BEIRUT-DAMASCUS TURNPIKE, PART "B"

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SCHOOL OF ENGINEERING

PROJECT REPORT

AMERICAN UNIVERSITY OF BEIRUT

B E I R U T - D A M A S C U S T U R N P I K E

Part " B "

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Chapter I

INTRODUCTION.

The Chtoura-Damascus Highway forms the second stretch of the Beirut-Damascus Turnpike. Beginning at the exit of Dahr-el-Baidar Tunnel, it spans the Beka'a Valley crossing three main rivers and then cuts the Anti-Liban mountains with two tunnels of total length of 13.250 kms. and four main bridges. At times when the mountain side becomes too steep, its lanes divide up in two and then join again after the critical spot is passed.

Once constructed, this highway will not only be an important improvement to the comfort and speed of vehicles, but it will also have a marked effect on the economic situation in both Syria and Lebanon.

In this report, the engineering aspect of this project is considered and a study of its location and construction is made within the limits of data and maps available.

The drainage of such a highway is a very important consideration specially at some places where the conditions are very bad. At the places where the road was over a fill, precautions were taken not to let the water reach it from the subgrade and when it was in a cut, drains were provided to keep the water from reaching it from slopes and then carry the water that comes on it directly from the rain.

The conditions at the Beka'a where the water table is very high are discussed in detail, and in retaining walls, a new method to this country has been introduced, namely the Massey Precast Reinforced Concrete Cribbing method. Its advantages are discussed at length in this report.

In designing this highway, modern standards as to right of way, grade, alignment, curvature and super-elevation have been followed very closely to give best results of speed of traffic and comfort of users. It is only in few cases, that use was made of extreme values permissible.

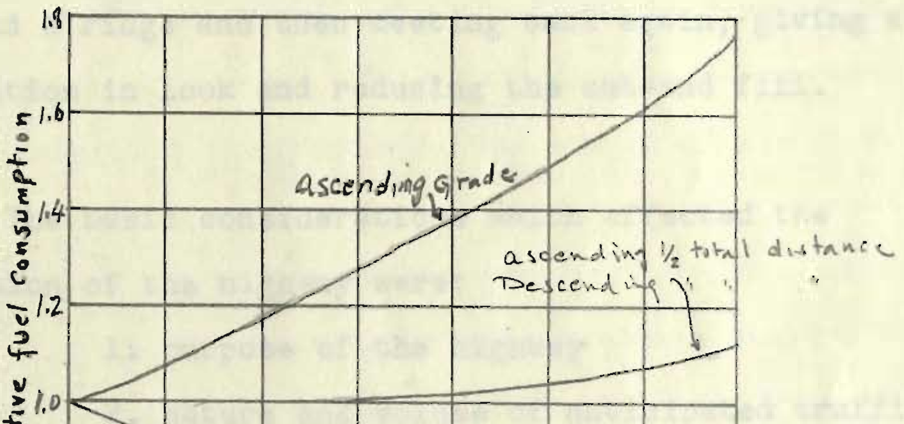
The type of pavement to use was the subject of a detailed study and the flexible type was deemed to be the best.

Chapter II

PRELIMINARY LOCATION SURVEY

Shtoura-Damascus highway was located by, first, joining the two terminii, the end of Dahr-El-Baidar tunnel and the beginning of the 40-meter boulevard of Damascus, with a straight line on a topographic map of a scale of 1/50,000 and 10-meter contour intervals. Then by inspection, the profile of this new road was found to be inconvenient because of the mountaineous region it passed through. A second and third route lines were drawn and kept as near as possible to the first line joining both terminii. Profiles of these routes were drawn and the best route location was selected, (as shown in the map), taking into consideration length, grade, curvature and cut-and-fill.

Tunnels were introduced shortening the distance by 7 Kms., reducing the grade to a maximum of 4 %. This means a lot of saving in fuel consumption (as shown in Fig.1), avoiding fogs which are too dangerous and annoying, reducing maintenance and eliminating all kinds of accidents due to bad alignment and



Relative fuel consumption
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
1
2
3
4
5
6
7
Per cent Grade
ascending Grade
ascending ½ total distance
Descending " "
Descending Grade

fig. 1

sight clearance.

In types "B & C" the one direction lanes are raised above the other lanes for the two cannot be carried on with the same elevation, thus reducing tremendously the cost of construction. Types "G & H", The two direction lanes were separated, each going around a ridge and then meeting back again, giving a variation in look and reducing the cut-and fill.

The basic considerations which affected the location of the highway were:

1. purpose of the highway
2. nature and volume of anticipated traffic
3. amount of fund available for construction

The purpose of Shtoura-Damascus international highway is to move the traffic between its terminii quickly and safely without any serious interruption. Entrance and exit to it is limited to Zahleh in Lebanon and Zabadani in Syria. Adjacent lands are not supposed to use it because they have their own auxilliary service roads.

This highway was designed for the use of both passenger and fright cars. The maximum grade was governed by the fright traffic and the curvature by the passenger's.

By no means this location survey is final and put to construction. Before starting construction the following surveys should be attempted:

1. reconnaissance of the whole area by plane, on a map with a scale of 1/2500 and 5-meter contour, or on an aerial photograph with the aid of stereoscope.

2. preliminary survey of the route lines selected after the reconnaissance surveys are completed.

3. location survey of the route adopted after a comparison and consideration of the lines over which preliminary surveys were run.

Only in type "A" preliminary survey should be omitted because of the flatness of the country. After the map reconnaissance and location were done a reach to the site, for a check on the topography and nature of soil was not possible. Such an investigation is recommended and could be done by a plane. Such a survey will reduce the cost of construction and add much to the success of the project.

Chapter III

DRAINAGE

The problem of drainage is divided into 3 parts:

1. cross-drainage
2. longitudinal or surface drainage
3. underdrainage

Drainage in general is very essential to road stability and permanence. In other words it could be said that highway is drainage. Surface water should be removed as quickly as possible so as not to introduce hazards to the traffic. The same thing is applicable to the sub-surface water for its presence in the sub-grade will reduce the bearing capacity of the soil and cause settlement and failure in both the rigid and non-rigid pavements. The existence of water near the surface of the earth or in the frost zone causes the up heave in the surface of the road.

Capillary action is another danger to road stability and should be eliminated . Water reaching the subgrade by capillarity finds its way through to the subbase, and no matter how well the subbase is rolled, channels will still be found to lead the water to the base course.

There it breaks the bond formed by both mechanical and chemical actions, and cracks will show off in the wearing course and extrusion will result from the deflection of pavement under moving vehicles. In time these craks will form patches and pits which will destroy the tyres and some parts of the vehicles and render the roadway uncomfortable for driving.

This chapter is confined to the study of drainage in the highway. It includes the study and estimation of the runoff reaching, calculation of water-shed areas for different places of culverts and for side ditches. The selection of types of structures are taken from Mr. S. Kuwatly who is working on the standardization of drainage structures in Syria and Lebanon. This chapter also includes the study of underdrainage in the highway, location and selection of standard underdrains, and retaining walls.

Bridges

Bridges are constructed to carry the roadway over the following rivers: El-Hafif, El-Djaher, Litani, Rhaziyel, Barada, El-Qaren, El-Baida and two others noted by B-8 and B-9.

The water-shed areas for these rivers are very difficult to locate on the map, due to the unknown underflow of melting ice and to the difficulty in reading the contours of the different mountains. Data for the following rivers are obtained from Point IV, Litani Project office, concerning the flow;

River	Max. flow M^3/sec.	Date 1952
Bardoni	10	March 13
Litani	17.5	March 7
Kzaiel	17.2	March 20

Bardoni joins the Litani before intersecting the designed highway thus making the total discharge of Litani at that place 27.5 M^3/sec. Kzaiel is given another name, so Rhaziyel flow will be 17.2 M^3/sec. The flows in the other rivers are all assumptions. Mr. Kaser, the responsible officer of Litani Project office, says that these values are by no means final and 100 % correct and are liable for alteration, because gauge stations were installed only last October. He also said that marks left by water ways indicate that only in 1940 the flow was greater.

Based on these data and allowing 20 % factor of safety for unexpected runoff, the following table is formed:

Name	Bridge No.	Discharge M cube/sec.	Slope %	Heights of embs. in M.	Waterway area in M sq.
El-Hafif	B-1	9	0.25	1.5	4.5
El-Djaher	B-2	9	0.25	1.5	4.5
Litani	B-3	33	0.10	1.5	16.5
Rhaziyel	B-4	21	0.15	1.5	10.5
Barada	B-5	18	0.25	1.5	9.0
----	B-8=B-1	-	-	-	4.5
----	B-9=B-5	-	-	-	9.0

For these calculations a velocity of 2 meters per sec. was assumed. For the following two rivers, El-Qaren and El-Baida, the water shed area was measured and by the help of "Harger" Page 1022, diagram 2, the following results are obtained:

Name	Bridge No.	Water shed area in sq.M.	Discharge M cube/sec.	Area in M.sq.
El-Qaren	B-6	3.9	14.2	7.1
El-Baidar	B-7	26.0	63.0	31.5

All are small span bridges except B-7

Culverts

Culverts are installed to carry surface water beneath the roadway. The axes of culverts are made in line with the direction of flow with the exception of very few which are called skew-culverts.

Water-way openings are taken from "Harger" page 191, table 49. The length of these culverts are made equal to the width of the embankment from shoulder to shoulder.

Culvert No.	Area in acres	Opening in Ft.	Opening in m.
1	6000	6 x 6	1.85 x 1.85
2	1100	6 x 6	1.85 x 1.85
3	600	6 x 6	1.85 x 1.85
4	120	4 x 4	1.25 x 1.25
5	900	6 x 6	1.85 x 1.85
6	Min.	2 x 2	0.65 x 0.65
7	200	4 x 4	1.25 x 1.25
8	1100	6 x 6	1.85 x 1.85
9-14	----	2 x 2	0.65 x 0.65
15	6000	6 x 6	1.85 x 1.85
16-42	----	2 x 2	0.65 x 0.65

Longitudinal Drainage

Intercepting ditches are established wherever ditches along the roadway are found. In such a case the runoff that comes from the mountain is intercepted there leaving the side ditches to carry only the water coming from the Right of Way area. By doing this the ditches could be as small as possible and have a low velocity which does not erode the sides. The section of the ditches are designed according to the flow and the slope. Discharge is found by taking 75 % of the rainfall of the area of 1/2 the total Right of Way. Assumed rainfall intensity is 100 mm/hr. Then the section will be tabulated as follows:

Type	R.W.in M.	Runoff M^3/hr.	Slope %	Section
A	60	---	---	None
B & C	35	1.00	5	
B'& C'		0.35	5	
D	--	---	---	---
E	45	1.65	5	
G	20	0.75	2	
H	20	---	---	---

Side ditches are constructed along the median strip and on the cut sides only. Relief culverts are installed at intervals of 100 meters.

Underdrains

Free water in subgrade occurs in either one of the following:

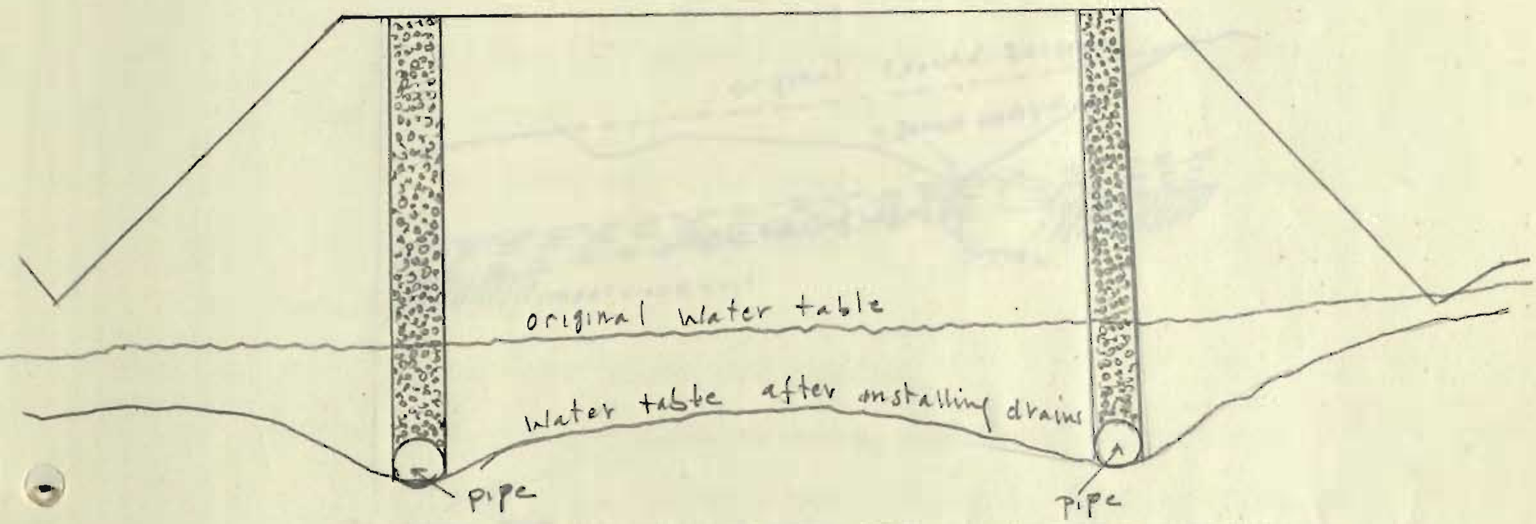
1. as a flow through a permeable soil overlying an inclined layer of impervious soil.

2. as storage water having a level water table.

In Beka'a type "A" where the water table is level and very near to the ground, two pipe drains of minimum diameter of 15 cms. are placed on both sides of the road in the embankment under the shoulders embedded in the coarse material used, for water follows the line of least resistance. The pipes are laid with a slope of minimum 0.5 % and relieved to the lowest ground at intervals of 100 meters.

Figure 8

A section showing the position of underdrains

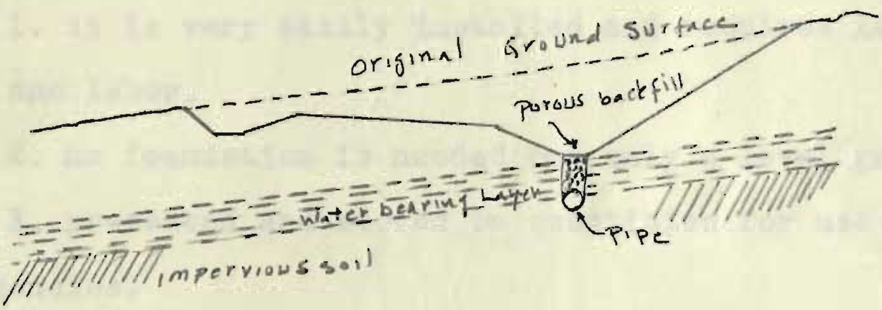


In the other part of type "A" no drain pipes are needed becuase the water table is very low and there is no fear of water rising by capillarity.

In type "B & C" on the cut side, the water seeps in aninclined porous layer over an impervious stratum. Pipe drain is installed under the ditch in the path of flowing water. The pipe extends into the impervious layer, and the trench above it is filled with coarse materials and sealed at the top by an impervious layer to prevent clogging caused by silt from the surface.

Figure 9

A section showing the position of underdrains.



In type "E" no underdrains are used. The ambankment is all rock and no water in any form is found except that of the surface which is drained very rapidly by the side ditches.

Type "H" is drained exactly in the same method like that of Beka'a type "A".

Retaining Walls

Retaining walls are structures used to hold the earth on the cut side from flowing into the roadway and/or to hold the embankment wherever the fill is very great, thus reducing the cost of fill specially in mountanious regions or in areas where the highway is crossing a depression.

Massey Reinforced Concrete Cribbing was introduced. This kind of retaining walls has proved to be better than the ordinary retaining walls now in use, for :

1. it is very easily installed and requires less time and labor.

2. no foundation is needed but only a level ground.

3. precasted and stored in quantities for use in emergencies.

4. no weep holes are needed.

5. units are free to move, no rigid connections.

6. its two point bearing insures against flexure failure.

7. It is cheaper.

With the help of figures 10 & 11 and table 1, the cost per meter run of both types is calculated.

Table I

Summary of Quantities

Item	Concrete 1:2:3		Reinforced steel	
	C.F.	M.C.	lbs.	Kgs.
Header A	1.8	0.053	11.25	5.11
Stretcher B	2.63	0.074	9.72	4.42
Stretcher C	2.53	0.072	9.72	4.42
Stretcher D	2.23	0.063	9.72	4.42
Stretcher E	1.48	0.042	9.72	4.42

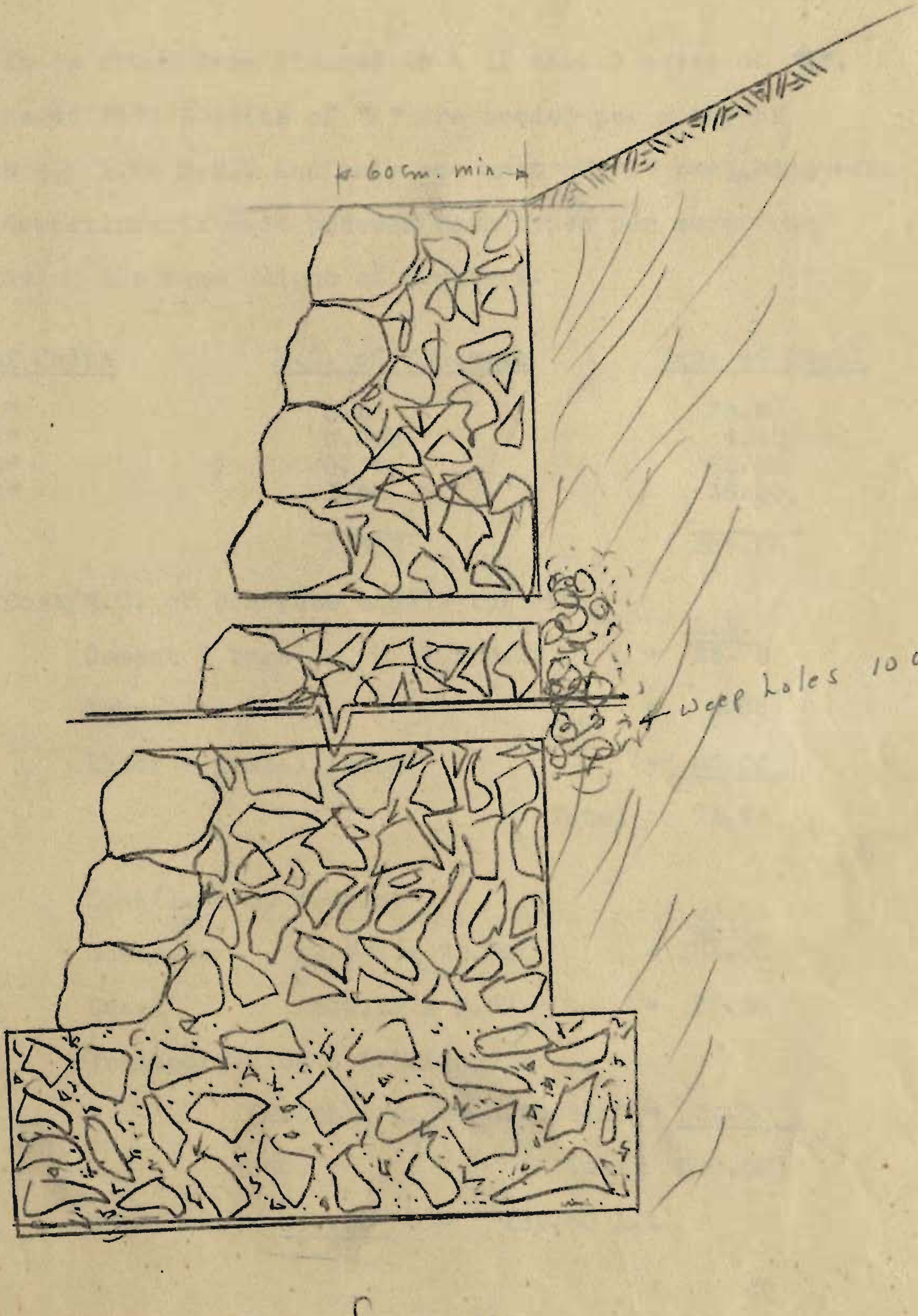


fig. 11

It is found from figures 10 & 11 that 3 units of "C", 3 units of "E", 3 units of "A" are needed per meter of height in 1.85 M.R., and only one unit of "D" per 1.85 m-run.

Comparison is made between both types per meter run and having the same height of 5 meters.

No. of Units	M.C. of Concrete	Kgs. of Steel
15 "A"	0.8	76.50
1 "D"	0.063	4.42
14 "E"	0.59	62.00
15 "C"	1.08	66.30
Total	2.533	209.22

Cost/M.C. of concrete equals to:

			L. L.
Cement 7 bags	7 x 3.25	=	22.75
Aggregate 1 M.C.		=	5.00
Labor & installation		=	45.00
		Total	72.75

Cost/1.85 m. equals:

			L. L.
Concrete	2.533 x 72.75	=	184.00
Steel	209.22 x 0.37	=	77.50
Transportation 6 L.L./ton			
	(2.533 x 2.5 + 0.2092)x6	=	39.00
		Total	300.50

$\therefore$ Cost/M.R. = $\frac{300.50}{1.85}$ = 162.50 L.L.

Cost/M.R. of Retaining wall

M.C. of rubble masonry	0.35 x 5	=	1.75
	0.5 x 5 x 1.5	=	3.75
	2.4 x 0.5	=	1.20
	Total		6.70

Sloping Face $= \sqrt{5^2 + 1.5^2} = 5.25$ m.

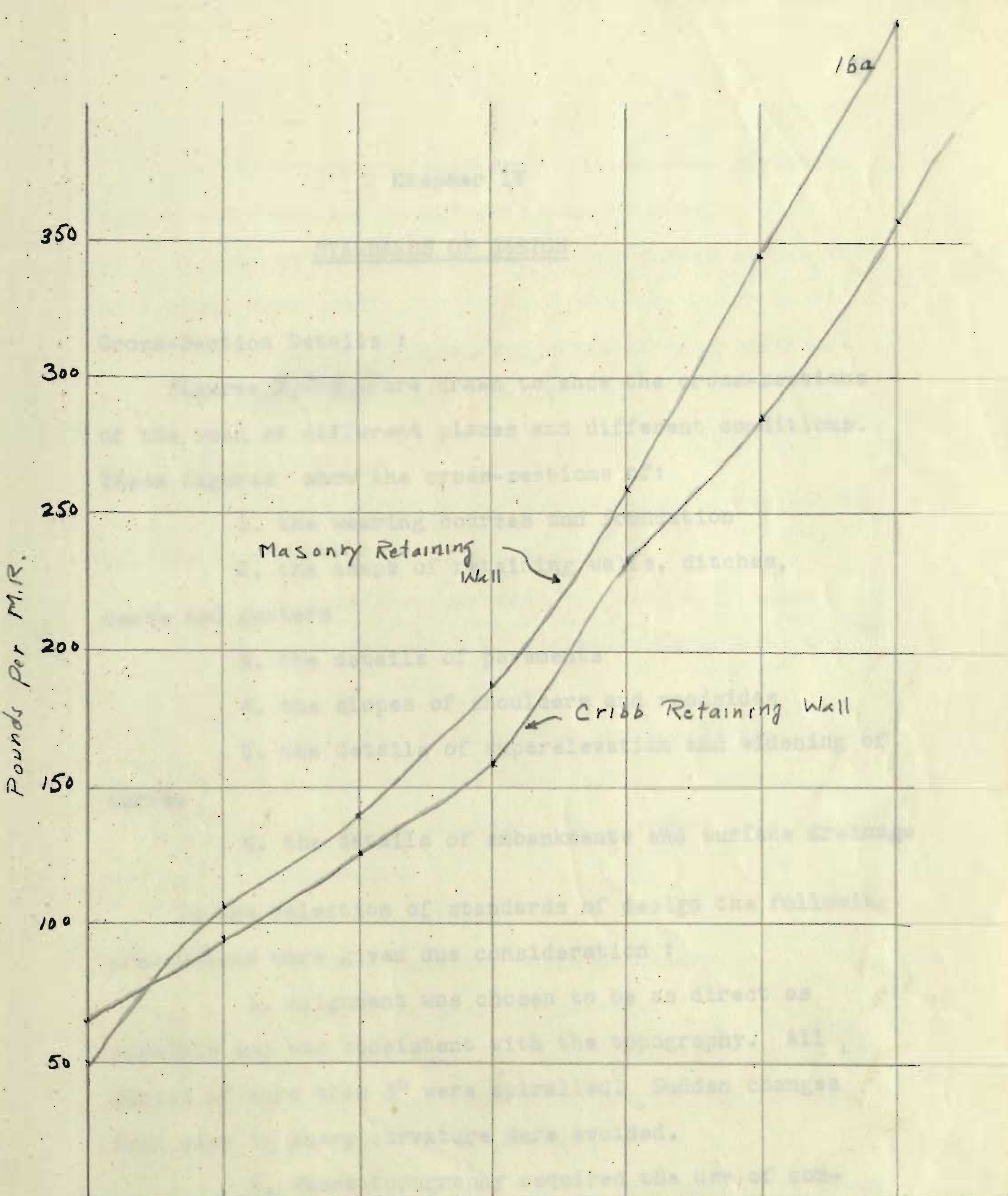
			L.L.
M.C. of debsh stone costs			3.00
Labor			8.00
Mortar 5 bags	$\frac{(5 \times 3.25) + 6}{3}$	=	7.50
	Total		18.50

Stone facing L.L. 14/M.S.

<u>Total cost/M.R.</u>

		L.L.
6.70 x 18.5	=	124.00
5.25 x 14	=	73.50
Total		197.50

Cost per meter run for different heights was calculated and a graph was drawn.



Cost Analysis

Chapter IV

STANDARDS OF DESIGN

Cross-Section Details :

Figures 2, 3, 4, -- are drawn to show the cross-sections of the road at different places and different conditions. These figures show the cross-sections of:

1. the wearing courses and foundation
2. the shape of retaining walls, ditches, curbs and gutters
3. the details of pavements
4. the slopes of shoulders and roadsides
5. the details of superelevation and widening of curves
6. the details of embankments and surface drainage

In the selection of standards of design the following precautions were given due consideration :

1. alignment was chosen to be as direct as possible and was consistent with the topography. All curves of more than 3° were spiralled. Sudden changes from easy to sharp curvature were avoided.

2. where topography required the use of compound curves, the difference in the length of radii was not to exceed half the length of the shorter.

3. broken curves, curves in the same direction with a short tangent in between, were avoided.

4. no compound curves, or any curves at the foot of a grade were used.

5. sudden changes from areas of easy curvature to area of sharp curvature were avoided.

Width of Right of Way

The width of right of way was selected sufficient to provide in general for:

a. a separated pavement of four 12-ft lanes

b. a median strip of variable width depending upon the topography (3.00 m.min.)

c. width for acceleration and deceleration lanes at points of access with the intersecting arteries.

d. two 3.0 m. shoulders for disabled cars and for the use in emergencies.

e. wide flat slopes.

f. service streets, where necessary.

g. size of ditches and gutters.

The Right of Way extended to the property line a bit behind the ditches, thus forbidding people from planting and obstructing the sight clearance.

The Right of Way of type "A" is 60 meters (as shown in fig.2). It provides an extra 3 m. unstabilized shoulder on both sides. At the intersection of Zahleh-Zabadani roads it is wider by 8 meters allowing for two acceleration and deceleration lanes of 350 meters length. At the crossings the R.W. is increased by 45 meters so as to give good alignment.

The Right of Way of types "B & C" is variable depending on the angle of repose of the earth but it is 35 m. minimum. (Fig.2)

The Right of Way of type "D" has been decided upon by Mr. Khabbaz.

The Right of Way of type "E" is 45 meters. (Fig.3) Type "F" Right of Way is 35 meters, same as types "B & C". Types "G & H" Right of Way is 20 meters.

Road Way Width

The Shtoura-Damascus highway consists of 4 traffic lanes, two in each direction.

4 lanes were preferred to two although they are more than needed now. When the volume of traffic exceeds 2000 cars per day, more than two lanes should be used; and since three lanes are not considered safe, 4 lanes are used. The theoratical capacity of a lane is calculated by the following equation :

$$N = \frac{5280\ V}{1.1V + 21}$$

N = the number of vehicles per hour

V = the speed of vehicles in miles per hour

1.1V + 21 = the clearance between the cars and the length of one car.

V = 60 mph, the design speed

This equation gives the throretical capacity of one lane which amounts approximately to 3000 cars per hour. Actual traffic surveys were done in the States in the most congested area and it was found that the practical capacity of a lane is 1500 passenger cars per hour and with 10 % of freight traffic it is reduced to 950 cars.

Due to the absence of data about the traffic between Shtoura and Damascus a 2000 cars per day was assumed. This assumption holds true for 15 years to come for nowadays in peak hours there are only 50-60 cars per hour which makes a total of 700-800 cars per day. (this figure is an approximation and on the safe side) The only justification for making it 4 lanes is its importance as an international highway.

The increase in consumption of fuel and more wear and tear due to interrupted traffic will disappear in the 4 lanes highway, but these savings won't equalize the extra 1st cost and depreciation. Another advantage is that more people would like to drive on it quickly and safely and avoid accidents; and by having more traffic the income of the road will increase.

Width of Lane

The minimum width of traffic lane depends upon the width of the vehicles and the clearance between two of them in motion.

The widest car is 2.45 meters; the minimum lateral clearance between moving cars is 0.90 m. The curb stone reduces the width of the pavement by 0.45 m., and, an allowance of 0.30 m. is given to primary highways; so the total width of the lane becomes 3.65 meters and that of the two one-direction lanes 7.25 meters.

Median or Dividing Strip:

The provision of median strip was found to be necessary for the separation of opposing traffic in adjacent lanes. Its function also is to reduce the effect of glare and to give a nice look to the highway. The minimum width of median strip is 1.85 m. and used in type "E" because in reducing the width of median in that area much money is saved because the cut there is done all in rock. The minimum width used there is 1.85 m. although 1.20 m. is enough for physical separation. No left or U-turns are allowed in all types except type "A" where the median strip is wide enough, i.e. equal to the width of the vehicle.

Median strip's width in type "A" is 7.5 m. of whcih 1.5 m. is a stabilized shoulder on each side. This width is necessary because left turns are permitted in this type so as to offer a good refuge for left turning vehicles and avoid the rear end type of accidents which is very common at crossings on highways. Openings in the median strip are limited to 7 meters to allow a passenger car to turn with a speed of 20 mph. Only two such openings are allowed in the whole highway. The 1st is at 2 Kms. before the entrance of the tunnel from Shtoura, and the second at 2 Kms. after the entrance to the Sahra f from Damascus. The reason of not making them too frequent is to control the kilometers covered by cars on the highway in order to facilitate the total payment. Only in median strip of type "A" trees are planted. And since the climate is not favorable except in Baka'a for trees to grow and their roots to reach down to the water, and other parts of the highway is arid during 6-8 months of the year, the other part is left to nature, green in winter and dry in summer. Evergreen trees as Poplar are planted in Beka'a median strip, Poplar roots go deep into the ground and do not spread more than 3-4 meters and so do the leaves. In this way the road bed would not be disturbed and enough sight clearance will still be available. In the Sahra, Poplar do not live; so a kind of tree called, in Arabic, "Miski" is planted. This tree lives mostly on the humidity of the air amd is watered once every two months.

In types "B,C,&F" the median strip is substituted by an elevation in the profile of the lanes. The minimum difference in hight of the longitudinal axes of the two opposite direction lanes is 1.40 m. which is the elevation of the driver's eyes from a point 10 cms. above the ground, so as to avoid the glare caused by cars in opposite directions. (Fig.2)

The distance between the end of the inside shoulders to the beginning of the other shoulders is variable depending on the angle of repose of the soil in that region and on the climate.

In types "G & H" the two direction lanes are separated each going alone. The median strip is in this case a ridge. By doing this the cost of excavation and filling is reduced too much. Instead of cutting in the mountains for a height of 20 meters on one side and filling the same height or more on the other end of the road to furnish a graded section of 30 meters, only a cut of 5 m. is needed and likewise a fill of 12-15 meters.(Fig.4)

Crown

Crown is needed to remove quickly the surface water from the pavement so as not to cause any hazard to the traffic. The normal crown decided upon is 10% from the longitudinal axis sloping towards the curb stone. This crown is consistent and carried the same all through.

Shoulders

Shoulders are provided on both sides of the road way. Each is 3 meters wide and made up of stabilized soil and left without pavement so as not to encourage drivers to drive on them. They have a slope of 5% towards the ditches . Such a slope is made to eliminate percolation of surface water and saturation of embankment. Shoulders of 3 meters are made so as to take disabled cars or allow for temporary parking and at the same time give a clearance of 60 cms. In type "A" an additional width of 1.75 m. is added to the shoulders without stabilization. This additional strip has no function but it adds rigidity to the embankment.

Curbs

Curb stones are provided all along both sides of pavements. They differ in height from 35 cms. in type "A" and the fill side of "B & C" to 15 cms. in type "E" where the subbase is rock. The height of curb stones is governed by the height of subbase, base course, and wearing course and an allowance of 2-3cms. of embedment in the subsoil to carry the horizontal thrust caused by rolling. In type "E", curbs might be dispensed with. Curb stones should be installed flush with the pavements, inclined to the outside and made mountable.

ALIGNMENT

Superelevation

On sharp curves, one-way uniforn banked ground to counteract the centrifugal force is used. This is called superelevation.

A well-banked curve reduces the tendency of cars to skid and increase comfort. Percentage of superelevation depends upon the radius and velocity and is calculated by the use of empirical formulae. Table below is taken from Civil Engineering, January 1953 and gives standards:

Radius in ft.	Radius in meters	Superelevation %
	300 - 500	5.0
	500 - 750	4.0
3200	1000	3.0
3500	1100	2.8
4000	1200	2.2
4500	1350	1.8
5000	1500	1.5
5500	1650	1.3
6000	1850	1.2
6500	2000	1.0
7000-10,000	2150-3000	1.0
Over 10,000	over 3000	None

Curves on Shtoura-Damascus highway are superelevated as follows:

Curve No.	Radius in meters	Superelevation %
1	1300	1.8
2	2300	1.0
3.	2000	1.0
4	Over 3000	None
5	2700	1.0
6	2000	1.0
7	1000	3.0
8	600	4.0
9	1200	2.2
10	Over 3000	None
11	500	5.0
12	500	5.0

A section through a typical superelevated curve is shown in figure 5.

Sight Distance

Sight distance, is the length of the road ahead of the vehicle which is visible to the driver. The minimum sight distance is the safe stopping distance of the vehicle travelling at the designed speed of 60 mph., and it is the sum of two distances; the distance travelled during the reaction time of the driver, and the brake stopping distance and is expressed as follows:

$$\text{Minimum sight distance} = 1.47\ Vt + \frac{V^2}{30\ f}$$

f = Coefficient of friction

Substituting V = 60 mph , sight distance = 475 ft = 145 m.

Horizontal Curves

The sight distance along any horizontal curve in general is determined by the approximate formula:

$$m = \frac{0.125\ S^2}{R}$$

m = the distance from the center line of the road way to the obstruction

R = the radius of the curve of the center line of the road way

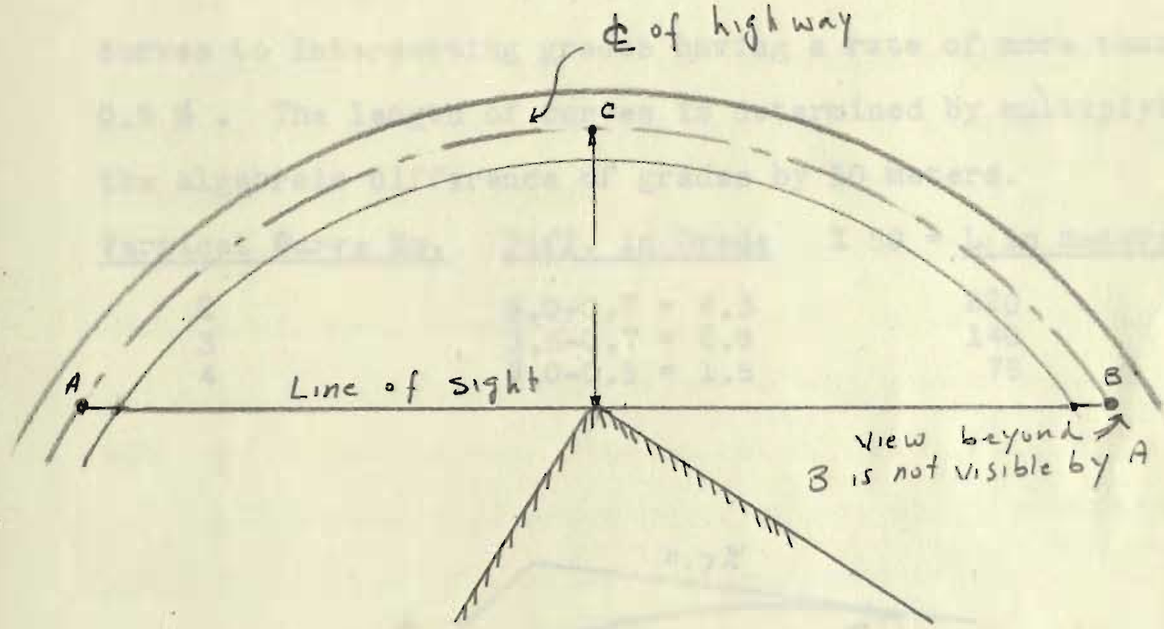
S = the sight distance along the center line of the road way (as shown in Fig.6)

This formula is based on the aaumption that the arc distance ACB is equal to the sum of the chord lengths AC and CB.

Sight distances of the horizontal curves of Shtoura-Damascus highway cannot be calculated due to the unknown topography and lack of accuracy in the map.

Grades

Maximum grade of 5% was used only for a distance of 2.5 Kms. at the entrance of the first tunnel from Damascus. The minimum grade of 0.4 % was used in type "A" at Beka'a to allow for underdrainage.



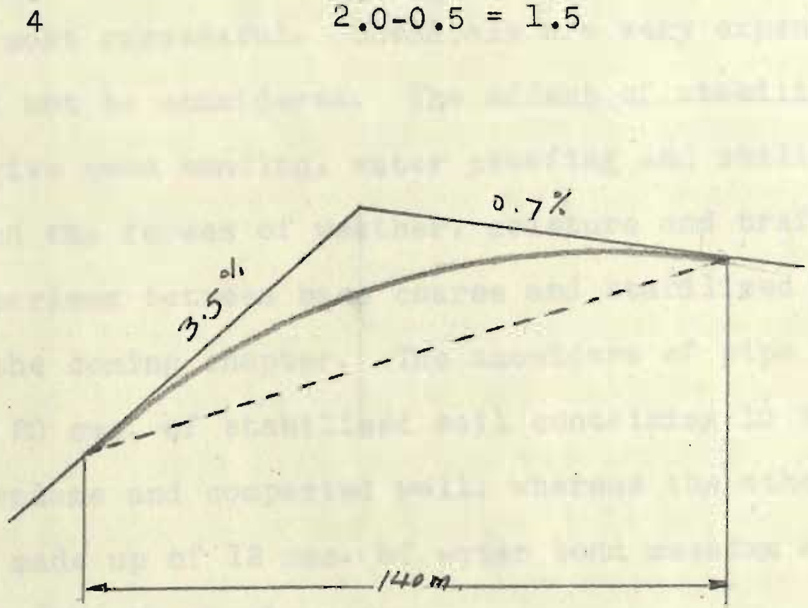
Sight dist. along the roadway on a horizontal curve

fig. 6

Vertical Curves

Comfort and safety require the use of vertical curves to intersecting grades having a rate of more than 0.5 % . The length of curves is determined by multiplying the algebraic difference of grades by 50 meters.

Vertical Curve No.	Diff. in Grade	X 50 = L in meters
2	5.0-0.7 = 4.3	220
3	3.5-0.7 = 2.8	140
4	2.0-0.5 = 1.5	75



Curve No 3

fig 7

Widening of pavements and curves is not needed because the shortest radius of curvature is 500 meters.

Chapter V

EMBANKMENT

Embankments are constructed to transmit the live loads to the subgrade, and are designed to prevent any settlement in the roadway.

Soil stabilization of embankment is done in several methods of which cement-soil has proved to be the cheapest and most successful. Chemicals are very expensive and will not be considered. The effect of stabilization is to give good bonding, water proofing and ability to withstand the forces of weather, moisture and traffic. The comparison between base coarse and stabilized base follows in the coming chapter. The shoulders of pipe "A" & "H" are 20 cms. of stabilized soil containing 10 % of cement by volume and compacted well, whereas the other shoulders are made up of 12 cms. of water bond macadam and spread with asphalt at the top.

On cut and fill slopes and on stabilized shoulders, Bermuda grass is planted to prevent erosion. This grass has proved to be the best of its kind to fit this locality and climate.

Soil samples from the Beka'a were tested in Batch Hall by Mr. F. Kandalaft and showed that the constituent are 17 % sand, 57 % silt and 26 % clay with a specific gravity of 2.7.

From experience and from the angle of repose of this soil, which is one of the worst type of soils, it was found that a slope of 2:1 for the embankment is sufficient but to encourage the growth of vegetation a minimum slope of 4:1 was specified.

Embankment in Beka'a type "A" is the only dangerous one and needs special study and tests. The width at the bottom where it is in contact with the ground is 38 m. as shown in figure 3. Such a soil has a high capillarity so a coarse layer of finely crushed stones and sand mixed together 45 cms. thick is laid first on the ground and in which the two underdrains are embedded as shown in Figure 12. This layer reduces the capillary action of water flowing in it for water will follow the lines of least resistance and flow through the pipes and drain to the sides. A 50 cms. of existing soil is brought from the sides of the highway and added on top. This new layer is compacted up to 88-95 % with an optimum moisture content of 17 % to attain the maximum possible density. Capillarity now is reduced to a minimum, and there is no fear of future settlement. Then another layer of 30 cms. of sand or granular soil, taken from the mountain near by, is spread over to prevent saturation of the subgrade soil in contact with the subbase. Then over this, the subbase, base coarse and wearing coarse are laid. This will total up to a height of 1.75 m. from the ground to the top of the wearing coarse.

In type "B&C" the embankment is made from the materials of cuts. Notches are dug on steep side fills to hold the earth from sliding.

In type "E" the embankment is solid rock and nothing is added except a 7.5 cms. layer of wearing coarse.

The embankment of type "G" is the same like that of type "B&C".

The embankment of type "H" is the same like that of type "A" but masonry retaining walls are erected on both sides to hold it from being washed away by the running water on both sides.

In general, embankments are made to keep the water away as far as possible, preserve the subgrade from saturation and furnish a smooth roadway surface comfortable for driving.

Chapter VI

FLEXIBLE PAVEMENT

The flexible type of pavement is used on Shtoura-Damascus Highway because of the following advantages over the rigid one:

1. it is flexible and not affected by slight deflection due to the movement of heavily loaded trucks.
2. less labor is involved.
3. no joints are needed.
4. no corner breaks
5. no warping due to internal stresses or blow ups.
6. no faultings and pumping failures.
7. reduction of transmitted pressure is effected through lateral distribution of the concentrated load with depth and not by beam action.
8. no snow but only frost
9. if well constructed it lasts for 25 years which is enough to secure good service for the life of the highway bonds.
10. it is much cheaper.

Thickness of slab ranges between 15-40 cms. and 3.4 kgs./M.S. of steel reinforcement is used. Transportation is the same for both types. The subbase is also the same but the base coarse is omitted in the rigid one. 1:2:4 concrete is used. A 20 cms. slab and 3 kgs. per meter superficial are assumed for cost analysis, and comparison of costs is made.

Cost/M.S. of rigid pavement		L.L.
0.2 M.C. of concrete costs	$\frac{6x3.25+6}{5}$	= 5.10
3 kgs. of steel	" 3 x 0.37	= 1.11
	Total	6.11

Cost/M.S. of flexible pavement

Assume 6 cms. of wearing coarse, 12 cms. of base coarse and 30 cms, of subbase.

Costs as given by the Ministry of Public Works are:

	L.L./M.C.
Subbase (Blockage)	3.00
Macadam	4.25
Rolling	3.00

Wearing coarse 3 cms. thick 1.5/M.S.

	L.L./M.S.
Wearing coarse 6 cms. costs	3.00
Base coarse	0.50
Rolling	0.25
Total	3.75

Cost of labor, if added to the rigid type, will raise it to 7.25. This rise includes a difference in cost of cement in Syria which is 75 piasters per bag.

Therefore, the total cost of rigid pavement will be twice as much as that of the other.

A comparison between subbase + base coarse and stabilized base is made as follows.

As cement soil stabilization has proved to be the most economical in addition to its successful results, it is taken as standard for comparison. 10% by volume of cement is used and 20-30 cms. of thickness; subbase(blockage) is 25-30 cms. thick of local crushed stones;for base coarse a 12 cms. thickness is used.

A square meter of stabilized soil consists of 0.2 M.C. of soil plus cement, which needs 0.5 bag of cement.

0.5 x 3.25 = L.L. 1.63 . To this 75 piasters is added for mixing and rolling totalling up to 2.38 L.L.

0.25 cm. of blockage costs	0.75
0.12 m. of base coarse costs	0.32
Rolling	0.81
L.L.	1.88

∴ the use of subbase and base course is still cheaper on condition that the subbase is laid properly, the wide base at the bottom and the pointed facing the top; so that under rolling the spaces at the top will be filled with crushed materials and make a good seal: the bottom of stones will be in good contact with the subgrade and transmit the concentrated loads on wider areas.

Design of Flexible Pavement.

Flexible pavement consists of subgrade, subbase, base coarse and wearing course.

The subgrade is the natural soil on which the pavement is to be built.

The subbase are used where indicated to provide proper drainage, prevent damage due to frost action, provide intrusion of the subgrade, and increase the support of the pavement.

Base course is used to distribute the loads to the subbase, to resist shearing failure and to prevent consolidation under traffic.

The bituminous wearing course is used to furnish protection to the bases used. It is a Dense Graded Hot Mix surface and very well designed and compacted and practically impervious and possesses a high degree of structural strength.

The design of flexible pavement is done emperically due to lack of methods by which the bearing capacity of subgrade soil is determined.

The following thicknesses are chosen paying due consideration to low temperature and high rainfall where the thickness of pavement is greater to fight against frost action' depth of water table to prevent water from rising by capillarity to the base course and wearing course, surface and subsurface conditions, and finally the amount of traffic anticipated.

A Dense-Graded Hot Mix of 7.5 cm. thickness is used as a wearing course all through the highway.

This wearing course must contain from 4-7 % by weight bitumen and the limits for grading as follows:

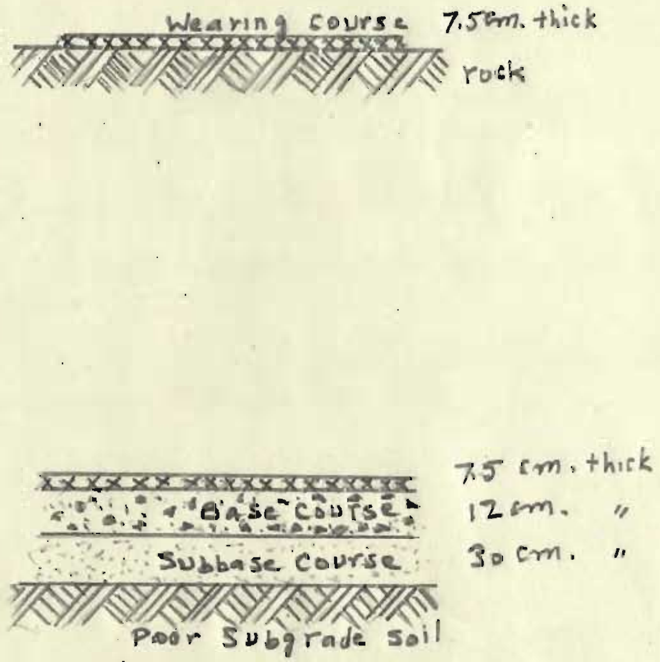
Passing 25.4 mm. sieve	100 %
Passing No. 4.76 sieve	50-70 %
Passing No. 2.00 sieve	35-60 %
Passing No. 0.42 sieve	20-40 %
Passing NO. 0.074 sieve	5-14 %

This design is made to take a 12 tons axle load although a 16 tons axle load might pass over it but very frequently.

A 12 cms. of macadam base of local crushed stone average 5 cms. in diameter is used in all the highway except in type "E" where a base course is not needed.

A subbase of 30 cms. thickness is used in Beka'a type "A". The average base is 18 cms. and placed flat bottom in contact with the subgrade.

In type "B&C" a thickness of 25 cms. is used. In type "E" no subbase is used. In "F & G" the thickness is 25 cms. and 30 cms. in type "H".



Relative position of pavement components.

Fig. 13

On curves No.1,7,8,9,11 and 12 where the radius of curvature is less than 200 meters, a 10 cms. wearing course is used. This is due to the torsional stresses caused by wheel loads going at full speed on the curve.

R E F E R E N C E S

1. Highway Engineering Handbook - Harger & Bonney

2. Highway Engineering - Bateman

3. Principles of Highway Construction - Public Roads Administration Federal Works Agency, June 1943

4. Manual of Highway Construction Practices & Methods American Association of State Highway Officials.

5. Civil Engineering Magazine, January 1952.

6. Compaction of Embankments, Subgrades & Bases, Highway Research Board, Bulletin 58

7. A Summary Report on Soil Stabilization, R. C. Mainfort Airport Division, Report No. 136

8. Theory and Practice of Highway Improvement and Utilization in the United States of America - 1952 - Bureau of Public Roads, Department of Commerce.

9. Railroad Construction, Webb

10. Construction of Roads and Pavements, Agg

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APPENDIX

The practicing engineers in charge of the Beirut-Damascus turnpike held a preliminary meeting on Tuesday May 5 to discuss the general financial patterns of their project. All unit prices were analysed and final figures were set as follows:-

	Unit cost per meter run
6 - Lane portion of road (Beirut-Bekaa')	1000,00 LL.
4 - Lane portion of road (Beirut-Bekaa')	700,00 LL.
4 - Lane bridge	10000,00 LL.
4 - Lane tunnels	5000,00 LL.
4 - Lane portion of road (Bekaa'-Damascus)	475,00 LL.

These costs are average figures and include drainage structures, retaining walls, cost of expropriation, and all other standard items which the road design requires. They do not include engineering costs and other incidental items. These unit prices were arrived at after a careful breakdown (Analysis) of the assumed figures and are comparable to other similar projects' costs. However, no exact prices can be specified for many undeterminable factors are involved.

The total cost of the project based on the assumed costs is as follows:-

Item	Unit cost in L.L.	Quantity K.M.	Total cost in L.L.
6 - Lane portion (Hazmieh-Jamhour)	1000,00	5,5	5500000
4 - Lane portion (Jamhour-Ras-el-Harf	700,00	10.3	7210000
4 - Lane bridge at exit of first tunnel	10000,00	0.2	2000000
4 - Lane tunnels (Khabbaz)	5000,00	14.2	71000000
4 - Lane road (Bekaa' - Damascus	475,90	42.5	20200000
4 - Lane tunnels (Shabhar)	5000,00	13.25	66300000
	TOTAL	L.L.	172210000

Engineering costs are estimated as being 10% of the total cost.

On the final meeting of practicing engineers Balabanian, Khabbaz, Khuri and Shabhar, which was held on May the 7 th., the financial study was given a final consideration and the following decisions were unanimously arrived at: -

1 - The constructions of the projected highway be a completely mechanized process. This will definetely cut down the total cost of the project.

2 - The total assumed cost of 190000000 L.L. renders the project unjustifiable economically with the present traffic intensity.

3 - Dependable and extensive traffic surveys are necessary before issuing a final tolling scheme.

Since the assumed tunneling costs render the project unfeasible, the practicing engineers find it necessary that they consult a tunneling specialist before arriving at a final decision. A revision of the tunneling costs by a consultant would clarify the pending economic problem further and put more light on the possibility of a more economical relocation.

The practicing engineers recommend the following schematic procedure to arrive at a satisfactory result.

1 - That the 5.5 kms. 6 - Lane portion of the proposed highway between Hazmieh and Jamhour be constructed at the expense of the Lebanese Public Works Department and supervised and maintained by the highway authority. Since is justifiable due to the fact that this portion will be mainly used by summer resorts bound traffic such as Aley, Bhamdoun and adjoining areas.

2 - That the project be extended and carried out as a Pan-Arabian International Highway System where the

Tunneling expenses of the projected road will be shared by all concerned countries.

3 - The tolling system be directly charged on the basis of kilometers covered by the vehicular traffic on the highway. Electronic and mechanical devices will be utilized to register the number of vehicles that enter and leave the highway at each access point.

4 - A bond issue of 190,000,000 L.L. will be floated as follows:-

a - 100000000 L.L. worth of stock will be issued by the highway authority as collateral paper and floated as series "A" bonds. These bonds will be sold to banking agencies and will received a guaranteed fixed interest of 3%. These bonds will mature in x 30 years from the start of the highway's operation. This series will have priority until retirement against net refenues. If at any instant the acquired net revenues do not cover the service charges of this series the concerned states should make up the deficit from their national treasuries, or other national incomes since the project is a source of wealth to the concerned nations.

b - 90000000 L.L. worth of stock will be issued by the highway authority and floated as series "B" bonds. These bonds will be sold to the concerned states, private concerns, and individuals who wish to participate in the project. These bonds will participate in the returns of the project similar but subordinate to series "A" provided the net income is more than what is required to cover the series "A" service charges.

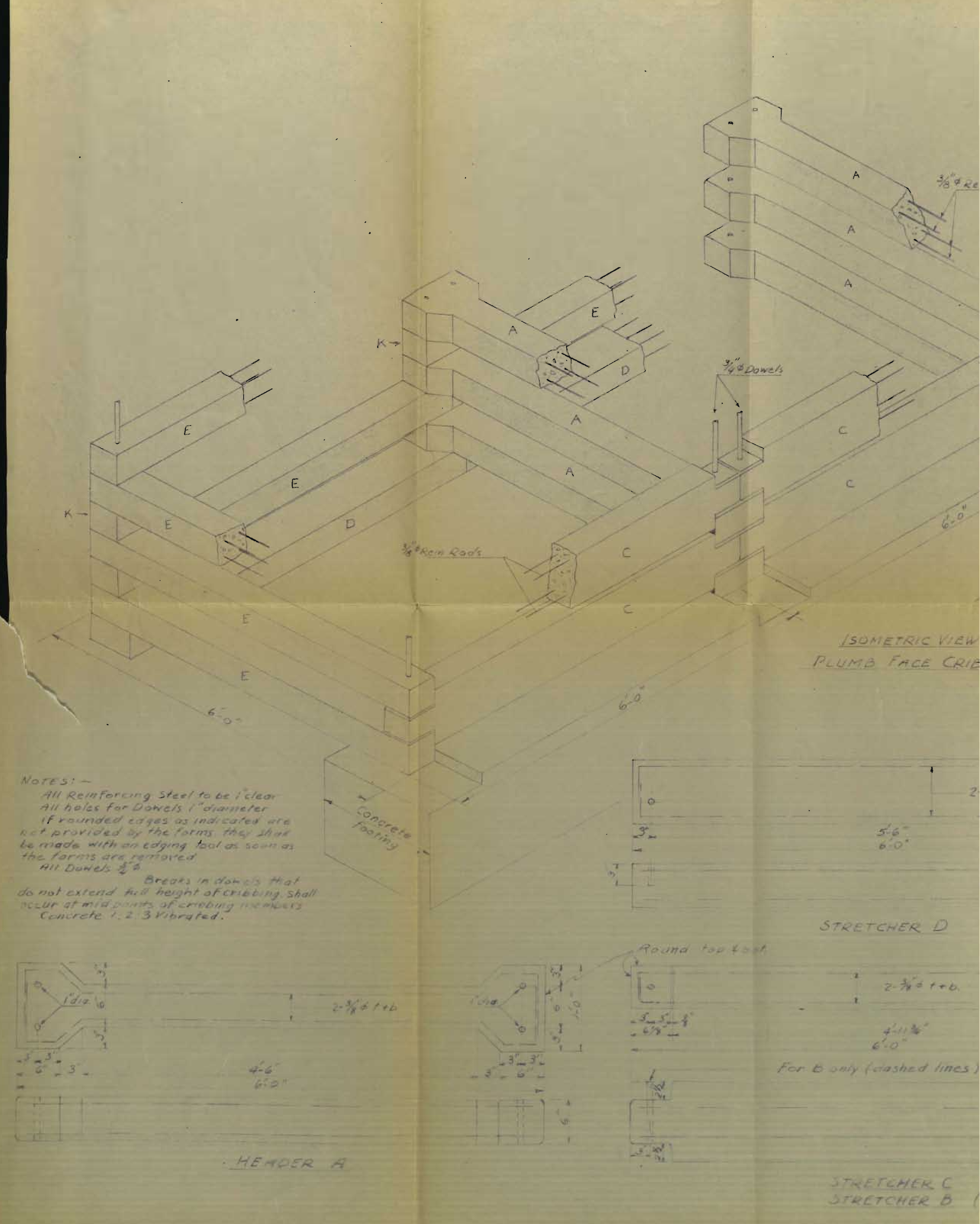
In case the returns are insufficient all x income will be applied against the series "A", the deficit should be made up by the concerned states. However, if the returns exceed the total expenditures and requirements of the project, the surplus would proportionally be distributed between the concerned states and partly applied against the "A" series bonds expecting their retirement.

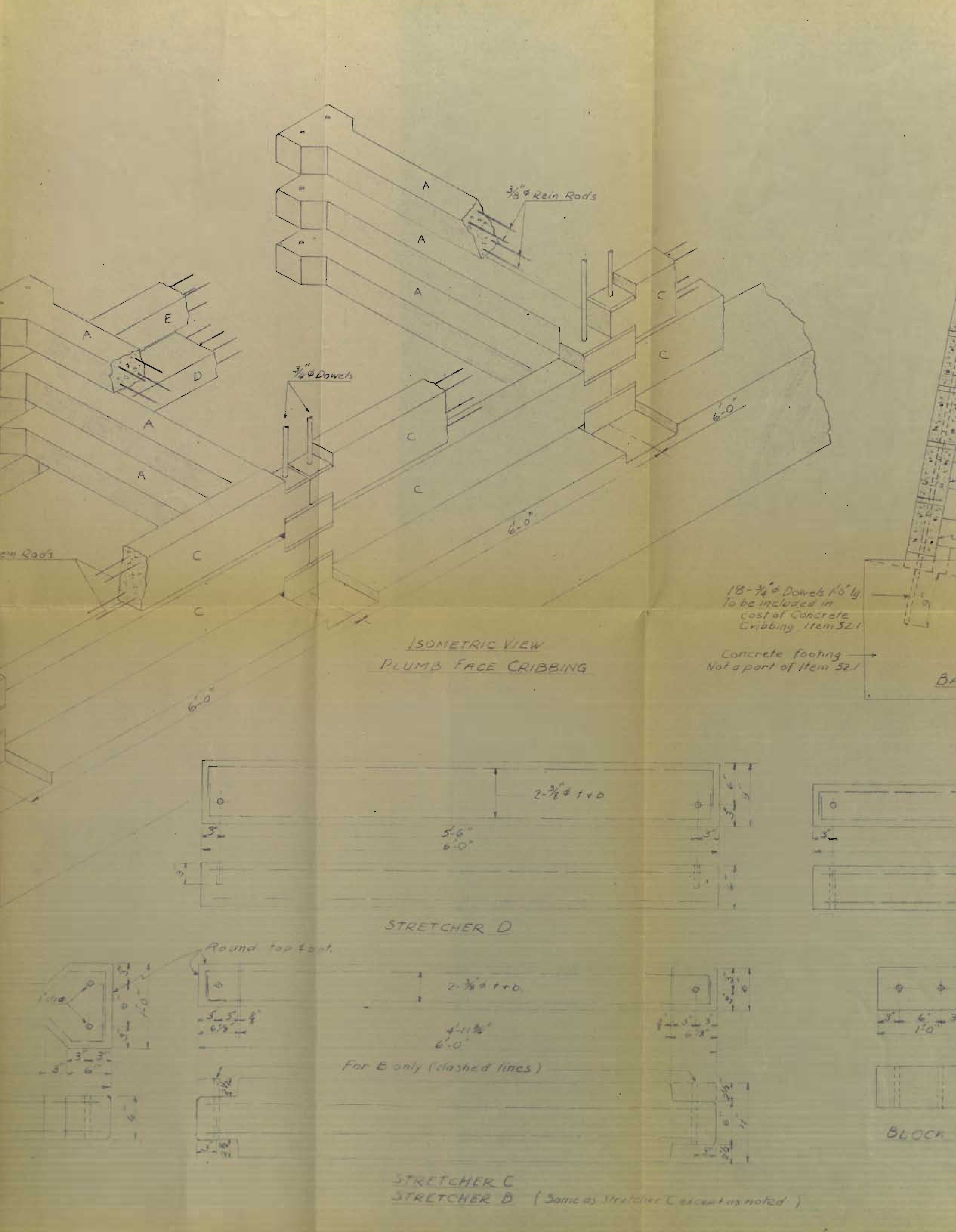
5 - An equivalent of 10000 Beirut- Damascuss vehicular movements have to be achieved daily in order to make the project economically feasible. This is based on the 190,000,000, L.L . cost.

6 - The average daily traffic of 10,000 Beirut-Damascusx movements or their equivalent is based on a break - even yearly budget of 15,000,000 L.L. This budget's breakdown is as follows:-

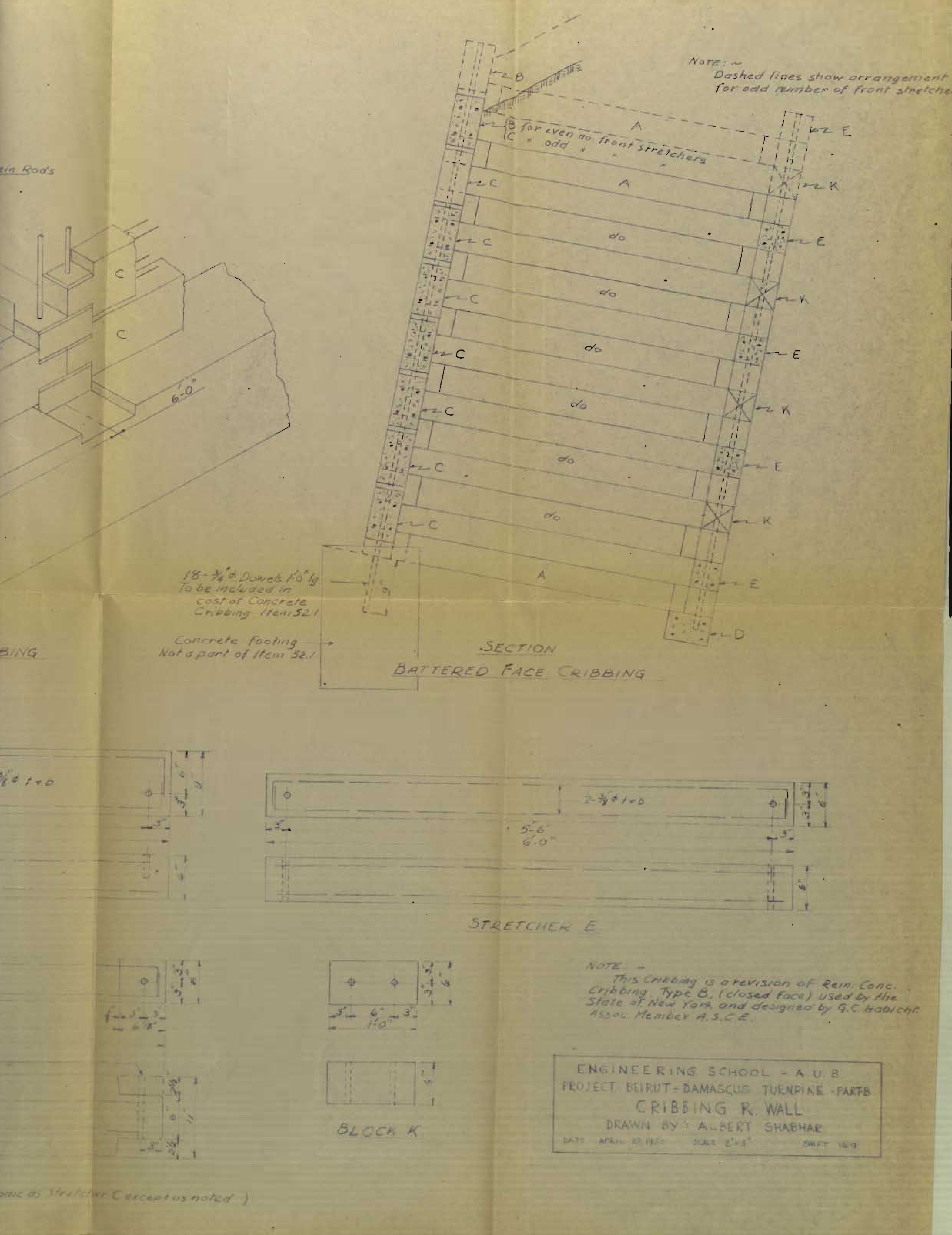
ITEM	Cost in L.L.
Yearly depreciation for 30 years (sinking - fund)	2,800,000
Fixed interest on 100,000,000 L.L. bonds at 3%	3,000,000
Interest on 90,000,000 L.L. shares at 6%	5,400,000
Maintenance and other incidental expenses (2% of total capital)	3,800,000
TOTAL	15,000,000

All the estimates are subject to variations since they are very rough ones based on factors many of which are undeterminable. The suggestions do not recommend any particular administrative set up since this require much more extensive studies that fall outside the scope of this report. In this connection and other corporate matters, useful information is obtainable through studies of the organizational patterns of similar projects which have been executed such as the New Gersey turnpike, and the Pennsylvania Turnpike.

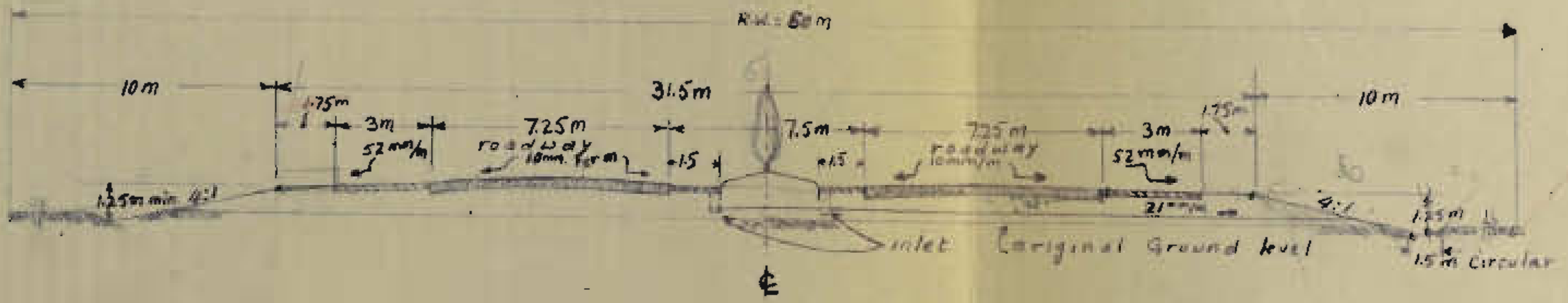

ISOMETRIC VIEW
PLUMB FACE CRIB
A
A
A
E
E
E
E
E
E
D
D
C
C
C
K →
K →
3/8" ⌀ Re
3/4" ⌀ Dowels
3/8" ⌀ Rein Rods
6'-0"
6'-0"
6'-0"
Concrete footing
NOTES: —
All Reinforcing Steel to be 1" clear
All holes for Dowels 1" diameter
If rounded edges as indicated are not provided by the forms they shall be made with an edging tool as soon as the forms are removed.
All Dowels 3/4" ⌀
Breaks in dowels that do not extend full height of cribbing shall occur at mid points of cribbing members
Concrete 1:2:3 Vibrated.
1" dia
2-3/8" ⌀ t+b
4'-6"
6'-0"
HEADER A
5'-6"
6'-0"
STRETCHER D
Round top & bot
2-3/8" ⌀ t+b.
4'-11 3/4"
6'-0"
For B only (dashed lines)
STRETCHER C
STRETCHER B



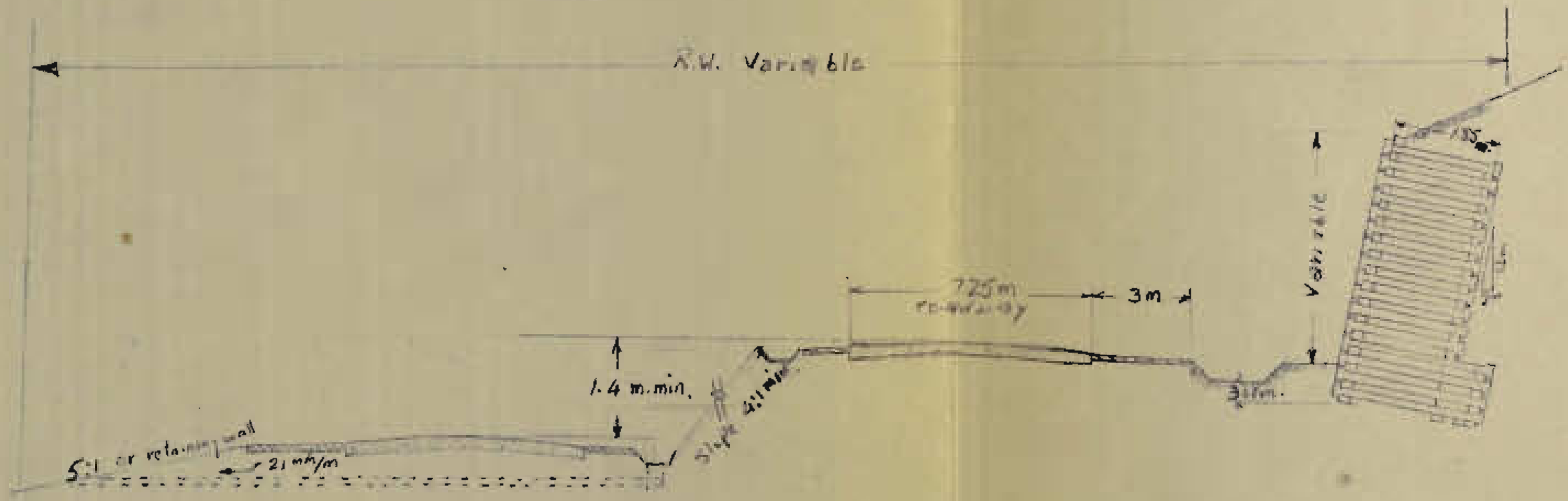
3/8" ϕ Rein Rods
3/4" ϕ Dowels
Rein Rods
A
E
D
C
6'-0"
ISOMETRIC VIEW
PLUMB FACE CRIBBING
18-3/4" ϕ Dowels 1'-6" lg
To be included in
cost of Concrete
Cribbing Item 52.1
Concrete footing
Not a part of Item 52.1
2-3/8" ϕ t + b
5'-6"
6'-0"
STRETCHER D
Round top 4 ft.
2-3/8" ϕ t + b.
4'-11 3/8"
6'-0"
For B only (dashed lines)
STRETCHER C
STRETCHER B (Same as Stretcher C except as noted)
BLOCK



NOTE: ~
Dashed lines show arrangement for odd number of front stretche
B
B for even no front stretchers
C " odd " " "
A
C
K
E
do
D
ein Rods
6'-0"
18-3/4"⌀ Dowels 1'-0" lg.
To be included in cost of Concrete Cribbing Item 52.1
Concrete footing
Not a part of Item 52.1
SECTION
BATTERED FACE CRIBBING
BING
2-3/8"⌀ t+b
5'-6"
6'-0"
STRETCHER E
BLOCK K
NOTE. –
This Cribbing is a revision of Rein. Conc. Cribbing Type B. (closed Face) used by the State of New York and designed by G.C. Habicht. Assoc. Member A.S.C.E.
ENGINEERING SCHOOL - A.U.B.
PROJECT BEIRUT - DAMASCUS TURNPIKE - PART B
CRIBBING R. WALL
DRAWN BY : ALBERT SHABHAR
ame as Stretcher C except as noted)

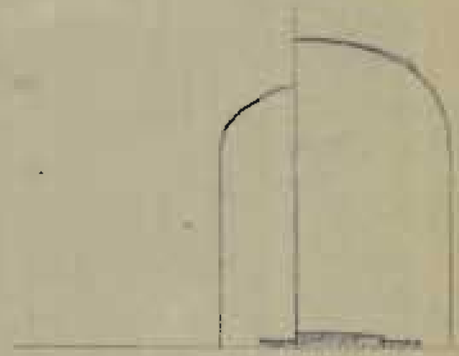


Type "A"



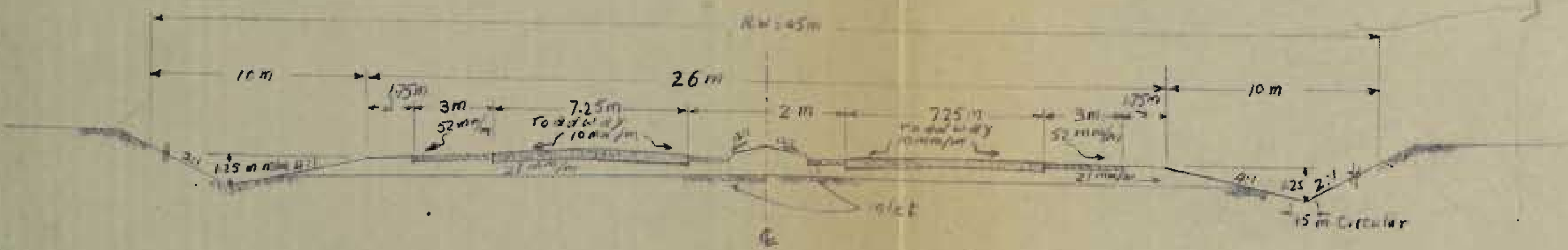
Type "B&C"

Fig 2 Typical Cross-sections



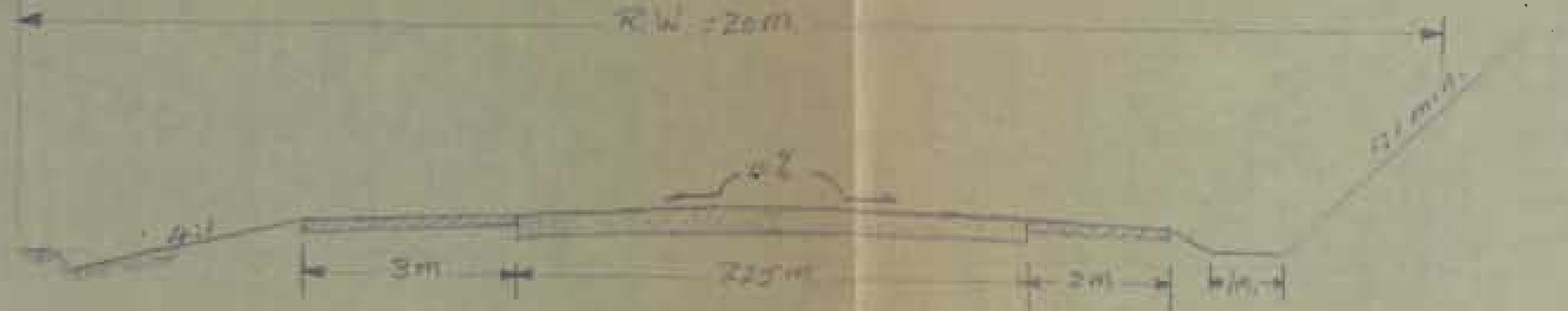
Dimensions & Standards of Design are studied by Mr. Knobbez

Type "D"



Type "E"

fig. 3 Typical Cross-sections



Typical Section Type "G"

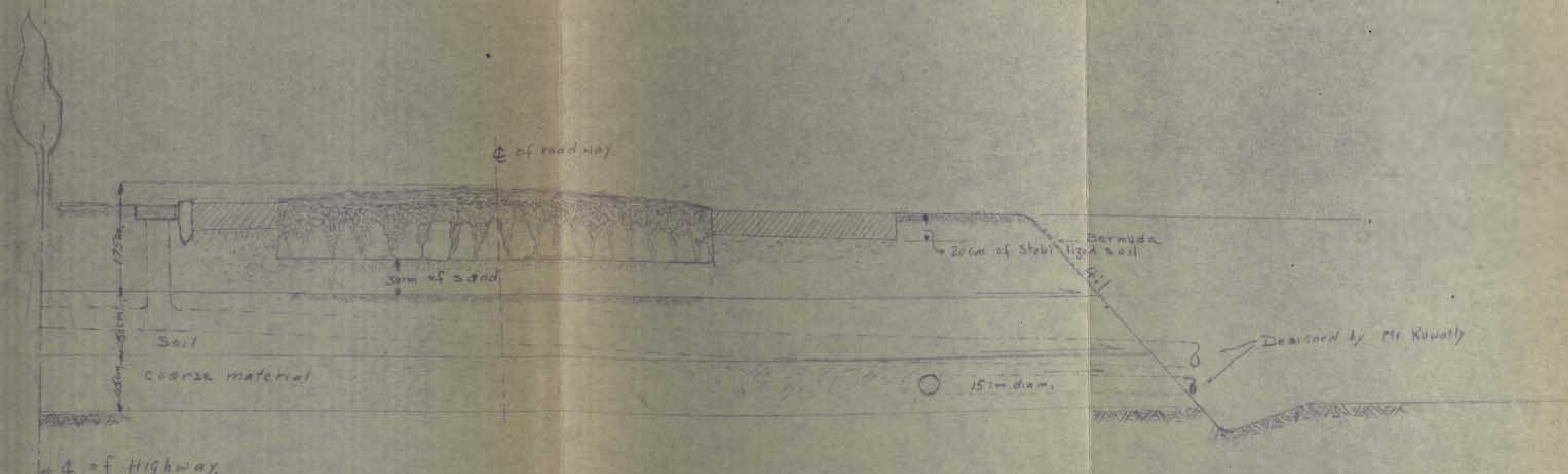
Typical Section Type "H"

N.B. Type "F" is a combination of all types.

Fig. 4

Typical Section of Superelevated Curve

fig. 5



Typical Section of Embankment Type "A" Beka'a Scale: Horiz. 1:100 Vert. 1:25

Fig. 12