

W = load per linear ft. of length of joist = wl

l = inches length of joist between beams

L = length of joist in feet

BM = RM.

$$\therefore A_s = \frac{WL \times 12 \times spacing}{8 \times 16000 \times .86 \times d}$$

5" Slab

4" tile + 2" concrete.   Spacing 17" C.c.

Weight on slab of roof 71#

" of slab itself 39#

Total weight 110# sq. ft.

$$A_s = \frac{110 \times 12 \times 1.42 \times L^2}{8 \times 16000 \times .86 \times 4.25}$$

$$A_s = .004L^2$$

Flat is .004 x (length of joist in ft.)^2 will give us the area of steel necessary to place in the bottom of a joist of a 5" slab in order to carry the total load put upon it.

6" Slab

4" tile + 2" concrete.   17" c.c.

Wt. on slab 71#

" of " 51

Total 122# sq. ft.

$$A_s = \frac{122 \times 12 \times 1.42 \times L^2}{8 \times 16000 \times .86 \times 5.25} = .0036L^2$$

7" Slab

Wt. on slab 71#

" of " 49

Total 120# sq. ft.

$$A_s = \frac{120 \times 12 \times 1.42 \times L^2}{8 \times 16000 \times .86 \times 6.25} = .003L^2$$

Calculations Slab II, clear span 11' - 9½"

$11.8^2 \times .004 = .556$ A" steel necessary in one joist.

42 joist in floor x .556 = 23.35 sq. in. of steel for whole floor. Put in ½" x 1½" K.B. sheared center area .25 sq. in. every 3rd joist for top reinforcement. 13 bars on each side. Total top reinforvement (13 + 13).25 = 6.5 sq. in. of steel. Subtract this from the total steel required gives 23.35 - 6.5 = 16.85 sq. in. Area of standard ½" x 1½" K.B. = .41 sq. in. No. joist 42. .41 x 42 = 17.2 sq. in. against 16.85 required. Therefore safe.

Design of a Typical Beam

Minimum size of beams as limited by practice is 10" x 10" reinforced with 2 - ⅝" x 2 3/16" Kahn Bars and 1 - ½" Cup Bar. Minimum size of lintels used is 8" x 8" reinforced with 2 - ½" K. B. and 1 - ½" C. B.

The Cup Bar is used as an auxiliary reinforcement to the Trussed Bar wherever direct tension or compression stresses are to be resisted. The area of the Cup Bar is kept as near ½ the area of the steel in the beam as possible in order that it may be extended over a column or beam and act as top reinforcement. For beams continuous on one end subtract ½ the area of the top reinforcement, which comes from the beam next to it, from the required area of steel to resist the bending moment. For beams continuous on both ends subtract ½ the area of the top reinforcement, which comes from each of the abbutting beams, from the required area of steel. The length of the Cup Bar is figured as follows:

For beams not continuous the length of the C. B. is equal to 1.2 times the length of the K. B. for the same beam. This gives us length enough for a hook on each end of the bar.

For beams continuous on one end, C. B. = 1.4 x length of K.B.

For beams continuous on both ends, C. B. = 1.6 x length of K. B.

When one beam is framed into another, the beam into which the load is carried should be at least 2" deeper than the first, so that the reinforcement of the second will lie below that extending over from the first named.

The depth of the beam should not be less than span, for to exceed this the deflection of the beam under load would crack the plaster.

In Fig. (10) we have the Kahn Bar (O) lying along the bottom of the beam with concrete (h) extending out to the side and below at least 2" for fire proofing. This bar passes into the column and is separated from the bar coming from the abutting beam by about 1 or 2". The diagonals project upward at and angle of 45° to very near the surface of the slab. (n) and (j) are cup bars showing the method of bending at angle of (30°) and carrying across the top of the column into the next beam as top reinforcement. (m) is a short bar bent at angles of 30° to carry the load coming from the A out and distribute it along the beam B. The area of this bar is not figured in the design.

Where a concentrated load acts on a beam it is multiplied by a factor from Kidder which gives us the distributed load which would produce the same bending moment.

Design of Beam V

Clear span 12' - 0"

Load from slab VIII 14/2 x 122 = 854#

" " " VII 11.8/2 x 110 = 649#

1503# linear ft.

Weight of beam 10"x 14" 140

1643# " "

$$A_s = \frac{wl}{8 \times .86 \times 16000 \times d} = \frac{wL^2 \times .000109}{d}$$

Where

w = load per linear ft.

l = length clear span ft.

d = depth of steel inches

$$A_s = \frac{1643 \times 12^2 \times .000109}{12} = 2.14 \square'' \text{ (steel)}$$

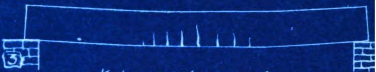
			Area
Beam V - 10" x 14"	(2 - ¾" K. B.		1.58
	(1 - ½" C. B.		.25
	½ C. B. from T		.28
	½ C. B. " W		.12
			2.23 Sq. in.

The drawings show clearly the exact location of each reinforcing bar and the detailed size of all the concrete work. Each bar when it leaves the factory is given a distinctive mark which corresponds with its marking on the drawing. Each bar is designed for a distinct place in the structure and the builder can tell at a glance where it belongs.

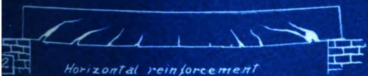
DGH

FAILURE of CONCRETE BEAMS.

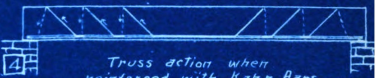
No reinforcement
Light load, failure-sudden.



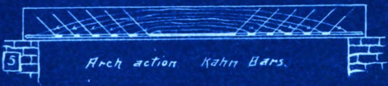
Kahn reinforcement
max. load. failure-slow.



Horizontal reinforcement
Light load. Ends slip.

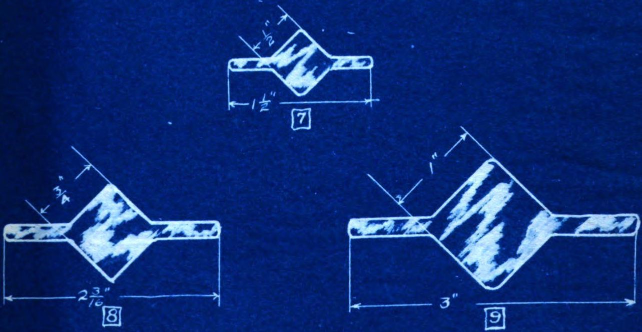


Truss action when
reinforced with Kahn Bars.

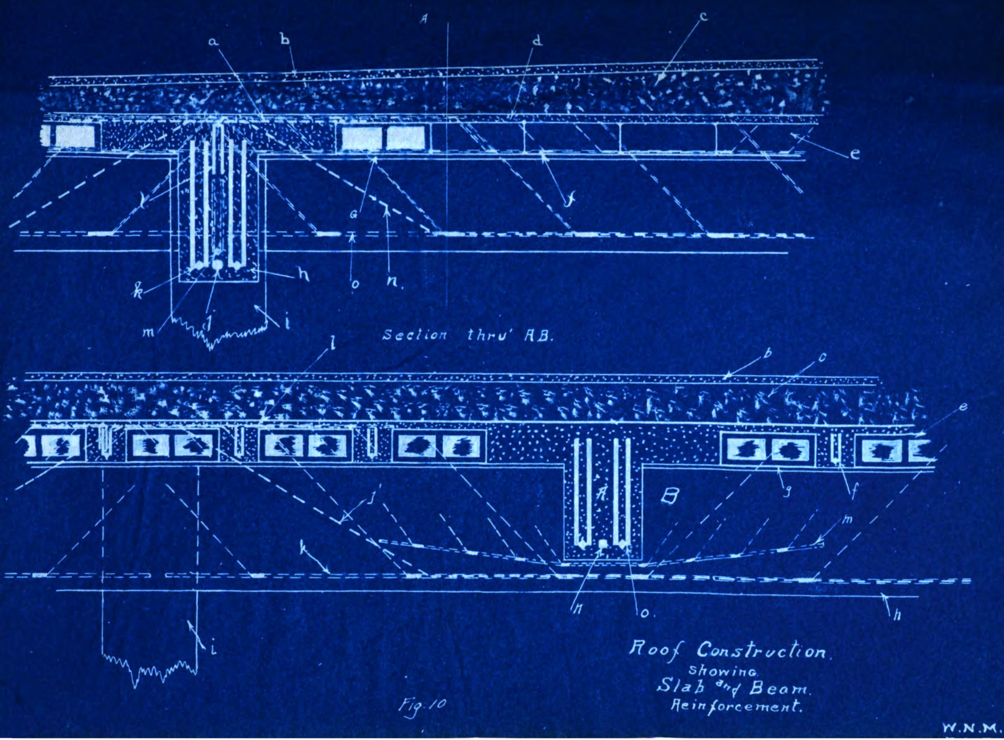


Arch action Kahn Bars.

KAHN TRUSSED BAR



Sections of Kahn
Trussed Bars.



Roof Construction. Showing Slab and Beam Reinforcement.

Fig. 10

Title of Slab	Clear Span in ft.	Depth of Slab	Total Load # per ft.	As for one joist	No joist	As for Slab.	Kahn Bars No	Kahn Bars size	Kahn Bars Area	Kahn Bars Mk	Total As for top reinforcement	Total As for slab.
I	11.75	Tile Corr. 4"+2"	126	.565	40	22.6	20 20	½"+1½" ¾"+2"	1.2	709 729	3.25	27.25
II	11.66	4"+1"	114	.49	42	20.6	42	½"x1½"	.41	702	6.5	23.9
III	9.29	"	114	.354	"	13.8	"	"	"	703	"	"
IV	14.29	4"+2"	126	.75	40	30.	20 20	" ¾"x2"	.79	704 724	"	30.5
V		Same as Slab II										
VI												
VII												
VIII	14'	6"+1"	124	.60	42	25.2	21 21	¾"x2" ½"x1½"	1.2	728 708	3.25	28.45
												~~7.75~~
IX	11.92	4"+1	114	.58	14	8.1		½"x1½"	.41	709	2.00	7.75
X	11.5	"	"	.55	"	7.7		"	"	702	"	"
XI	12.'	4"+2"	126	.52	"	7.3	7 7	" ¾"x2"	1.2	709 729	1.00	9.4
XII		Same as	slab	X								
XIII		"	"	"	XI							

No.	Clear span ft	Size of beam	Total load per ft	As	Kahn Bars no.	Kahn Bars size	Kahn Bars Area	Kahn Bars M.K.	Cup Bars no.	Cup Bars size	Cup Bars length	Cup Bars As □"	Contin. over ends	Area of Top reinf.	Total As.
A	11.66'	10X12	1640	2.42	2	3/4"x2"	1.58	753	1	5/8"	19' 8"	.39 □"	both	.47	2.44
O	12'	10X14	1660	2.17	"	"	"	750	"	"	17' 8"	"	"	.19	2.16
D	11.66'	10X16	2260	2.4	"	"	"	763	"	3/4"	18' 8"	.06	"	.39	2.53
J'	"	"	2580	2.72	"	"	"	"	"	"	19' 8"	"	"	.48	2.62
J	"	"	2280	2.42	"	"	"	"	"	"	17' 8"	"	one	.28	2.42
H	11.5'	10X14	1660	2.0	"	"	"	753	"	1/2"	19' 8"	.25	both	.32	2.15
I	11.92'	"	1660	2.14	"	"	"	750	"	"	20'	"	"	.25	2.08
G	11.75'	10X12	820	1.24	"	1/2"x1 1/2	.82	751	"	5/8"	15' 4"	.39	—	0	1.21
Q	3.66'	Joist	2058	.69	1	3/4"x2"	1.58	759	—	—	—	—	—	0	.79
P'	13.66'	10X16	1935	2.8	2	"	"	766	1	1"	20' 4"	1."	one	.12	2.8
K'	"	12X16	2500	3.62	"	1"x3"	2.82	756	"	7/8"	"	.76 □"	"	"	3.7
U	11.83'	10X14	1690	2.15	"	3/4"x2"	1.58	750	"	1/2"	20'	.25	both	.50	2.33
E	8.33'	10X12	1670	1.27	"	1/2"x1 1/2"	.82	754	"	"	14' 6"	"	"	.25	1.32
W	13.66'	10X14	1480	2.5	"	3/4"x2"	1.58	755	"	7/8"	20' 4"	.76	one	.13	2.47
X	11.83'	10X12	1460	2.23	"	"	"	767	"	1/2"	20' 4"	.25	both	.50	2.33
F	13.66'	"	1330	2.26	"	"	"	755	"	3/4"	"	.56	one	.13	2.27
K	"	12X16	2350	3.42	"	1"x3"	2.82	756	"	"	"	"	"	.12	3.50
L	10.5'	10X14	2300	2.3	"	3/4"x2"	1.58	757	"	1/2"	18'	.25	both	.56	2.39
M	11'	"	2300	2.53	"	"	"	758	"	3/4"	19'	.56	"	.32	2.46
S	12'	10X12	1080	1.69	"	1/2"x1 1/2"	.82	751	"	7/8"	18'	.76	one	.12	1.68
N	11.5'	"	"	1.56	"	"	"	752	"	1/2"	19' 8"	.25	both	.66	1.73
C	11.92'	"	"	1.67	"	"	"	751	"	3/4"	20'	.56	"	.25	1.63
T	13.66'	10X16	1710	2.48	"	3/4"x2"	1.58	766	"	7/8"	20' 4"	.76	one	.12	2.46
Z	12'	8X8			"	1/2"x1 1/2"	.82	762	"	1/2"	15' 3"	.25	—	—	1.07
B	22.25'	12X20	1590	4.8	"	1"x3"	2.82	760	"	1"	27' 8"	1.00	—	—	4.84
					1	1"x3"	1.00	764	"						

Remarks –

Beam Tabulation of Floor Design

Note. – Total area of steel = area of K.B's + area of C.B. + area of Top Bars.

Title of Slab	Clear Span	Depth of Slab	Total Load # per ft.	As for one joist	No joist	As for Slab	Kahn Bars				Total As for top reinforcement	Total As of bars for slab.
							No	Size	Area	MK		
I	10'-10"	4" Tile + 2" Con	122	.505	42	21.21	42	½" x 1½"	.41	803	3.25	21.5
II	11'-9½"	4" + 1"	110	.556	"	23.4	"	"	"	802	6.5	23.7
III	9'-3½"	4" + 1"	110	.346	"	14.5	"	"	"	804	"	"
IV	14'-3½"	4" + 2"	122	.735	40	31.0	20	"	"	805	"	
							20	¾" x 2 3/16"	.79	821		25.2
V	11'-9½"	4" + 1"	Same as II									
VI	"	"										
VII	"	"										
VIII	14'-0"	4" + 2"	122	.705	42	29.6	21	½" x 1½"	.41	808	3.25	
							21	¾" x 2 3/16"	.79	824		28.5
IX	12'-1½"	6" + 1"	120	.44	14	6.16	14	½" x 1½"	.41	811	1.00	6.74
X	11'-8"	4" + 1"	110	.545	"	7.62	"	"	"	802	2.00	7.74
XI	12'-1"	4" + 2"	122	.52	"	7.25	"	"	"	803	2.00	7.74
XII	11'-8"	Same as X										

Title of Beam	Clear Span	Size of Beam	Total Load	M/s A'	Kahn Bars.				Cup Bars.				Continuous on ends	Area of Top Reinforcement	[illegible]
					No	Size	Area	MK	No	Size	length	M/s A			
A	11'-9"	8"x10"	560	1.06	2	1/2"x1 1/2"	.82	819	1	1/2"	19'-10"	.25	both	.25	1.5[illegible]
B	12'-1"	"	"	1.12	"	"	"	806	"	"	20'-4"	"	"	"	"
D	13'-8"	10"x16"	1721	2.5	"	3/4"x2 3/16"	1.58	833	"	7/8"	"	.76	one	.25	2.59
E	11'-10"	8"x14"	945	1.18	"	1/2"x1 1/2"	.82	806	"	1/2"	18'-0"	.25	"	.12	1.19
F	11'-9"	10"x18"	1824	1.72	"	3/4"x2 3/16"	1.58	822	"	"	20'-0"	"	both	.25	2.08
G	12'-1"	8"x10"	560	1.12	"	1/2"x1 1/2"	.82	806	"	"	18'-0"	"	one	.12	1.19
H	12'-1"	10"x16"	2450	2.8	2 1	3/4"x2 3/16"	2.14	832 839	"	3/4"	15'-8"	.56	not	.00	2.70
I	22'-3"	12"x20"	1606	4.8	2 1	1"x3"	3.82	840 841	"	1"	28'-0"	1.00	"	.00	4.82
J	11'-10"	10"x12"	1320	2.02	2	3/4"x2 3/16"	1.58	827	"	5/8"	17'-10"	.39	one	.19	2.16
K	12'-1"	10"x10"	954	1.91	"	"	"	806	"	1/2"	20'-4"	.25	both	.25	2.08
L	13'-7"	10"x16"	1372	2.00	"	"	"	831	"	"	20'-8"	"	one	.12	1.95
M	11'-8"	10"x10"	954	1.77	"	"	"	830	"	"	20'-0"	"	both	.25	2.08
N	13'-7"	10"x16"	1850	2.66	2 1	3/4"x2 5/16"	2.14	831 835	"	3/4"	20'-4"	.56	one	.12	2.82
O	11'-10"	8"x10"	560	1.07	2	1/2"x1 1/2"	.82	806	"	1/2"	18'-0"	.25	"	"	1.19
P	12'-1"	10"x10"	954	1.9	"	3/4"x2 3/16"	1.58	832	"	"	"	"	"	"	1.95
R	11'-9"	10"x14"	1[illegible]90	2.38	"	"	"	822	"	5/8"	20'-0"	.39	both	.39	2.36
S	22'-3"	12"x24"	2739	6.7	2 1	1 3/4"x2 3/4"	5.60	850 851	"	1"	28'-0"	1.00	not	.00	6.60
T	13'-8"	10"x16"	1663	2.4	2	3/4"x2 3/16"	1.58	833	"	3/4"	20'-8"	.56	one	.28	2.92
U	13'-8"	"	2160	3.1	2 1	3/4"x2 3/16"	2.19	833 837	"	7/8"	20'-4"	.76	"	.25	3.15
V	12'-0"	10"x14"	1643	2.19	2	"	1.58	834	"	1/2"	"	.25	both	.40	2.23
W	8'-6"	10"x10"	1600	1.58	"	"	"	817	"	"	19'-9"	"	"	.25	2.08
X	11'-9"	10"x20"	3600	3.1	2 1	3/4"x2 3/16"	2.14	822 826	"	3/4"	19'-10"	.56	"	.20	3.00
Y	11'-2"	10"x12"	1320	1.83	2	"	1.58	836	"	1/2"	19'-0"	.25	"	.25	2.08
Z	10'-8"	10"x10"	1300	2.02	"	"	"	837	"	"	18'-0"	"	"	"	"