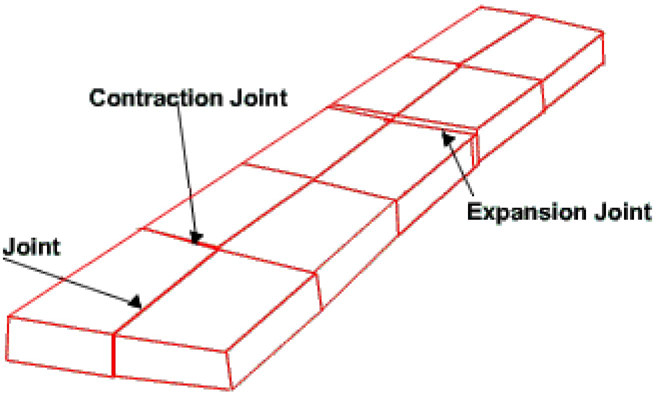
IAT-II April 2018- Scheme

1	(a) List the various requirements of joints in cement concrete slabs. Explain in detail with sketches (i) Expansion joints and (ii) Contraction joints.	[08]

Requirements – 3
Expansion joints – with sketches- 2.5
Contraction joints with sketches – 2.5

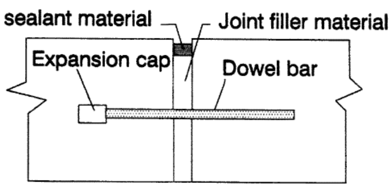
Following are the requirements of a good joint

- Joints should move freely
- Joint should not allow infiltration of rain water and ingress of grits
- Joints should not protrude out the general level of the slab



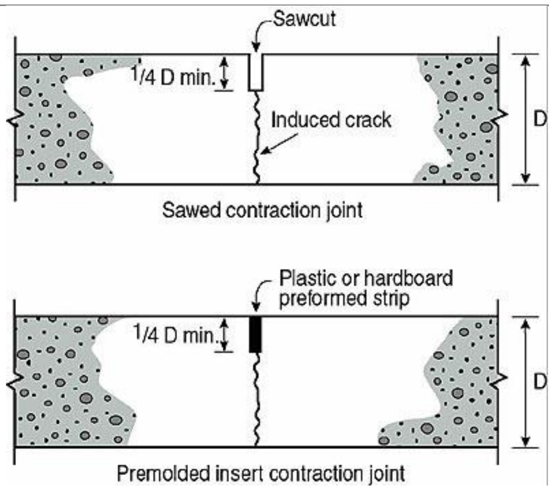
Expansion joints

- Allow for expansion of the slab
- Maximum spacing of expansion joint is 140 m
- Gap width ranges from 20 to 25 mm
- Dowel bars provided in expansion joints allows for load transfer(generally 40%)
- Metal cap provided at the ends of the slab allows for expansion of dowel bars.
- Length of dowel bar ranges from 40 to 73 cm
- Diameter of the dowel bar ranges from 20 to 30 mm



Contraction joints

- Maximum spacing of contraction joint is 4.5 m
- Allow for contraction of CC slab
- Provided at a closer spacing than expansion joint
- Load transference is mainly through the physical interlocking by the aggregates projecting out at the joint faces.



(b) Outline the IRC 37:2001 method of flexible pavement design. [08]

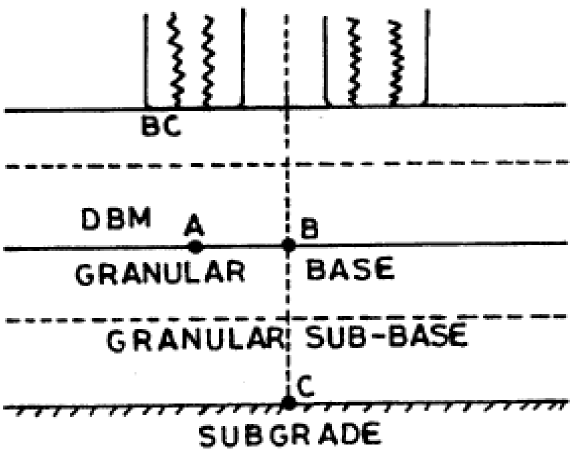
Critical conditions- 2
Traffic factors -3
Subgrade factors -3

The salient features of this document are

(i) Flexible pavement is designed as a four-layer structure.
(ii) The catalogues cover soils having CBR values in the range of 2-10.
(iii) Traffic upto 150 msa has been considered.
(iv) The damaging factor has to be estimated using load equivalency factors as
Equivalency factor for single axle load = $[Load/8160]^4$
Equivalency factor for tandem axle load = $[Load/14968]^4$
(v) The design catalogues are developed for different CBR value.

The three different types of distresses are considered

(i) Vertical compressive strain at the top of the subgrade
(ii) Horizontal tensile strain at the bottom of the bituminous layer
(iii) Pavement deformation within the bituminous layer



The two important parameters considered for the design are

(i) Design traffic in terms of msa
(ii) CBR value of soil.

Design Traffic in msa is calculated as

$$N = \frac{365 \times [(1+r)^n - 1]}{r} \times A \times D \times F$$

Where

- r is the traffic growth rate; generally assumed as 7.5%
- n is the design life; Expressways its 20 years; NH and SH its 15 years and for other roads its 10-15 years
- A is the traffic at the end of the construction period= $A = P(1+r)^x$ in CV/day
- Where x is the construction period
- P is the existing traffic
- D is the damage factor
- F is the lane distribution factor
- Design load is generally considered as standard axle load of 80 kN or 8160 kg.
- Damage factor is dependent upon the terrain and the axle load spectrum.
  - Equivalency factor for single axle load = $[Load/8160]^4$
  - Equivalency factor for tandem axle load = $[Load/14968]^4$
  - In the absence of axle load spectrum, it is computed based on terrain and the volume of traffic with a value ranging from 1.5 to 4.5.
- Lane distribution factor accounts for the wandering of traffic given as
  - Single lane road – 1
  - Two lane single CW roads – 0.75
  - Single CW four lane roads – 0.4
  - Dual CW - Three lane roads- 0.6
  - Dual CW - Four lane roads- 0.45

For different traffic repetitions, for different CBR values pavement design catalogues are available in IRC 37, 2001.

(c) What are the various design factors to be considered for the design of an airport pavement? Explain the significance of each. [08]

Traffic factors - 3
Climatic factors - 3

Design Life
Reliability
Subgrade strength
} Any two each of one mark

The different factors affecting an airfield pavement design are

(i) Design Life – there can be flexible airfield pavement (15-20 years) and rigid airfield pavement (20- 30 years). Accordingly the design life also varies

(ii) Reliability – the traffic prediction made should have a good level of relaibility

(iii) Traffic factors

- Wheel load applications – take off weight will be high. It will be around 350 t against 80 or 100 N used for highways. The tyre pressures are also very high as equal to 1.43 MPa against maximum tyre pressure of 0.8 MPa as applied in the case of highways.
- Impact – the magnitude of impact will be high especially during landing
- Repetition of wheel loads – there is a lot variation in the landing position both laterally and longitudinal. Hence, the repetition of load is very less in case of airfield pavements. On an average of one load repetition takes place after 265 landings. In highways we deal with millions of load repetitions as against 0.0038 per landing.
- Position of wheel load across pavement – the variations in wandering of wheels decrease the repetition of wheel load as explained previously.

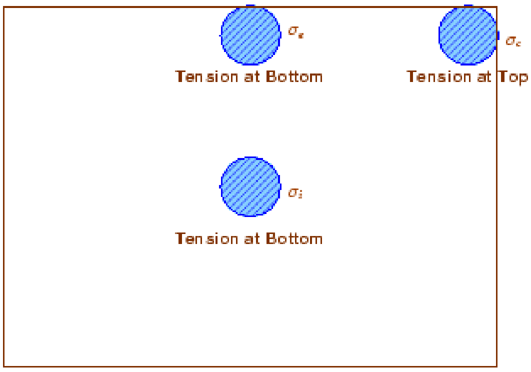
	➢ Type of pavement – the fuel and oil spillage will cause early disintegration of bituminous surfaces as against concrete pavements. ➢ Maintenance – the life of the pavement should be high as frequency maintenance cannot be considered. Similarly the surface should be free of dust and it should be anti skid. (iv) Climatic factors - The different factors that influence pavement performance are ➢ Temperature Asphalt being a visco-elastic material, its properties will change with temperature. However, for concrete pavements, temperature variations will induce warping stresses. To relieve such stresses, joints are provided with expansion and contraction joints. ➢ Precipitation Precipitation otherwise referred to as rainfall will also influence the pavement design. In the design of pavements, a minimum gradient has to be provided to facilitate the easy flow of water. Excessive rainfall can influence both flexible and rigid pavement design. If the joints are not sealed properly, water will enter the pavement and will weaken the subgrade. This excessive water will make the subgrade in the form of a slurry and rolling wheel loads, will cause the squeezing of slurry through the joints. This is called as mud pumping. Provision of a base or sub-base layer below a concrete pavement can help in the drainage of the percolated water and increase the longevity of the pavement. Too smooth a surface can also cause hydroplaning. ➢ Frost action *Frost heave.* An upward movement of the subgrade resulting from the expansion of accumulated soil moisture as it freezes. *Thaw weakening.* A weakened subgrade condition resulting from soil saturation as ice within the soil melts. (v) Subgrade strength – Here again CBR and modulus of subgrade reaction are the two parameters considered for the design.	
2	(a) Explain (i) Radius of relative stiffness (ii) Equivalent radius of resisting section (iii) critical load positions Each one two marks each – explanation+ sketch if any *Radius of relative stiffness:* A certain degree of resistance to slab deflection is offered by the sub-grade. The sub-grade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the sub-grade pressure. This pressure deformation characteristics of rigid pavement lead Westergaard to the define the term radius of relative stiffness l in cm is given by the equation $$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$ Where E is the modulus of elasticity of concrete, kg/cm^2 K is the modulus of subgrade reaction, kg/cm^3 μ is the Poisson's ratio h is the thickness of the slab *Equivalent radius of resisting section* When the interior point is loaded, only a small area of the pavement is resisting the bending moment of the plate. The radius of such an area is called as *Equivalent radius of resisting section.* Westergaard's gives a relation for equivalent radius of the resisting section in cm	[06]

$$b = \sqrt{1.6a^2 + h^2} - 0.675h \; for \; a \leq 1.724 \; h$$

Else if a > 1.724 h, b = a

Critical load positions

Since the pavement slab has finite length and width, either the character or the intensity of maximum stress induced by the application of a given traffic load is dependent on the location of the load on the pavement surface. There are three typical locations namely the interior, edge and corner, where differing conditions of slab continuity exist. These locations are termed as critical load positions.



(b) Check the adequacy of dowel bar system for a concrete pavement using the following data: Slab thickness = 33 cm; Joint width = 2 cm; Radius of relative stiffness = 103.53 cm; design wheel load = 8000 kg; percentage of load transfer = 40; spacing of dowel = 32 cm; modulus of dowel/concrete interaction = 41500kg/cm^3; E of steel = 2×10^6 kg/cm^2. [10]

Determination of allowable bearing stress – 2
Determination of Pt-2
Determination of actual bearing stress – 3
Comment on adequacy -1

Assume 30 mm as the diameter of the dowel bar;
f_{ck}=400 kg/cm^2

b = 3 cm

Allowable bearing stress on concrete = $F_b = \frac{(10.16-b)\times f_{ck}}{9.525}$

$$F_b = \frac{(10.16-3)\times 400}{9.525} = 300.68 \; kg/cm^2$$

Relative stiffness of the bar, $\beta = \sqrt[4]{\frac{kb}{4EI}} = \sqrt[4]{\frac{41500\times 3}{4EI}} = 0.35$

EI =(2×10^6×π×3^4)/64=7952156 kgcm^2

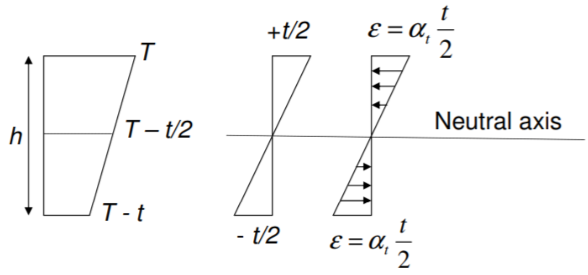
$$P_t\left[1 + \left[\frac{103.53-32}{103.53}\right] + \left[\frac{103.53-32\times 2}{103.53}\right] + \left[\frac{103.53-32\times 3}{103.53}\right]\right] = 0.4 \times 8000$$

$P_t[1 + 0.69 + 0.38 + 0.073] = 3200$

Or Pt = 1493.23 kg

	Maximum bearing stress developed $= \sigma_{max} = \frac{kP_t\,(2+\beta z)}{4\beta^3 EI}$ $\sigma_{max} = \frac{41500\times1493.21(2+0.35\times2)}{4\times0.35^3\times7952156} = 122.68\ kg/cm^2$ < 300.68 kg/cm^2. Hence the dowel bar system provided is adequate.	
	(c) The traffic studies and axle load distribution studies carried out during project preparation indicated that there are (i) 9800 vehicles per day with rear axle loads in the range of 2500 to 3500 kg and growth rate of 6.5% per annum (ii) 2800 vehicles per day with rear axle loads in the range of 11,000 to 13,000 kg and growth rate of 4% per annum. The road pavement is expected to be constructed in a period of 20 months after this study and the flexible pavement structure is to be designed for a life of 15 years. Determine the CSA value if the roads correspond to a two lane single carriage road. Calculation of VDF - 2 × 2 =4 Assumption of LDF - 1 × 2 =2 CSA determination for two cases – 2 × 2 =4 Case 1 P=9800 CV/day A=9800(1+0.065)$^{1.67}$ = 10887 CV/day Average load = 3000 kg $VDF = \left[\frac{3000}{8000}\right]^4 = 0.019$ $N = \frac{365\times[(1+0.065)^{15}-1]}{0.065}\times 10887\times 0.019\times 1\times 0.75 = 1.4\ msa$ Case 2: P=2800CV/day A=2800(1+0.065)$^{1.67}$ = 3111 CV/day Average load = 12000 kg $VDF = \left[\frac{12000}{8000}\right]^4 = 5.06$ $N = \frac{365\times[(1+0.065)^{15}-1]}{0.065}\times 3111\times 5.06\times 1\times 0.75 = 104.2\ msa$	[10]
3	(a) Discuss briefly about the temperature stresses induced in concrete pavements. Frictional stresses – description (2)+ sketch (1) Warping stresses - description (2)+ sketch (1) Temperature Stresses ➢ Due to the temperature differential between the top and bottom of the slab, curling stresses (similar to bending stresses) are induced at the bottom or top of the slab. ➢ If the temperature of the upper surface of the slab is higher than the bottom surface then top surface tends to expand and the bottom surface tends to contract resulting in compressive stress at the top, tensile stress at bottom and vice versa. ➢ Maximum temperature differentials occur during the day in the spring and summer months.	[06]

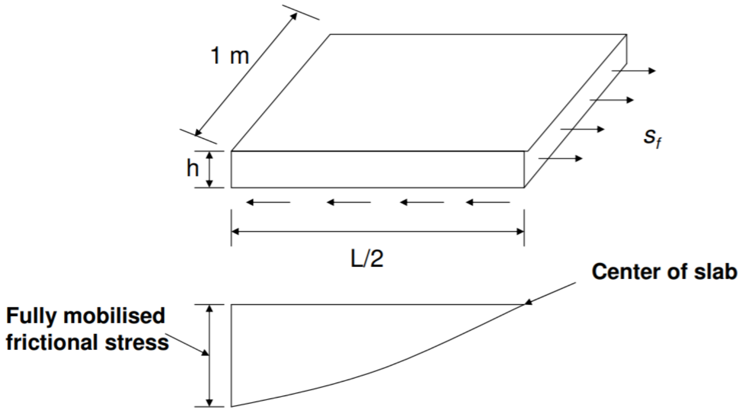
- During midday of summer, the surface of the slab, which is exposed to the sun, warms faster than the subgrade which is relatively cool.
- During night time the surface of the slab becomes cool when compared to the subgrade.
- The actual temperature differentials depend on the location..
- Temperature differential is expressed as temperature gradient per mm of slab thickness.



- Temperature at top = T
- Temperature differential = t
- Temperature at bottom = $T – t$
- Average Temperature (at mid height) = ($T+T-t)/2$ = T - $t/2$
- Increase in temperature of top fibre above average temperature = $t/2$
- Decrease in temperature of bottom fibre below average temperature = $t/2$

Frictional stresses

- Due to the contraction of slab due to shrinkage or due to drop in temperature tensile stresses are induced at the middle portion of the slab.
- The friction between a concrete slab and its foundation causes tensile stress – in the concrete.
- For plain concrete pavements, the spacing between contraction joints is so chosen that the stresses due to friction will not cause the concrete to crack.
- Longer joint spacing than that above requires the provision of temperature steel to take care of the stresses caused by friction.
- The number of tie bars are also determined by frictional stresses.



Variation of frictional stress

(b) Determine the warping stresses for a 25 cm concrete pavement with 13.5 m transverse joints, width of the lane is 3.75 m. The modulus of subgrade reaction is 2.8 kg/cm^3. Assume temperature differential for day conditions to be 1° per cm for computing warping stresses at the corner. Take thermal coefficient of concrete is 8×10^{-6}/°C, modulus of elasticity of concrete is 2.8×10^5 kg/cm^2, Poisson's ratio is 0.15, radius of contact area is 16 cm. [10]

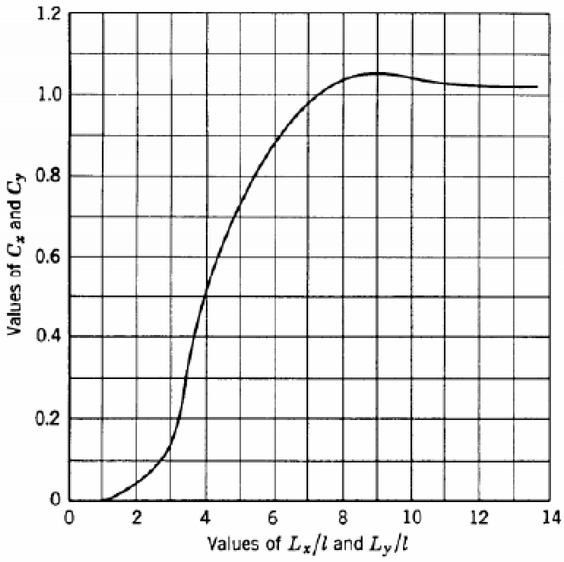
Determination of l – 2

Determination of Bradbury's stress coeffecients – 2
Warping stresses for interior, edge and corner – 2+2+2

Lx= 13.5 m
Ly=3.75 m

$$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4} = \left[\frac{2.8\times10^5\times25^3}{12\times2.8\times(1-0.15^2)}\right]^{1/4} = 107.43\ cm$$

Lx/l= 1350/107.43 = 12.57 ; Ly/l = 375/107.43 = 3.49



Cx =1.01 ; Cy = 0.35

Warping stress at interior = $Ste = \frac{Eet}{2}\left[\frac{C_x+\mu C_y}{1-\mu^2}\right] = \frac{2.8\times10^5\times8\times10^{-6}\times1\times25}{2} \times \left[\frac{1.01+0.15\times0.35}{1-0.15^2}\right]$

S_{ti} =30.44 kg/cm^2

Warping stress at edge= $Ste = \frac{C_x Eet}{2} = \frac{1.01\times2.8\times10^5\times8\times10^{-6}\times1\times25}{2} = 28.28\ kg/cm^2$

Warping stress at corner= $Stc = \frac{Eet}{3(1-\mu)}\sqrt{\frac{a}{l}} = \frac{2.8\times10^5\times8\times10^{-6}\times1\times25}{3(1-0.15)} \times \sqrt{\frac{16}{107.43}}$

$$Stc = 8.475\ kg/cm2$$

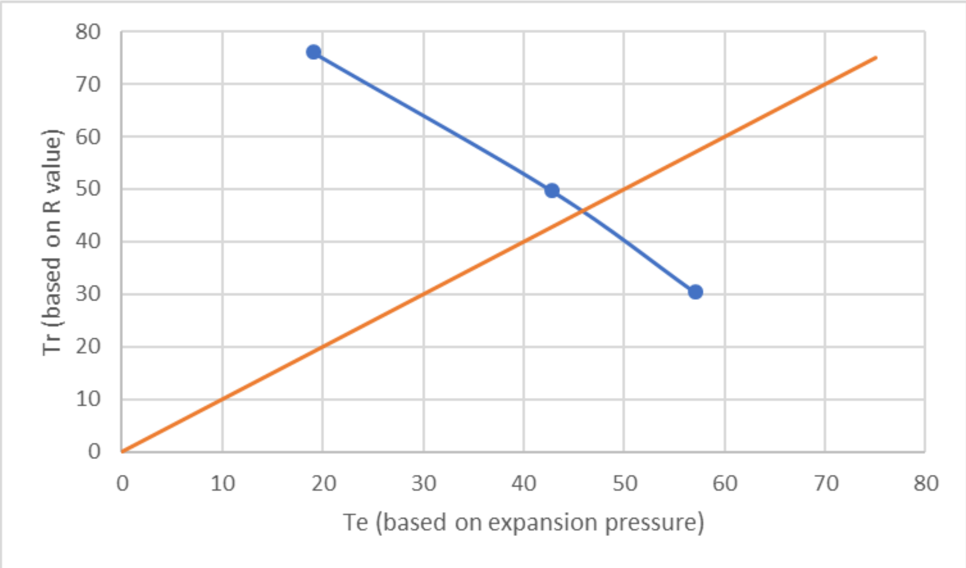
(c) Design pavement thickness by California R value method using the following data: [10]
Traffic index = 10.5
C value of base course =15
C value of 8 cm thick bituminous surface course =60
Test results on subgrade soil are as under:

Moisture content, %	R Value	Expansion pressure kg/cm^2	Exudation pressure, kg/cm^2
16.5	60	0.12	46.5
19	41	0.09	32
22.5	15	0.04	20

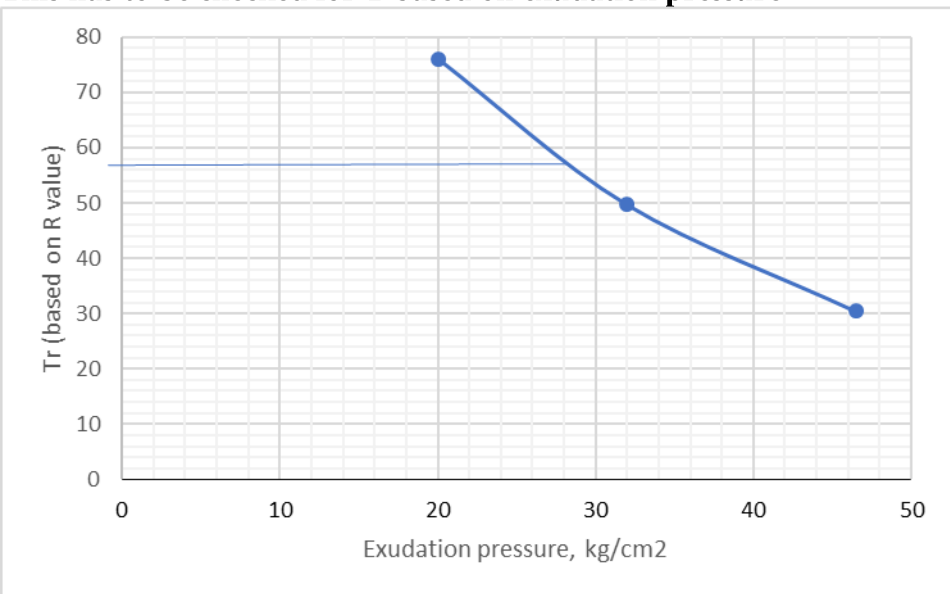
Calculation of T based on R value - 2
Calculation of T based on expansion pressure – 2
Calculation of optimum thickness from graph -2
Calculation of optimum thickness from exudation pressure -2
Calculation of equivalent pavement thickness – 2

$$T = \frac{k(TI)(90 - R)}{C^{\frac{1}{5}}}$$
$$k = 0.166$$

R value	Tr based on base course (using the above equation)	Te, based on expansion pressure = expansion pressure/(2.1×10^{-3})
60	**30.42**	**57.1**
41	**49.69**	**42.86**
15	**76.06**	**19.05**



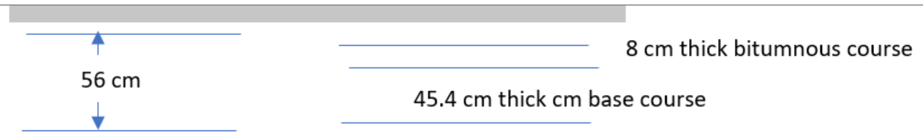
From the graph optimum thickness is 46 cm
This has to be checked for T based on exudation pressure



The highest T value is obtained from II graph = 56 cm. Hence, take 56 cm as the thickness of base course.
Converting bituminous course to equivalent base course thickness

$$\frac{8}{t} = \left[\frac{15}{60}\right]^{1/5}$$
$$or\ t = 10.6\ cm$$

Therefore, thickness of base course = 56-10.6 = 45.4 cm



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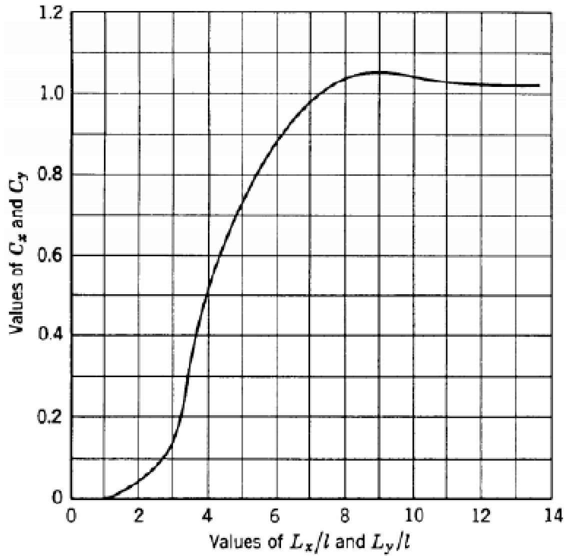

Chart 1.

Signature of CI

Signature of CCI

Signature of HoD

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Internal Assessment Test II – April 2019

Sub :	PAVEMENT DESIGN				Sub Code:	15CV833/10CV833	Branch:	CIVIL
Date:	20.04.2019	Duration:	90 min's	Max Marks: 50	Sem / Sec:	VIII A, VIII B and Exit Scheme		OBE

<u>Part A</u> is **<u>compulsory</u>** and Answer any **<u>one question from Part B</u>** **<u>Assume any missing data suitably. Provide neat sketches wherever necessary</u>**	MARKS	CO	RBT

PART A

		MARKS	CO	RBT
1	(a) Explain the California Resistance Value method of flexible pavement design.	[08]	CO3	L2
	(b) Explain IRC recommendations for the design of a concrete pavement.	[08]	CO3	L2
	(c) With neat sketches explain the different types of joints in cement concrete pavements? Also enlist the requirements of good joint sealant and joint fillers. Highlight the different materials that are commonly used for the same.	[08]	CO3	L2

PART B

		MARKS	CO	RBT
2	(a) Explain (i) Radius of relative stiffness (ii) Equivalent radius of resisting section (iii) critical load positions	[06]	CO1	L2
	(b) It is proposed to widen an existing 4 lane NH to 3 lane dual carriage way road. Design the pavement for the new carriage way with the following data:	[10]	CO3	L3

Initial traffic in both directions: 4950 CVPD
Construction period = 26 months
Design life: 15 years
Design CBR =7%
Traffic growth rate = 8%
VDF =4.5

Pavement Design Catalogue
Plate 2- Recommended Designs for Traffic Range 10-150 msa

CBR 7%				
Cumulative traffic (msa)	Total pavement thickness (mm)	Pavement Composition		
		Bituminous Surfacing		Granular base and sub-base (mm)
		BC (mm)	DBM (mm)	
10	580	40	60	
20	610	40	90	
30	630	40	110	Base = 250
50	650	40	130	
100	575	50	145	Sub-base = 230
150	695	50	165	

		MARKS	CO	RBT
	(c) Calculate the stresses at interior, edge and corner regions of a CC pavement using Westergaard's stress equation using the following data: Wheel load = 5100 kg, E = 3×10^5 kg/cm^2; μ =0.15; pavement thickness = 18 cm, modulus of subgrade reaction =6kg/cm^3, radius of contact area =15 cm.	[10]	CO3	L3

3	(a)	Differentiate between frictional stresses and warping stresses. Also explain critical combination of stresses.	[06]	CO1	L2
	(b)	A plate bearing test using 30 cm diameter plate carried out on a subgrade which yielded a pressure of 3kg/cm^2 after 10 load repetitions at 0.5 cm deflection. Design a highway pavement for a wheel load of 5100 kg with a tyre pressure of 7 kg/cm^2.	[10]	CO3	L3
	(c)	A CC pavement has a thickness of 18 cm and has two lanes of 7.2 m with a longitudinal joint along the centre. Design the dimensions and spacing of the tie bar. The other data are allowable working stress in tension = 1400kg/cm^2; unit weight of concrete = 2400 kg/m^3; coefficient of friction =1.5; allowable bond stress in deformed bar in concrete = 24.6 kg/cm^2.	[10]	CO1	L3

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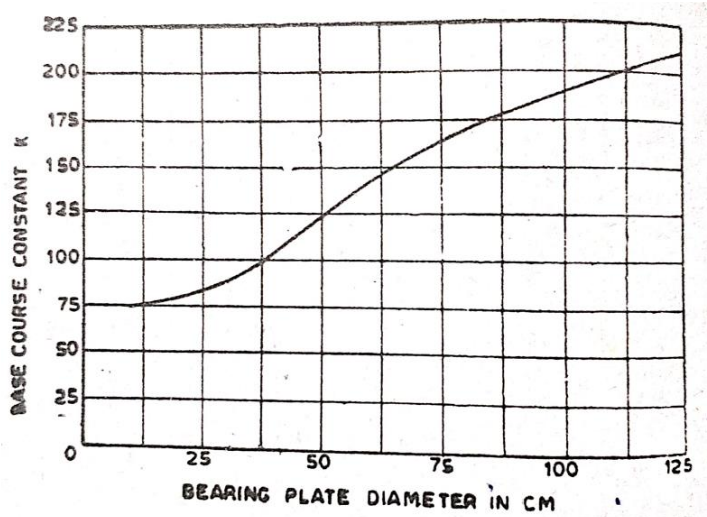

Fig. 1 Relation between Plate Diameter and Base Course Constant

Chart 1.

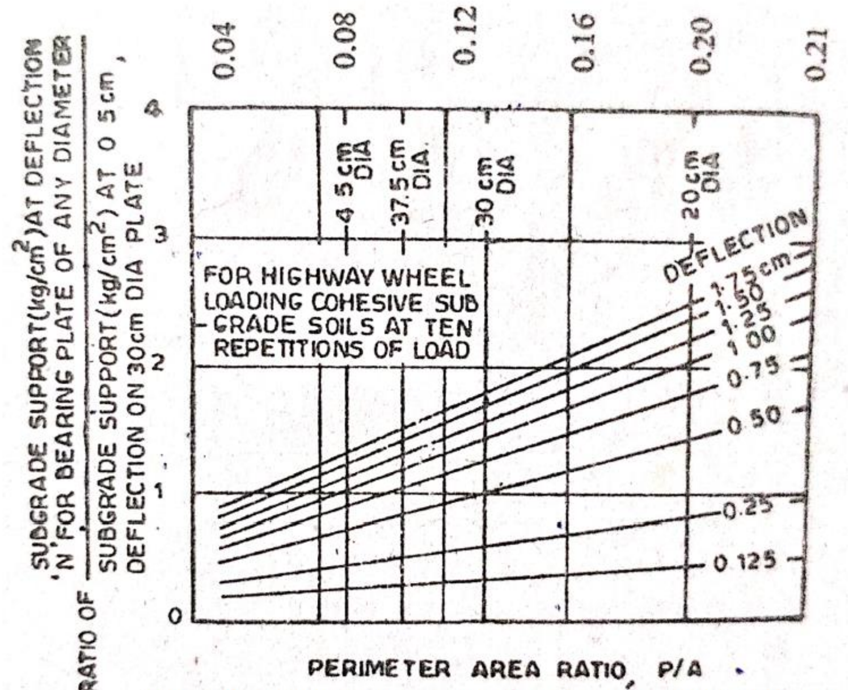

Fig. 2. Relationship between subgrade support with P/A ratio

Chart 2

Signature of CI	Signature of CCI	Signature of HoD