THE PRELIMINARY LOCATION AND DESIGN OF A PEDESTRIAN UNDERPASS BELOW GRAND RIVER AVENUE AT M. A. C. AVENUE, EAST LANSING, MICHIGAN

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE

William N. Ryan

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Subways

The Preliminary Location and Design Of
A Pedestrian Underpass Below Grand River Avenue
At M.A.C. Avenue, East Lansing, Michigan

A Thesis Submitted to

The Faculty of

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of

AGRICULTURE AND APPLIED SCIENCE

by

William N. Ryan

Candidate for the Degree of

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FOREWORD

Grateful acknowledgement is made to Professor C. L. Allen of the Civil Engineering Department and to the Michigan State Highway Department for assistance and suggestions given the author during the compilation and writing of this paper.

W.N.R.

June, 1939

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ARTICLE I. NEED FOR UNDERPASS

The need for a solution to the pedestrian-automobile traffic problem in the business district of East Lansing has long been felt. Several solutions have been offered, each having its own peculiar advantages and disadvantages.

One solution is that of taking U. S. Highway 16 around the city of East Lansing. Its advantage lies in the fact that all through traffic would be removed from Grand River Avenue. This plan, however, is and will continue to be for some time, far too expensive for the benefits to be derived therefrom. Right-of-way would have to be purchased and a new superhighway would have to be built.

Another plan is to install traffic signal lights at certain corners through the city. Although cheap by comparison with the first plan, the State Highway Department must keep the highway as free from congestion and tie-ups as possible. At the present time the traffic signal at Grand River and Abbott Road causes congestion often over a block long. This congestion occurs at the times when both vehicular and pedestrian traffic are at or near their maximum values, presenting a serious hazard to the drivers as well as a menace to the lives of pedestrians. Due to the necessity for keeping through traffic moving, this plan

is very unfavorable in the eyes of the Highway Planning Commission and the State Highway Department.

The third solution presented, and one which is similar to the one I wish to present, is one which calls for a pedestrian overpass at the heavily trafficed corners. This has the advantage of being reasonably inexpensive and it takes the pedestrian traffic off of the highway. The great disadvantage of this plan lies in the psychology of the human being. People do not like to climb up, cross, and climb down again. This statement will be offered without proof as the situation does not demand the long dissertation necessary for explanation. Winter offers the second disadvantage to the overpass due to the fact that people using it would be subject to the elements, and ice and snow present added dangers as well as upkeep on the structure. To assure truck clearance for the highway below, the floor of the structure would be sixteen feet above the level of the walk, allowing two feet above the fourteen required for the superstructure. The many disadvantages to this plan make it undesirable as a solution.

Before taking up the underpass I wish to present, a brief summary of both pedestrian and vehicular traffic will be made.

Assuming the enrollment at the college to be 5000 students, those living off campus must cross the highway not

less than twice daily. However, not less than 4000 of these students must go to either the business or residential district for their noon meal. These 4000 will cross the highway four times daily. Not including numerous crossings by individuals between classes or those of the college employees, this gives a total of approximately 25,000 crossings between the hours of 7:45 A.M. and 6:15 P.M., or for each hour there is an average of 2,400 crossings made. The peaks occur, however, between 7:45 and 8:15 A.M., 8:45 and 9:15 A.M., 11:00 A.M. and 1:15 P.M., and 4:00 to 6:15 P.M.. At these times it is estimated that a maximum of 3,000 crossings are made by pedestrians.

The Michigan State Highway Planning Commission took a traffic toll just east of East Lansing on U.S. 16 in 1936. Their figures show that the out-of-town traffic averaged 4,550 cars per day over a period of a year. Maximum values were 6000 cars per day. The greatest amount of traffic occurs on U.S.16 between 9:00 A.M. and 9:00 P.M..‡ That is, the majority of the traffic is between those hours. This brings peaks in both vehicular and pedestrian traffic together. The traffic survey <u>did not</u> include local traffic.

In the face of these facts it is evident that there is a very definite problem to be met in eliminating the traffic hazard and the menace to the pedestrians.

‡ Not survey figures.

The solution I wish to offer to this problem is the installation of one or more pedestrian underpasses to carry pedestrian traffic below Grand River Boulevard from the business and residential districts to the campus.

I have chosen to design the proposed underpass at M.A.C. Avenue as its design is fundamental and basic for the designs of the remaining structures in the system.

In an underpass are embodied all the advantages of the overpass. Upkeep on the structure would be lower due to the minimum of exposed surfaces requiring attention and repair. In winter, only the entrances would need be cleared, and at no time during the year would there be abutments, piers, or columns rising from the walks or center boulevard strip to endanger people on the walks or traffic on the highway. The structure is designed to attract people to use it instead of taking chances in crossing the traffic. All-concrete in design, illuminated semi-indirectly throughout, attractive entrances and drinking fountains being provided, the structure will be attractive not only to the eye, but to the mind. This with the view in end of overcoming natural distaste of people for passages without these features. The structure was designed throughout with these features in mind.

The campus entrance lends itself remarkably well to harmonious landscaping, detracting none from the campus.

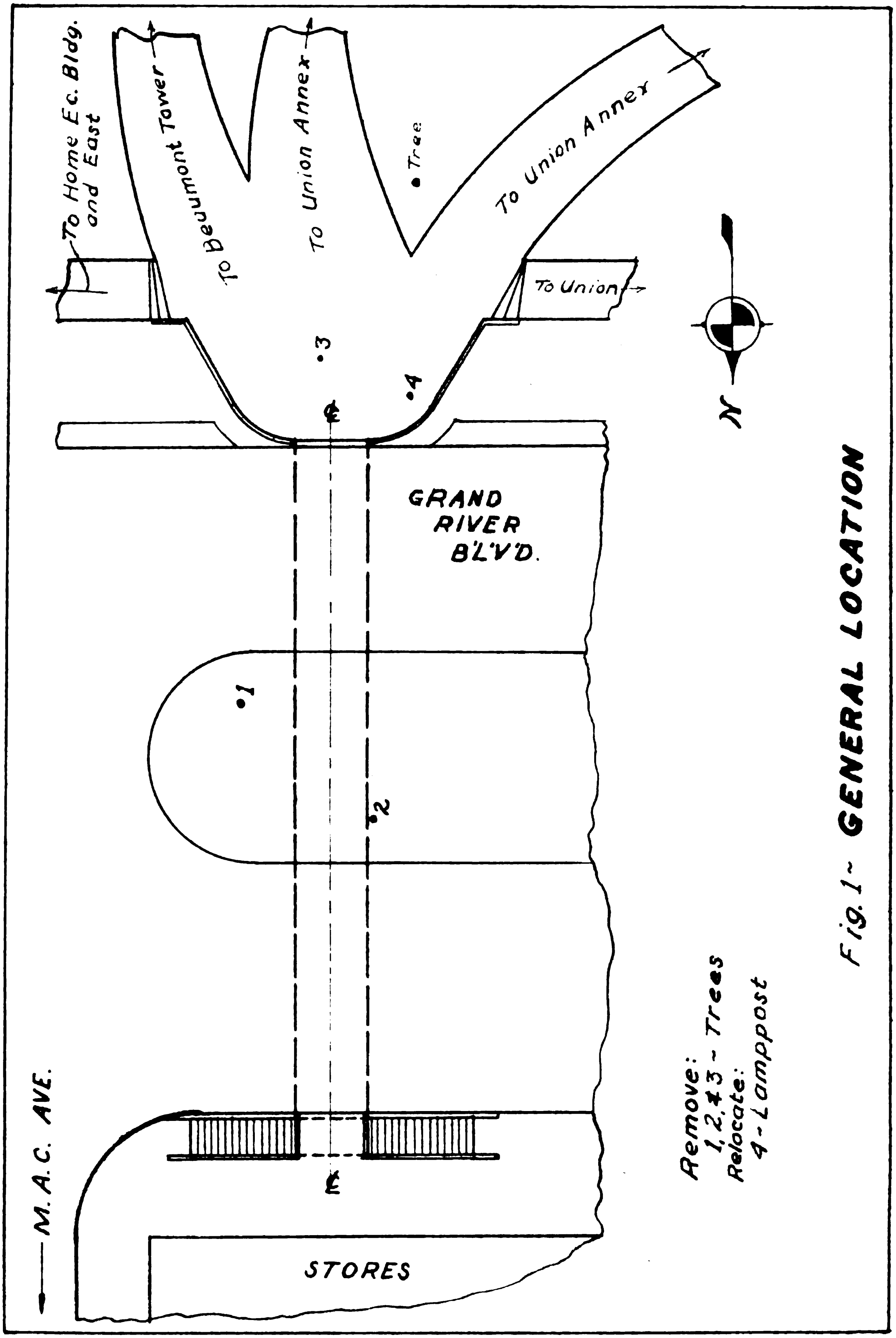


Fig. 1 ~ **GENERAL LOCATION**

ARTICLE II. TYPE OF STRUCTURE

Due to its relative simplicity in erection and the fact that it answers the demands of the situation and has functioned so well in similer types of structures, the rigid frame type has been adopted. The expense of this type is less than others as applied to this particular case.

Figure 1 shows the general location of the underpass. The centerline lies at 90° from the centerline of Grand River Boulevard and intersects the north side of the boulevard 25 feet west of the southeast corner of the brick building now standing there.

ARTICLE III. LOADING OF STRUCTURE

A. Live load. Since the type of highway to be carried across the underpass demands a Class AA structure as designated by Michigan State Highway specifications, the H-20 type of loading will be used. Figure 2 shows the typical truck.

Maximum loading will occur when two trucks are on the structure, their rear axles in line and directly above the centerline of the underpass. The circles of loading will intersect as shown in Figure 3, creating maximum conditions in the shaded area. This load will be used throughout.

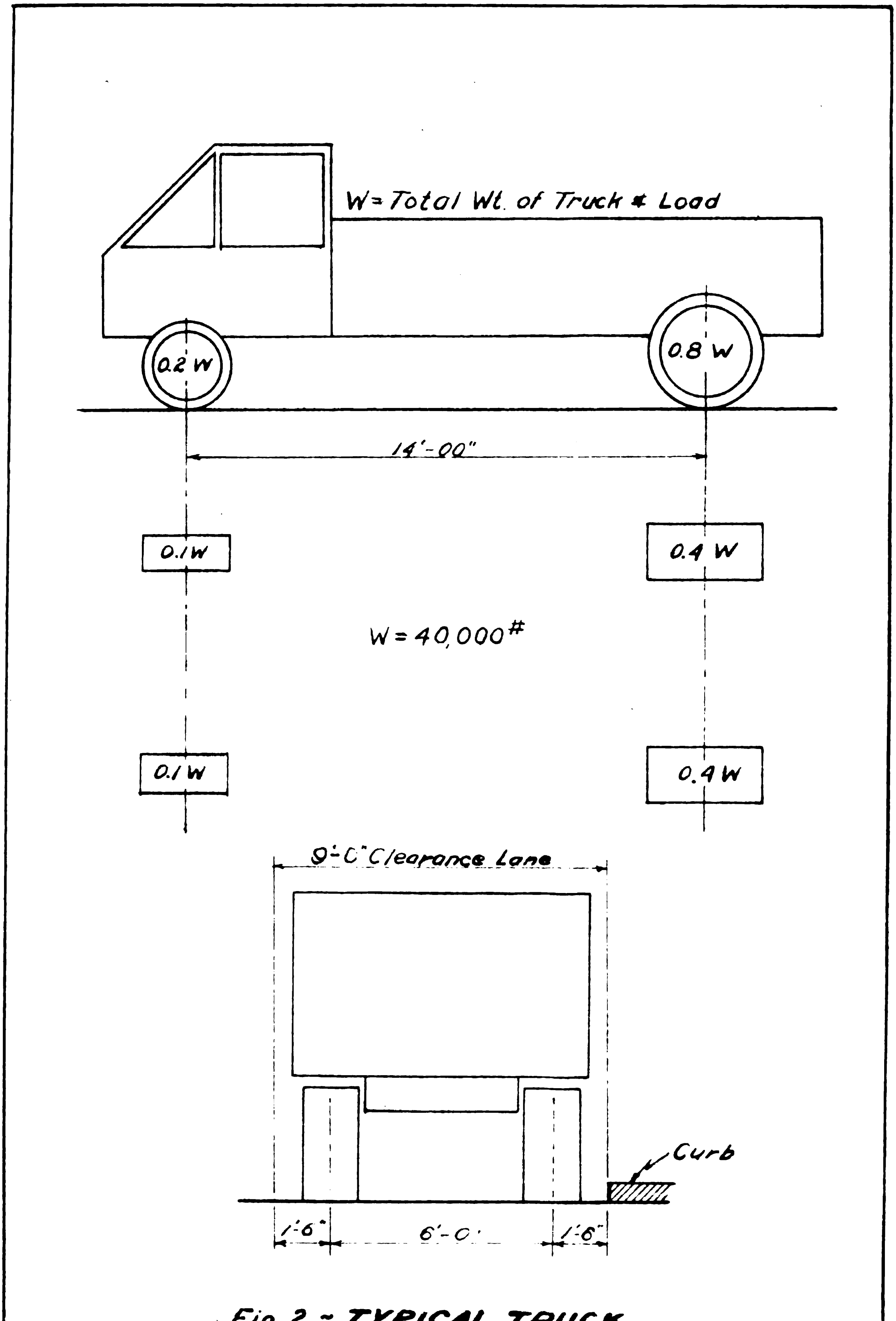


Fig. 2 ~ TYPICAL TRUCK

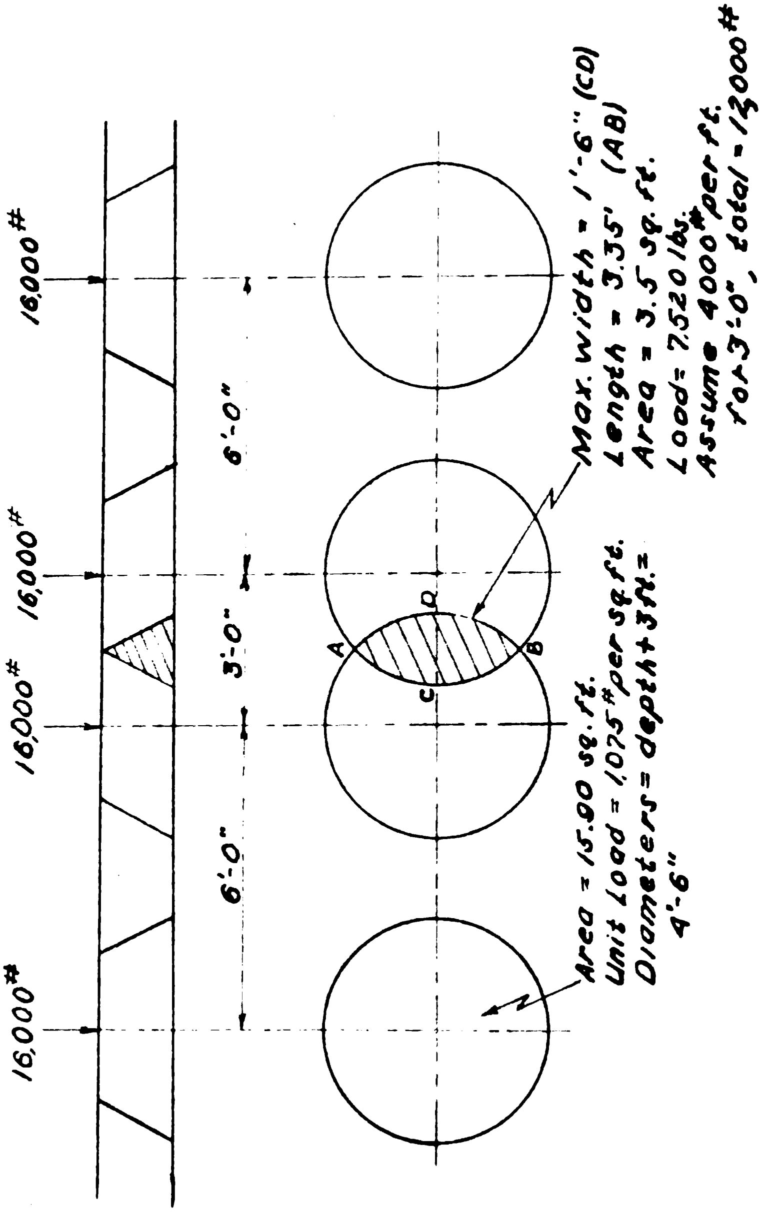
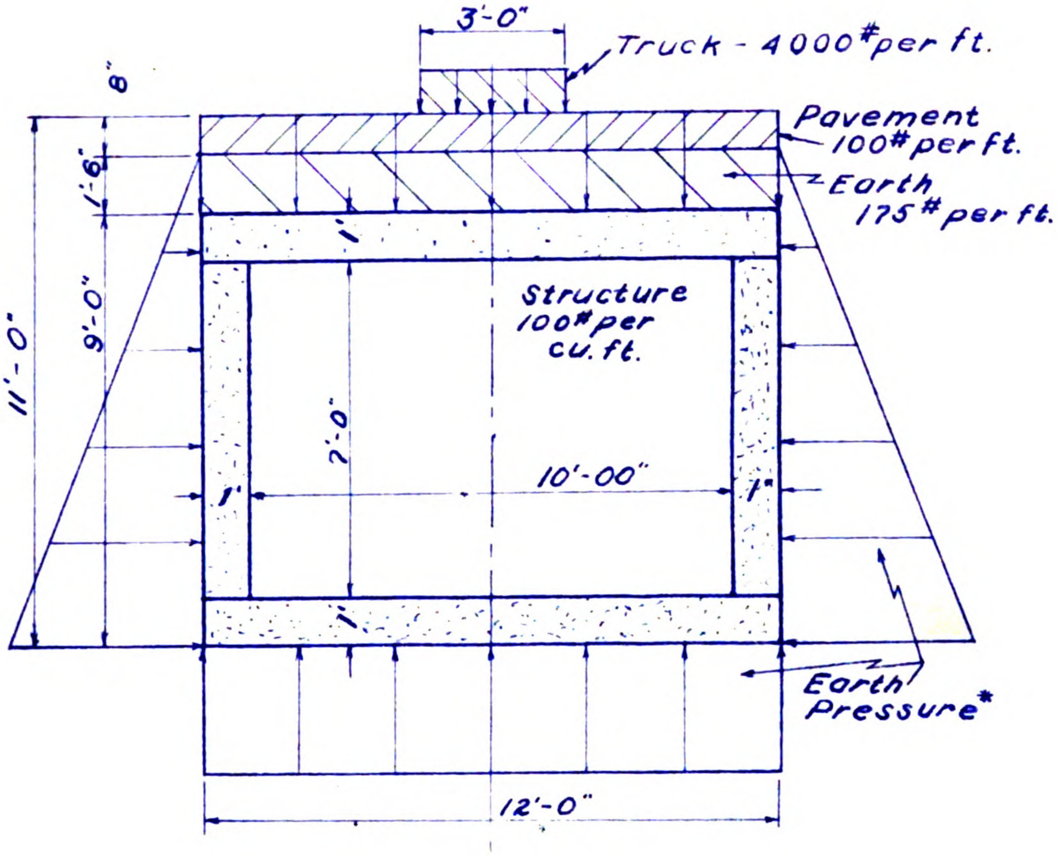


Fig. 3 - LIVE LOAD

B. Distributed load. The distributed load on the structure will consist of three parts. First, there will be weight of the highway slab which will be considered as eight inches thick and weighing 150 pounds per cubic foot. This gives a distributed load of 100 pounds per foot. Beneath this there will be 1'-6" of earth weighing 120 pounds per cubic foot, giving a distributed load of 175 pounds per foot. It will be assumed that the thickness of the top slab of the underpass will be 12", weighing 150 pounds per cubic foot, and giving a distributed load of 150 pounds per foot. The total distributed load will be the total of these or 425 pounds per square foot. (See Figure 4.)

C. Earth pressure on walls. Earth pressure on the walls shall be considered as acting liquid pressure with a unit weight of 28.8 pounds per cubic foot. (See Figure 4).

D. Bottom pressure. The bottom pressure will be governed by the weight of the structure and its loads. In arriving at the value for this load it is assumed that the walls and floor slab are 12" thick. The ceiling slab will be assumed as 12" thick as before. With these values, the section under the truck will be at maximum loading which gives a total pressure on a strip measured one foot along the centerline and 12 feet wide of 21,000 pounds. The unit pressure is 1750 pounds per square foot.



*Side pressure considered as equivalent fluid at 28.8 lbs. per cu. ft. Bottom pressure governed by weight of structure and load. Value = 1750 lbs. per sq. ft.

Fig. 4 - **EFFECTIVE LOADING**

ARTICLE IV. DESIGN OF STRUCTURE.

A. Maximum moments. The following notation will be used throughout the design. Taking the uoper left-hand corner of a section 90° to the centerline of the structure as point "A" and reading clockwise, the corners will be called "A", "B", "C", and "D".

M_{ab} = moment at end A of member AB.

M_{ba} = " " " B " " BA.

C_{ab} = moment at end A of a member AB that is fixed at both ends, and for which there is no deflection of one end relative to the other.

E = modulus of elasticity.

h = length of a vertical member.

I = moment of inertia of a cross-section of a member.

l = length of a horizontal member.

K = moment of inertia divided by length $\frac{I}{l}$ or $\frac{I}{h}$.

n, p, and s = relations between K's of the members of the structure.

1. Moments due to truck.

Maximum moment occurs when the trucks are in the center of the span.

$$M_{ab} = M_{bc} = -\frac{1}{2}\left\{C_{ba}\left[\frac{2n + 3p}{\alpha} - \frac{1}{\beta}\right] + C_{ab}\left[\frac{2n+3p}{\alpha}\right] + \frac{1}{\beta}\right\}$$

$$M_{cd} = M_{da} = \frac{1}{2}\left\{C_{ba}\left[\frac{n}{\alpha} - \frac{1}{\beta}\right] + C_{ab}\left[\frac{n}{\alpha} + \frac{1}{\beta}\right]\right\}$$

$$C_{ab} = \frac{W}{l2l^2} d^3(4l - 3d) - b^3(4l - 3b) = C_{ba}$$

$$C_{ab} = C_{ba} = \underline{14{,}716\ '\#}$$

$$K = \frac{I_{ab}}{l} = \frac{12^4}{12^3} = 144$$

$$n = Kh/I_{ad} = 1$$

$$p = Kl/I_{dc} = 1$$

$$\alpha = \beta = 8$$

$$M_{ab} = M_{bc} = \underline{9{,}197\ '\#}$$

$$M_{cd} = M_{da} = \underline{1840'\#}$$

2. <u>Moments due to distributed load</u>.

$$M_{ab} = M_{bc} = -Wl(2n + 3p)/12 = -\underline{2214'\#}$$

$$M_{cd} = M_{da} = \frac{Wln}{12} = \underline{443'\#}$$

3. <u>Due to pressure on sides</u>.

$$u = 28.8$$

$$ml = 201.6$$

$$C_{ad} = l^2/60(5u + 3ml)$$

$$= 49/60(144 + 605)$$

$$C_{ad} = \underline{612'\#}$$

$$C_{da} = l^2/60(5u + 2ml)$$

$$= 49/60(144 + 403.2)$$

$$C_{da} = \underline{447'\#}$$

$$M_{ab} = M_{bc} = -n/\alpha\left[C_{ad}(n + 2p) + pC_{da}\right]$$
$$= -1/8\ 612(1 + 2) + (1 \times 447)$$
$$= \underline{-285'\#}$$

$$M_{cd} = M_{da} = -n/\alpha\left[C_{ad} + C_{da}(n + 2)\right]$$
$$= -1/8(612 + 447 \times 3)$$
$$= \underline{-244'\#}$$

4. Moments due to earth reaction on bottom.

$$M_{cd} = M_{da} = (-Wl/12)(2n + 3p)$$
$$= -16000(2 + 3)/96$$
$$= \underline{-833'\#}$$
$$M_{ab} = M_{bc} = Wln/12$$
$$= (16000 \times 10 \times 1)/96$$
$$= \underline{1666'\#}$$

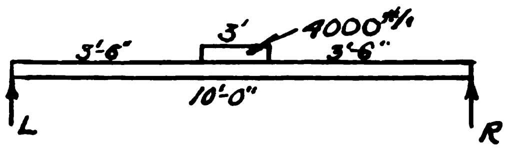
5. Total moments acting.

$$M_{ab} = M_{bc} = -9197 - 2214 - 285 + 1666$$
$$= \underline{-10030'\#}$$

$$M_{cd} = M_{da} = 1840 + 443 - 244 - 833$$
$$= \underline{+1206'\#}$$

B. Design of ceiling slab.

Loading:



Left and right reactions equal.

$L = R = (425 \times 5) + (1.5 \times 4000)$

$= 8125\#$

$M_{max} = (8125 \times 5) - (425 \times 25)/2 - (1.5^2 \times 4000)/2 + M_{ab}$

$= 30{,}810 - 10030$

$= \underline{20780'\#}$

$f_s = 16000$; $f_c = 800$; $n = 15$; assume $d = 10"$

from tables, $k = .430$; $j = .857$

Area of steel $= A_s = M/f_s jd$

$A_s = (20{,}780 \times 12)/16000 \times .857 \times 10$

$= 1.82$ sq. in.

<u>Use 7/8" round bars, 4" center-to-center.</u>

<u>Check for shear and web reinforcement.</u>

Maximum shear will occur when the truck load reaches the end of the span.

<u>Loading</u>:

$V_{max} = (4000 \times 3 \times 8.5)/10 + (425 \times 10 \times 5)/10$

$= 10{,}500 + 2125$

$= \underline{12625\#}$

$v = V/bjd$

$= 12625/12 \times .857 \times 10$

$= \underline{120\#/\text{sq. in.}}$ This is greater than the 60#/sq.in. allowable for no web reinforcement but with special anchorage of longitudinal steel.

Since this condition exists, it is necessary to use web reinforcement.

Web reinforcing.

A_s = 2V x 12 x .7/3$f_s$jd

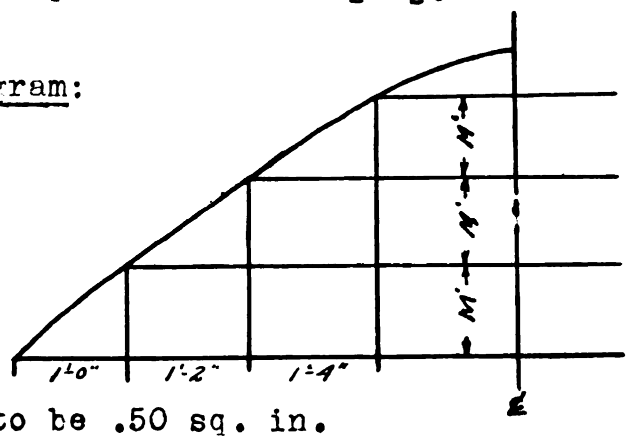
= (2 x 12625 x 12 x .7)/(3 x 16000 x .857 x 10)

= 0.50 sq. in.

Spacing of web reinforcement.

Stirrups shall be placed by use of the moment diagram. (See Hool and Johnson, Concrete Engineers' Handbook, pp. 291-2.) In this method the moment diagram is drawn to scale and the multiples of the moment M' are laid off. Where they intersect the moment corve is the location of the stirrups. M' = 1.5 A_s $f_s$jd

Moment diagram:



Assume A_s to be .50 sq. in.

M' = 1.5 x .50 x 16000 x .857 x 10

= 8,500'#

Spacing as given from diagram = 12", 26", and 42" from the left or right reaction.

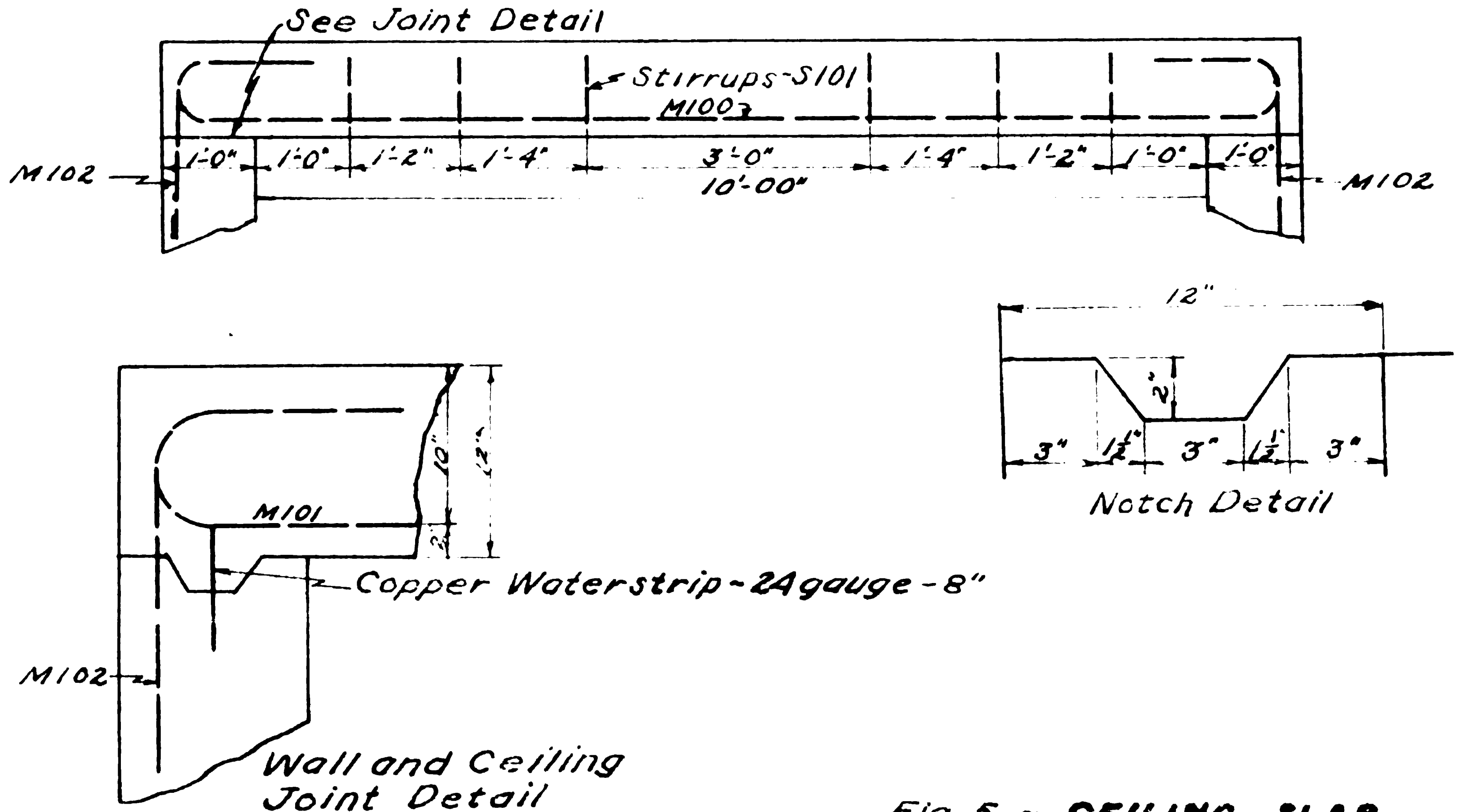


Fig. 5 ~ **CEILING SLAB**

With this condition of design, the allowable $v = 180\#/sq.\ in.$ which is greater than the actual (120 #/sq. in.).

Shrinkage and temperature steel.

$$A_s = 0.002bd$$

$$= .002 \times 12 \times 10$$

$$= 0.24 \text{ sq. in.}$$

Use: 3/8" round bars, 4" center-to-center.

C. Design of the walls.

1. The pressure exerted horizontally on the sides by the earth is found by use of the following formula:

$$P = (w/2)(H^2 - h^2)$$

H = Distance from top of ground surface to the bottom of the wall.

h = Distance from ground surface to top of wall.

$$P = 907.2\#$$

2. The distance above the bottom of the wall that the resultant acts is found by the following formula:

$$y = \frac{H - h}{3} \times \frac{H + 2h}{H + h}$$

= 2.6' from bottom, 4.4' from top, considering wall as 7'-00" in height.

3. The horizontal forces acting at the top and bottom of the wall are found by taking moments about the ends of

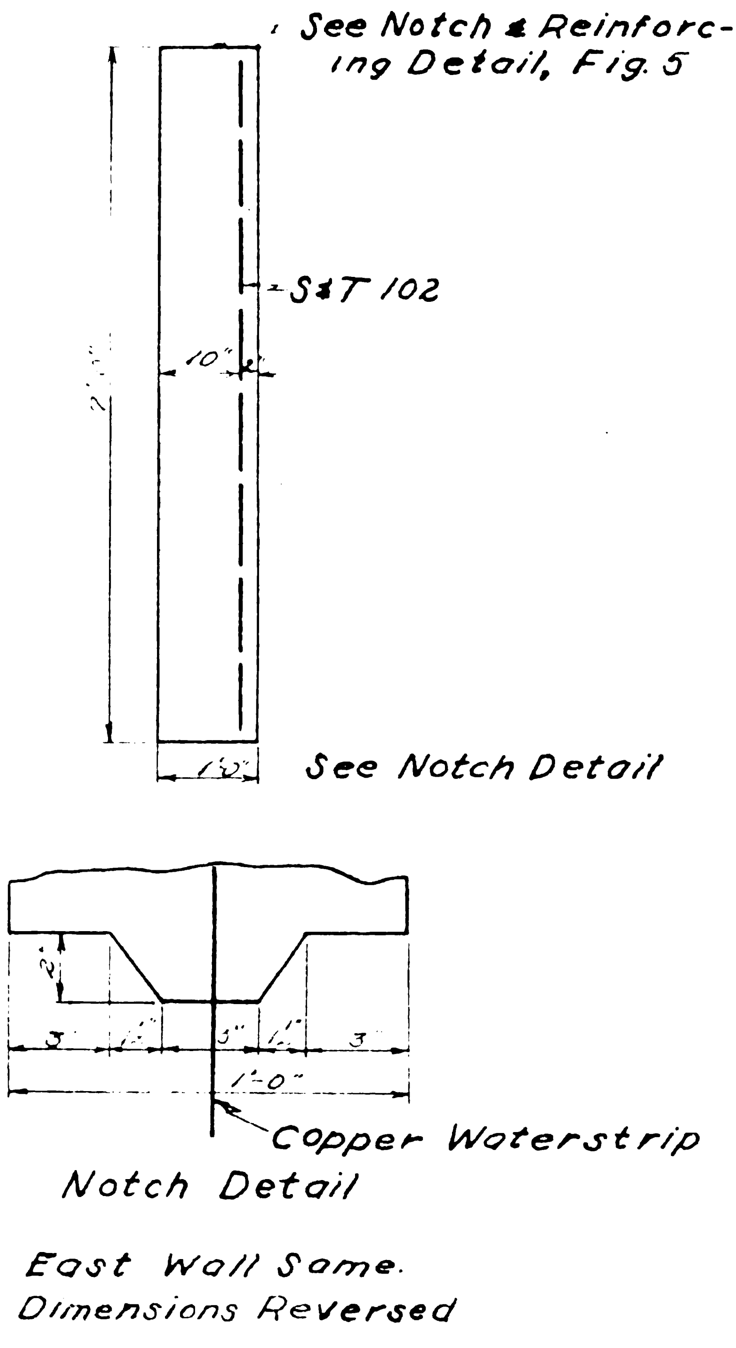


Fig. 6 - WALL (WEST)

a section through the wall, giving H_a and H_d as:

H_a = 336.0#

H_d = <u>571.2#</u>
907.2# Total which checks.

M_{max} = (336 x 3.5) + 10030

= <u>11205 '#</u>

V_{max} = <u>571#</u>

<u>4</u>. <u>Steel</u> <u>reinforcing</u>.

f_s = 16000; f_c = 800; n = 15; b = 12"; d = 10"

j = .857; k = .430

A_s = $M/f_s jd$

= 11205/16000x.857x10

= <u>.0816</u> <u>sq</u>. <u>in</u>.

<u>Use</u>: <u>½"</u> <u>round</u> <u>steel</u> <u>bars</u>, <u>6"</u> <u>center-to-center</u>.

No shear need be considered in this design, thus no web reinforcing.

<u>Shrinkage</u> <u>and</u> <u>temperature</u> steel as in ceiling slab; <u>3/8"</u> <u>round</u> <u>bars</u>, <u>4"</u> <u>center-to-center</u>.

<u>D</u>. <u>Design</u> <u>of</u> <u>the</u> <u>floor</u> <u>slab</u>. The weight of the structure and the loading upon it give a force of 9600# per foot acting along the base of the wall. Assuming 12" thickness for the floor slab, and with a earth reaction of 1750# per square foot, the uniformly distributed load may be considered as 1600# per square foot acting up. The wall load-

ing will be considered as acting along the centerline of the well, giving a loading span of 11'-00". The upward pressure acts over the twelve-foot span.

1. Maximum moment.

The maximum moment will occur at the center of the span.

$M_{max} = (+1600x6x3) - 1206 - (9600x5.5)$

$= \underline{-25,200'\#}$

2. Maximum shear.

Maximum shear will occur when the truck load is at one end of the span. The maximum wall load on the floor will then be 14,100# per foot.

$V_{max} = (1600x.5x.25) -14100$

$= \underline{-13,900\#}$

3. Main reinforcing steel.

Assume d = 10.5". From table, j = .857; jd = 9.0

$A_s = M/f_s jd$

$= (25200/16000x9)12$

$= \underline{2.1 \text{ sq.in.}}$

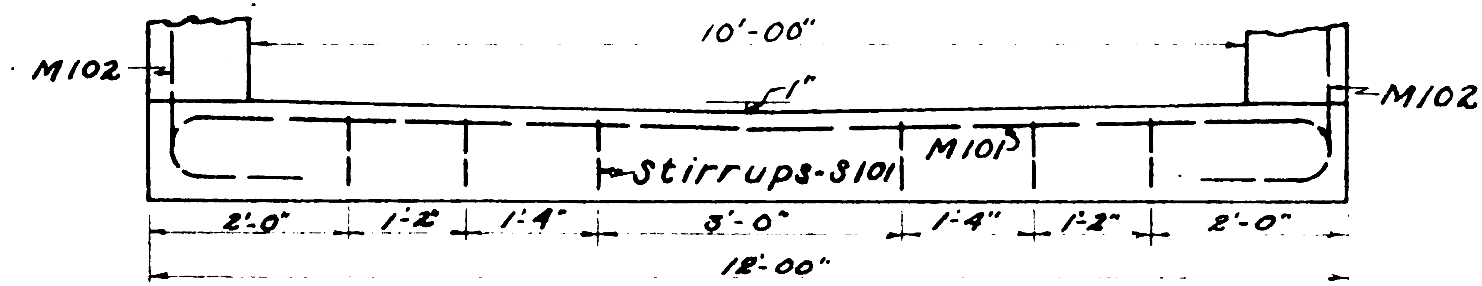
Use: 1" round bars, 4" center-to-center.

4. Web reinforcing steel.

$v = V/bjd$

$= 13900/12x9$

= 128.7# per sq.in. This is greater than that allowed without web reinforcing, therefore, stirrups will be used.



Drains placed every 5' along center line.
See joint notch & reinforcing details, Figs. 5 & 6

Fig. 7 ~ **FLOOR SLAB**

Again using the moment diagram interception method as in the design of the top or ceiling slab, values of the spacing are found that so nearly coincide with those of the ceiling slab that the previous values will be used.

Shrinkage and temperature steel as in ceiling slab:

3/8" round bars, 4" center-to-center.

E. Design of the steps at north entrance.

The steps are designed as simple beams, supported at the ends. The sloping slab which is formed by these beams is considered as supporting the stairs and their loads, this being considered as 100# per square foot of horizontal surface. The steps are connected to the supporting retaining walls by reinforcing steel which runs from each wall and overlaps the centerline of the stairway 1'-6". These are placed in the wall on a line which is three inches above the bottom line of the completed stairway in place. Longitudinal reinforcing is placed at the time of pouring and spaced every six inches across the breadth of the step, none being placed nearer than 4" from the end of the step. For tread and riser dimensions see Fig. 8. Safety treads are placed either at the time of pouring the steps, or provision is made so that they can be placed later, depending

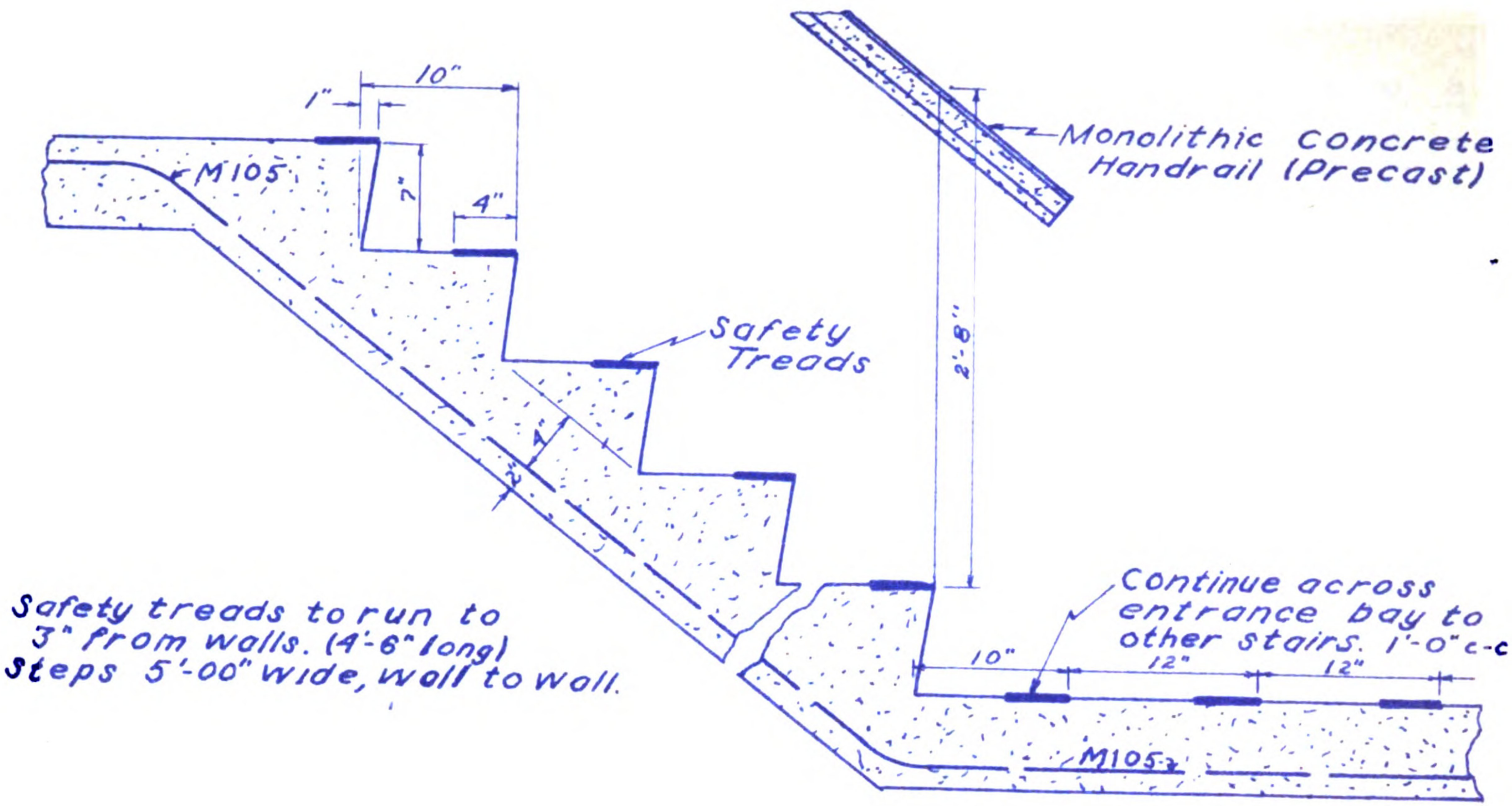


Fig. 8 ~ **STAIRS ~ NORTH**

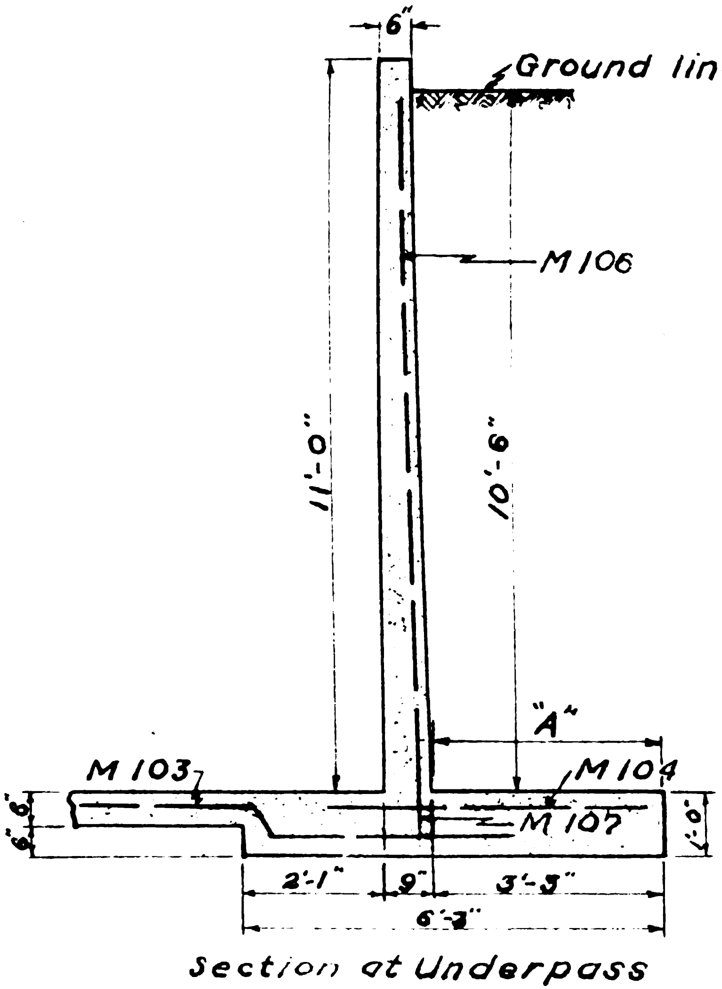
upon the design requirements. These treads are to be of such a design as to have their safety strips replacable or to allow replacement of the entire unit as normal wear occurs. The floor of the entryway at the north end shall have the same length strips laid parallel to the centerline of the underpass and running from the east to the west steps. These strips shall be placed 1'-00" o-c.

Handrail. A precast concrete handrail shall be anchored to the supporting walls on each side of the steps. Fittings are to be placed at the time of pouring of the walls. The handrail shall be so positioned as to bring to top of the railing 2'-8" above the nose of the steps. This railing shall run from the entrance to the stairs, down, and across the entryway and continue up the stairs on the opposite side and out into the entrance. This is for the north wall. On the south wall of the north entrance this railing is to run around the corner of the entrance and into the tunnel a distance of 5'-00".

B. Fundamental design of all retaining walls used in the structure.

Type of wall. The cantilever type of retaining wall will be used due to simplicity in erection and the conditions of its use.

Design. The walls were designed from tables contained in "Concrete Engineers' Handbook" by Hool and Johnson.



Retaining wall footing reduces at "A" uniformly as a function of the depth to a value of 1'-6" where depth = 4'-0". Below this value of the depth, A = 0.

Where side entrance steps intersect, the footing distance "A" shall equal the value of that of the retaining wall at their point of intersection.

Fig. 9 ~ **RETAINING WALL**

See pages 587-592. Values to be used in the tables are: k - 1/3; fw' - 50; w' - 30; K - 147; and M - 60,000"#. From these values it was found that the steel at the base of the wall must have an effective depth of 7". The base was to be 6'-3" in width, with 2'-1" projecting from the face of the wall. The base depth is 1'-00". The wall tapers from a total depth or thickness of nine inches (9") at the base to six inches (6") at the top. All reinforcing steel is to be placed 2" below the surface of the concrete. For details, see fig. 9.

G. Design of the ramp entrance (south).

No specific design for the ramp entrance to be placed at the campus end of the underpass will be offered. This design will be left entirely arbitrary and at the discretion of the college landscape architects. It is only suggested here that the ramp be of reinforced concrete and laced with the same safety tread strips as are used on the stairs. Entrances to the ramp from main walks (the 8' walks which are approx. 18' from the curb) should be made by either steps or individual ramps joining the main one. In either case it is suggested that the fundamental design of the underpass be carried out in the design and construction of the ramp.

H. Design of the sump.

A reinforced concrete sump shall be constructed near the center of the structure to take care of interior and side drainage. Walls and bottom of the sump are to be 8" thick with shrinkage and temperature steel of 3/8" rods 4" on center and meshed placed two inches from the interior face of the concrete. The sump shall have dimensions (interior) of 4'x4'x4' with its top level six inches below that of the lowest level of the floor of the underpass. The sump shall be provided with a centrifugal pump having a capacity of 25 g.p.m., controlled by a float guage set to keep the water level in the sump at two foot depth maximum and six inch depth minimum. This pump is to discharge into the sewer system immediatelt adjacent to the underpass. The pump shall be powered by a suitable electric motor.

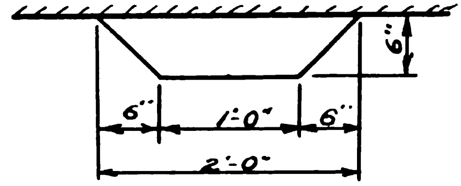
I. Special features.

Drainage of the ground immediately adjacent to the structure shall be accomplished by tile drains and an 8" layer of 1" gravel placed on the sides and bottom of the underpass. These tiles shall drain into the sump.

Drainage of the structure's interior is to be accomplished by drains placed every five feet allong the centerline of the underpass, these also draining into the sump. In addition to these, at each end of the tunnel a grilled drain is to be placed across the entire width of the floor, its purpose to be that of intercepting water coming from the ramp or stairs.

Drinking fountains shall be installed as follows: Recessed, wall-type fountains shall be placed, one each, in the north-west and south-east walls of the tunnel, water supply to come from the city pipe at the north end of the underpass which is now furnishing water for the drinking fountain on the north side of Grand River. The exception to this may be that water for the south fountain may be obtained from the pipe running under the north edge of the boulevard and now furnishing water for the fountain at the west end of the boulevard.

Lighting will be considered as a special feature as it is different from methods now employed. The interior or tunnel of the underpass shall be lighted by a demi-indirect unit running the length of the underpass. A cross-section is shown here with approximate dimensions. The depth should not be exceeded due to headroom limitations.



The steps shall be illuminated by flush-type units fitted with louvred lenses to give directional lighting over the step surfaces. The ramp lighting must be handled by bracket lamps or semi-direct surface-type fixtures placed near the entrance to the tunnel. These fixtures to be chosen to conform with the entrance may be supplemented by pole lights at the upper end of the ramp.

ARTICLE V SUMMARY

The need for a solution to the pedestrian-motorist problem existing has already been brought forward and will not be repeated.

The changes necessary in the site selected for this design are comparatively minor in nature, involving the removal of three trees, lowering one 8" water main, and the moving of one lamppost. It may not possibly be deemed necessary to remove the tree to the east of the underpass, leaving the boulevard well shaded as before. The Bell Telephone Company lines will involve an estimated cost of $333.00 to lower them or raise them over the underpass.

Benefits to be gained are innumerable, but a few of the most felt are the following:

After military parades, football and other atheletic contests, and other public functions, dangerous congestion at the main crossings will be eliminated. These conditions are liable to grow more freouent since the addition of new buildings which will house and hold more people at concerts, plays, and other entertainment features.

The crossing of slippery streets will be eliminated in winter, and splashing of pedestrians by motorists in rainy weather.

Both motorists and oedestrians alike will benefit by having a dangerous hazard, caused for each by the other, eliminated.

It is with these and many other needs and benefits in mind that I submit my solution to this problem, hoping that in the near future it may be used, if not verbatim, as a basis for the construction of a series of pedestrian underpasses connecting the campus with East Lansing.

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Hool and Johnson

"Concrete Engineers' Handbook"

Michigan State Highway Department

"Standard Specifications for Road and Bridge Construction"‡

"Specifications for the Design of Highway Bridges"‡‡

‡ Sept., 1934 Edition

‡‡ Jan., 1936 Edition

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