University Of Technology
Building and Construction Eng. Dept.
Final Exam 2012/2013

Subject : Highway Eng. **Class : 3rd**
Branch : Building & Const. Manage. Eng. **Time : 3 Hours**
Examiner : Munther Ali **Date : 11/6/2013**

Note: Attempt Four questions only

Q1:

(a) Define or explain each of the following: **(15 marks)**

(1) Traffic Density, (2) Trip distribution, (3) Benefit-Cost Ratio,
(4) Spot Speed, (5) Reconnaissance survey.

(b) Calculate the amount of superelevation required for a horizontal circular curve with a radius of 500 meters if the design speed is 100 kph and the side friction coefficient is 0.15. **(10 marks)**

Q2: Given the following end areas of cut and fill, complete the earthwork calculation using a shrinkage factor of 10%, and draw the M.H.D. and the longitudinal profile of the earthworks and find the following: **(25 marks)**

a) Limit of Economic Haul (L.E.H.).
b) Freehaul volume (F.H.V.).
c) Overhaul volume (O.H.V.).
d) Waste volume.
e) Borrow volume.
f) Total cost of the earthworks.

If you know that:
- Cost of overhaul = 3000 ID/m^3.station.
- Cost of borrow = 15000 ID/m^3.
- Cost of freehaul = 5000 ID/m^3.
- Freehaul Distance (F.H.D.) = 300m.

Station	0	2	4	5	6	9	10	13	14	15
Cut area(m^2)	-	-	-	-	12	16	10	6	-	-
Fill area(m^2)	10	13	16	8	-	-	-	-	12	18

Q3: The percent passing by weight of aggregate and filler used for the design of an asphaltic concrete mixture is shown below. If the bulk specific gravities of coarse aggregate, fine aggregate, and filler used in this mixture are 2.60, 2.71, and 2.69. Determine the optimum asphalt content as a percentage weight of the total mix to product an asphaltic concrete mixture complying with the specifications shown below. The test results obtained using the Marshall method and the maximum specific gravity of paving mixture are shown below. The specific gravity of asphalt is 1.02. **(25 marks)**

Specifications: Min. Stability=8 kN, Flow (mm)=2-4, % Air Voids=3-5%, Min. %VMA=10.0%.

Sieve Size (inch)	Sieve Size (mm)	% Passing by weight
1½	37.5	100
1	25.0	95
¾	19.0	85
½	12.5	70
⅜	9.5	62
No. 4	4.75	55
No. 8	2.36	32
No. 50	300μm	13
No. 200	75μm	5

% by wt. of asphalt	Wt. of sample in air (gm)	Wt. of sample in water (gm)	Stability (kN)	Flow (mm)	Max. specific gravity of mixture
4.0	1325.3	785.6	9.57	3.25	2.57
4.5	1330.1	793.3	9.80	3.50	2.55
5.0	1336.2	800.8	9.93	4.00	2.53
5.5	1342.0	804.5	9.70	5.00	2.51
6.0	1347.5	805.1	9.10	6.25	2.49

Q4: According to the AASHTO guide for structural design of flexible pavement 1993, design a suitable pavement structure for an urban freeway highway to carry the Equivalent Single Axle Load of 7,000,000 applications. It is estimated that the quality of drainage of pavement layers is poor and the pavement structure will exposed to moisture levels approaching saturation for 10% of time. The CBR values of subgrade, subbase, and base materials are 10%, 45%, 100% respectively, and the resilient modulus of asphalt concrete surface layer is $300*10^3$ psi.

(25 marks)

Q5:

(a) State and explain the basic elements of transportation planning. **(10 marks)**

(b) A vehicle is driven between two points (A & B) with a running speed of 100kph and journey speed of 70kph. Calculate the delay time (in seconds) between these two points if you know that the travel distance is equal to 20 km. **(5 marks)**

(c) Prove that: $R = \frac{V^2}{127(e+f)}$ **(10 marks)**

Functional classification	Recommended level of reliability — Urban	Rural
Interstate/freeway	85–99.9	80–99.9
Principal arterials	80–99	75–95
Collectors	80–95	75–95
Local	50–80	50–80

TABLE 3.25 Recommended m_i Values for Modifying Structural Layer Coefficients of Untreated Base and Subbase Materials in Flexible Pavements

Quality of drainage	Percent of time pavement structure is exposed to moisture levels approaching saturation — Less than 1%	1–5%	5–25%	Greater than 25%
Excellent	1.40–1.35	1.35–1.30	1.30–1.20	1.20
Good	1.35–1.25	1.25–1.15	1.15–1.00	1.00
Fair	1.25–1.15	1.15–1.05	1.00–0.80	0.80
Poor	1.15–1.05	1.05–0.80	0.80–0.60	0.60
Very poor	1.05–0.95	0.95–0.75	0.75–0.40	0.40

Source: *Guide for Design of Pavement Structures*, American Association of State Highway and Transportation Officials, Washington, D.C., 1993, with permission.

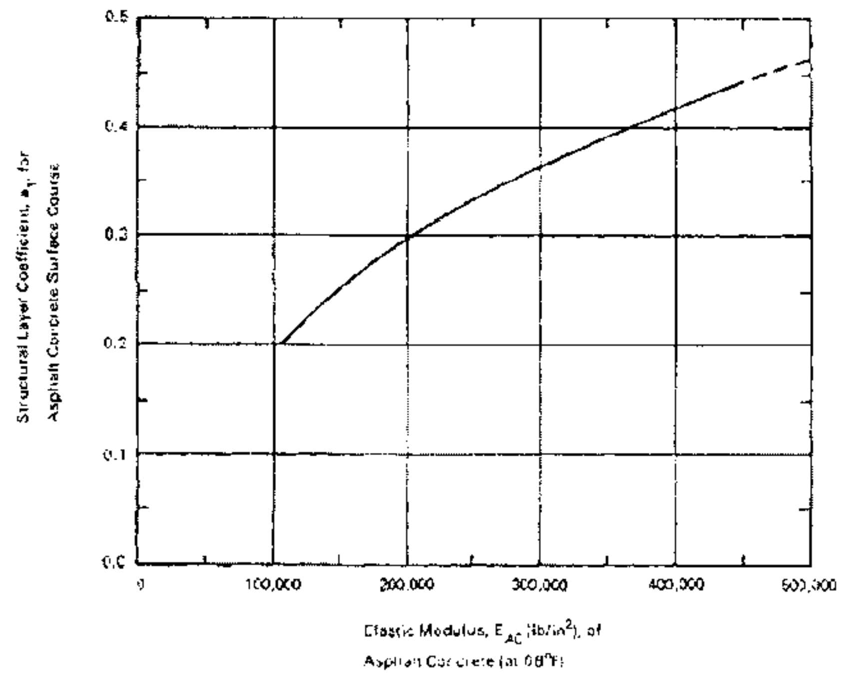
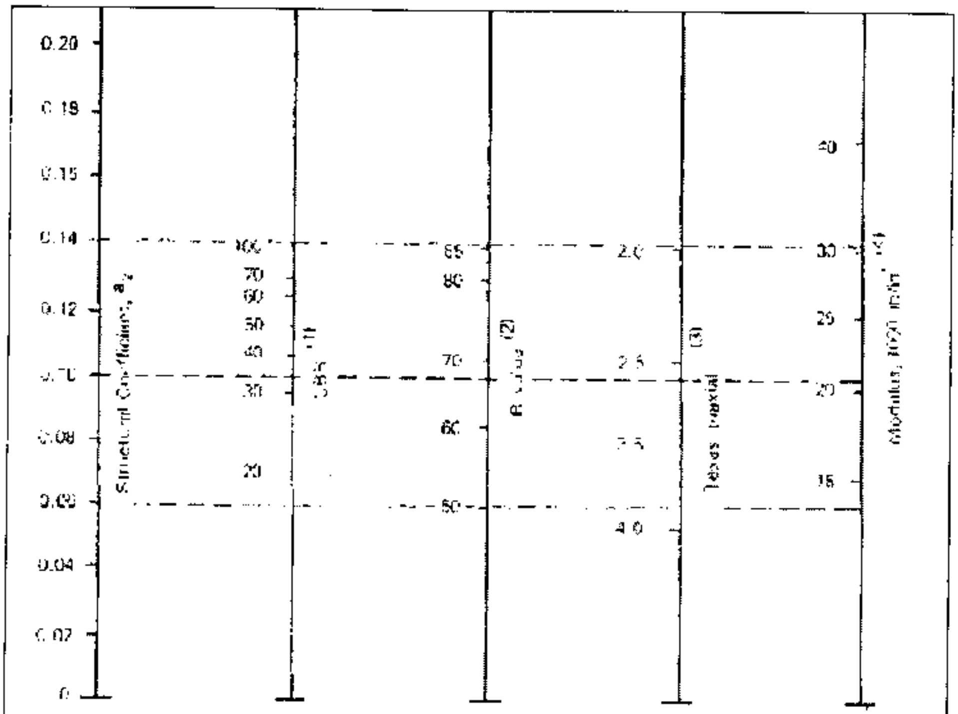
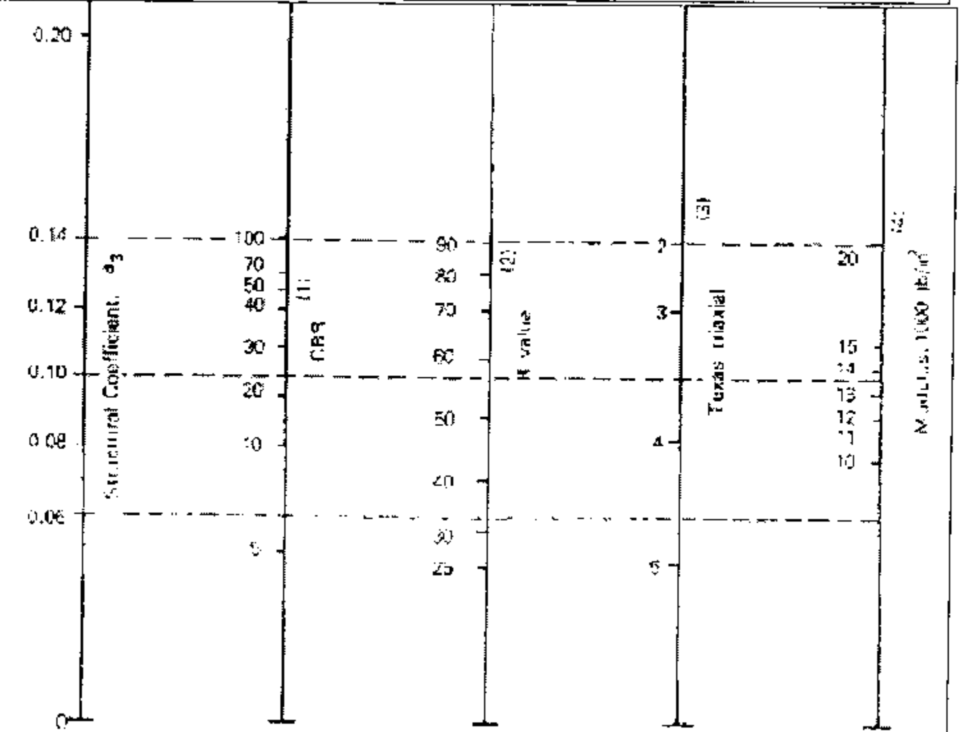


FIGURE 3.18 Chart for estimating structural layer coefficient a_1 of dense-graded asphalt concrete based on the resilient modulus (*From* Guide for Design of Pavement Structures, *American Association of State Highway and Transportation Officials, Washington, D.C., 1993, with permission*)



(1) Scale derived by averaging correlations obtained from Illinois.
(2) Scale derived by averaging correlations obtained from California, New Mexico, and Wyoming.
(3) Scale derived by averaging correlations obtained from Texas.
(4) Scale derived on NCHRP project.

FIGURE 3.19 Variation in granular base layer coefficient (a_2) with various base strength parameters. *(From Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington, D.C., 1993, with permission.)*

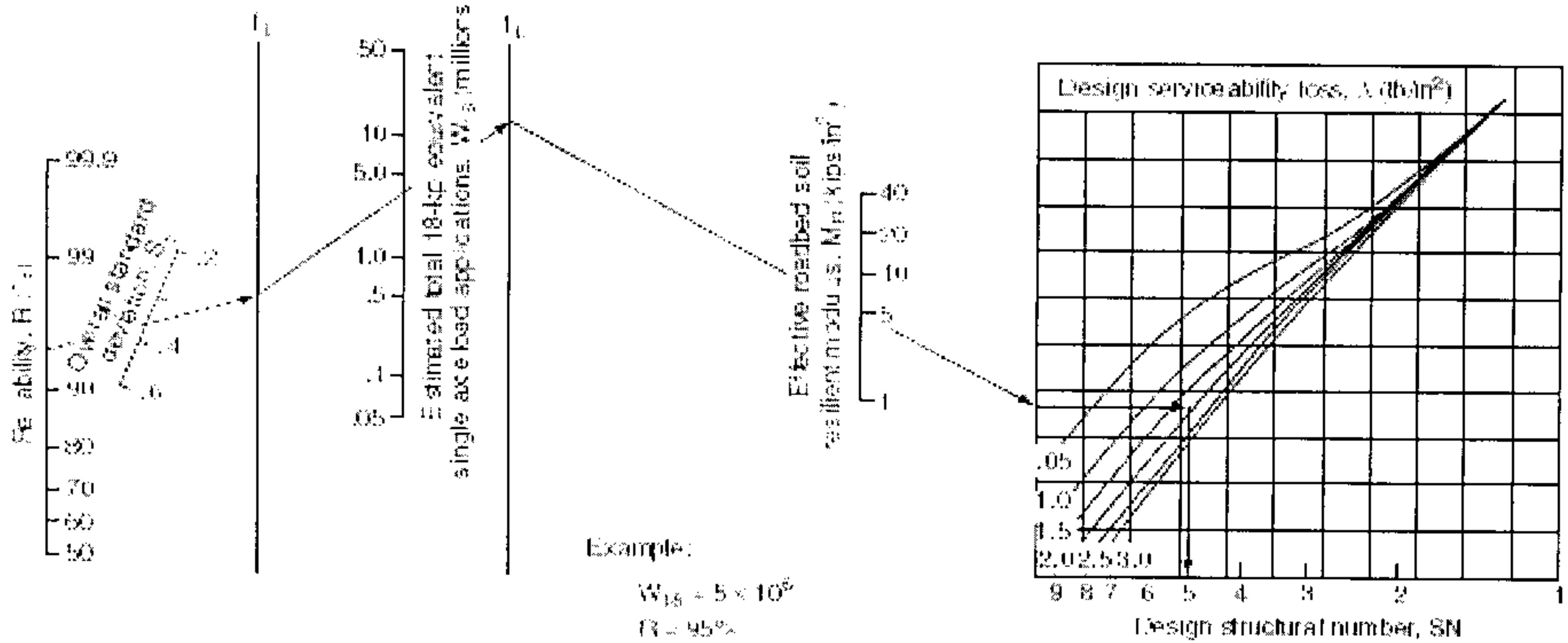


(1) Scale derived from correlations from Illinois.
(2) Scale derived from correlations obtained from the Asphalt Institute, California, New Mexico, and Wyoming.
(3) Scale derived from correlations obtained from Texas.
(4) Scale derived on NCHRP project.

FIGURE 3.20 Variation in granular base layer coefficient (a_3) with various subbase strength parameters. *(From Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington, D.C., 1993, with permission.)*

Nomograph solves:

$$\log_{10} W_{18} = Z_R \cdot S_o + 9.36 \cdot \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \cdot \log_{10} M_R - 8.07$$



Example:

$W_{18} = 5 \times 10^6$

$R = 95\%$

$S_o = 0.35$

$M_R = 5000$ lb/in²

$\Delta PSI = 1.9$

Solution: SN = 5.0

FIGURE 3.17 Design chart for flexible pavements based on using mean values for each variable. (From Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington, D.C., 1993, with permission.)

Good Luck…

Q1:

(a)

Traffic Density: Is defined as the number of vehicles occupying a given length of a lane or roadway (veh. /mile-vpm) (veh. /km-vpkm).

Trip distribution: Is a process by which the trips generated in one zone are allocated to other zones in the study area. For example, if the trip generation analysis results in an estimate of 200 Home-Based Work (HBW) trips in zone 10, then the trip distribution analysis would determine how many of these trips would be made between zone 10 and all the other zones.

Spot Speed: Is the instantaneous speed of vehicles at any specified point.

Reconnaissance survey:

The object of this phase of the study is to identify several feasible routes, each within a band of a limited width of a few hundred meters. When rural roads are being considered, there is often very little or no information available on maps or photographs, and therefore aerial photography is widely used to obtain the required information. Feasible routes are identified by a stereoscopic examination of the aerial photographs, taking into consideration factors such as:

- Terrain and soil conditions.
- Serviceability of route to industrial and population areas.
- Crossing of other transportation facilities, such as rivers, railroads, and other highways.
- Directness of route.

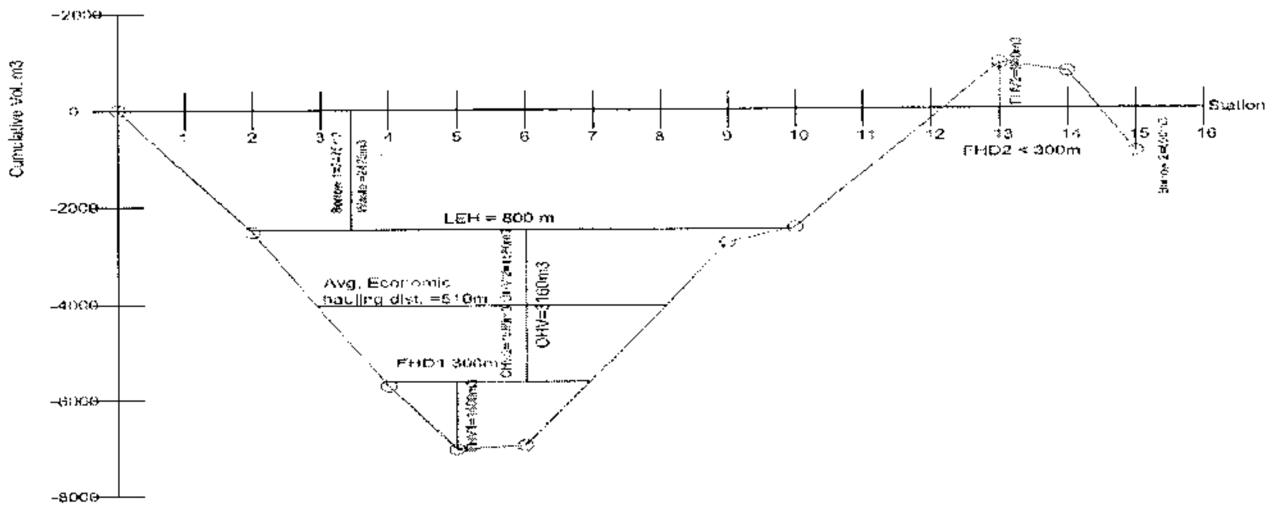
Benefit-Cost Ratio: Is a method used for the economic evaluation for route alternatives. Factors usually taken into consideration include road user costs, construction costs, maintenance costs, road user benefits, and any disbenefits, which may include adverse impacts due to dislocation of families, businesses, and so forth.

(b)

$$R = \frac{V^2}{127(e+f)} \rightarrow e = \frac{V^2}{127 * R} - f = \frac{100^2}{127 * 500} - 0.15 = 0.0074$$

Q2:

Station	Area (m^2)		Volume (m^3)			Net Vol. (m^3)		Cum. Vol.
	Cut	Fill	Cut	Fill	Corr. fill	Cut+	Fill-	
0	0	10						0
			0	2300	2530		2530	
2	0	13						-2530
			0	2900	3190		3190	
4	0	16						-5720
			0	1200	1320		1320	
5	0	8						-7040
			300	200	220	80		
6	12	0						-6960
			4200	0	0	4200		
9	16	0						-2760
			1300	0	0	1300		
10	10	0						-1460
			2400	0	0	2400		
13	6	0						+940
			150	300	330		180	
14	0	12						+760
			0	1500	1650		1650	
15	0	18						-890



- Economic overhaul limit (L) = (cost of borrow/cost of overhaul) = (12000/3000) = 5 stations.
- Therefore, Limit of Economic Haul (L.E.H.) = Free haul distance + Economic overhaul limit = 3 + 5 = 8 stations.
- Freehaul volumes = (FHV1+FHV2) = (1400+940) 2340 m^3
- Overhaul volume 3160m^3
- Waste volume = 2475m^3
- Borrow volume = 2475+890=3365m^3
- Total cost of the earthworks =
  [cost of freehaul*(FHV1+FHV2)] + [cost of waste*waste vol.] + [cost of borrow*borrow vol.] + [cost of freehaul*(OHV)] + [(cost of overhaul*OHV*(average hauling distance1-FHD)) =
  [5000 * (1400+940)] + [5000 * 2475] + [15000 * 3365] + [5000*(3160)] + [3000 * 2920* (5.1 - 3)] = 84,678,475 ID

Q3:

From the table of gradation:

% by weight of coarse aggregate = (100-55) = 45%

% by weight of fine aggregate = (55-5) = 50%

% by weight of filler = 5%

$$- dbulk = \frac{Wd}{Wd - Ww} \rightarrow dbulk\ (4\%) = \frac{1325.3}{1325.3 - 785.6} = 2.455$$

d_{bulk} (4.5%)=2.477, d_{bulk} (5.0%)=2.495, d_{bulk} (5.5%)=2.497, d_{bulk} (6.0%)=2.484

The bulk densities respectively are (gm/cm3): 2.455, 2.477, 2.495, 2.497, 2.484

$$\text{- bulk Ga} = \frac{45+50+5}{\frac{45}{2.60}+\frac{50}{2.71}+\frac{5}{2.69}} = 2.66$$

$$\text{- VMA} = 100 - \frac{dbulk * Pa}{BulkGa}$$

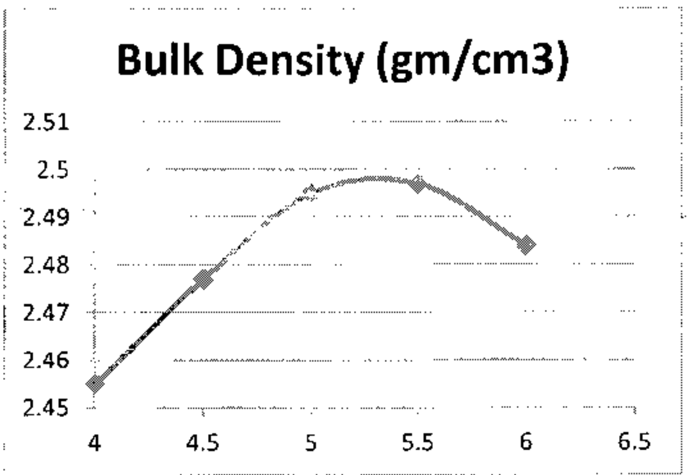
VMA (4%) = $100 - \frac{2.455*96}{2.66}$ = 11.40%, VMA (4.5%)= 11.07, VMA (5%)= 10.89, VMA (5.5%)= 11.29, VMA (6%)= 12.22

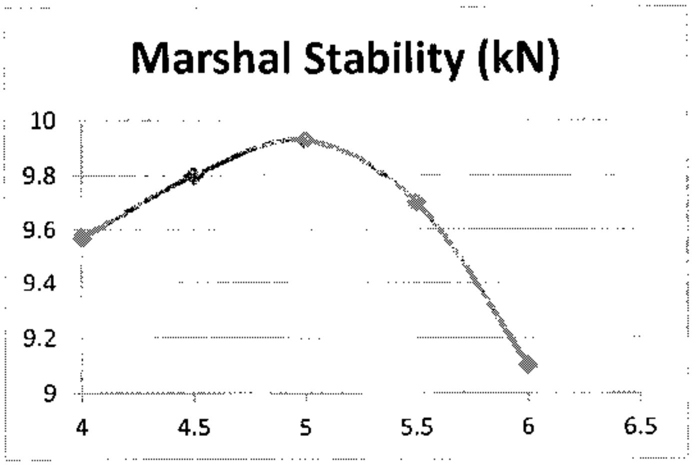
- % Air voids = $\frac{Gm-dbulk}{Gm} * 100 \rightarrow \%\ Air\ voids\ (4\%) = \frac{2.57-2.455}{2.57} * 100 = 4.47\%$

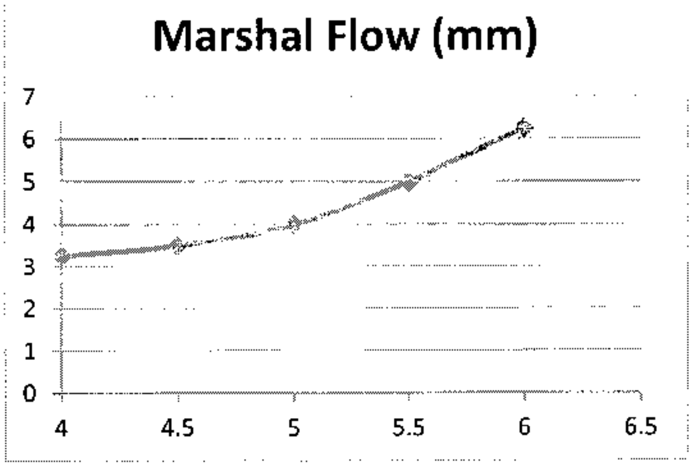
% Air voids (4.5%) = 2.86, % Air voids (5%) = 1.38, % Air voids (5.5%) = 0.52,

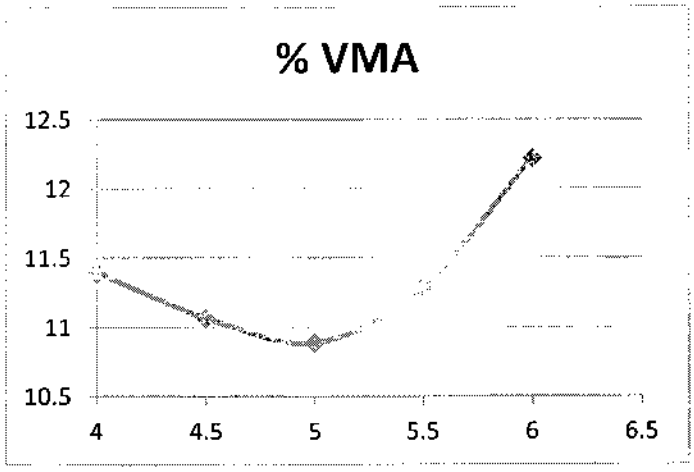
% Air voids (6%) = 0.24

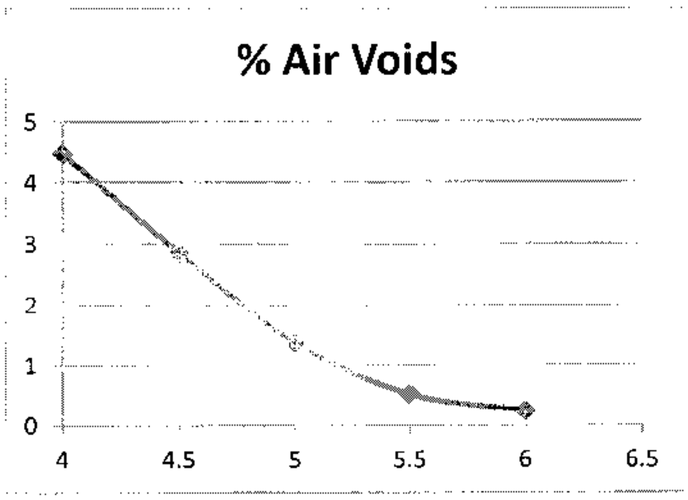
Plotting the % asphalt content by weight of total mix against (bulk density, stability, flow, % air voids, & %VMA)




Marshal Stability (kN)
10
9.8
9.6
9.4
9.2
9
4
4.5
5
5.5
6
6.5


Marshal Flow (mm)
7
6
5
4
3
2
1
0
4
4.5
5
5.5
6
6.5


% VMA
12.5
12
11.5
11
10.5
4
4.5
5
5.5
6
6.5


% Air Voids
5
4
3
2
1
0
4
4.5
5
5.5
6
6.5

- The asphalt content at the max. bulk density = 5.5%.
- The asphalt content at the max. stability = 5.0%.
- The asphalt content at 4% of air voids = 4.2%

The optimum asphalt content is determined as the average.
Therefore the optimum asphalt content = 4.9%
The properties of the paving mixture containing the optimum asphalt (4.9%) content should now be determined and compared with the given specifications:
@ 4.9% of asphalt content the stability = 9.88 > 8 ok
@ 4.9% of asphalt content the flow = 3.8 (between 2-4mm) ok
@ 4.9% of asphalt content the % Air voids = 1.5% (between 3-5%) **not ok**
@ 4.9% of asphalt content the %VMA = 10.9 > 10.0 ok
In the fig. of Air voids the value of air voids = 3% at asphalt content = 4.5% now check for this new value:
@ 4.5% of asphalt content the stability = 9.80 > 8 ok
@ 4.5% of asphalt content the flow = 3.5 (between 2-4mm) ok
@ 4.5% of asphalt content the % Air voids = 3% (between 3-5%) **ok**
@ 4.5% of asphalt content the %VMA = 11.1 > 10.0 ok

Therefore the optimum asphalt content of this mixture is 4.5%

Q4:

Mr of subgrade = 1500 * 10 = 15000 psi.
m2=m3= 0.60-0.80, use 0.6
Reliability Level for urban freeway = 85-99.9%, say 99%
a1 = 0.36 for $300*10^3$ (psi) Elastic modulus of asphalt concrete
a2 = 0.14, Modulus of elasticity of base course = $30*10^3$ (Psi) for 100% CBR
a3 = 0.11, Modulus of elasticity of subbase course = $17*10^3$ (Psi) for 45% CBR
Standard Dev. For flexible pavement from 0.4~0.5, use 0.45.
Assume Pi = 4.5, Pt = 2.5: ΔPSI = 2
SN3 = 4.2, SN2 = 4, SN1 = 3.3

$SN1 = a1 * d1 \rightarrow 3.3 = 0.36 * D1 \rightarrow D1 = 9.16\ inch, use\ 10\ inch$

$\therefore SN1' = 0.36 * 10 = 3.6$

$SN2 = SN1' + (a2 * m2 * d2) \rightarrow 4 = 3.6 + (0.14 * 0.60 * D2) \rightarrow D2 = 4.76\ inch, use\ 5\ inch$

$\therefore SN2' = 3.6 + (0.14 * 0.60 * 5) = 4.02$

Therefore the base course is not required.

$SN3 = SN2 + (a3 * m3 * D3) \rightarrow 4.2 = 4.02 + (0.11 * 0.60 * D3) \rightarrow D3 = 3\ inch, use\ 4\ inch.$

Q5:

(a):

1) Situation definition: This is the first step in the planning process. It involves all of the activities required to understand the situation that gave rise to the perceived need for a transportation improvement.
2) Problem definition: The purpose of this step is to describe the problem in terms of the objectives to be accomplished by the project and to translate those objectives into criteria that can be quantified.
3) Search for solutions: In this phase of the planning process, consideration is given to a variety of ideas, designs, locations, and system configurations that might provide solutions to the problem.
4) Analysis of performance: The purpose of performance analysis is to estimate how each of the proposed alternatives would perform under present and future conditions.
5) Evaluations of alternatives: The purpose of evaluation phase is to determine how well each alternative will achieve the objectives of the project as defined by the criteria. The performance data produced in the analysis phase are used to compute the benefits and costs that will result if the project is selected.
6) Choice of project: The final project selection is made after considering all the factors involved. In a simple situation, for example, where the project has been authorized and is in the design phase, a single criterion (such as cost) might be used and the chosen project would be the one with the lowest cost.
7) Specifications and construction: Once the transportation project has been selected, a detailed design phase is begun, in which each of the components of the facility is specified. For a transportation facility, this involves its physical location, geometric dimensions, and structural configuration.

(b):

Running speed = Distance/ running time

100 km/hr = 20 km /Tr

Tr = 0.2 hr = 12 min.

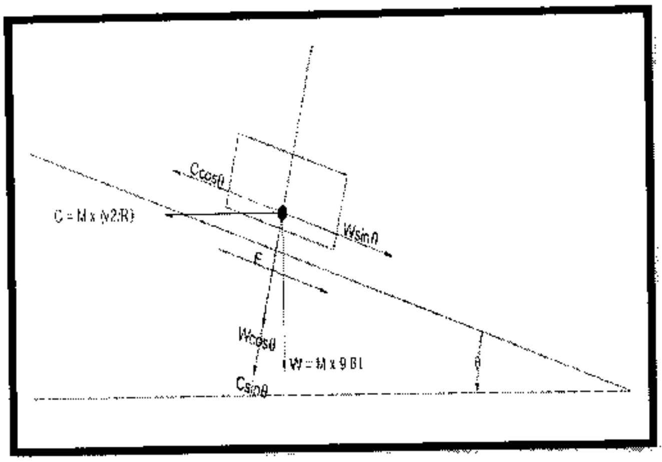
Journey speed = Distance/ total time = 20 km /Tj

70 km/hr = 20 km /Tj

Tj = 0.2 hr = 17.14 min.

Delay = Tj – Tr = 17.14 min. - 12 min. = 5.14 min

(c):



C = Centrifugal Force = Mass * Acceleration = $\frac{W}{9.81} * \frac{v^2}{R}$

Summation of acting forces:

C*cosθ = F + W*sinθ

$$\frac{W}{9.81} * \frac{v^2}{R} * \cos\theta = F + W\sin\theta \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The side frictional force, F, can be expressed as:

$$F = f[W\cos\theta + C\sin\theta] \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

(f is defined as the side friction factor)

Substituting Equation (1) into Equation (2),

the following expression is derived:

$$\frac{W}{9.81} * \frac{v^2}{R} * \cos\theta = f[W\cos\theta + C\sin\theta] + W\sin\theta$$

By dividing the above equation by (Wcosθ):

$$\rightarrow \frac{v^2}{9.81 * R} = f + (f * \frac{C}{W}\tan\theta) + \tan\theta$$

If we ignore the term $(f * \frac{C}{W}\tan\theta)$ on the basis that it is extremely small, the following final expression is derived:

$$\frac{v^2}{9.81 * R} = f + \tan\theta$$

The term $\mathbf{\tan\theta}$ is in fact the superelevation (e). If in addition we express velocity in kilometers per hour (kph) rather than meters per second (m/sec.), the following generally used equation is obtained:

$$\boxed{\frac{V^2}{127R} = f + e}$$

Where:

$v = Design\ Speed\ in \frac{m}{sec.}, V = Design\ Speed\ in\ kph,$

$R = Radius\ of\ the\ Horizontal\ Curve\ in\ Meters,$

$e = Rate\ of\ the\ roadway\ superelevation.$