INVESTIGATION OF THE ENGINEERING PROBLEMS OF THE M. A. C. GYMNASIUM

E. BOLDUC C. M. GREIFFENDORF

1916

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THESIS

FOR DEGREE B.S.

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The investigation as presented by this thesis comprises largely an analysis of the main roof truss, swimming pool roof truss, running track balcony, balcony over swimming pool and reinforced concrete construction of swimming pool and first floor.

The engineering problems involved in an investigation of this nature are practical problems and invaluable to a student of structural engineering.

This thesis has been chosen for the purpose of obtaining a true insight of the structural engineering and architectural fields.

The success of the investigation has been due to the technical instruction received of Prof. C. A. Melick and to assistance furnished by Mr. Nichols.

Division Of Drawings.

No.1. Main roof truss showing all details of angles, gusset plates, bearing plates, rivets and purlin supports.

No.2. Portion of main roof and truss showing position of rafters, roof boards and copper on purlins, construction of copper gutter, method used in supporting purlins to truss and position of hangers for running track balcony.

No.3. Section of running track balcony indicating position of hanger, construction of beam, rail and hanger.

No.4. Stress diagrams for dead and live loads on main roof truss. All stresses are tabulated.

No.5. Eccentricity of rivet joint TA1-5-6 (See marking diagram pge. 6 and drawing No.1.)

No.6. Swimming pool roof truss showing all details of angles, gusset plates, bearing plates, rivets and purlin supports. A section of gallery is shown with method of construction. Note the Hy-rib floor and ceiling.

No.7. Stress diagrams for dead and live loads on swimming pool roof truss. All stresses are tabulated.

No.8. Details of all lintels in gymnasium.

No.9. Details of all purlins and details of beams in running track gallery.

No.10. Details of all beams in swimming pool gallery.

No.11. Details of beams in running track gallery.

No.12. Plan of basement showing construction and size of swimming pool and position of lintels.

No.13. Plan of first floor showing position of lintels.

No.14. Plan of second floor showing position of lintels and beams over middle section gymnasuim.

No.15. Plan of upper part second floor.

No.16. Marking diagram of bearing plates, purlins, beams and trusses.

No.17. Plan and marking diagram of footings and columns showing a typical footing. All steel for footings and columns is tabulated.

No.18. Side elevation of swimming pool and method used in determination of column loads.

No.19. Plan, side elevation and end elevation of swimming pool showing all steel in place. All steel is tabulated. All beams are defined.

No.20. Slabs, beams and girders in detail. Showing size and position of steel.

No.21. Slab of first floor showing size and position of steel.

No.22. Marking diagram of bearing plates and beams of running track balcony, swimming pool balcony and middle section gymnasium.

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CONCLUSIONS.

Truss of section Z-Z supports less load in proportion to size of members than truss of section X-X (See drawings Nos. 1, 16 & 2). Members of truss section Z-Z are safe with no exception as noted page 15, consequently it is safe to conclude that all trusses in the gymnasium are adequate.

Beams and hanger of running track are safe compared to section of balcony analyzed (See drawings Nos. 3, 22 & 11).

Trusses for swimming pool roof are all similar. Analysis shows these to be adequate with no exception noted page 20.

Beams of swimming pool balcony are all safe compared to section analyzed (See drawings Nos. 6, 10 & 22).

Purlins for main roof are all safe compared to analysis of purlin P1 (See drawings Nos. 9 & 16).

Purlins for swimming pool roof are adequate compared to analysis of purlin P3 (See drawings Nos. 9 & 16)

Concrete Hy-rib in swimming pool gallery floor is safe.

Footings of swimming pool are not adequate if a load of one ton per. sq.ft. is considered the safe allowable unit load.

Steel in footings of swimming pool is not adequate.

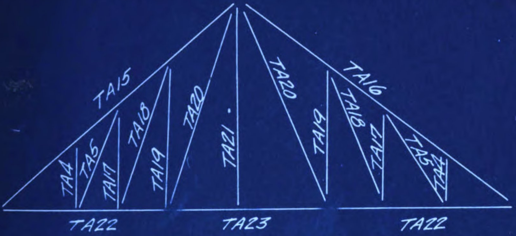
Steel in columns is adequate for load.

Steel in slabs of swimming pool is not adequate.

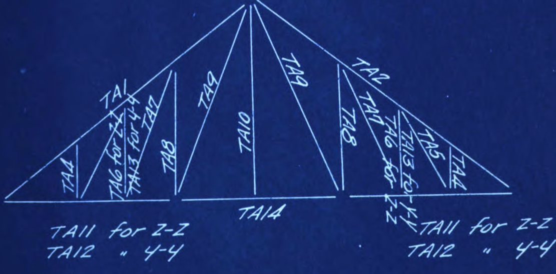
Steel in girders and beams of swimming pool is slightly deficient.

Steel in floor slab of first floor is adequate.

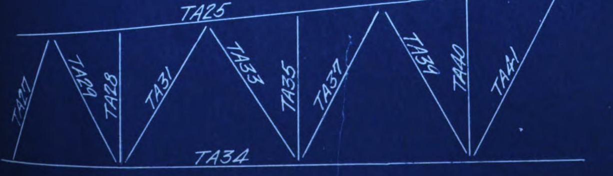
Marking Diagram
Main Truss



Sec X-X



Swimming Pool Truss Marking Diagram



WEIGHT TRUSS

See sec. z-z marking diagram

ANGLES

TA11 - 2-Ls 5" x $3\frac{1}{2}$" x $\frac{3}{8}$" x 27'-$6\frac{3}{4}$"

2-Ls 5" x $3\frac{1}{2}$" x $\frac{3}{8}$" = 20.8#/foot gross

2-Lengths 55'-3" @ 20.8# = 1150#

TA14 - 2-Ls 5" x $3\frac{1}{2}$" x $\frac{3}{8}$" x 15'-$7\frac{1}{2}$"

2-Ls 5" x $3\frac{1}{2}$" x $\frac{3}{8}$" = 20.8#/ft. gross

15'-$7\frac{1}{2}$" @ 20.8# = 325#

TA1 - 2-Ls 6" x 4" x $\frac{7}{16}$" x 41'-$5\frac{1}{4}$"

2-Ls 6" x 4" x $\frac{7}{16}$" = 28.6#/ft. gross

41'-$5\frac{1}{4}$" @ 28.6# = 2368#

TA4 - 2-Ls $2\frac{1}{2}$" x 2" x $\frac{1}{4}$" x 6'-5"

2-Ls $2\frac{1}{2}$" x 2" x $\frac{1}{4}$" = 7.24#/ft. gross

6'-5" @ 7.24# = 93#

TA6 - 2-Ls $3\frac{1}{2}$" x 3" x $\frac{5}{16}$" x 11'-9"

2-Ls $3\frac{1}{2}$" x 3" x $\frac{5}{16}$" = 13.2#/ft. gross

11'-9" @ 13.2# = 310#

TA8 - 2-Ls 5" x $3\frac{1}{2}$" x $\frac{5}{16}$" x 17'-$0\frac{1}{4}$"

2-Ls 5" x $3\frac{1}{2}$" x $\frac{5}{16}$" = 17.4#/ft. gross

17'-$0\frac{1}{4}$" @ 17.4# = 592#

TA10 - 2-Ls $2\frac{1}{2}$" x 2" x $\frac{5}{16}$" x 22'-$0\frac{1}{4}$"

2-Ls $2\frac{1}{2}$" x 2" x $\frac{5}{16}$" = 9#/ft. gross

22'-$0\frac{1}{4}$" @ 9# 198#

TA5 - 2-Ls $2\frac{1}{2}$" x 2" x $\frac{1}{4}$" x 13'-$4\frac{1}{2}$"

2-Ls $2\frac{1}{2}$" x 2" x $\frac{1}{4}$" = 7.24#/ft. gross

13'-$4\frac{1}{2}$" @ 7.24# = 193.4#

TA7 - 2-Ls $2\frac{1}{2}$" x 2" x $\frac{5}{16}$" x 17'-11"

2-Ls $2\frac{1}{2}$" x 2" x $\frac{5}{16}$" = 9#/ft. gross

17'-11" @ 9# = 322.6#

TA9 - 2-Ls $2\frac{1}{2}$" x 2" x $\frac{5}{16}$" x 22'-10"

2-Ls $2\frac{1}{2}$" x 2" x $\frac{5}{16}$" = 9#/ft. gross

22'-10" @ 9# = 411.6#

Total weight angles 5967#

Gusset Plates

No.	Plate	Dimension	Area □"	Area □'	Wt. #/□'	Wt. #
2	TA11-1	23" x 3/8" x 4'-1 1/2"	755.7	5.24	15.3	160
2	TA11-4-5	21" x 3/8" x 2'-0"	417.7	2.90	15.3	89
2	TA11-6-7	18" x 3/8" x 1'-9"	304.0	2.1	15.3	64
2	TA11-8-9-14	27" x 3/8" x 2'-0 1/2"	451.0	3.1	15.3	96
1	TA11-10	12" x 3/8" x 1'-3"	132.0	.92	15.3	14
2	TA1-4	6" x 3/8" x 1'-1 1/2"	57.3	.39	153	12
2	TA1-5-6	18" x 3/8" x 2'-5"	416.7	2.9	15.3	88.4
2	TA1-7-8	20" x 3/8" x 2'-2 1/2"	409.5	2.8	15.3	87
1	TA1-9-10-9-2	25" x 3/8" x 3'-5"	656.0	4.5	15.3	69
			Total Weight =			681 #

Note :- See drawing No.1.

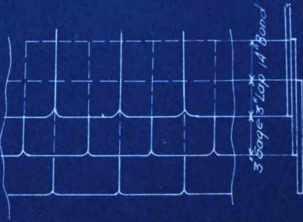
7/8" φ Heads of Rivets = 24 # per. 100

Number rivets main truss = 248

248 @ 24 # per. 100 = 59.5 #

Total Weight	Angles =	5963 #
" "	Gusset Plates =	681 #
" "	Rivets =	70 #
" "	Truss =	6714 #

Roof Loading



Slate Roofing

Size 10" x 20" x 1/4"

Lap = 3 in. exposed. 3 in. laid on felt. Number slates per. 100 □' = 169 (See sketch)

Wt. per. slate = $\frac{20" \times \frac{1}{4}" \times 10"}{1728} \times 174$ = 5.05 #

Wt. slate per. 100 sq ft. = 5.05 x 169 = 852 #

Area slate roof = 31.25 x 163.83 x 2 = 10240 Sq ft.

Weight roof slate = 102.40 x 852 = 87274 #

31980#

45875#

3880#

2330#

3500#

SECTION C … = 25#/sq ft.

14500#

3.625 K.

…ction)

…13)

…7.8 sq ft.

RAFTERS

Size $1\frac{5}{8}$"x6" 16" c. to c. (See drawing No.2.)
Number rafters = $163.83 \div \frac{16}{12} = 123$
Length " = 2 x 40 = 80 feet (approx.)
Weight per. lin. foot = 3.25#
Total weight = 80 x 123 x 3.25 = 31980#

SHEATHING

Size $\frac{7}{8}$"x6" (See drawing No.2.)
Weight per. sq.ft. = $\frac{7}{8} \times 4 = 3.5$#
Area = 2 x 163.83 x 40 = 13106 sq.ft.
Total weight = 3.5 x 13106 = 45875#

RAFTERS (FOR COPPER COVER)

Size $4\frac{1}{2}$' x $1\frac{5}{8}$"x6" 16" c. to c. (See drawing No. 2.)
Weight per. lin. foot = 3.25#
Number rafters = 123 x 2 = 246
Total weight = $246 \times 4\frac{1}{2} \times 3.5$ = 3880#

FELT ROOFING

Weight per. 100 sqft. = 17#
Area roofing = 13107 sqft.
Total weight = 17 x 13107 = 2330#

COPPER ROOFING

Size 20"x28"-16 oz. (See drawing No. 2.)
Area = 8 x 163.8 x 2 = 2624 sqft.
Total weight = $2624 \times \frac{16}{12}$ = 3500#

WIND LOAD

Max. wind pressure = 30#/sqft. (Horizontal)
Roof pitch = 1:3 (See page 13)
Normal wind pressure by Duchemin formula = 25#/sqft.
Wind surface per. half truss = 40 x 14.5 x 25 = 14500#
Wind load per. panel point = 14500 ÷ 4 = 3625# 3.625 K.

SNOW LOAD

Max. snow load = 20#/sqft. (Horizontal projection)
Area snow. horizontal projection (See page 13)
= $2 \times \cos\frac{8}{12} \times 40 \times 163.83 = 2 \times 33.29 \times 163.83 = 10907.8$ sqft.

Total snow load = 10907 x 20 = 218156#
Weight of snow per. sqft. = 218156 ÷ 13106 = 16.6#

CONCENTRATED PANEL POINT LOAD

ANGLES

1-L 6" x 4" x $\frac{3}{8}$" x 0'-6$\frac{1}{4}$" (See drawings Nos. 2, 1 & 9)

1-L 6" x 4" x $\frac{3}{8}$" = 12.3#/ft.

.521' @ 12.3 = 6.4#

PLATES

1-Pl. 6$\frac{1}{2}$" x 1" x 0'-6$\frac{1}{4}$"

Area plate = 40.62 sqin. = .282 sqft.

Weight 1" plate = 40.8#/sqft.

.282 sqft. @ 40.8# = 11.5#

1-Pl. 6$\frac{1}{4}$" x 2" x 1"

Area plate = 12.5 sqin. = .0868 sqft.

.0868 sqft. @ 40.8# = 3.5#

BOLTS & NUTS

Bolts (Hexagon heads) $\frac{3}{4}$"ϕ x 4" = 88#/100

2 Bolts @ 88#/100 = 1.76#

PURLIN P1

1-8" I @ 18# (See drawings Nos. 1, 2, 9 & 16)

14.5' @ 18# = 261#

RIVET HEADS

Weight rivet heads = 16#/100

4 @ 16#/100 = .64#

PURLIN CASING

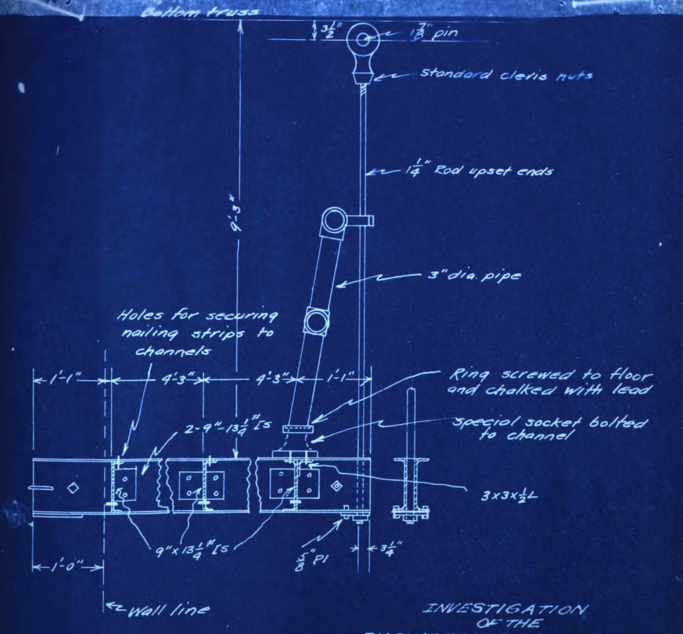
2-10" x 1" x 14.5'-0"

Area = $\frac{10}{12}$ x 14.5 x 2 = 24.16 sqft.

1" L.L.Y.P. = 4#/sqft.

24.16 sqft. @ 4# = 96.9#

HANGER



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DRAWING NO. 3.
THESIS
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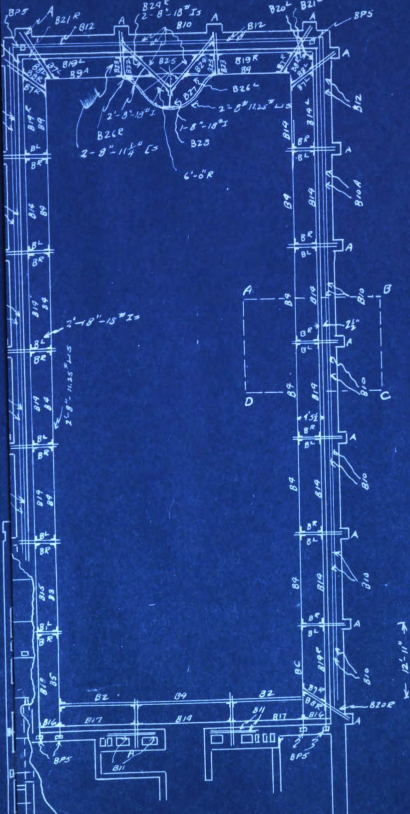
JUNE 1, 1916 EAST LANSING MICH



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RUNNING TRACK BALCONY

BEAMS (See drawings Nos. 3, 2, 11 & 22)

B42 - 1 [9 @ $13\frac{1}{4}$# x 14'-$1\frac{1}{2}$"

14'-$1\frac{1}{2}$" @ $13\frac{1}{4}$# = 187#

B43 - 2 [s 9" @ $13\frac{1}{4}$# x 14'-$1\frac{1}{2}$"

28'-3" @ $13\frac{1}{4}$# = 374#

B36 - 2 [s 9" @ $13\frac{1}{4}$# x 9'-10"

19'-8" @ $13\frac{1}{4}$# = 261#

ANGLE CONNECTIONS

10 Ls 6" x 6" x $\frac{5}{8}$" x 0'-6"

10 Ls 6" x 6" x $\frac{5}{8}$" = 242#/ft.

.5 @ 242# = 121#

CLEVIS

Weight = 8#

ROD

Weight = 4.173#/ft.

10.75 @ 4.173# = 44.82#

PLATE

Size 5" x 6" x $\frac{5}{8}$"

Area = $\frac{30}{144}$ = .242 sq ft.

Weight $\frac{5}{8}$" plate = 25.5#/sq ft.

.242 @ 25.5# = 6.17#

NUT

1 Nut $1\frac{5}{8}$" φ = 1.89#

PIPE

Weight 3" pipe = 7.575#/ft.

" 2" " = 3.652#/ft.

1'-6" of 3" pipe @ 7.57# = 11.36#

1'-2" " " " " " = 8.83#

7'-1" " " " " " = 53.6#

7'-1" " 2" " " 3.65# = 26.7#

COUPLINGS

Weight 2 couplings — 60.0#

BRACKETS

Weight 2 brackets — 60.0#

SOCKET

Weight 1 special socket — 3.0#

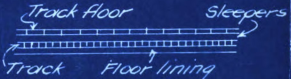
TRACK FLOOR

Floor lining 14'-6" x 9'-10"

Area = 14.5 x 9.83 = 142.6 sqft.

Material $1\frac{5}{8}$" x $3\frac{1}{2}$" #1 L.L.Y.P.

Weight $1\frac{5}{8}$" L.L.Y.P. = 6.5#/sqft.



142.6 sqft. @ 6.5# = — 926.8#

Track 1" L.L.Y.P.

Weight 1" L.L.Y.P. = 4#/sq.ft.

142.6 sqft. @ 4# = — 570.4#

Sleepers 2" Spruce 16" c. to c.

Size 2" x 4" x 9'-10"

Weight 2" spruce = 3#/sqft.

Number sleepers required = 14.5 ÷ $\frac{4}{3}$ = 9

Area lumber = $\frac{4}{12}$ x 9.83 x 9 = 29.2 sqft.

29.2 sqft. @ 3# = — 87.5#

Upper surface track: Material $\frac{7}{8}$" maple.

Weight $\frac{7}{8}$" maple = 3.75#/sqft. Area lumber = 36.2 sqft.

36.2 sqft @ 3.75# = — 135.7#

Nailing strips 3" x 9" L.L.Y.P. Weight 3" L.L.Y.P. = 12#/sqft.

2 strips 14.5' = 21.75 sqft. 21.75 sqft. @ 12# = — 261.2#

Bolts 20-$\frac{9}{16}$"φ. Weight = 50#/100 20 @ 50#/100 = — 10.0#

CEILING

Material = $\frac{7}{8}$" x $2\frac{1}{2}$" L.L.Y.P. Weight $\frac{7}{8}$" L.L.Y.P. = 3.5#/sqft.

Area = 142.6 sqft. 142.6 sqft. @ 3.5# = — 498.5#

LIVE LOAD

Area floor per panel concentrated at TA22-4-5

(See marking diagram pge.6) = $\frac{142.6}{2}$ sqft.

Specified live load = 100#/sqft.

Total live load $\frac{142.6}{2}$ sqft. @ 100# = — 7130#

WIND & SNOW LOAD

Max. snow load = 20#/sqft. Horizontal projection.
Min. snow = 10#/sqft. Horizontal projection.
Max. wind = 25#/sqft. Normal.
Min. snow = $\frac{4.821}{6.024} \times 6$ = 4.8 kips Max wind = 2.18 kips
Total snow & wind = 6.98 kips
Max. snow load = 6.0 kips.
Use Max. snow load & Min. wind load.

CONCENTRATED LOAD AT JOINT TA11-4-5 UNIFORM LOAD RUNNING TRACK

PART	SIZE	WEIGHT	PART	
Clevis	—	8#	B42	187#
Rod	—	4.1#	B43	374#
Plate	5"x6"x $\frac{5}{8}$"	6.1#	B36	261#
Nut	1 $\frac{5}{8}$" ϕ	1.9#	Angle Connections	121#
Pipe	3"	11.4#	Track	570.4#
"	3"	8.8#	Floor lining	926#
"	3"	53.6#	Sleepers	87.5#
"	2"	26.7#	Upper surface Track	135.7#
Couplings(2)	—	6.0#		
Socket	Special	3.0#	Nailing Strips	261.2#
Brackets(2)	—	6.0#	Bolts	10.0#
	Total weight =	129.7#	Ceiling	498.5#
		129.7# +	Total weight =	3432.3#

Weight concentrated at joint TA11-4-5 = $\frac{3432.3}{2}$ = 1716.1#

CONCENTRATED LIVE LOAD JOINT TA11-4-5

TRACK FLOOR LIVE LOAD

Area floor = 142.6 sqft. (See page 12)
Specified live load = 100#/sqft.
Total live load at TA11-4-5 = $\frac{100 \times 142.5}{2}$ = 7130#

TOTAL CONCENTRATED LOAD AT JOINT TA11-4-5

PART	WEIGHT	WEIGHT PER TRUSS
Concentrated load	129.7#	260#
Uniform load running track	1716.1#	2832#
Concentrated live load	7130#	14260#
Total weight =	8976#	17352#

ROOF LOADING MAIN TRUSS

PART	PORTION	WEIGHT	WEIGHT PER TRUSS
Slate	Entire roof	87274#	9983#
Rafters	"	31980#	3619#
Sheathing	"	45875#	5104#
Rafter for copper cover	"	3880#	440#
Coppe roofing	"	3500#	394#
Felt "	"	2330#	266#
Snow (Max.)	"	218156#	19256#
Steel	— " —	——	6714#
	Total weight = 45776#		

Load per. panel = $\frac{45776}{8}$ = 5718#

CONCENTRATED ROOF PANEL POINT LOAD

MEMBER	SIZE	WEIGHT
Angles	6"x4"x$\frac{3}{8}$"x0'-6$\frac{1}{4}$"	6.4#
Plate	1"	11.5#
"	1"	3.5#
Bolts	$\frac{3}{4}$"ϕ	1.76#
Purlin	8"I@18#	261#
Rivet heads		.64#
Purlin casing	10"x1"x14'-6"	28.3#
Total weight = 306#		

TOTAL LOAD PER. TRUSS

PART	WEIGHT
Steel	6714#
Balcony	17352#
Purlins	3060#
Roof	41962#
Total weight	69088#

Reactions = $R_1 = R_2$
= $\frac{69088}{2}$ = 34544#

10 Purlins @ 306# = 3060#

TOTAL LOAD PER. PANEL

Load per. panel = 5718#
Purlin panel load = <u>306#</u>
Total load per. panel = 6025# = 6.025 kips.

BEARING PLATES

$R_1 = R_2$ = 34544 (See drawing No.1.)
Required size = $\frac{1}{2}$ in. Actual size = $\frac{3}{4}$ in.
Pressure on bearing plate = 34544# Area plate = 16"x16"
= 256 sqin. Pressure per. sqin. = $\frac{34544}{256}$ = 135#
All' [illegible] sqin. = 250#

MAIN TRUSS

MEMBER	LENGTH FEET	MAX. STRESS	MAKE UP	GROSS AREA	NET AREA	R	$\frac{L}{R}$	ALL'D. UNIT SPEC.	ALL'D VALUE SEC.
Ba	9.859	-66.99 K.	2Ls 6"×4"×$\frac{7}{16}$"	8.36	7.16	{1.92 / 1.63	72.5	10.92 K.	78.22 K.
Cb	7.474	-67.12	"	"	"	"	55.0	12.15	86.99
Dd	7.474	-49.61	"	"	"	"	"	"	"
Ef	7.474	-39.88	"	"	"	"	"	"	"
Ma	5.906	+55.69	2Ls 5"×3$\frac{1}{2}$"×$\frac{3}{8}$"	6.10	5.44	{1.60 / 1.46	48.5	16.0	97.6
Lc	6.531	+40.97	"	"	"	"	53.7	12.24	66.59
Le	6.531	+32.67	"	"	"	"	"	"	"
Lg	6.531	+27.38	"	"	"	"	"	"	"
ab	5.218	-6.43	2Ls 2$\frac{1}{2}$"×2"×$\frac{1}{4}$"	2.12	1.68	{.78 / .93	80.1	10.39	17.46
cd	9.802	-18.67	2Ls 3$\frac{1}{2}$"×3"×$\frac{5}{16}$"	3.86	3.32	{1.10 / 1.35	106.8	8.52	28.29
ef	15.073	-19.50	2Ls 5"×3$\frac{1}{2}$"×$\frac{5}{16}$"	5.12	4.58	{1.61 / 1.46	123.8	7.33	33.58
gg'	20.114	0.0	2Ls 2$\frac{1}{2}$"×2"×$\frac{5}{16}$"	2.62	2.08	{.78 / .95	—	—	—
bc	11.427	+26.52	2Ls 2$\frac{1}{2}$"×2"×$\frac{5}{16}$"	2.12	1.68	{.78 / .93	176	16.0	26.88
de	15.968	+20.43	2Ls 2$\frac{1}{2}$"×2"×$\frac{5}{16}$"	2.62	2.08	{.78 / .95	245.5	"	33.28
fg	20.468	+20.35	2Ls 2$\frac{1}{2}$"×2"×$\frac{5}{16}$"	2.62	2.08	{.78 / .95	308.7	"	33.28

MEMBER	NO. RIVETS	ALL'D. VALUE PER	TOTAL		ALL'D. VALUE ...ETS ...NG	TOTAL VALUE JOINT
					...0	102500
						—
						—
						—
						—
						—
						—
						—
					...0	90000
					...0	28150
						"
						22520
					...0	9000
					...0	28150
						33780

...IVETS JOINT TA1-5-6

...2.125

...17 = 63.75 kip.in. = $4a(d_1^2+d_2^2+d_3^2+d_4^2+d_5^2+d_6^2+d_7^2+d_8^2)$

...ivet 5.

...M kips	S kips	R kips
.41	2.125	1.95
.25	"	2.0
.135	"	2.05
.0356	"	2.08
.104	"	2.10
.22	"	2.325
.27	"	2.30
.32	"	2.40
	17.0 kips	

...shear on rivet 5

...nt.

... load P.

...L ...E ...T	MAX. STRESS KIPS
...0	18.33
	7.63
...0	32.67
	27.38
...0	6.43
...0	14.75
...0	8.5
...0	39.8
	—

INVESTIGATION
OF THE
ENGINEERING PROBLEMS
OF THE
M.A.C. GYMNASIUM
DRAWING NO.5.
THESIS
FOR
DEGREE B.S.

E. BOLDUC C.M. GREIFFENDORF
JUNE 1, 1916 EAST LANSING, MICH.

MAIN TRUSS

MEMBER	NO. RIVETS	ALL'D. VALUE PER RIVET DOUBLE SHEAR	TOTAL VALUE JOINT		ALL'D. VALUE RIVETS BEARING	TOTAL VALUE JOINT
Ba	13	10600#/□	137800	No ---- Eccentricity	7880	102500
Cb	—	—	—		—	—
Dd	—	—	—		—	—
Ef	—	—	—		—	—
Ma	—	—	—		—	—
Lc	—	—	—		—	—
Le	—	—	—		—	—
Lg	—	—	—		—	—
ab	2	10600#/□	21200		4500	90000
cd	5	"	53000		5630	28150
ef	5	"	"		"	"
gg'	4	"	42400		"	22520
bc	5	"	53000		4500	9000
de	5	"	"		5630	28150
fg	6	"	63600		"	33780

JOINT	NO. RIVETS	ALL'D. VALUE PER RIVET DOUBLE SHEAR	TOTAL VALUE JOINT	ECCENTRICITY	ALL'D. VALUE RIVET BEARING	TOTAL VALUE JOINT	MAX. STRESS KIPS
TAII-4-5	7	10600#/□	74250	Not considered	6750	47250	18.33
TAII-6-7	7	"	"	"	"	"	7.63
Le	4	"	42400	None	"	27000	32.67
Lg	4	"	"	"	"	"	27.38
TAI-4	2	"	21200	Not considered	7880	15760	6.43
TAI-5-6	8	"	84800	see drwg. No.5	"	63040	14.75
TAI-7-8	11	"	166600	"	"	86680	8.5
TAI-2-9-10	12	"	127200	"	"	94560	39.8
TAII-8-9	8	"	—	None	—	—	—

WEIGHT TRUSS (SWIMMING POOL)

ANGLES (See drawing No. 6.)

TA34 - 2Ls 6"x4"x $\frac{5}{8}$" x 52'-0"
2Ls 6"x4"x $\frac{5}{8}$" = 40#/ft.
52'-10" @ 40# = 2113.2#

TA25 - 2Ls 6"x4"x $\frac{11}{16}$" x 26'-4$\frac{1}{2}$"
2Ls 6"x4"x $\frac{11}{16}$" = 43.6#/ft.
52'-9" @ 43.6# = 2300#

TA27 - 2Ls 6"x4"x $\frac{11}{16}$" x 2'-2"
2Ls 6"x4"x $\frac{11}{16}$" = 43.6#/ft.
4'-4" @ 43.6# = 189#

TA29 - 2Ls 5"x3$\frac{1}{2}$"x $\frac{5}{16}$" x 3'-4$\frac{1}{4}$"
2Ls 5 x 3$\frac{1}{2}$" x $\frac{5}{16}$" = 17.4#/ft.
6'-8$\frac{1}{2}$" @ 17.4# = 117#

TA28 - 2Ls 2$\frac{1}{2}$"x2x$\frac{1}{4}$" x 2'-4"
2Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" = 7.24#/ft.
4'-8" @ 7.24# = 34.7#

TA31 - 2Ls 3$\frac{1}{2}$"x2$\frac{1}{2}$"x$\frac{1}{4}$" x 3'-8"
2Ls 3$\frac{1}{2}$"x2$\frac{1}{2}$"x$\frac{1}{4}$" = 9.8#/ft.
7'-4" @ 9.8# = 71.8#

TA33 - 2Ls 2$\frac{1}{2}$"x2"x$\frac{5}{16}$" x 3'-10$\frac{1}{4}$"
2Ls 2$\frac{1}{2}$"x2"x$\frac{5}{16}$" = 9.0#/ft.
7'-8$\frac{1}{2}$" @ 9# = 69.4#

TA35 - 2Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" x 2'-10"
2Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" = 7.29#/ft.
5'-8" @ 7.24# = 41.1#

TA37 - 2Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" x 4'-2$\frac{1}{2}$"
2Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" = 7.24#/ft.
8'-6" @ 7.24# = 60.9#

TA39 - 2Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" x 4'-3$\frac{1}{2}$"
2Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" = 7.24#/ft.
8'-7" @ 7.24# = 62.1#

TA40 - 2Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" x 3'-4"
2-Ls 2$\frac{1}{2}$"x2"x$\frac{1}{4}$" = 7.24#/ft.
6'-8" @ 7.24# = 48.2#

TA41 - 2Ls $2\frac{1}{2}" \times 2" \times \frac{1}{4}" \times 4'-8\frac{1}{2}"$

2Ls $2\frac{1}{2}" \times 2" \times \frac{1}{4}"$ = 7.24#/ft.

9'-5" @ 7.24# = 68.2#

Total weight angles 5175#

Gusset Plates

Plate	No.	Dimension	Area ☐	Wt. #/☐	Wt. #
Left end	2	$40" \times \frac{3}{8}" \times 8'-2"$	25.6	15.3	784
TA33-34-37	2	$15" \times \frac{3}{8}" \times 2'-4\frac{1}{2}"$	2.84	"	87
TA25-31-33	2	$18" \times \frac{3}{8}" \times 3'-1\frac{1}{2}"$	4.12	"	126
TA25-37-39	2	$12" \times \frac{3}{8}" \times 1'-10\frac{1}{2}"$	1.88	"	57
TA34-39-41	2	$13\frac{1}{2}" \times \frac{3}{8}" \times 1'-10\frac{1}{2}"$	2.11	"	64
Center top.	1	$16" \times \frac{3}{8}" \times 11'-0"$	7.34	"	224
Note: See drawing No. 6.			Total weight = 1343#		

Roof Loading

Roof

Size 48'-8" x 145'-8". Area = 145.66 x 48.66 = 7087.8 sqft.

Gutter roof area = 2 x 1'-8" x 145.66 = 485.04 sqft.

Total area roof = 485.04 + 7087.81 = 7572.85 sqft.

Concrete

Material Hy-rib (7-Rib) $2\frac{1}{2}"$ slabs #26 gauge.

Weight = 30#/sqft.

Total area Hy-rib concrete construction = 7572.8 sqft.

7572.8 sqft. @ 30# = 227185.5#

Flat surface roof supported by truss C-7

= $16'-11\frac{3}{4}"$ x 50.285 = 853.25 sqft.

Concrete Hy-rib area = $16'-11\frac{3}{4}"$ x 50.5 = 857.5 sqft.

857.5 sqft. @ 30# = 25725#

Panel load (Truss C-7) Concrete Hy-rib

= 25725 ÷ 13 = 1978#

Barretts Roofing

Composition :- Pitch, 3 plies felt, Pitch, 2 plies felt, Pitch and gravel.

Pitch

Weight = 120#/100 sqft. Total wt. per panel = $\frac{120 \times 8.53}{13}$ = 78#

GRAVEL

Weight = 400#/100 sq.ft.

Total weight per panel = (400 x 8.53) ÷ 13 = 262#

FELT

Weight = 17#/100 sq.ft. (single thickness)

$= \frac{91}{57} \times 17 = 27.1$ #/100 sq.ft. (lap)

Total weight per panel (Truss C-7)

= (8.5325 x 27.1 x 5) ÷ 13 = 89.1#

PURLINS (See drawings Nos. 6, 16 & 9)

P4 - (8"@18#I x 17'11½")(13)

17'-11½" @ 18# = 323.2# 8'-11¾" @ 18# = 161.6#

P6 - (8"@18#I x 14'-2½")(13)

14'-2½" @ 18# = 256# 7'-1¾" @ 18# = 128#

P5 - (8"@18#I x 17'-9½")(13)

17'-9½" @ 18# = 320# 8'-9¾" @ 18# = 160#

P3 - (8"@18#I x 16'-0")

16'-0" @ 18# = 288# 8'-0" @ 18# = 144#

Total weight purlins per panel = 272# (Truss C-7)

SNOW

Weight = 19.5#/sq.ft.

Area (Truss C-7) = 853.25 sq.ft. 853.25 sq.ft. @ 19.5

= 16637.37# Weight per panel = $\frac{16637.37}{13}$ = 1280#

ROOF LOADING

PART	WEIGHT PER UPPER PANEL
Concrete	1978#
Pitch	78#
Gravel	262#
Felt	89#
Purlins	272#
Snow	1280#

Total wt. per upper panel

= 3959# (Truss C-7) No wind load

SUSPENDED CEILING

Area per panel = $\frac{853.25}{7}$

= 121.89 sq.ft.

Material 7-Rib #28-2½" slabs

Weight = 30#/sq.ft.

121.89 sq.ft. @ 30 = 3656.7#

Total weight per lower panel = 3656.7# (Truss C-7)

BEARING PLATES

PLATE (See drawing No. 6.

Required size = $\frac{1}{2}$ in. Actual size = 1 in.

Pressure per. plate = $\frac{76064}{2}$ = 38032 #

Area plate = 12" × 24" = 288 sq in. Pressure per. sq in.

= $\frac{38032}{288}$ = 132 #/□ All'd. press. per. sq in. = 250 #/□

SWIMMING POOL TRUSS

MEMBER	LENGTH INCH.	MAX. STRESS	MAKE UP	GROSS AREA	NET AREA	R	L/R	ALL'D. UNIT SPEC.	ALL'D. VALUE SEC.
Bb	48.0	-67.4	2-Ls 6" × 4" × 11/16"	12.8	10.4	{+.89 1.69	25.4	14.2	147.9
Cc	15.01	-67.4	"	"	"	{+.89 1.69	8.95	15.37	159.8
De	20.05	-111.5	"	"	"	"	11.9	15.16	157.7
Ef	24.03	-111.5	"	"	"	"	14.3	14.99	155.9
Fh	22	-121.5	"	"	"	"	13.1	15.08	156.8
Gi	48.0	-121.5	"	"	"	{1.89 +.69	25.4	14.22	147.9
ji	38.05	-9.0	2-L 2½" × 2" × ¼"	2.12	1.68	{.78 .93	48.7	12.59	21.15
hi	26.12	-3.6	"	"	"	"	33.5	13.65	22.94
hg	43.12	+3.4	"	"	"	"	55.2	16.00	26.88
gf	41.12	-10.2	"	"	"	"	52.7	12.31	20.68
ef	20.12	-3.7	"	"	"	"	25.7	14.20	23.85
ed	46.07	+22.9	2-Ls 2½" × 2" × ¼"	2.62	2.08	{.78 .95	59.0	16.00	33.28
dc	10.05	-33.2	2-Ls 3½" × 2½" × ¼"	2.88	2.44	{+.12 1.09	9.22	15.35	37.46
cb	28.0	-3.8	2-Ls 2½" × 2" × ¼"	2.12	1.68	{.78 .93	30.0	13.90	23.35
ba	40.25	+50.5	2-Ls 5" × 3½" × 5/16"	5.12	4.02	{1.61 +.96	26.4	16.00	64.32
jR	74.12	+116.4	2-Ls 6" × 4" × 5/8"	11.72	9.54	{+.9 1.67	44.4	"	152.64
gs	74.12	+119.0	"	"	"	"	"	"	"
dT	60.12	+93.4	"	"	"	"	36.0	"	"
aU	71	+25.2	"	"	"	{1.9 +.69	32.4	"	"
Aa	26	-43.6	2-Ls 6" × 4" × 11/16"	12.8	10.04	{1.89 +.69	13.7	15.04	150.41

SWIMMING POOL TRUSS

MEMBER	NO. RIVETS	ALL'D VALUE PER RIVET DOUBLE SHEAR	ALL'D VALUE OF JOINTS	ECCENTRICITY	ALL'D VALUE RIVET BEARING	TOTAL VALUE JOINTS
Bb	—	—	—	—	—	—
Cc		10600	222600	None	12380	259980
De	—	—	—	—	—	—
Ef	—	—	—	—	—	—
Fh	27	10600	752600	None	12380	878980
Gi	—	—	—	—	—	—
Ji	3	10600	31800	None	4500	13500
hi	3	"	"	"	"	"
hg	3	"	"	"	"	"
gb	3	"	"	"	"	"
ef	3	"	"	"	"	"
ed	5	"	53000	"	5630	28150
dc	7	"	74200	"	4500	31500
cb	7	"	"	"	"	"
ba	10	"	10600	"	5630	56300
jk	—	—	—	—	—	—
gs	—	—	—	—	—	—
dT	24	10600	254400	None	11250	270000
oU	—	—	—	—	—	—
Aa	13	10600	137800	None	11250	270000

SWIMMING POOL TRUSS

JOINT	NO. RIVETS	ALL'D. VALUE RIVET DOUBLE SHEAR	ALL'D. VALUE JOINT	ALL'D. VALUE RIVET BEARING	ALL'D. VALUE JOINT	ECCENTRICITY	MAX. STRESS
TA25-31-33	11	10600#/ea	116600	12380	136180	Not considered	44 K.
TA25-35	3	"	31800	"	37140		-3.7
TA25-37-39	7	"	74200	"	86660		11.0
TA34-39-40-41	7	"	"	11250	78750		10
TA34-33-35-37	8	"	84800	"	90000		25.5

PURLINS MAIN ROOF

PURLIN

P1 (See drawings Nos. 16, 9 & 1) Size: 8"@18#I x 14'-1" c. to c. bolt holes. 14.08 ft. @ 18# = 253.5#

SLATE

Weight per. purlin (See page 8) = $\frac{852.3}{100}$ x 14.08 x 9.58 = 1149.6#

RAFTERS

Weight per. purlin (See page 9) = $\frac{14.08}{1.25}$ x 9.58 x 3.25 = 350.5#

SHEATHING

Weight per. purlin (See page 9) = 3.5 x 14.08 x 9.58 = 471.8#

FELT

Weight per. purlin (See page 9) = 17 x $\frac{14.08 \times 9.58}{100}$ = 22.9#

SNOW

Weight per. purlin (See page 9) = 14.08 x 9.58 x 16.6 = 2237.6#

WIND

Weight per. purlin (See page 9 max. wind) $\frac{3625}{5}$ = (Min. Wind) 725#

PURLIN LOAD, MAIN ROOF

PART	WEIGHT PER. PURLIN
Steel	254#
Slate	1150#
Rafters	351#
Sheathing	472#
Felt	23#
Snow (Max.)	2238#
Wind (Min.)	0.0

Total wt. per. purlin 4488#

Total uniform load per. purlin = 4488 ÷ 14.08 = 319

Max. Moment = $\frac{1}{8}wl^2 = \frac{1}{8} \times \overline{14.08}^2$ = 7904#ft. = 94857#ins.

$S = M\frac{c}{I}$ = 94857 x $\frac{1}{14.2}$ = 6680#/sqin.

All'd. stress = 16000#/sqin.

Purlins are amply safe.

PURLINS SWIMMING POOL ROOF

PURLIN P3 (See drawings Nos. 16, 6 & 9)

Size 8"@8#I 15'-7$\frac{5}{8}$" c. to c. bolt holes. 15'-7$\frac{5}{8}$" @18# = 281.4#

CONCRETE

Weight per. purlin (See page 18) = 4.0 x 15.635 x 30 = 1876.2#

FELT

Weight per purlin (See page 19)
$= 4.0 \times 15.635 \times 27.1 \times 5 \div 100 =$ 87.7#

PITCH & GRAVEL

Weight per purlin (See page 19) $= \frac{4.0 \times 15.635 \times 520}{100} = 325.2$#

SNOW

Weight per purlin (See page 19) $= 4 \times 15.635 \times 16.6 =$ 1038#

WIND

Flat roof - No wind.

PURLIN LOAD SWIMMING POOL ROOF

PART	WT. PER PURLIN
Steel	281#
Concrete	1876#
Felt	88#
Pitch & Gravel	325#
Snow	1038#

Total wt. per purlin = 3608#

Total uniform load per purlin = 3608 ÷ 15.635 = 231#

Max. Moment $= \frac{1}{8} wl^2$
$= \frac{1}{8} \times 231 \times 15.635^2 = 7089$ #ft.
= 85068 #ins. $\frac{c}{I} = 14.2$
$S = M\frac{c}{I} = 85068 \div 14.2 = 6000$ #/□"
All'd. tensile stress = 16000 # per. sqin.
Purlin is amply safe.

BEAM "B_L^R" SWIMMING POOL BALCONY

STEEL B_L^R - Section A-B-C-D (See drawings Nos. 6, 10 & 22)
2-8" @ 18# I's $4\frac{3}{4}$" c. to c. 4'-9" to wall.
19'-6" @ 18# = 351#

CONCRETE FLOOR

Material Hy-rib $2\frac{1}{2}$" slab (7-rib) #26 gauge
Area = 4.75 × 16.06 = 77.88 sqft. $2\frac{1}{2}$" slab = 30# per. sqft.
78.88 sqft. @ 30# = 2360#

CONCRETE CEILING

Material Hy-rib $1\frac{1}{2}$" slab. Area = 4.75 × 16.06 = 78.88 sqft.
$1\frac{1}{2}$" slab = 18#/sqft. 78.88 sqft. @ 18# = 1420#

LIVE LOAD

Area = 4.75 × 16.06 = 78.88 sqft. Specified live load
= 80#/sqft. 78.80 sqft. @ 80# = 6300#

UNIFORM LOAD B_L^R

PART	WEIGHT PER B_L^R
Steel	351#
Conc. floor	3414#
Conc. ceiling	1420#
Live load	6300#

Total uniform load per. B_L^R = 10431#

Total uniform load per. ft. = 10431 ÷ 4.75 = 2196#

ANGLES

4-Ls 6"×4"×3/8" @ 6.5# = 26#

BEAMS

B14 1-8" @ 18# I × 16'-1"

16.06 ft. @ 18# = 289#

4-Ls 6"×4"×3/8" @ 6.5# = 26#

B4 2-8" @ 11 1/4# [s × 16'-1"

32.16 ft. @ 11.25# = 361.5#

NEWEL & RAILING Weight (approx.) = 220#

CONCENTRATED LOAD B_L^R

PART	WEIGHT PER. B_L^R
Angles	26#
Beams	362#
Newel & Railing	220#

Total concentrated load per B_L^R = 608#

Max. Moment due to uniform load = $\frac{1}{2}wl^2 = \frac{1}{2} \times 2196 \times \overline{4.75}^2$ = 24770.8# ft. = 297249# in.

Max. Moment due to concentrated load = Pl. 608 × 4.75 = 2888# ft. = 34656# in.

Total Max. Moment = 231905# in.

$S = M\frac{c}{I}$ $\frac{I}{c} = 2 \times 14.2 = 28.4$

$= 231905 \times \frac{1}{28.4} = 8164$ #/sqin. All'd. tensile stress = 16000 #/sqin. Beam B_L^R is amply safe.

BEAM B4 SWIMMING POOL BALCONY

CONCRETE FLOOR Material Hy-rib 2 1/2" slab (7-rib) # 26 Ga.

Area = $\frac{4.75 \times 16.06}{2}$ (See page 43) = 38.94 sqft.

38.94 sqft. @ 30# = 1180#

CONCRETE CEILING

Material Hy-rib 1 1/2" slab.

Area = $\frac{4.75 \times 16.06}{2}$ (See page 43) = 38.94 sqft.

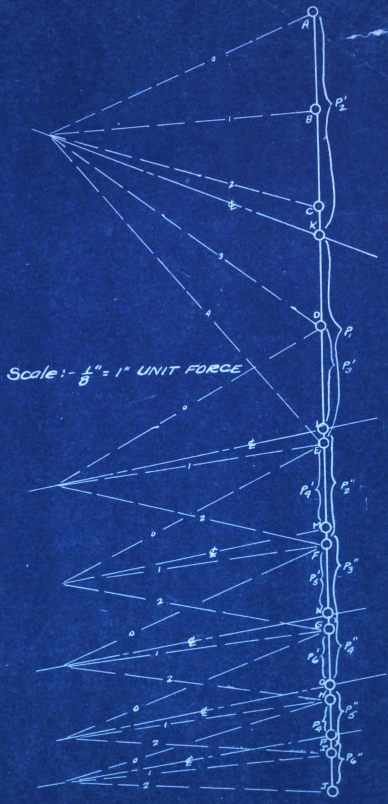
38.94 sqft. @ 18# = 710#

BEAM B4

Weight (See page 23) = 361.5#

LIVE LOAD

Weight (See page 23) 3150#



INVESTIGATION
OF THE
ENGINEERING PROBLEMS
OF THE
M.A.C. GYMNASIUM
DRAWING NO. 18.
THESIS
FOR
DEGREE B.S.

E. BOLDUC C.M. GREIFFENDORF
JUNE 1, 1916. EAST LANSING, MICH.

UNIFORM LOAD BEAM B4

PART	WT. PER. B4
Conc floor	1180#
" ceiling	710#
Steel	362#
Live load	3150#

Total uniform load per. beam B4 = 5402#

Total uniform load per. ft. = 5402 ÷ 16.06 = 337.6#

Max. moment = $\frac{1}{8}wl^2$

= $\frac{1}{8}$ × 338 × $\overline{16.08}^2$ = 10924 #ft.

= 131088 #ins.

$S = M\frac{c}{I}$ = 131088 × $\frac{1}{16.15}$

= 8117 #/sqin. I = 32.3

All'd. tensile stress = 16000 #/sqin. c = 4 in.

Beam B4 is amply safe. $\frac{2I}{c}$ = 16.15

RIVETS BEAM B4

NO. RIVETS	ALL'D VALUE DOUBLE SHEAR	MAX. LOAD	ECCENTRICITY
4	42400/□	2701	None

CONCRETE HY-RIB

Safe live load per. sqft. span 4 feet = 225#

Safe live load per. sqft. span 5 feet = 133#

Specified live load = 80#/sqin.

BEAMS RUNNING TRACK

B36 (See drawings Nos. 11, 3 & 22)

Concentrated load. (See pge 13) Total load = 8976#

Size 2'-9"-13¼#[s 10'-9½" I = 47.3 × 2 = 94.6 c = 4.5"

$\frac{I}{c} = \frac{94.6}{4.5}$ = 21.1 Max. Moment = Pl. = 8976 × 9.833

= 88261 #ft. = 1059132 #ins. $S = M\frac{c}{I}$ = 1059132 × $\frac{1}{21.1}$ = 50435 #/□

All'd. tensile stress 16000 #/sqin. Beam is amply safe with 1¼" rod to main truss. (See drawing No. 3)

B43 (middle beam)

Size 9"@13¼#[14'-2⅜"

Total load (See pages 13 & 11 - Drawings Nos. 11, 3 & 22)

= 8976 - 129 - $\frac{374}{2}$ - ($\frac{121}{10}$ × 4) = 8712# Uniform load = $\frac{8712}{14.19}$ = 613#

Max. Moment = $\frac{1}{8}wl^2$ = $\frac{1}{8}$ × 613 × $\overline{14.19}^2$ = 15419 #ft.

= 185028 #ins. $S = M\frac{c}{I}$ = 185028 × $\frac{4.5}{47.3}$ = 17621 #/sqin. $\frac{I}{c} = \frac{4.5}{47.3}$

All'd. tensile stress = 16000 #/sqin.
Beam is safe. Floor lining and sleepers carry load.
(See sketch page 12)

HANGER (See drawing No. 3)

Load (See page 13) = 8976 #

Size = $1\frac{1}{4}$" Rod. Tensile stress = $\frac{8976}{1.22}$ = 7757.3 #/sqin.

All'd. tensile stress = 16000 #/sqin.

Hanger spacing (See drawing No. 22) = 14'-5". Railing consists of 3" pipe. Design of railing is not adequate for gallery use.

COLUMN DEAD LOADS (WATER SWIMMING POOL)

COLUMNS 8 & 9

Volume water (See drawings Nos. 17, 18 & 19)
= 16.625 x 134.47 = 2234.9 cu.ft. Weight = 2234.9 x 62.5
= 139680.6 #

See Force & Equilibrium polygons drwg. No. 18:
$P_2' + P_1$ = 139680.6 . $19x + 17.75x$ = 139680.6 #
x = 3800 # Weight of water of section Q supported by column 8 = 3800 P_1
= 3800 x 17.75 = 67450 #

Weight of water of section Q supported by column 9 = 3800 P_2' = 19 x 3800 = 72200 #

COLUMNS 9 & 10.

Volume water (See drawings Nos. 18, 19 & 17) =
141.83 x 16.63 = 2357.2 cu.ft. Weight = 2357.2 x 62.5
= 147325 # $P_3' + P_2''$ = 147325 # $8.75x + 9.75x$ = 7963

Weight of water supported by column 9 =
9.75 x 7963 + 72200 # = 149839 #

COLUMNS 10 & 11

Volume water = 120.72 x 16.625 = 2006 cu.ft.
Weight = 2006 x 62.5 = 124393 # $P_3'' + P_4'$ = 124393 #
$8.75x + 7.25x$ = 124393 # x = 7774 #

Weight of water supported by column 10
= 8.75 x 7963 + 7.25 x 7774 = 126037 #

COLUMNS 1, 2 & 15

Volume = 7.875 x 134.47 = 1058.3 cu ft.
Weight = 62.5 x 1058.3 = 66141.8 # 19x + 17.75x = 66141
x = 1865 Wt. water supported by columns 1 & 15
= 17.75 x 1865 = 33103 #

COLUMNS 2, 3 & 16

Volume = 7.875 x 141.83 = 1095.8 cu ft. Weight = 1095.8 x 62.5 = 68487.5 #. 8.75x + 9.75x = 68487.5 # x = 3702 #
Weight water supported by columns 2 & 16 = 71531 #

COLUMNS 3 & 4.

Volume = 7.875 x 120.72 = 953 cu ft. Weight = 953 x 62.5 = 59593 # 8.75x + 7.25x = 59593 # x = 3725
Weight water supported by columns 3 & 17
= 8.75 x 3702 + 3725 + 7.25 = 59398 #

COLUMN DEAD LOADS (CONCRETE SWIMMING POOL)

COLUMN 8

Volume (Lining considered concrete) = 1.75 x 13 x 16.625 = 370 cu ft. $2\left(\frac{6'-8''}{2} \times 11'' \times 16.625\right)$ = 103 cu ft. 7.25 x 1.5 x 16.625 = 180 cu ft. Total = 653 cu ft. 653 cu ft. @ 150 # = 97950

COLUMN 9

Volume = 7.25 x 1.5 x 16.625 = 181 cu ft. 7.66 x 1.5 x 16.625 = 191 cu ft. 1.75 x 1.75 x 16.625 = 51 cu ft. Total = 423 cu ft.
423 cu ft. @ 150 # = 63450 #

COLUMNS 10, 11 & 12.

Volume = 15.5 x 1.5 x 16.625 = 387 cu ft. 1.75 x 1.75 x 16.625 = 51 cu ft. Total = 438 cu ft. 438 cu ft. @ 150 # = 65700 #

COLUMNS 1 & 15.

Volume = 13 x 1.75 x 7.875 = 179 cu ft. 7.25 x 1.5 x 7.875 = 85 cu ft. 2(3.33 x 9.625 + {3.33 + 8} 3.3) .91 = 126 cu ft. 8 x 1.75 x 1.3 = 182 cu ft. Total = 572 cu ft. 572 cu ft. @ 150 # = 85800 #

COLUMNS 2 & 16.

Volume = 13 x 1.75 x 14.92 = 340 cu ft. 1.5 x 14.75 x 7.875 = 175 cu ft. 14.92 x 3.33 x .91 x 2 = 91 cu ft. Total 606 cu ft.
606 cu ft. @ 150 # = 90900 #

COLUMN 3 & 17.

Volume = 13 x 1.75 x 15.3 = 348 cu.ft. 15.5 x 1.5 x 7.875 = 184 cu.ft. 2(15.3 x 3.33 x .91) = 93 cu.ft. Total = 625 cu.ft.

625 cu.ft. @ 150# = 93750#

COLUMN LOAD

COLUMN	WEIGHT WATER	WEIGHT CONCRETE	TOTAL
8	67450#	97950#	165400#
9	149839#	63450#	213289#
10	126037#	65700#	191737#
1-15	33103#	85800#	118903#
2-16	71531#	90900#	162431#
3-17	59398#	93750#	153148#

FOOTINGS SWIMMING POOL

See drawings Nos. 17, 18 & 19

FOOTING	AREA	ALLD. UNIT SOIL	ACTUAL UNIT SOIL	BENDING MOMENT P(Area REFS + 1.2 Area CDER)SF / 2 Area ADGJ	AREA STEEL
8	7'-3" x 7'-3" x 1'-6" = 62.5 □	2000#/□	2646#/□	2646/2 x 12.25 x 2.25 x 12 = 437582#in.	1.52 □
9	8'-6" x 8'-6" x 1'-8" = 72.2 □	"	2952 "	2952/2 x 17.8 x 2.87 x 12 = 906412#in.	2.55 "
10	8'-0" x 8'-0" x 1'-3" = 64 □	"	2996 "	2996/2 x 15.4 x 2.62 x 12 = 723834#in.	1.96 "
1-15	6'-0" x 6'-0" x 1'-3" = 36 □	"	3303 "	3303/2 x 7.5 x 1.62 x 12 = 240876#in.	1.17 "
2-16	7'-4" x 7'-4" x 1'-6" = 53.6 □	"	3029 "	3029/2 x 12.6 x 2.29 x 12 = 524395#in.	1.52 "
3-17	7'-0" x 7'-0" x 1'-5" = 49 □	"	3126 "	3125/2 x 10.3 x 2.12 x 12 = 409422#in.	1.37 "

FOOTING	d	% Steel	$n = 15$, $k = \sqrt{2pn + p^2n^2} - pn$	$j = 1 - \frac{1}{3}k$	b	f_s	ALLD. VALUE f_s
8	1'-5" to 1'-4"	.00107	.163	.946	75.9	22300#/□	16000#/□
9	1'-7" to 1'-6"	.00139	.178	.941	85.5	24920 "	"
10	1'-7" to 1'-6"	.00113	.164	.943	82.5	25450 "	"
1-15	1'-2" to 1'-1"	.00125	.175	.942	65.4	18480 "	"
2-16	1'-5" to 1'-4"	.00108	.165	.943	78.5	25650 "	"
3-17	1'-4" to 1'-3"	.00108	.165	.943	73.3	24420 "	"

FOOTING 8

Resisting Moment $M_s = pbdf_sjd$

$f_s = \frac{M_s}{pbjd^2} = \frac{437582}{.00107 \times 75.9 \times .946 \times 256} = 22300\#/\text{sqin.}$

(Steel see drwg's. No. 17 & 18) = 16 - $\frac{1}{2}$" R.B. per footing.

$A_s = 8 \times .1963 = 1.52$ sqin. $p = \frac{A_s}{bd} = \frac{1.52}{\frac{12 \times 7.25 \times 16}{12}} = .00107$

$b' = N0 + CN + d = (2.75 + 2.25 + 1.33)$

Note: Earth on footing giving a negative bending moment not considered

FOOTING 8

Punching shear $= \frac{P(\text{Area CDFS})}{\text{Area ADGJ}} = \frac{2646}{144} \times 144 \times 11.25 = 29767^{\#}$

P = Pressure on total footing.

Resisting area $= (2.75 + 2.25) \times 12 \times jd = 60 \times .94 \times 16 = 785$ □

Unit shear $= 29767 \div 785 = 37^{\#}$ per. sqin.

All'd unit shear $= 120^{\#}$ per. sqin.

BOND stress $= \frac{V}{msjd} = 23^{\#}/$□ $= \frac{2646 \times 16.31}{8 \times 1.57 \times 1 \times .94 \times 16}$ V = Vertical shear

All'd unit bond adhesion $= 75^{\#}/$□ m = number reinforcing rods

Diagonal tension shear $= \frac{(\text{Area ADGJ} - \text{Area Q'R'S'T'})P}{\text{Area ADGJ}}$

$= \frac{2664}{144}(144 \times 7.25 \times 7.25 - 144 \times 5.25 \times 5.25)$

$= 66600^{\#}$ Unit shear $N = \frac{V}{bjd} = \frac{66600}{5.25 \times 4 \times 12 \times .94 \times 16} = 18^{\#}/$□

All'd. value diagonal tension shear $= 40^{\#}$ per. sqin.

FOOTINGS

FOOTING	ALL'D VALUE PUNCHING SHEAR	ACTUAL PUNCHING SHEAR	ALL'D UNIT BOND ADHESION	ACTUAL UNIT BOND ADHESION	ALL'D UNIT DIAGONAL TENSION	ACTUAL UNIT DIAGONAL TENSION
8	120#/□	38#/□	75#/□	23#/□	40#/□	18#/□
9	"	41# "	"	21# "	"	18# "
10	"	38# "	"	29# "	"	18# "
1,15	"	36# "	"	28# "	"	19# "
2,16	"	38# "	"	29# "	"	9# "
3,17	"	39# "	"	30# "	"	21# "

COLUMNS

COLUMN 8

Area = 21 × 21 = 441 sqin. (See drwg's. Nos. 17, 18 & 19)

Working stress in conc. = 450#/□ Specifications Michigan State Highway Dept. Modulus of Elasticity of conc. = $\frac{1}{15}$ modulus steel. Strength column

$= f_c A\{1 + (n-1)\rho\} = 450 \times 441\{1 + (15-1)\frac{1.227}{491}\}$ $A_s = 4 - \frac{5}{8}$" R.B. $= 1.227$ □

$= 206110^{\#}$ Actual load $= 165400^{\#}$ $\rho = \frac{A_s}{A} = \frac{1.227}{441}$

Column 8 is safe.

COLUMNS

COLUMN	f_c	n	ρ	STRENGTH COLUMN	ACTUAL LOAD
8	650#/□	15	.0028	206110#	165400#
9	"	"	"	"	213289#
10	"	"	"	"	191737#
1,15	"	"	"	"	118903#
2,16	"	"	"	"	162431#
3,17	"	"	"	"	[illegible]#

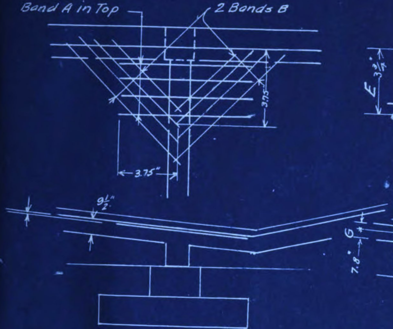


Fig. 2.

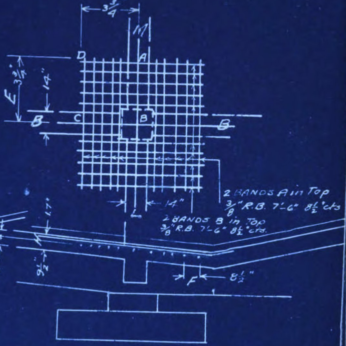


Fig. 1.

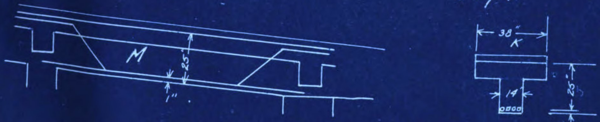


Fig. 3

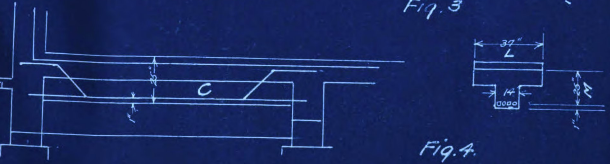


Fig. 4.

	E	F	G	H	I	J	K	L	M		
SLAB V	3.75"										
" VI		10.5"	5.3"	7"	1.7"						
GIRDER Q						17"	38"				
BEAM F								37"	17"		

TABLE I

INVESTIGATION
OF THE
ENGINEERING PROBLEMS
OF THE
M.A.C. GYMNASIUM

DETAILS OF BEAMS, SLABS & GIRDERS

DRAWING NO. 20.

THESIS
FOR
DEGREE B.S.

E. BOLDUC C. M. GREIFFENDORF

JUNE [illegible]

FLOOR SLABS SWIMMING POOL

SLAB (I)

Sec. A'-A' (Longitudinal) See drawings Nos. 19 & 20

$(Weight)_1$ water = 9.29 × 62.5 #/sqft. $(Weight)_2$ water = 1.44 × 62.5 #/sqft. Max. Moment $= \left(W_1 l + \frac{W_2 l^2}{2}\right) \frac{l}{12} c'$ $\quad c' = \frac{\left(\frac{L_2}{L_1}\right)^4}{1 + \left(\frac{L_2}{L_1}\right)^4}$ See sketch

Max. Moment $= \left(W_1 l + \frac{W_2 l^2}{2}\right) \frac{l}{12} c'$

$= .52\left(8.53 \times 62.5 \times 14.16 + \frac{1.44}{2} \times 62.5 \times 14.16^2\right) \frac{14.16}{12}$

= 9592.6 #ft = 115104 #ins. $\quad = \frac{\left(\frac{14.4}{14.1}\right)^4}{1 + \left(\frac{14.4}{14.1}\right)^4} = .519$

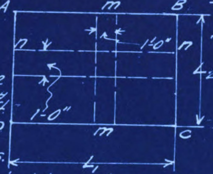
Weight conc. & finish $= \frac{13.5}{12} \times 1 \times 1 \times 150$ = 169 #/sqft.

Max. Moment (m-m) $= \frac{1}{12} wcl^2$

$= \frac{1}{12} \times 169 \times .52 \times 14.16^2 = 1468.3$ #ft

= 17619 #ins. Total Max. Moment

= 115104 + 17619 = 132723 #ins.



Sec. B'-B' (Transverse) Weight water = 9.00 × 62.5 #/sqft.

Max. Moment $= \frac{1}{10} cwl^2 = \frac{1}{10} \times 9.0 \times 62.5 \times 14.4^2 \times .48$ $\quad c = \frac{1}{1 + \left(\frac{L_2}{L_1}\right)^4}$

= 5997 #ft = 71964 #ins.

Weight concrete & finish $= \frac{13.5}{12} \times 1 \times 1 \times 150$ $\quad = \frac{1}{1 + \left(\frac{14.4}{14.1}\right)^4} = .48$

= 169 #/sqft. Max. Moment (n-n) $= \frac{1}{10} wcl^2$

$= \frac{1}{10} \times 169 \times .48 \times 14.4^2 = 1682.1$ #ft = 20185 #ins.

Total Max. Moment = 71964 + 20185 = 92149 #ins.

Note:- Steel running transversely of pool is in lower layer: $f_s = \frac{M_s}{pbd^2j} = \frac{92149}{.0053 \times 12 \times 59 \times .89}$ = 306856 #/sqin.

All'd value f_s = 16000 #/sqin. $\quad p = \frac{.3068}{7.5 \times 7.68} = .0053$ See drwg No. 14.

Michigan State Highway Specification. $\quad d = 7.68 \quad d^2 = 59$

Sec B'-B' (Longitudinal) $\quad n = 15$

Total Max. Moment = 132723 #ins. $\quad k = \sqrt{2pn + p^2n^2} - pn = .33 \quad j = 1 - \frac{1}{3}k = .89$

$f_s = \frac{M_s}{pbd^2j} = \frac{132723}{.0055 \times 12 \times 43 \times .8895}$ = 52667 #/sqin.

All'd. value f_s = 16000 #/sqin. $\quad p = \frac{.3060}{8.5 \times 6.56} = .0055$

SLAB (II) See drwgs. Nos. 19 & 20 $\quad d = 6.56 \quad d^2 = 43 \quad k = \sqrt{2pn + p^2n^2} - pn = .3315$

Weight water = 10.2 × 62.5 Fig. 1 $\quad j = 1 - \frac{1}{3}k = .889$

= 637.5 #/sqft. Weight conc. $= 1 \times 1 \times \frac{9.5}{12} \times 150$ = 118.8 #/sqft.

Total weight = 756.3 #/sqft. Max. Moment $= \frac{W}{2}$ Area ABCD × .6 AD $= \frac{756.3}{2} \times 14.06 \times .6 \times 3.75$ = 11850 #ft = 242009 #ins.

$f_s = \frac{M_s}{pbd^2j} = \frac{142200}{3.17 \times 12 \times 61 \times .00185 \times .931}$ = 35600 #/sqin. $\quad p = \frac{.5520}{7.81 \times 3.17 \times 12} = .00185$

All'd value f_s = 16000 #/sqin. $\quad k = \sqrt{2pn + p^2n^2} - pn \quad d = 7.81 \quad d^2 = 61 \quad n = 15$

Girders

GIRDER M See drawings Nos. 19 & 20 (Fig. 3)

Size 14"×36". Max. Moment due to water

$= \left(W_1 l + \frac{W_2 l^2}{2}\right) \frac{bl}{12}$ (See page. 30) $= \left(8.53 \times 14.16 \times 62.5 + \frac{1.44}{2} \times 62.5 \times 14.16^2\right) \frac{14.16 \times 15}{12} = 171207$ #ft. $= 2054489$ # ins.

Steel $\begin{cases} 1\text{-}\frac{3}{4}" \times 2" \times 15'\text{-}3" \\ 1\text{-}\frac{1}{2}" \times 2\frac{1}{4}" \times 15'\text{-}3" \\ 1\text{-}\frac{3}{4}" \text{ R.B.} \times 24'\text{-}3" \\ 1\text{-}\frac{3}{4}" \text{ R.B.} \times 23'\text{-}9" \end{cases}$

Weight concrete $= \frac{26 \times 14}{144} \times 150 \times 1 + \frac{13 \times 12 \times 9.5}{2\,144} \times 150 = 1924$ #/ft.

Max. Moment $= \frac{1}{12} wl^2 = \frac{1}{12} \times 1924 \times \overline{15.33}^2 = 37691$ #/ft. $= 452292$ # ins.

Total Max. Moment $= 452292 + 2054489 = 2506776$ # ins.

$d = \frac{t(f_c n + f_s)}{f_c n} = \frac{9.5(650 \times 15 + 16000)}{650 \times 15} = 25"$ $d = 25$ $p = \frac{5.75}{38 \times 25} = .00606$

Neutral axis is within slab.

$f_s = \frac{M_s}{pbd^2 j} = \frac{2506776}{38 \times .006 \times \overline{25}^2 \times .89} = 19760$ #/sqin. $k = \sqrt{2pn + p^2n^2} - pn = .335$ $j = 1 - \frac{1}{3}k = .889$

All'd value $f_s = 16000$ #/sqin.

T-Beams

T-BEAM Ⓒ See drwgs. Nos. 19 & 20 (Fig. 4) Size 14"×26"

Weight water per. beam C

$= \frac{15 \times 15.33 \times 8.53 \times 62.5}{15} = 8072$ #/ft.

Steel $\begin{cases} 2\text{-}1\frac{1}{2}" \times 2\frac{1}{4}" \times 16'\text{-}6" \\ 1\text{-}\frac{3}{4}" \text{ R.B.} \times 22'\text{-}9" \\ 1\text{-}\frac{3}{4}" \text{ R.B.} \times 22'\text{-}6" \end{cases}$

Weight conc. $= \left(\frac{16.5 \times 14}{144} \times 150 \times 1 + \frac{14.1 \times 12 \times 9.5}{144}\right) \times 1 \times \frac{150}{144} = 1932$ #/ft. Total uniform wt. per. ft. = 10004 #

Max. Moment $= \frac{1}{10} wl^2 = \frac{1}{10} \times 10004 \times \overline{14.4}^2 = 207442$ # ft. $= 4559304$ # ins.

$d = \frac{t(f_c n + f_s)}{f_c n} = \frac{9.5(650 \times 15 + 16000)}{650 \times 15} = 25"$ $p = \frac{7.63}{37 \times 25} = .0082$

Neutral axis is within slab.

$f_s = \frac{M_s}{pbd^2 j} = \frac{4559304}{37 \times .0082 \times \overline{25}^2 \times .83} = 28970$ #/□ $k = \sqrt{2pn + p^2n^2} - pn = .511$ $j = 1 - \frac{1}{3}k = .83$

All'd value $f_s = 16000$ #/sqin.

Shearing stresses between beam & slab. See drwgs. Nos. 19 & 20 and Figs. 3 & 4. Shearing force $= S_h = 3bzL$

Compressive stress $= \frac{1}{2} cb'kd = S_h$ z = unit shearing force

$= \frac{1}{2} \times 650 \times 37 \times .511 \times 25 = 134448$ # $= 3 \times 37 \times 14.4 z$ $z = 84$ #/□

All'd. value unit shear = 120 #/sqin.

Vertical shear plain beam C

Total load $= 10004 \times 14.4 = 144057$ # Max. shear $= 144057 \div 2 = 72028$ # $jd = .83 \times 25 = 20.75$ $d = 25$, $b = 14"$

$v = \frac{V}{b(jd)} = \frac{72028}{14 \times 20.75} = 248$ #/sqin. All'd value unit shear = 120 #/sqin. Area turned up bars = .88 sqin. Tensile strength $= .88 \times 16000 = 14080$ #/sqin.

Turned up bars cannot take total vertical end shear, but bands take part of this shear. Web reinforcement is required.

SLABS

FLOOR SLAB (III) See drwgs. Nos. 19 & 20 (Fig. 2)

Weight water = $9.97 \times 62.5 = 623.1$ #/sqft.

Weight conc. = $\frac{9.5}{12} \times 1 \times 1 \times 150 = 118.7$ #/sqft. Total wt = 741.8 #

Max. negative moment = $\frac{1}{2} wl^2 = \frac{1}{2} \times 741.8 \times \overline{3.75}^2 \times 3.75$ per □

$= 19558$ #/ft. $= 234696$ #ins. $f_s = \frac{M_s}{pbd^2j} = \frac{234696}{3.75 \times 12 \times .0014 \times 8.8^2 \times .924}$

$= 52154$ #/sqin. All'd value $f_s = 16000$ #/sqin. $p = \frac{A_s}{bd} = \frac{.552}{3.75 \times 12 \times 8.8} = .0014$

SIDE SLAB (IV) See drwg. No. 19.

Average water pressure = $\frac{10.2}{2} = 5.1$ #/□ $\quad k = \sqrt{2pn + p^2n^2} - pn = .228$

Max. Moment = $\frac{1}{10} wl^2 = \frac{1}{10} \times 5.1 \times 62.5 \times \overline{11.5}^2$

$= 4215$ #ft. $= 50580$ #ins. $\quad j = 1 - \frac{1}{3}k = .924$

$f_s = \frac{M_s}{pbd^2j} = \frac{50580}{10 \times \overline{10.25}^2 \times .0019 \times .929} = 22681$ #/sqin.

All'd. value $f_s = 16000$ #/sqin. $\quad p = \frac{.1963}{10 \times 10.25} = .001963$

$k = \sqrt{2pn + p^2n^2} - pn = .2136$

FLOOR SLAB (V) See drawings Nos. 19 & 20 $\quad j = 1 - \frac{1}{3}k = .929$

Sec. A''-A'' (Longitudinal) Table I

$(\text{Weight})_1$ water = 3.25×62.5 #/sqft. $(\text{Weight})_2$ water = 1.29×62.5 # per sqft.

Max. Moment = $\left(w_1 l + \frac{w_2 l^2}{2}\right) \frac{l}{12} c' = \left(3.25 \times 62.5 \times 14.62 + \frac{1.29 \times 62.5}{2} \times \overline{14.62}^2\right) \frac{14.62}{10} \times .487 = 6719$ #ft. $= 80628$ #ins. $\quad c' = \frac{\left(\frac{L_2}{L_1}\right)^4}{1 + \left(\frac{L_2}{L_1}\right)^4}$

Weight concrete and finish = $\frac{11}{12} \times 1 \times 1 \times 150 = 137$ #/sqft.

Max. Moment = $\frac{1}{10} wcl^2 = \frac{1}{10} \times 137 \times .4875 \times \overline{14.62}^2 \quad = \frac{\left(\frac{14.4}{14.6}\right)^4}{1 + \left(\frac{14.4}{14.6}\right)^4}$

$= 200.29$ #ft. $= 2403.4$ #ins. Total Max. Moment = 83031 # ins. $\quad = .4875$

Note: Steel running transversely of pool is in lower layer

(See Sketch pge 30)

$f_s = \frac{M_s}{pbd^2j} = \frac{83031}{.0071 \times 12 \times 16.56 \times .877} = 67504$ #/sqin. $\quad p = \frac{.3068}{10.5 \times 4.07} = .0071 \quad d = 4.07 \quad d^2 = 16.56$

All'd. value $f_s = 16000$ #/sqin. $\quad k = \sqrt{2pn + p^2n^2} - pn = .3665$

Sec B''-B'' (Transverse) $\quad j = 1 - \frac{1}{3}k = .877$

Weight water = $\frac{2}{3} \times 1.29 + 3.25 \times 62.5 = 174.6$ #/sqft. $\quad c = \frac{1}{1 + \left(\frac{L_2}{L_1}\right)^4}$

Max. Moment = $\frac{1}{10} cwl^2 = \frac{1}{10} \times .513 \times 174.6 \times 62.5 \times \overline{14.4}^2 \quad = \frac{1}{1 + \left(\frac{14.4}{14.6}\right)^4}$

$= 1810$ #ft. $= 21720$ #ins. Weight concrete = $\frac{11}{12} \times 1 \times 1 \times$ 150 = 137 #/sq.ft. Max. Moment = $\frac{1}{10} wcl^2 = \frac{1}{10} \times 137 \times .513 \times \overline{14.4}^2 = 1455$ #/ft. $= 17460$ #ins. Total Max. Moment $= 39180$ #ins. $\quad = .513$

$f_s = \frac{M_s}{pbd^2j} = \frac{39180}{.0071\times12\times26.8\times.87} = 19788$ #/sqin. $p = .0071$

All'd. value $f_s = 16000$ #/sqin. $d = 5.18$ $d^2 = 26.8$ $k = .3665$ $j = .87$

FLOOR SLAB (VI) See drawings Nos. 19 & 20 (Table I)

Weight water = 4.5 × 62.5 = 281.2 #/sqft. Weight concrete = $1\times1\times\frac{11}{12}\times150$ = 137 #/sq.ft. Total weight = 418 #/sqft.

Max. Moment = $\frac{W}{2}$ area ABCD × 0.6AD (See fig. 4)

$= \frac{418}{2}\times.375\times3.75\times.6\times3.75 = 6610$ #ft. = 79320 #ins.

$f_s = \frac{M_s}{pbd^2j} = \frac{79320}{3.17\times12\times5.31^2\times.00109\times.924} = 73971$ #/sqin.

All'd. value $f_s = 16000$ #/sqin. $k = \sqrt{2pn+p^2n^2} - pn = .2267$ $p = \frac{.2208}{5.31\times3.17\times12} = .00109$ $j = 1-\frac{1}{3}k = .924$

FLOOR SLAB (VII) See drawings Nos. 19 & 20 (Table) Weight water = 5 × 62.5 = 312.5 #/sqft.

Weight concrete = $\frac{9.5}{12}\times1\times1\times150$ = 118.7 #/sqft. Total wt. = 431.2 #/□

Max. Negative Moment = $\frac{1}{2}wl^2 = \frac{1}{2}\times431.2\times\overline{3.75}^2\times3.75$

= 15359 #ft. = 184308 #ins. $f_s = \frac{M_s}{pbd^2j} = \frac{184308}{12\times3.75\times\overline{6.3}^2\times.00097\times.94}$

= 11447 #/sqin. All'd. value $f_s = 16000$ #/□

$p = \frac{A_s}{bd} = \frac{.22}{3.7\times12\times6.3} = .00074$ $k = \sqrt{2pn+p^2n^2} - pn = .182$ $j = 1-\frac{1}{3}k = .94$

SIDE SLAB (VIII) See drawing No. 19.

Average pressure = $\frac{4.54}{2}$ = 2.27 #/sqft. Max. Moment = $\frac{1}{10}wl^2 = \frac{1}{10}\times2.27\times62.5\times\overline{12}^2$ = 2093 #ft. = 24516 #ins.

$f_s = \frac{M_s}{pbd^2j} = \frac{24516}{12\times\overline{10.25}^2\times.00088\times.919} = 23748$ #/sqin. All'd. value $f_s = 16000$ #/sqin. $p = \frac{.11}{12\times10.25} = .00089$ $k = \sqrt{2pn+p^2n^2} - pn = .2407$ $j = 1-\frac{1}{3}k = .919$

GIRDERS

GIRDER Q Size 14"×18" See drwgs. Nos. 19 & 20 (Table I)

Max. Moment due to water = $\left(W_1 l + \frac{W_2 l^2}{2}\right)\frac{bl}{10}$ (See pge.) $= \left(3.25\times62.5\times14.62 + \frac{1.29\times62.5}{2}\times\overline{14.62}^2\right)\frac{14.62\times3.16}{10}$ = 53093 #ft. = 637116 #ins.

Steel:
- 1 – 3/4" × 2" × 15'-3"
- 1 – 1 1/2" × 2 1/4" × 15'-3"
- 1 – 3/4" R.B. × 24'-3"
- 1 – 3/4" R.B. × 23'-9"

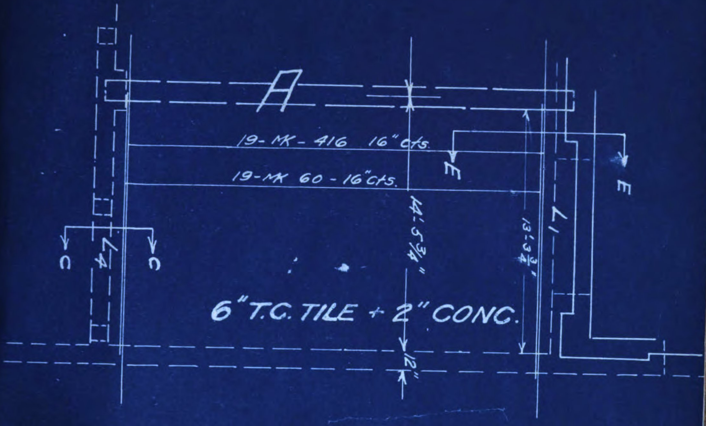
Weight conc. = $\left(\frac{17\times14}{144} + \frac{13.46\times12\times7}{2\cdot144}\right)\frac{1\times150}{144}$ = 1423.3 #/ft.

Max. Moment = $\frac{1}{10}wl^2 = \frac{1}{10}\times1423\times\overline{16.08}^2$ = 36608 #ft. = 439296 #ins. Total Max. Moment = 1076412 #ins.

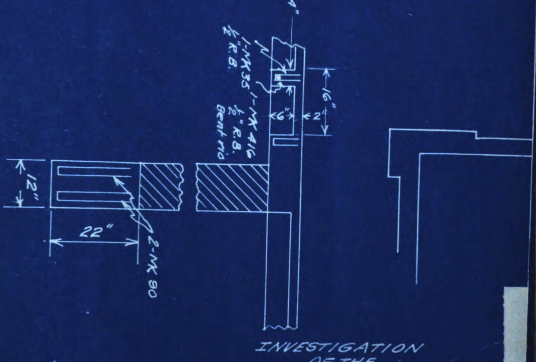
$d = \frac{t(f_c n + f_s)}{f_c n} = \frac{7(650\times15+16000)}{650\times15} = 18.41$" Neutral axis is within slab

$f_s = \frac{M_s}{pbd^2j} = \frac{1076412}{38\times.0089\times\overline{17}^2\times.86}$ $d = 17$ $p = \frac{5.75}{38\times17}$

= 12700 #/sqin. All'd value $f_s = 16000$ # per. sqin. $k = \sqrt{2pn+p^2n^2} - pn = .4$ $j = 1-\frac{1}{3}k = .867$



SECTION OF FIRST FLOOR



SECTION CC.

INVESTIGATION
OF THE
ENGINEERING PROBLEMS
OF THE
M.A.C. GYMNASIUM
DRAWING NO. 21.
THESIS
FOR
DEGREE B.S.

E. BOLDUC C. M. GREIFFENDORF

JUNE 1, 1916 EAST LANSING, MICH.

T-BEAMS

T-BEAM F See drwgs. Nos. 19 & 20 (Table I) Size 14"x18"

Weight water supported by beam F

$= \frac{15 \times 16.06 \times 4.54 \times 62.5}{15} = 4557$ #/ft. Steel $\begin{cases} 2\text{-}1\frac{1}{2}" \times 2\frac{1}{4}" \times 16'\text{-}6" \\ 2\text{-}\frac{3}{4}" \text{ R.B.} \times 22'\text{-}0" \end{cases}$

Weight concrete $= \left(\frac{10 \times 14}{144} + \frac{14.4 \times 12 \times 7}{144}\right) \times 1 \times \frac{150}{144} = 1403.5$ #/ft.

Total uniform weight = 6060 #/ft.

Max. Moment $= \frac{1}{10} wl^2 = \frac{1}{10} \times 6060 \times \overline{14.6}^2 = 129138$ #ft. = 1549656 #ins.

$d = \frac{7(650 \times 15 \times 16000)}{650 \times 15}$ (See pge. 33) = 18.41"

Neutral axis is within slab. $f_s = \frac{M_s}{pbd^2j} = \frac{1549656}{37 \times .012 \times \overline{17}^2 \times .85}$

= 14243 #/sqin. $p = \frac{7.63}{37 \times 17} = .0121$ $k = \sqrt{2pn + p^2n^2} - pn = .4475$

Shearing stresses between beam & slab. $j = .8509$

See drawings Nos. 19 & 20 (Table I) Shearing force $= S_h = 3bzL$, z = Unit shearing force. Compressive stress $= \frac{1}{2} c b' k d = S_h = \frac{1}{2} \times 650 \times 37 \times .447 \times 17 = 91377$ #

91377 = 3 × 37 × 14.4 z z = 57.1 # All'd. unit shear = 120 #/□

Vertical shear plain beam F

Total load = 6060 × 14.4 = 87264 # Max. shear = 87264 ÷ 2 = 43632 # $jd = .85 \times 17 = 14.45$ $d = 17"$, $b = 19"$

$v = \frac{V}{b(jd)} = \frac{43632}{14 \times 14.45} = 215$ #/sqin. Area turned up bars = .88 sqin. Tensile strength = .88 × 16000 = 14080 #

Turned up bars cannot take total vertical end shear, but bands take part of this shear. Web reinforcement is required.

FIRST FLOOR SLABS

SLAB (IX) (See drawing No. 21) Area T-Beam (I) = 1.33 × 13.3 = 17.689 sqft. Total live load = 80 × 13.3 = 1064 # Total dead load conc. $= \frac{13.3 \times 150}{144}\left(\frac{1.33 \times .166}{144} \times 13.3 + \frac{.5 \times .33 \times 13.3}{144}\right) = 867$ # Total load T-Beam (I) = 1931 #

Uniform load T-Beam (I) $= \frac{1931}{13.3} = 145$ #/ft. Max. Moment $= \frac{1}{10} wl^2 = \frac{1}{10} \times 145 \times \overline{13.3}^2 = 2274$ #ft. = 27298 #ins.

$d = \frac{t(f_c n + f_s)}{f_c n} = \frac{2(650 \times 15 + 16000)}{650 \times 15} = 5.3"$ $x = \frac{t}{3} \times \frac{3kd - 2t}{2kd - t} = \frac{2}{3} \times \frac{3 \times .34 \times (7-4)}{2 \times .34 \times (7-2)}$

Neutral axis is below slab.

$f_s = \frac{M_s}{pbd(d-x)} = \frac{27298}{.00172 \times 16 \times 7(7-.76)}$ $p = \frac{1963}{16 \times 7} = .00172$ $k = .344$, $j = .886$, $d = 7" = .764$

= 2270 #/sqin. All'd. value f_s = 16000 #/sqin. $d = 7"$, $b = 16"$

Max. shear = 1931 ÷ 2 = 965 # $jd = .886 \times 7 = 6.202$

$v = \frac{V}{b(jd)} = \frac{965}{16 \times 6.2} = 92$ #/sqin. Turned up bar is not required

ROOM USE ONLY