Lecture-8

25/04/19

Q-(31)

P = 56%
W_L = 40%
W_P = 15%

$I_p = W_L - W_p = 40 - 15 = 25$

G.I. Value = 0.2a + 0.005ac + 0.01bd
= 0.2 × 21 + 0.05 × 21 × 0 + 0.01 × 40 × 15
= 10.2

a = (P − 35)% = (56 − 35) = 21 ≯ 40
b = (P − 15) = 56 − 15 = 41 ≯ 40, b = 40
c = W_L − 40 = 40 − 40 = 0 ≯ 20
d = I_p − 10 = 25 − 10 = 15 ≯ 20

GI value	
10	62 cm
10.2	~
15	78 cm

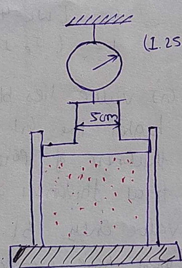
$t_{pavement}$ = 62.64 cm Ans

linear interpolation

$y_2 = \frac{(x_2-x_1)(y_3-y_1)}{(x_3-x_1)} + y_1$

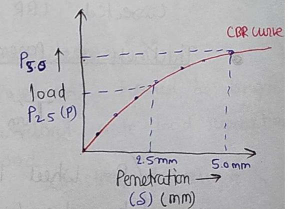
Method ② CBR - (california bearing ratio)

- soil sample taken over the vessel and the load is applied through mechanical arrangement of loading system (1.25 mm/min upto 10 min)
- Load corresponding to different penetration value is noted and CBR curve is plotted (load vs penetration)



- For no error in CBR test CBR curve should be convex through out.
- load corresponding to 2.5 mm and 5.0 mm penetration are noted from CBR curve
- As $P_{2.5}$ and $P_{5.0}$ respectively.

these load value is compared with standard load value and CBR value is found that



CBR Value = max of {
$CBR_{2.5} = \frac{P_{2.5}}{1370} \times 100$
$CBR_{5.0} = \frac{P_{5.0}}{2055} \times 100$
}

Note① (generally CBR (2.5) > CBR (5.0)) but if $CBR_{5.0}$ found more then the test should be repeated after repeatation which ever found more should be excepted as CBR value.

Note② (Standard load value for standard aggregate)

For 2.5 mm Penetration

load = 1370 kg

pressure = $\frac{P}{A} = \frac{1370}{\frac{\pi}{4}(5)^2}$ = 69.79 ≈ 70 kg/cm²

for 5.0 mm penetration

load = 2055 kg

Pressure = $\frac{P}{A} = \frac{2055}{\frac{\pi}{4}(5)^2}$

= 104.66 kg/cm²

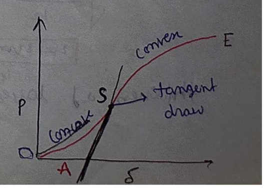
≈ 105 kg/cm²

Note③ Some time initial concavity may form due to following reason

[A] Improper compaction

[B] Top surface of soil / bottom surface of plunger may not be truely Horizontal.

- Initial concavity can be corrected by drawing the tangent at the junction of concave and convex



- Original CBR curve OSE
  Corrected CBR curve ASE

- Thickness of Pavement by CBR method :-

$$T_{cm} = \sqrt{\frac{1.75P}{(CBR\%)} - \frac{P}{\pi p}}$$

we can write $\frac{P}{\pi \times \frac{P}{A}} = \frac{A}{\pi}$ or $\frac{\pi a^2}{\pi} = a^2$

P = Wheel load in (Kg)
p = tyre / contact pressure (Kg/cm²)
A = contact area in cm²
a = Radius of contact area (cm)

layer 4 (CBR 4)
layer 3 (CBR 3)
layer 2 (CBR 2)
layer 1 (CBR 1)
(T, T_1, T_2, T_3)

- Limitations
1. Quality of Pavement material is not considered.
2. this method is not valid for higher value of (CBR). (CBR ≯ 12%)

(P3) - (32) thickness of Pavement

a) above soil subgrade

$$T_1 = \sqrt{\frac{1.75 \times P}{CBR\%} - \frac{P}{\pi p}} = \sqrt{\frac{1.75 \times 4100}{4.38} - \frac{4100}{\pi \times 7}}$$

T_1 = 38.10 cm

$$T_2 = \sqrt{\frac{1.75 \times 4100}{6} - \frac{4100}{\pi \times 7}}$$

= 31.77 cm

$$T_3 = \sqrt{\frac{1.75 \times 4100}{12} - \frac{4100}{\pi \times 7}}$$

= 20.26 cm

Bitumin su (4cm)
WGA = (6%)
PGA = 12%
C.S (6%)
Subgrade
(T, T_1, T_2, T_3)

CBR of soil subgrade

$= CBR_{2.5} = \frac{60}{1370} \times 100 = 4.38$

$= CBR_{5.0} = \frac{82}{2055} \times 100 = 3.99\%$

thickness of layers (1) $T_2 - T_1$ = 38.1 − 31.77 = 6.33 cm
T_{CS} //
(2) $T_{PGA} = (T_2 - T_3)$ = 31.77 − 20.28 = 11.49 cm

(c) $T_{WGA} = (T_3 - 4)$ = 20.28 − 4 = 16.28 cm
(d) T_{BC} = 4 cm

- Method (3) IRC Method of thickness design***

As per IRC: 37 − 1980 the flexible Pavement should be design in terms of cumulative no. of standard axle load repetation through out the design life of road construct of design in term of "commercial vehicle / day"**

As per this method thickness of Pavement depend upon the CBR value of soil subgrade and cumulative no. of standard axle load repetation.

** Imp [2018] [2014] Numerically cumulative no. of ~~commer~~ standard axle load repetation throughout the design of life of road is calculated as

कितने साल के लिए design करना है

important: $$N_s = \left(\frac{365A\left((1+r)^{n} - 1\right)}{r}\right) . D. F. (LSF)_{CSA}$$

unit CSA (cumulative standard Axle)
MSA (~~Med~~ million Standard Axle) = 1×10^6 CSA

MSA = 1×10^6 CSA

A = Initial traffic in the year of completion of construction in terms of commercial vehicle per day
r = Rate of growth of traffic in % per year
n = design life of road
D = lane distribution factor
F = Vehicle damage factor
LSF = load safety factor (assume 1 = factor of safety for load when not given in the question)

- Concept / trick

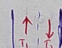
A = (Initial traffic in the year of completion of construction in term of commercial vehicle per day) (CVPD)

① Any vehicle with cross weight min 3 TON is consider as commercial vehicle

② If present traffic volm is $(P)_{CVPD}$ then traffic volm after x years of construction period will be –

$$A = P(1+r)^x$$ In (0.05) If (5%) [r = 0.05]

③ for single carriage way road A should be taken sum of both dirn traffic

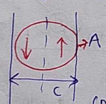


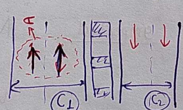
= $(T_1 + T_2)$

for dual carriage way road A should be taken as sum of 1 dirn traffic (total on one carriage way)

2 lane – 2 way single carriageway

2 lane – 2 way dual carriage





② Lane distribution factor (D) → It is the factor which distribute the commercial traffic in each dirn on each lane. As per (IRC: 37-2012)

① Single lane road – the design should be based on total no. of commercial vehicle in both dirn (D = 1)

② two lane single carriage way road – design should be based on 50% of total no. of commercial vehicle in both dirn (D = 0.5)

③ Four lane single carri way road – the design should be based on 40% of total no. of commercial vehicle in both dirn (D = 0.4)

⑤ Dual 2 lane carriage way road → Design should be based on 75% of total no. of commercial vehicle in each dirn (D = 0.75)

⑥ Dual 3 lane carriage way road → the design should be based on 60% of total no. of commercial vehicle in each dirn. (D = 0.6)

⑦ Dual 4 lane carriage way road → Design should be based on 45% of total no. of commercial vehicle in each dirn (D = 0.45)

Vehicle damage factor (F) :- It is equivalent to No. of standard axle per commercial vehicle. This is the factor which convert the no. of commercial of different axle load to the no. of standard axle load repetition.

- 4th Power Law → Equivalent axle load factor (EALF)

$$EALF = \left[\frac{L_o}{L_s}\right]^4 = \left(\frac{\text{other axle load}}{\text{std. axle load}}\right)^4$$

If L_1 axle load has (%) frequency (f_1)

L_2 axle load has (%) frequency (f_2)

⋮

L_n axle load has (%) frequency (f_n) then vehicle damage factor would be

$$F = \frac{f_1}{100}\left(\frac{L_1}{L_s}\right)^4 + \frac{f_2}{100}\left(\frac{L_2}{L_s}\right)^4 + \frac{f_3}{100}\left(\frac{L_3}{L_s}\right)^4 + \cdots \frac{f_n}{100}\left(\frac{L_n}{L_s}\right)^4$$

(F → vehicle damage factor)

Note. If L_1 (load axle) repeated N_1 times

L_2 repeated N_2 times

⋮

L_n repeated N_n times then

No. of repetition in term of L_o (axle load)

$$N_o = N_1\left(\frac{L_1}{L_o}\right)^4 + N_2\left(\frac{L_2}{L_o}\right)^4 + \cdots N_n\left(\frac{L_n}{L_o}\right)^4$$

Pb - (33) $N_0 = N_1\left(\frac{L_1}{L_0}\right)^4 + N_2\left(\frac{L_2}{L_0}\right)^4$ ★★★★

$= 800\left(\frac{40}{80}\right)^4 + 400\left(\frac{80}{80}\right)^4 = 450$

$L_1 = \frac{35+45}{2} = 40KN$ | $N_1 = 800$

$L_2 = \frac{75+85}{2} = 80KN$ | $N_2 = 400$

Pb - (34) P = 2500 CVPD

$A = P(1+r)^x = 2500(1+0.08)^2$ (x = construction time period)

$= 2700$ CVPD

r = 0.08, F = 3.5, D = 0.75, n = 10 yrs, LSF = 1

$N_s = \left(\frac{365 \times 2700 (1+0.08)^{10} - 1] \times 0.75 \times 3.5 \times 1}{0.08 \times 10^6}\right)$

$= 37.47$ MSA

Pb - (35) A = 5640

$A = 5640 (1+0.075)^{20} = 23957.88$

r = 7.5%

n = 20 yrs

D = 0.75

LSF = 1.3

$f = 0.1\left(\frac{18}{8.2}\right)^4 + 0.2\left(\frac{14}{8.2}\right)^4 + 0.35\left(\frac{10}{8.2}\right)^4 + 0.15\left(\frac{8}{8.2}\right)^4 + 0.2\left(\frac{6}{8.2}\right)^4 = 4.988$

(8.2 ton (standard axle load))

$N_s = \left(\frac{365A((1+r)^n - 1) \times D \times F \times L.S.F}{r \times 10^6}\right)$

$= \frac{365(5640)((1+0.075)^{20} - 1) \times 0.75 \times 4.988 \times 1.3}{0.075 \times 10^6}$

$= 437.14$ MSA

Pb - (25) $F = \left(\frac{11885}{8160}\right)^4 = 4.5$

A = 5640 CVPD, n = 10 years, r = 0.08, D = 0.75

$N_s = \left(\frac{365 \times 5640 \times ((1+0.08)^{10} - 1) \times 0.75 \times 4.5 \times (1)}{0.08 \times 10^6}\right)$

$= 100.65$ MSA

Pb - (26) D = 0.75 (because 2 lane 2 way dual way traffic)★★

r = 0.08

n = 10 years

$N = N_1 + N_2 = \left(\frac{365 A_1[(1+r)^n - 1]}{r \times 10^6} \times D \times F_1 \cdot LSF\right)$

$+ \left(\frac{365 A_2((1+r)^n - 1) \times D \times F_2 \times LSF}{r \times 10^6}\right)$

$= \frac{365\left(2000 \times 5 + 200 \times 6\right)\left((1+0.08)^{2} - 1\right) \times 0.75}{0.08 \times 10^6}$

$= 44.40$ MSA

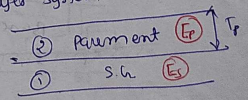
Method (4)

- **Triaxial method**

thickness of pavement Road above sub-grade

$T_p = \sqrt{\left(\frac{3PXY}{2\pi E_s \Delta}\right)^2 - a^2}\left(\frac{E_s}{E_p}\right)^{\frac{1}{3}}$ ---- 2 layer system

2 layer system



ESE Note (1) for single layer system

$T_p = \sqrt{\left(\frac{3P}{2\pi E_s \Delta}\right)^2 - a^2}$

$[E_s = E_p$ and $X = Y = 1]$

P = wheel load (Kg)

X = traffic coefficient

Y = Rainfall coefficient

E_s = Modulus of elasticity of subgrade

Δ = Design deflection

E_p = modulus of elasticity of Pavement

a = Radius of contact area

For three layer system ***

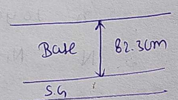
third layer can be replace with Pavement material using the relation

$$T_P \propto \left(\frac{1}{E_P}\right)^{\frac{1}{3}}$$

$$\left[\frac{T_1}{T_2} = \left[\frac{E_2}{E_1}\right]^{\frac{1}{3}}\right]$$ ** MQ

Q-(37) thickness of Pavement in term of Base

T_B = 82.3 cm A



with $E_{Bitu} = 1000\ kg/cm^2$

Q 7.5cm of Bituminous course in ~~term of base~~

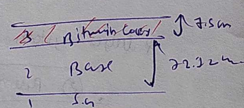
$$\frac{T_{Bo}}{T_{Bt}} = \left(\frac{E_{BT}}{E_B}\right)^{\frac{1}{3}}$$

$$\frac{T_{Bo}}{7.5} = \left(\frac{1000}{400}\right)^{\frac{1}{3}}$$

T_{Bo} = 10.18cm

① to Provide 7.5cm Bitum. course 10.18 cm of base should be remove

eq. thickness of base = 82.3 − 10.18 = 72.12 cm



Burmister method

Method is based on modulus of elasticity of different layers of Pavement.

Assumption-

① Material in each layer = Homogeneous = isotropic = Elastic

② layer are in continuous contact

③ { Horizontal dirⁿ = Pavement infinite
   vertical dirⁿ = Pavement finite }

Displacement eqⁿ by burmister →

1] [Plate load test / Plate bearing / rigid Plate method] (anywhere)

$$\Delta = \frac{1.18\, p.a}{E_s} \times F_2$$

p = (tyre pressure / contact pressure)

a = (Radius of contact area)

2] Wheel load test / flexible plate method (On the top)

$$\Delta = \frac{1.5\, p.a\, F_2}{E_s}$$

Burmister curve-

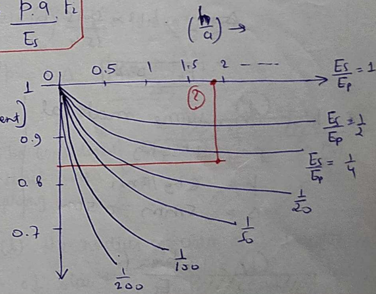
[E_p = modulus of elasticity of Pavement]

[Δ = design deflection] $F_2 \downarrow$

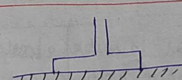
[E_s = modulus of elasticity of subgrade]

[F_2 = deflection factor]

[h = thickness of Pavement]



Test on Soil subgrade

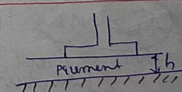


SS

h=0

F_2=1

Test on Pavement layer



h≠0

F_2<1

(36) PBT on soil subgrade

$a = \frac{30}{2} = 15\ cm$

$F_2 = 1$

$p = 1\ kg/cm^2$

$\Delta = 5\ mm = 0.5\ cm$

$\Delta = \frac{1.18\ p.a.\ F_2}{E_s}$

$0.5 = \frac{1.18 \times 1 \times 15 \times F_2(1)}{E_s}$

$E_s = 35.4\ kg/cm^2$

PBT on 18cm Base

$a = 15\ cm$

$p = 5\ kg/cm^2$

$\Delta = 5\ mm = 0.5\ cm$

$\Delta = 1.18\ \frac{pa}{E_s}.\ F_2 = 0.2$

$0.5 = \frac{1.18 \times 5 \times 15}{35.4} \times F_2$

$\boxed{F_2 = 0.2}$

$\frac{h}{a} = \frac{18}{15} = 1.2$; $F_2 = 0.2$

from Burmister curve

$\frac{E_s}{E_p} = \frac{1}{100}$ } $E_p = 35.4 \times 100 = 3540\ kg/cm^2$

WLT on same material

$P = 4100\ kg$

$p = 6\ kg/cm^2$

$\Delta = 5\ mm = 0.5\ cm$

$p = \frac{P}{\pi a^2}$

$6 = \frac{4100}{\pi a^2}$

$\boxed{a = 14.75\ cm}$

$\Delta = 1.5\ \frac{p.a}{E_s} \times F_2$

$F_2 = 0.133$

$F_2 = 0.133$; $\frac{E_s}{E_p} = \frac{1}{100}$

from burmister curve

$\frac{h}{a} = 1.9$

thickness of of Pavement

$h = 1.9a$

$= 1.9 \times (14.75)$

$= \boxed{28.025\ cm}$