PRELIMINARY LOCATION, DESIGN, AND COST JUSTIFICATION OF A PEDESTRIAN UNDERPASS USING ARMCO TUNNEL LINER PLATES

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

Malcolm W. Whitford

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Preliminary Location, Design, and Cost Justification of a Pedestrian Underpass Using Armco Tunnel Liner Plates

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by

Malcolm W. Whitford

Candidate for the Degree of

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LIST OF ILLUSTRATIONS

ACKNOWLEDGEMENT

Grateful acknowledgement
is made by the author to
his wife, who kept food
in his mouth, clean clothes
on his back, and two very
small girls happy and quiet
so that their father might
study.

M.W.W.

I. Introduction

During the author's four year stay in East Lansing the problem of pedestrian and vehicular cross-traffic in East Grand River Avenue has been discussed many times. That the matter is not limited to that particular period is evidenced by newspaper articles and several previous theses. And yet, in spite of the generally accepted existence of such a problem, few personal injury accidents involving a pedestrian and a motor vehicle have occurred to bear this out. Therefore, the first purpose of this paper is to prove that a problem does exist which requires a solution.

Assuming that a problem does exist, an adequate solution must be found. Many types of solution have been offered in the past. However, a solution should be found which takes advantage of the location, the situation, and cognizance of the number of pedestrians and vehicles involved. This represents the second purpose of this paper.

Having found a method which meets the needs of the problem, it should be justified on an economic basis. This constitutes the third purpose of this paper.

II. Results

In order that the reasoning involved in later proofs and that the purpose behind the approach may be more readily apparent, the end results of the work will be given here.

A problem does exist in that there are an average of eighteen pedestrian crossings and fifteen vehicular passings every minute. Peak traffic is much higher, of course.

The best solution of the problem involves a pedestrian underpass built by tunneling under the street using Armco Tunnel Liner Plates.

Comparative costs show that this method will cost no more than other methods which adequately solve the problem.

III. The Need

The most recent figures available on vehicular and pedestrian traffic on East Grand River Avenue may be taken from a Michigan State Highway Department survey dated November 7, 1947. Several factors are significant in relation to the data. November 7, 1947, was a cloudy, cool day. The same survey taken in warm spring or fall days would probably show an increase in pedestrian traffic. Also, at that time evening classes were held regularly until 10:00 P.M. The survey on pedestrian traffic covered a twelve hour period - 7:00 A.M. to 7:00 P.M. The pedestrian traffic was spread over a greater time period in any one day than it is now that evening classes have been eliminated for the most part. Vehicular traffic figures are based on the previous six month period, so that they may be assumed to be fairly representative. With these facts in mind a better interpretation of the data may be made.

For the pertinent data taken from the Michigan State Highway Department survey dated November 7, 1947, see data sheets IIIa and IIIb.

DATA SHEET IIIa

Michigan State Highway Department - November 7, 1947

<u>Twenty-four Hour Vehicular Totals</u>

(Results of six month average)

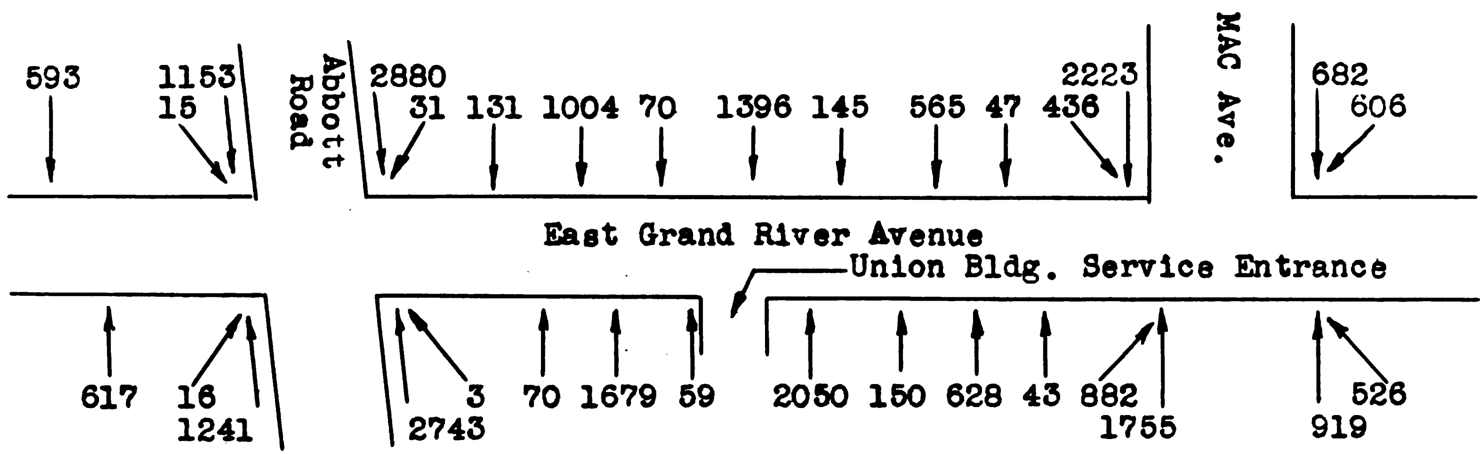
	Charles St. to MAC Ave.	MAC Ave. to Abbott Road
Total	19418	21432
Westbound		
Local	5672	6628
Through	4130	4130
Eastbound		
Local	5536	6594
Through	4080	4080
check total	19418	21432

In addition to the above there are 3477 vehicles entering or leaving MAC Avenue during each twenty-four hour period.

DATA SHEET IIIb

Michigan State Highway Department - November 7, 1947

Twelve Hour Pedestrian Count - 7:00 A.M. to 7:00 P.M.



Diagonal arrows indicate jaywalkers.

DATA SHEET IIIb

Michigan State Highway Department - November 7, 1947

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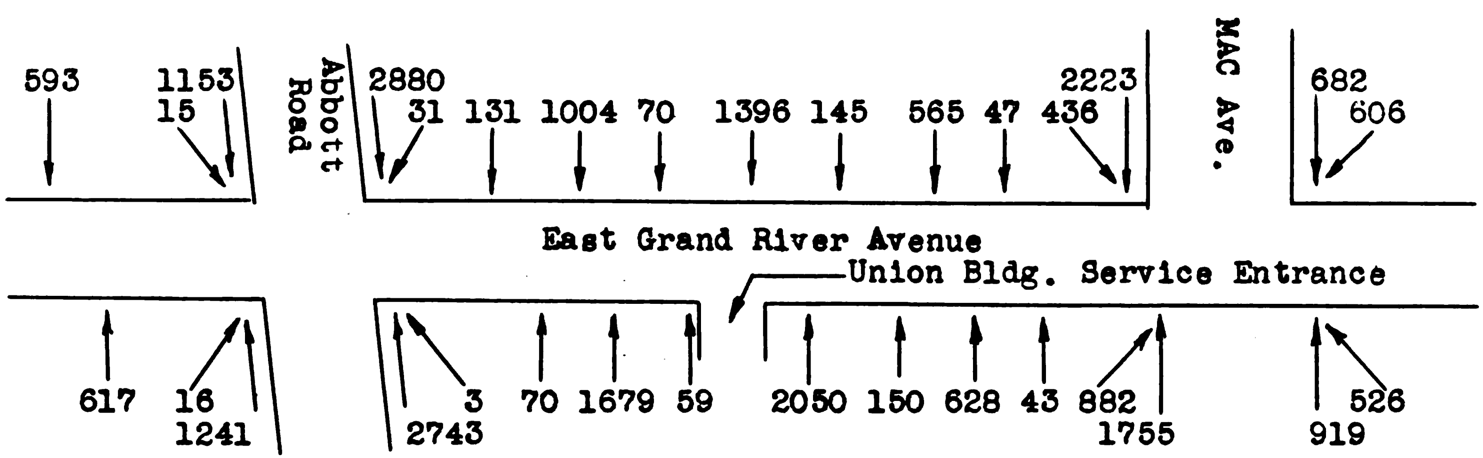

Diagonal arrows indicate jaywalkers.

These figures as presented have little significance. A more complete breakdown is necessary to the case more clearly. As far as pedestrian traffic is concerned, the half of the block from Abbott Road to the middle toward MAC Avenue has little effect on the situation. Pedestrians crossing in this area are protected by the traffic light at Abbott Road. The pertinent part of pedestrian crossings is in the remaining one-half of the block. Also it may be seen that practically all the jaywalking is done at the intersection of MAC Avenue and East Grand River Avenue. The total number of pedestrian crossings in the eastern one-half of the block for a twelve hour period is 13,073.

$$1 \text{ hour} = \frac{13073}{12} = 1089.4 \text{ crossings}$$

$$1 \text{ minute} = \frac{1089.4}{60} = 18.15 \text{ crossings}$$

This is equal to approximately one crossing every three seconds. Assuming an average crossing to require fifteen seconds, there will be at least five persons crossing at any time on the average. Any greater crossing time will place more persons in the street at any time.

For vehicular traffic all units are applicable. For a twenty-four hour period there were 21432 vehicles in the block between MAC Avenue and Abbott Road.

$$1 \text{ hour} = \frac{21432}{24} = 897 \text{ vehicles}$$

$$1 \text{ minute} = \frac{897}{60} = 15 \text{ vehicles}$$

This means that <u>on the average</u> there will be one vehicle passing every four seconds. This figure is based, as stated above, on a twenty-four hour basis. All results are then conservatively low, considering that approximately seventy-five percent of the traffic will pass between 7:00 A.M. and 10:00 P.M. (62.5% of one day). In addition to this there is another factor to consider. Peak periods (7:00 - 8:30 A.M.; 11:00 A.M. - 1:30 P.M.; 4:00 - 6:00 P.M.) will be considerably higher. The traffic lights at Abbott Road and Haslett Street will regulate traffic to some degree. Peak periods, however, will bring traffic from the campus as well as from East and West Grand River Avenue. This will cause nearly a steady flow of traffic on East Grand River Avenue at peak periods.

For all of the above reasons it may be concluded that a problem does exist and that it does require solution, a proper solution being one which will eliminate cross traffic, thus saving time for the pedestrian and vehicular traffic and reducing the possibility of accidents.

IV. Choice of Solution

In order to choose a suitable method from the standpoints of economy and adequate solution of the problem at hand it is necessary to keep several things in mind. The final cost of any project lies with the taxpayer or, in this case, the motor vehicle operator. Whether he should pay the price in the form of taxes or increased operating costs is of little importance. Therefore the solution should be as inexpensive as possible to the ultimate source of payment, the motor vehicle operator. The economy, however, should be guided by an adequate solution to the problem. An inadequate solution to the problem is an expensive "saving".

All solutions offered here will be designed and estimated on the basis of a thirty year life.

There are two general solutions to the problem, a surface treatment and an underground treatment. There are three types of solution using surface treatment: barricades in the center strip providing limited pedestrian access to the street; installation of a traffic light; and erection of a pedestrian overpass. The first type, barricades permitting limited access, accomplish but one purpose. They tend to prevent accidents by providing safety zones where the driver may exercize extra care. However, as has been pointed out previously the number of personal injury accidents is surprisingly low due to an existing awareness on the part of drivers. This method does not eliminate the actual cross traffic between pedestrians and vehicular traffic and may be discarded for this reason.

The second surface treatment, installation of a traffic light, may be more expensive than appears on the surface, (see data sheet IVa for cost estimate). As may be seen from these figures, the total cost to the vehicle operator is approximately $200,000.00, and still the problem is not entirely solved. All the pedestrians must cross in a thirty second period. Conflicting with these pedestrians will be 3477 vehicles per day which must turn either east or west from MAC Avenue. Thus the problem is only partially solved.

The third surface treatment, an overpass, will entail a great deal of expense. The expense amounts to construction costs, cost of detour (detailed later), and extremely high maintenance costs. In addition to this there is a constant danger from ice and snow in the winter months. Also, the loss of certain esthetic values in a high, ungainly structure is inestimable.

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There remains the underground treatment. A tunnel designed for pedestrians will eliminate all pedestrian - vehicular cross traffic. The expense may be higher than that for the methods already mentioned, but the solution is adequate. There are two general methods of constructing such a structure. One is the conventional method in which the pavement is broken up, a trench excavated, and the tunnel built up using forms to place the concrete slabs. This will involve a detour which can be expensive to vehicular traffic. (See data sheet IVb for these figures.) From this it may be seen that a detour will cost approximately $35,000.00. This figure makes no allowance for lost time or inconvenience to city traffic. A method using Armco Tunnel Liner Plates represents the general method of tunneling and will eliminate the detour or any other interference with normal traffic. Also there will be less actual excavation, a resulting smaller amount of excavated material to be hauled for some distance, elimination of a sand backfill, and other money saving items. This method will require no special equipment or tools and no high cost labor with special skills. A working space is excavated and the tunnel is dug beneath the street supporting it with the liner plates which are bolted on from the inside as excavation proceeds. This type of liner is used rather than jacking since corrugated pipe which can be jacked through the fill does not come in a size large enough to be suitable in this instance.

The material used in this method may be more expensive, but lower companion costs will make the method less expensive. A cost comparison of the two methods mentioned above will be made after design.

DATA SHEET IVa

Estimate of Cost of Traffic Light

	Quantity Results	Cost Results
Time Period	30 years	
Initial Cost (cost of light, wiring, control, installation, replacements)		$ 500.00
Operate 6:00 A.M. - 12:00 P.M. =	18 hours	
Total Traffic westbound 5672 + 4130 eastbound 6594 + 4080 12266 + 8210 =	20476 vehicle	
Assume even flow of traffic vehicles per day = $\frac{18}{24}$ 20476 = actual flow will be higher on the average and much higher at peak periods	15357 vehicle	
Use 60 - 30 second light light will be green 2/3 of the time, red 1/3 of the time vehicles stopping = $\frac{15357}{3}$ =	5119 vehicles	
Assume 15% commercial vehicles number of commercial vehicles =	768 vehicles	

DATA SHEET IVa (continued)

Estimate of Cost of Traffic Light - continued

	Quantity Results	Cost Results
Gasoline Consumption (extra)		
idling requires 1/3 to 1/2 gal. per hour in cars, 1 gal. per hour in trucks - also extra fuel is required to accelerate from rest - for all vehicles, stopping and accelerating, assume	3/4 gal/hr.	
cost - 3/4 gal/hr @ \$0.25/gal =	\$0.1875/hr.	
idling - 5119/day @ 30 seconds ea $\frac{30 \cdot 5119}{3600} =$	42.658 hr/day	
30 year cost = hrs/day • days/yr • yrs • cost/hr 42.658 • 365 • 30 • .1875 =		\$ 87582.21
Labor Cost		
assume driver's wage = \$1.50/hr. labor cost = drivers/day • hrs • days/yr • yrs • wage/hr. = $768 \cdot \frac{30}{3600} \cdot 365 \cdot 30 \cdot 1.50 =$		\$105120.00
Total Cost =		\$193202.21

DATA SHEET IVb

<u>Estimate of Cost of Detour</u>

	Quantity Results	Cost Results
Suggested Detour		
Westbound on US 16, turn north on Hagadorn Road. Follow Hagadorn Road one mile north to Mich. 78. Turn west on Mich. 78 and follow to junction of Mich. 78 with US 16 west of East Lansing. Assume distance from junction US 16 and Hagadorn Road to junction US 16 and Mich. 78 as being equal to the distance from junction Mich. 78 and Hagadorn Road to junction US 16 and Mich. 78. Detour distance is equal to distance traveled on Hagadorn Rd.		
Assume		
length of detour	1 mile	
operating cost per mile	$0.07	
Number of Vehicles (through traffic)		
westbound 4130		
eastbound 4080		
8210	8210	
Approximate Duration of Detour		
<u>excavation</u>, relocating water mains, etc. — 7 days		
<u>form work</u>, placing, curing — 14 days		
<u>filling</u>, replacing surface, curing, etc. — 14 days		
35 days		
<u>contingencies</u> 20% — 7 days		
<u>total time</u> — 42 days	6 weeks	

DATA SHEET IVb (continued)

<u>Estimate of Cost of Detour</u> - continued

	Quantity Results	Cost Results
Cost for Longer Distance cost per week = cars/day • no.of days • cost/vehicle/mile • number of miles 8210 • 7 • $0.07 • 1 =		$ 4022.90
total cost of detour = cost per week • number of weeks $4022.90 • 7 =		$24137.40
Repairs for Detour assume: 1 mile @ $10,000.00/mile		$10000.00
<u>Total Cost</u> =		$34137.40

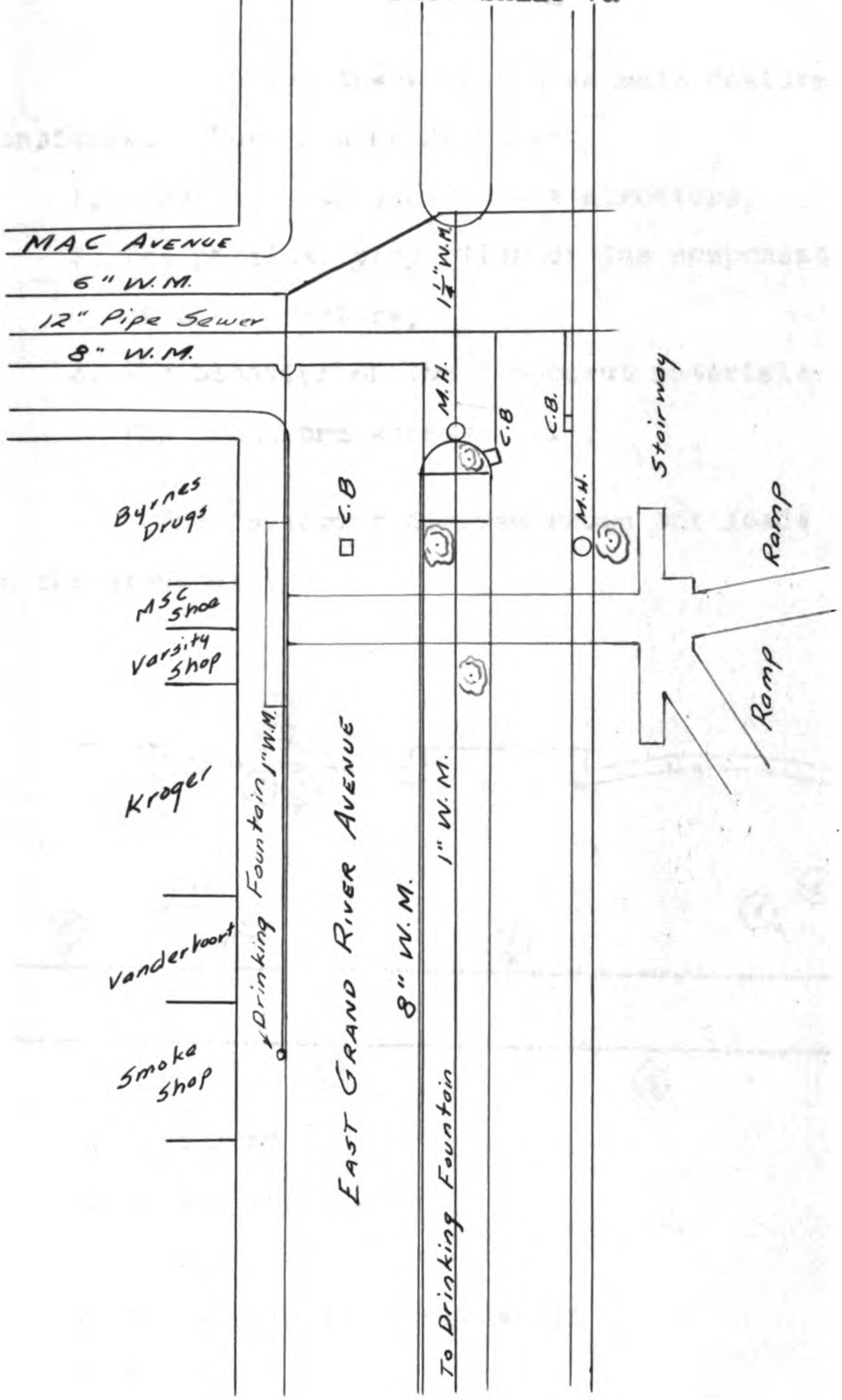
V. Location

The general location of the tunnel will be under East Grand River Avenue in East Lansing, Michigan. It will be located partly on City of East Lansing property and partly on the property of Michigan State College.

In selecting the approximately correct location for the structure there are two factors to be considered. First, while remembering the data concerning pedestrian traffic incidence, a location must be selected which will serve the greatest number of persons with the greatest degree of convenience. Second, the utilities which are beneath the surface of the street must be considered.

The utilities present in the street are indicated in data sheet Va. From this it may be seen that the only structure that cannot be eliminated is the eight inch water line in the north side of the street. By placing the tunnel far enough west the solution will be greatly simplified. Also the nearer the center of the eastern one-half of the block between MAC Avenue and Abbott Road the structure is placed the better will it serve the pedestrian traffic. For a clearer solution of the problem see data sheet Va. Suggested location for the entrances and exits are also shown on the data sheet.

DATA SHEET Va

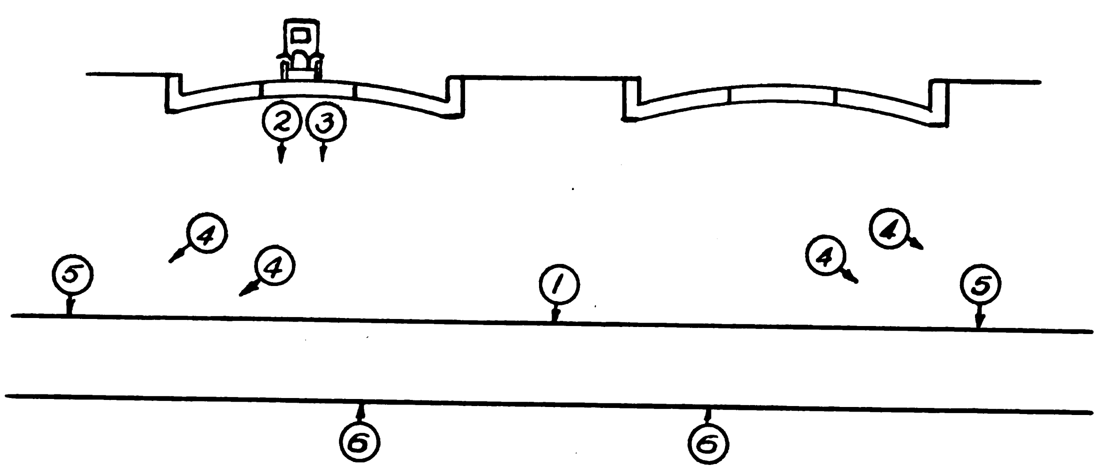


VI. Design

In design there are three main features to be considered. They are as follows:

1. Loads and stresses on the structure,
2. The physical properties of the component materials of the structure,
3. The behavior of the component materials (2) under the loads and stresses (1).

The following diagram shows the loads and stresses on the structure:



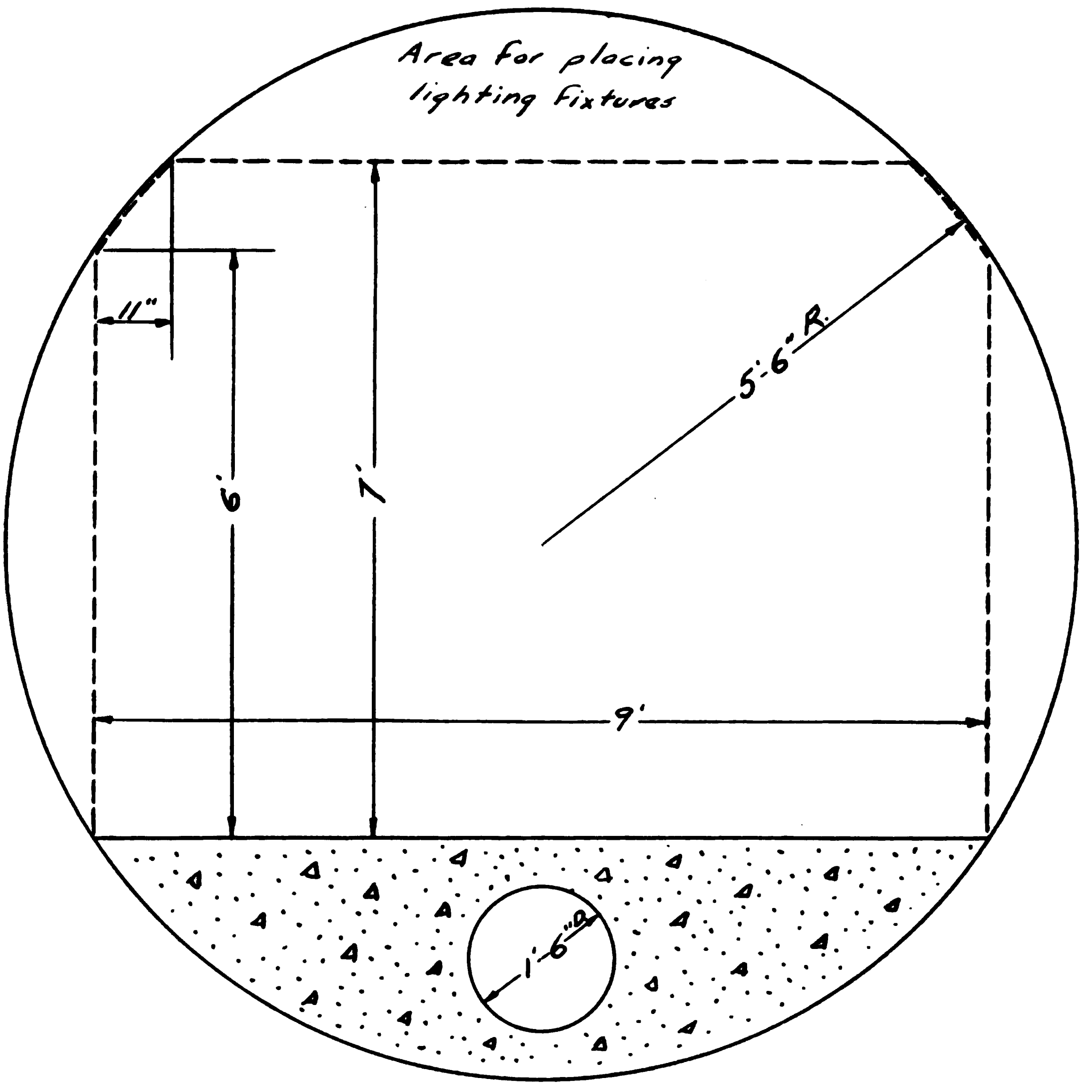
1. Dead load
2. Static super-load
3. Impact
4. Transverse earth pressures
5. Frost
6. Soft, uneven foundation

Finding the physical properties of any material is only a matter of referring to the numerous tables of data which are available. Little is known, however, of the behavior of tunnels or other closed conduits under a fill. What data is available merely allows for imperical design, a statement that under certain conditions a particular method has succeeded. The handbook to be used is the "Handbook of Culvert and Drainage Practise" offered by the Armco Drainage & Metal Products, Inc.

Final design data given here were obtained by deflection measurements on varying diameters of pipe, gages of plate, and height of fill. The final size plate must resist deflection properly and have a strong longitudinal seam in order to meet requirements. Figures given in design tables have allowed for a five percent deflection which is equal to a safety factor of approximately three for unstrutted structures.

Three controlling factors must be established before proceeding with the design. They are: diameter of pipe, loading, and minimum height of cover, in that order. The diameter of tunnel to be used is eleven feet or 132 inches. Loading to be used is highway H-20. From Table 30F, page 118F, for highway loading H-15 and H-20, round pipe with diameter greater than 120 inches, minimum cover is eighteen inches with a three inch cushion

DATA SHEET VIa



Dotted red line indicates the effective cross sectional area of the tunnel. The interior does not require finishing but if this is done it is along these lines that the finished surface should lie. Floor needs no reinforcing, the pipe being strong enough.

under the slab. However, since there is a water main in the street at a depth of four to five feet, the tunnel should be placed at a depth five feet below surface, amply meeting cover requirements.

From Table 26, page 98, seven gage steel is recommended for top and side plates using four - 3/4 inch bolts per foot of longitudinal seam for 132 inch diameter, H-20 loading, five foot cover. Minimum allowable gage for 121 inch to 150 inch diameters is number eight gage, so this is sufficient. From Table 26A, page 98A, section modulus required for the same conditions outlined above is .083 per inch. From Table I., page 5B, of the supplement, number seven gage steel in Tunnel Liner Plates has a section modulus of .0797 per inch and number five gage steel plate has a section modulus of .0918 per inch. Therefore, number five gage steel in Tunnel Liner Plates should be used. Bottom plates are designed to resist greater wear, so that the bottom plates should be of number three gage steel Tunnel Liner Plates. Also from Table 26A, page 98A, it may be seen that the longitudinal seam bolts must carry 8.3 kips per foot in shear. The 3/4 inch bolts will carry 25 kips with number five gage plates in shear and 28.5 kips with number three gage plates in shear. From this it may be assumed that the 3/4 inch bolts will be satisfactory.

The covering width of an Armco Tunnel Liner Plate is eighteen inches. This means that each ring of plates will add eighteen inches to the length of the tunnel. The covering lengths of the plates are 37-3/4 inches (12 π), 44 inches (14 π), and 50-1/4 inches (16 π). The 132 inch diameter will require 6 - 14 π plates and 3 - 16 π plates or a total of 9 plates to make a complete circle. The 3 - 16 π plates compose approximately 3/8 of the circumference. These three plates are enough to form what will be considered the bottom plates and should be of number three gage steel. Since these plates will weigh close to twenty pounds each more than the 14 π plates of number five gage steel, using them for the bottom plates will save considerable manual labor.

For a summary of the above:

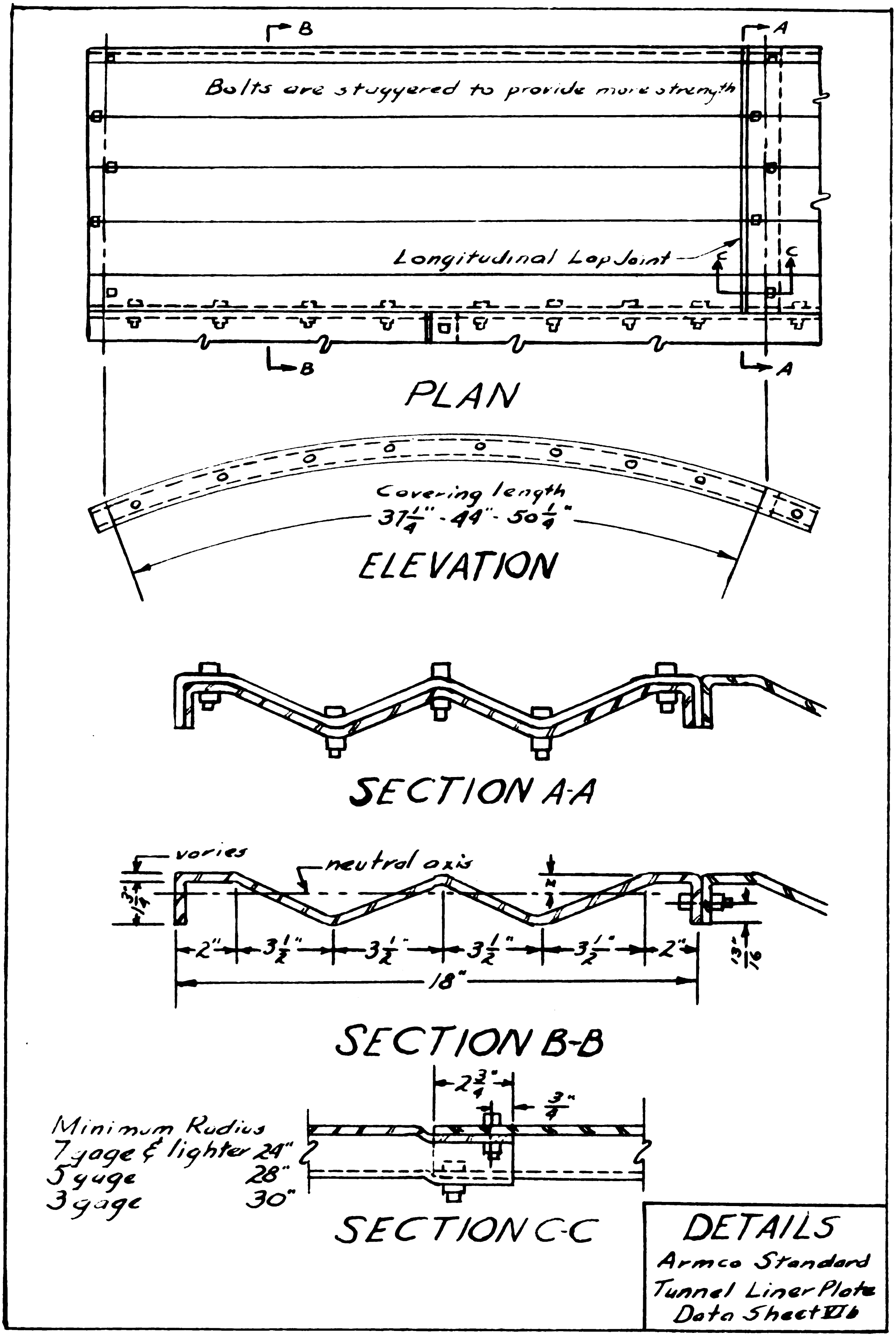
<u>USE</u> - per circle

Top and sides - 6 #5 gage Armco Tunnel Liner Plates

Bottom - 3 #3 gage Armco Tunnel Liner Plates

Gage	In.	Area SqIn	Section Modulus Per In.	Per Sec.	Radius of Gyration	X	Approx. Wt. 12 π	14 π	16 π
5	.2092	4.881	.0918	1.654	.614	.846	61	70	79
3	.2391	5.581	.1035	1.863	.614	.858	70	80	90

Neut. Axis Dia. Inches	Approx. O.D. Inches	Approx. I.D. Inches	Approx. Outside Area Sq. Ft.
132	129-1/4	133-1/4	96.8



B
A
Bolts are staggered to provide more strength
Longitudinal Lap Joint
C
PLAN
Covering length
37 1/4" - 44" - 50 1/4"
ELEVATION
SECTION A-A
varies
neutral axis
3 1/4"
2"
3 1/2"
3 1/2"
3 1/2"
3 1/2"
2"
18"
13/16"
SECTION B-B
2 3/4"
3/4"
Minimum Radius
7 gage & lighter 24"
5 gage 28"
3 gage 30"
SECTION C-C
DETAILS
Armco Standard
Tunnel Liner Plate
Data Sheet VIb

As to the appurtenances for the tunnel the following are necessary:

1. Stairway and approach ramp,
2. Interior lighting,
3. Drainage.

Both a stairway and approach ramp are suggested. The access to the tunnel at the northern extremity is limited by the store buildings and their basements. Therefore, a stairway is the only feasible means of access. The southern approach has quite a different aspect, there being no limit to the space that may be used. A ramp will drop slowly to the tunnel level and has several advantages. There is a natural reluctance on the part of the individual to use most pedestrian underpasses, the public reasoning that it would be quicker to hazard the vehicular traffic than to climb two flights of stairs in order to cross. There is less consciousness of ascending or descending with a ramp, so the tunnel will be more readily used and thus accepted. Also there is considerably less danger of tripping and falling on a ramp. Thus another source of accidents would be eliminated. See data sheet VIc for stairway details.

As may be seen from data sheet VIb there is a clearance of approximately one foot at the ceiling. This space may be used to receive standard lighting fixtures.

Also, there is a space of approximately two and one-half feet at the bottom of the tunnel which may be utilized for placing a drainage pipe. Grates placed at the entrance to the tunnel at the low points of the stairs and and the ramp will collect surface water which flows into the tunnel, conduct it through the collection pipe to a sump which will pump to the sewer nearby.

DATA SHEET VIc

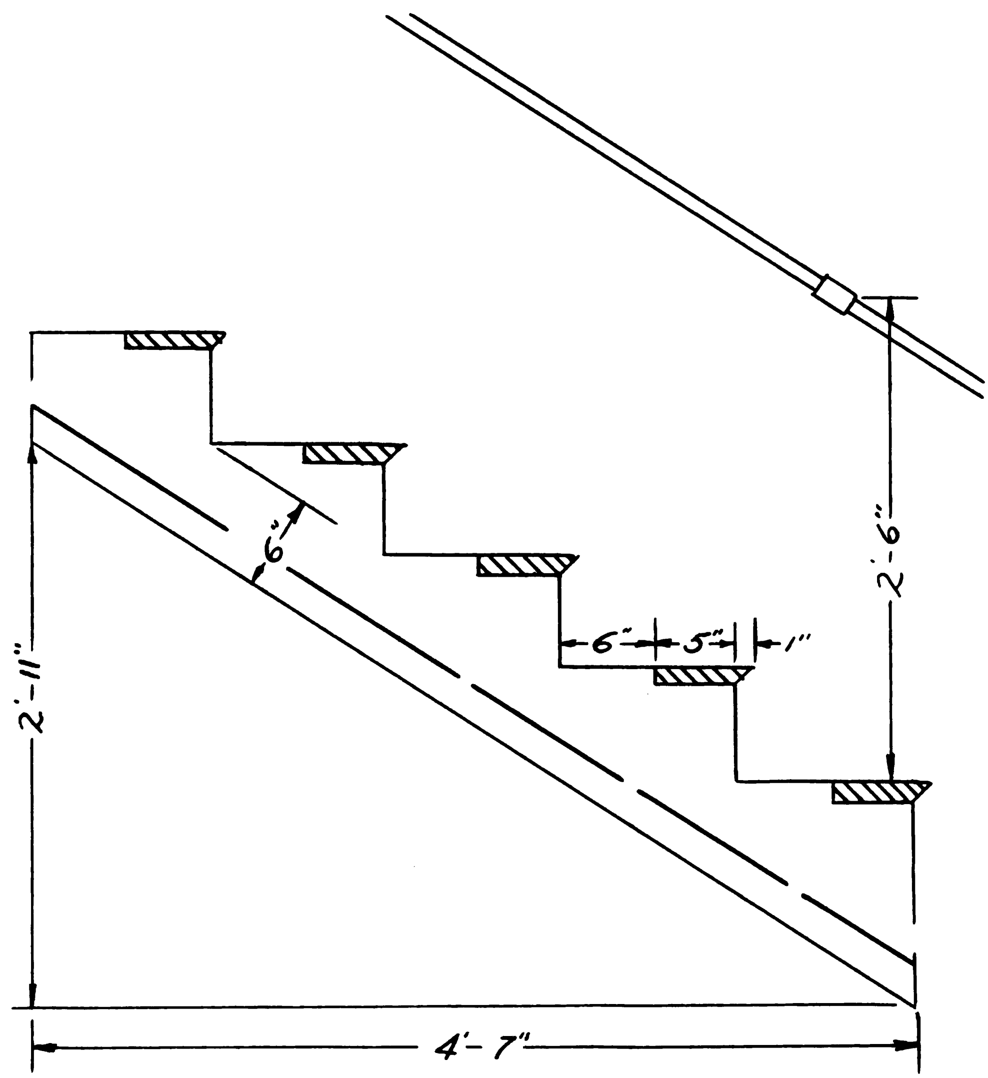
Steps - 11" Tread, 7" Riser, 6" Safety Tread, extending
to within 3" of each side

Height of Stairs = 5 ≠ 11 - 2-1/2 =- 13'-6" approximately

Requires approximately $\frac{13.5}{.583}$ = 23 steps

Length of Stairway = 11" • No. of steps = 253" = 21'-1"

Set metal safety treads in concrete to improve wearing qualities and decrease possibility of falling.



VII. Comparison of Costs

All the costs presented herein are based on a comparative cost, i.e.; the items which appear identically in each method of construction are not included. All costs are based on a one hundred foot length of tunnel. For a cross section of the conventional tunnel see data sheet VIIa. The total comparative costs are given in data sheets VIIb and VIIc. From this it can be seen that the method using Armco Tunnel Liner Plates costs approximately 2/3 as much. With all appurtenances the cost will be about 7/8 as much. Also, it may be seen that the total cost will be less than that of a traffic light.

Dimensions and design data for the conventional method of construction are taken from a thesis written by William N. Ryan in June, 1939.

DATA SHEET VIIa

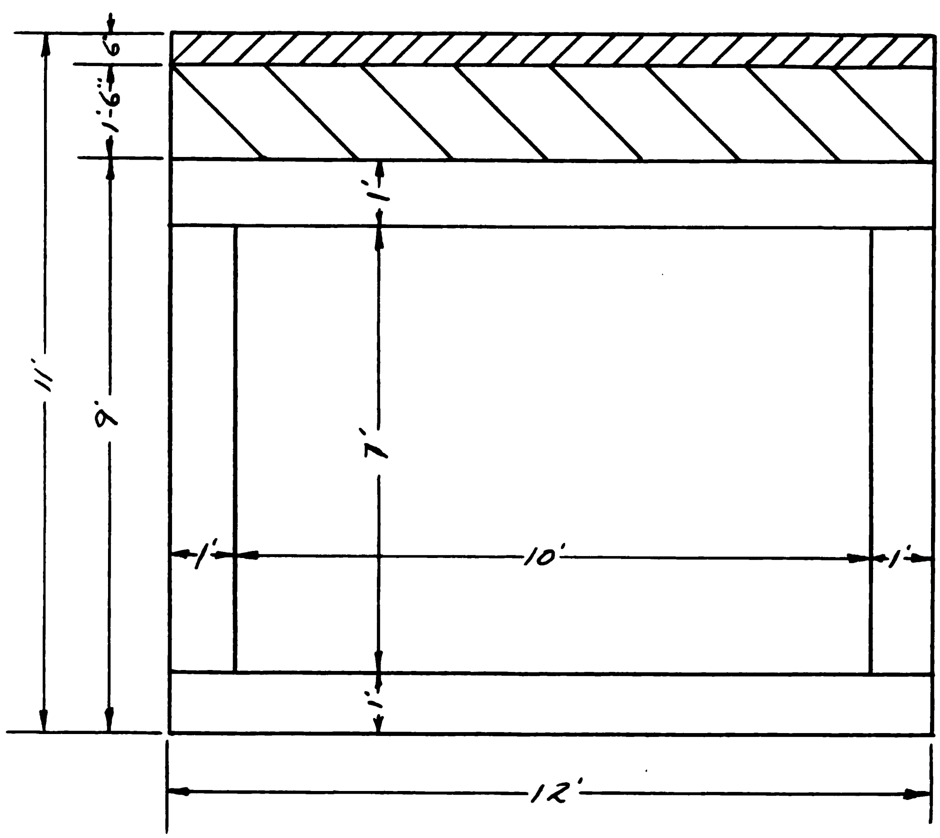
Cross Section of Conventional Tunnel

Reinforcing steel:

Ceiling - 7/8" ø bars, 4" ctr. to ctr. both ways

Walls - 3/8" ø bars, 4" ctr. to ctr.

Floor - 1" ø bars, 6" ctr. to ctr. both ways



DATA SHEET VIIb

Conventional Method of Construction	Quantity Results	Cost Results
Excavation		
allow 2 ft. on each side for forms		
$\frac{16 \cdot 11 \cdot 100}{27} =$	652 CuYds	
price per cu. yd. varies from \$0.40 to \$0.60 - considering the concrete pavement to be broken up use \$0.60		
652 • \$0.60 =		\$ 391.20
Formwork		
area		
2 • 9 • 100 = 1800 sq. ft.		
2 • 7 • 100 = 1400 " "		
10 • 100 = 1000 " "		
total area =	4200 SqFt	
all costs will average \$0.25 per sq. ft. of form surface		
cost = 4200 • \$0.25 =		\$ 1050.00
Steel Reinforcing		
ceiling - 7/8" ø bars 4" ctr - ctr both ways		
100 • 3 • 12 = 3600 ft.		
12 • 3 • 100 = 3600 "		
7/8" ø bars = 7200 ft.		
wt. 7/8" ø bars = 2.044#/lin. ft.		
7200 • 2.044 =	14716.8 #	
walls - 3/8"ø bars 4" ctr - ctr		
2 • 100 • 3 • 9 = 5400 ft.		
wt. 3/8" ø bars = 0.376#/lin. ft.		
5400 • 0.376 =	2030.4 #	
floor - 1" ø bars 6" ctr - ctr both ways		
2 • 12 • 100 = 2400 ft.		
2 • 100 • 12 = 2400 "		
1" ø bars = 4800 ft.		
wt. 1" ø bars = 2.670#/lim. ft.		
4800 • 2.670 =	3204.0 #	
total weight -	19951.2 #	

DATA SHEET VIIb (continued)

Steel Reinforcing - continued

	Quantity Results	Cost Results
assume \$0.07 per pound delivered on the job - \$0.03 per pound bending and placing		
total cost =	\$0.10/lb	
cost = 19951.2 · \$0.10 =		\$ 1995.12
Concrete		
$\frac{2 \cdot 1 \cdot 12 \cdot 100}{27} = 88.889$ cu. yds.		
$\frac{2 \cdot 2 \cdot 7 \cdot 100}{27} = 51.852$ " "		
total concrete =	140.741 CuYd	
assume \$10.00 per cu. yd. for concrete, \$5.00 per cu. yd. for placing and finishing =	\$15.00/CuYd	
cost = 140.741 · \$15.00 =		\$ 2111.02
Backfill		
2 · 2 · 10.5 · 100 = 4200 cu. ft.		
12 · 1.5 · 100 = 1800 " "		
total = 6000 cu. ft.		
cu. yds. =	222.22 CuYds	
assume sand @ \$2.00/yd		\$ 444.44
Replacing Surface		
street $\frac{20 \cdot 70}{9}$ =	155.6 SqYds	
sidewalk	3 SqYds	
assume street @ \$3.50/sq. yd.		
155.6 · \$3.50 =		\$ 544.60
assume sidewalk @ \$1.00/sq. yd.		\$ 3.00
Detour (See data sheet IVb, page 14)		\$34137.40
Total Cost		\$40690.78

DATA SHEET VIIc

Armco Tunnel Liner Plates	Quantity Results	Cost Results
Number of plates required		
each ring - 1.5 ft.		
$\frac{100}{1.5}$ = 67 rings = 100.5 ft.		
each ring - 6-14π plates		
3-16π plates		
14π plates are #5 gage steel		
16π plates are #3 gage steel		
67 • 6 =	402 14π	
67 . 3 =	201 16π	
Weight of plates		
402 14π plates, #5 gage, @ 70#/pl		
402 • 70 =	28140 #	
201 16π plates, #3 gage, @ 90#/pl		
201 • 90 =	18090 #	
total weight =	46230 #	
assume $0.50/lb. delivered on the job		
46230 • $0.50 =		$23115.00
Excavation		
volume = $\dfrac{\frac{\pi d^2}{4}\ 100}{27}$ =	351.68 CuYd	
Labor		
assume production approximately		
1.25 cu. yds./hr./man		
use 3 men		
time required = $\frac{351.68}{3.75}$ =	94 hrs.	
3 men to dig @ $1.50/hr. $4.50		
4 laborers to remove dirt, carry, and bolt plates @ $1.25/hr. $5.00		
1 foreman @ $2.00/hr. $2.00		
$11.50		
$11.50 • 94 hrs.=		$ 1081.00
assume $1.00/yd. to haul excavation		

Concrete	Quantity Results	Cost Results
2/3 · 9 · 2.5 · 100 =	55.56 CuYds	
assume cost $10.00 + $5.00 per cu. yd. placing		
55.56 · $15.00 =		$ 833.40
Total		$25381.08
Overhead and Machinery assume 10%		$ 2538.11
Total Cost		$27919.19

VIII. Conclusions and Suggestions

There are several conclusions which may be drawn from this paper. They do not deal so much with the particular problem as with the type of problem in general.

First, it may be seen that the design of any structure is interrelated with all the other factors involved in the problem, economic and physical. Second, it can be concluded that any problem requires individual solution. No general design is possible to fit every problem well. Third, the utilization of standard, mass produced material, such as Armco Standard Tunnel Liner Plates, can greatly reduce construction costs. Fourth, any interference with traffic, such as a detour, is an item to be considered and computed in cost analysis. In this case the cost of the detour makes the standard method more expensive than the method suggested.

Very little is known, as has been stated previously, concerning the reaction of closed conduits and tunnels under the weight of fill and super-load. If space and equipment were available at some future time this matter would warrant the time and effort given to it.

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