

STEP 1: DESIGN DATA				STEP 4: CALCULATION OF REPETITIONS OF AXLE LOADS FOR DIFFERENT MAGNITUDES DURING DESIGN LIFE							
Sr.No.	CRITERIA	=	VALUE ADOPTED	Typical Axle Load Distribution				Expected Repetitions during the design life			
				Single Axle Loads		Tandem Axle Loads		Single Axle Loads		Tandem Axle Loads	
				Axle Load, Tonnes	Distribution	Axle Load, Tonnes	Distribution	Axle Load, Tonnes	Expected Repetitions	Axle Load, Tonnes	Expected Repetitions
				(I)	(II)	(III)	(IV)	(V)	(VI) = (ESAL) x (II)	(I)	(VI) = (ESAL) x (IV)
1	Compressive Strength of Concrete (F _{ck})	=	350 Kg/cm ² =35 mpa								
2	Flexural Strength of Concrete = 0.7 √F _{ck}	=	41.41 Kg/cm ² =4.14 mpa								
3	Elastic Modulus of Concrete (E)	=	300,000 Kg/cm ² (CI.4.7.2- IRC-58)								
4	Poission's Ratio (μ)	=	0.15 (CI.4.7.2- IRC-58)								
5	Coefficient of Thermal Expansion of Concrete (α)	=	1.0E-05 /°C (CI.4.7.3- IRC-58)	19-21	0.00%	34-38	0.00%	20	0	36	0
6	Tyre Pressure (q)	=	8 Kg/cm ² (CI.4.2- IRC-58)	17-19	0.00%	30-34	0.00%	18	0	32	0
7	Rate of Increase of Traffic for every 5 year (r)	=	4% 3% 3% 2%	15-17	0.00%	26-30	0.00%	16	0	28	0
8	Spacing of Contraction Joints (L)	=	450 Cm	13-15	1.48%	22-26	0.00%	14	76,296	24	0
9	Width of Slab (B)	=	375 Cm	11-13	2.97%	18-22	0.00%	12	153,108	20	0
10	Present Traffic Volume	=	2660 ESAL/Day	9-11	11.28%	14-18	15.38%	10	581,501	16	792,862
11	Design Life of Pavement	=	20 Years	<9	84.27%	<14	84.62%	<10	4,344,243	<16	4,362,286
12	Number of Lanes/ Carriageway	=	2	Total	100.00%	Total	100.00%				
13	Dual Carriageway (Y/N)	=	Y	ITERATIONS FOR STRESS CALCULATIONS :-							
14	Type of Subgrade	=	S (R for Rocky & S for Soil)	STEP 5: TEMPERATURE (WARPING) STRESS CALCULATION							
15	If Soil Subgrade, CBR of Subgrade (%)	=	3	S _{te} = $\frac{E \alpha t C}{2}$ =temperature stresses in the edge region, Kg/cm ²							
16	Temperature Differential (t)	=	21 °C (Table-1- IRC-58)	h = Assumed Thickness of PQC Slab= 30 cm.							
17	Load Safety Factor (LSF)	=	1.2 (CI.4.2- IRC-58)	I = $\frac{(E h^3)^{1/4}}{(12(1-\mu^2) K)^{1/4}}$ = radius of relative stiff ness, cm.							
18	c/c distance of two tyres in dual wheel assembly, (S)	=	31 cm	= 84.106 cm							
STEP 2: DESIGN TRAFFIC CALCULATION (EQUIVALENT STANDARD AXLE LOADS):-				therefore							
	Present Traffic	=	760 Commercial Veh.per day.	L/I = 5.350							
	Weighted average of Vehicle Damage Factor	=	3.500 (refer enclosed Traffic Data)	B/I = 4.459 } rounded largest Value= 5.4							
	∴ Equvalent Std.Axles/Day (ESAL) = 3.5X760	=	2660	C = Bradbury's Coefficient, which can be ascertained directly from Bradbury's Chart against values of L/I and B/I (Fig.2 of IRC:58 - 2002)							
	Direction Distribution Factor (D _r)	=	25%	C = 0.82 For L/I and B/I = 5.4,							
	No. of Repetitions per lane:-=365 x 2660 x 0.25 x [(1+0.04) ⁵ - 1]/0.04+365 x2660 x 0.25 x [(1+0.03) ⁵ - 1]/0.03+	=	5155148 ESAL								
	365 x2660 x 0.25 x [(1+0.03) ⁵ - 1]/0.03+	=	5.1551 MSAL (Million std.axles)								
	365 x2660 x 0.25 x [(1+0.02) ⁵ - 1]/0.02	=									
STEP 3: CALCULATIONS FOR MODULUS OF SUBGRADE REACTION "K"				S _{te} = 25.830 Kg/cm ²							
For CBR 3.0 % , K value of DLC of 150 mm Thick- from Table 4,											
Therefore K Value of the DLC = 13.8											

CONSULTING ENGINEERING SERVICES (I) PVT.LTD.

DPR of Roads in Nanded Waghala City- Road NO.32

DESIGN OF PLAIN JOINTED RIGID PAVEMENT

(FOR THICKNESS = 30cm)

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STEP 6: CALCULATION OF LOAD STRESS IN CRITICAL REGION (EDGE)

(WESTERGAARD EQUATION)

$$\sigma = 0.529 (P/h^2) (1+0.54\mu) [4 \text{Log}_{10} (l/b) + \text{Log}_{10}b - 0.4048]$$

where
 σ = Load stress in edge region (Kg/cm²)

P = design wheel load
 = half of the single axle load
 = one fourth of the tandem axle load

h = pavement thickness in cm.
 μ = poissons ratio for concrete
 E = modulus of elasticity of concrete

k = modulus of subgrade reaction
 l = radius of relative stiffness, cm.
 a = radius of load contact area, assumed circular, cm.

= $\left[\frac{0.8521 P_d + S}{q \pi} + \frac{S}{\pi} \left(\frac{P_d}{0.5227 q} \right)^{0.5} \right]^{0.5}$ for single axle dual wheels

b = radius of equivalent distribution of pressure
 = a for a/h > 1.724
 = $(1.6 a^2 + h^2)^{1/2} - 0.675 h$ for a/h < 1.724

P_d = load on one tyre
 S = c/c distance of two tyres in dual wheel assembly =31cm
 q = tyre pressure, 8 Kg/cm²

STRESS RATIO, SR = $\frac{\text{(EdgeStress } \sigma \text{ calculated as above)}}{\text{(Flexural Strength of Concrete)}}$

Fatigue Life = N = Unlimited for SR < 0.45

$$N = \left[\frac{4.2577}{(SR) - 0.4325} \right]^{3.268}$$
 when 0.45 < SR < 0.55

$$\text{Log}_{10} N = \frac{0.9718 - SR}{0.0828}$$
 when SR > 0.55

STEP 7: CALCULATION OF LOAD STRESS IN CRITICAL REGION (EDGE)

Sl. No.	Axle Load (AL) Tonnes	(AL) x (LSF)	Wheel Load (P) (Kg)	a	b	Edge Stress (σ) from chart (Kg/cm ²)	Total* Stress (Kg/cm ²)	Check**	Stress Ratio (SR)	Expected Repetitions	Fatigue Life (N)	Fatigue Life Consumed (X) / (XI)
(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)	(XI)	(XII)	
Single Axle												
1	20	24	12000	24.025	22.453	21.000	46.83	UNSAFE	0.60	0	146507	0.00
2	18	21.6	10800	23.188	21.706	19.000	44.83	UNSAFE	0.54	0	1225917	0.00
3	16	19.2	9600	22.295	20.924	17.000	42.83	UNSAFE	0.49	0	INFINITE	0.00
4	14	16.8	8400	21.334	20.101	15.500	41.33	OK	0.44	76,296	INFINITE	0.00
5	12	14.4	7200	20.288	19.228	13.000	38.83	OK	0.38	153,108	INFINITE	0.00
6	10	12	6000	19.132	18.294	11.500	37.33	OK	0.32	581,501	INFINITE	0.00
7	<8	9.6	4800	17.826	17.279	9.000	34.83	OK	0.26	4,344,243	INFINITE	0.00
Tandem Axle												
8	36	43.2	10800	23.188	21.706	16.000	41.83	OK	0.54	0	146,507	0.00
9	32	38.4	9600	22.295	20.924	14.000	39.83	OK	0.49	0	1,225,917	0.00
10	28	33.6	8400	21.334	20.101	12.500	38.33	OK	0.44	0	INFINITE	0.00
11	24	28.8	7200	20.288	19.228	11.500	37.33	OK	0.38	0	INFINITE	0.00
12	20	24	6000	19.132	18.294	9.500	35.33	OK	0.32	0	INFINITE	0.00
13	16	19.2	4800	17.826	17.279	8.000	33.83	OK	0.26	792,862	INFINITE	0.00
14	<16	19.2	4800	17.826	17.279	6.250	32.08	OK	0.26	4,362,286	INFINITE	0.00
Overall Average Distribution							5.98	OK	0.05	10,310,295	INFINITE	0.00

* = Total Stress = Temperature Stress + Edge Stress.
 ** = Check whether Total Stress is < 43 Kg/cm² (Flexural Strength of Concrete)

STEP 8: CALCULATION OF CORNER STRESS

Check For Corner Stress		98th PERCENTILE LOAD CALCULATION					
		Single Axle Loads		Tandem Axle Loads		Equivalent Single Axle Load	
Axle Load	Distribution	Single Axle Load	Distribution	Equivalent Single Axle Load	Distribution	Equivalent Single Axle Load	
98 Percentile Axle Load = 8 Tonnes	19-21	0.00%	20T	34-38	0.00%	18T	
98 Percentile Wheel Load = 4000 Kg	17-19	0.00%	18T	30-34	0.00%	16T	
Radius of load contact area (i= 17.826 Cm	15-17	0.00%	16T	26-30	0.00%	14T	
Radius of Relative Stiffness (= 84.11 Cm	13-15	1.48%	14T	22-26	0.00%	12T	
Depth of Slab = 30 Cm	11-13	2.97%	12T	18-22	0.00%	10T	
	9-11	11.28%	10T	14-18	15.38%	8T	
Corner Stress = 11.1575 kg/Cm² <44.27	<9	84.27%	8T	<14	84.62%	6T	

therefore OK

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Distribution on Equivalent Single Axle Load				
ESAL	Distribution	Percentile		
20T	0.00%	200.00%	say=200	NA
18T	0.00%	200.00%	say=200	NA
16T	0.00%	200.00%	say=200	NA
14T	1.48%	200.00%	say=200	NA
12T	2.97%	198.52%	say=199	NA
10T	11.28%	195.55%	say=196	NA
8T	99.65%	184.27%	say=184	NA
6T	84.62%	84.62%	say=85	8

Therefore, 98 Percentile Axle Load = 8 T

Bradbury's Coeff (C)

L/I	C
1	0
2	0.04
3	0.175
4	0.44
5	0.72
6	0.92
7	1.03
8	1.077
9	1.08
10	1.075
11	1.05
12	1

K Value for Subgrade
CBR (%) K

1	0
2	2.10
3	2.80
4	3.50
5	4.20
6	4.50
7	4.80
8	5.03
9	5.27
10	5.50
11	5.64
12	5.78
13	5.92
14	6.06
15	6.20
16	6.34
17	6.48
18	6.62
19	6.76
20	6.90

K Value for DLC
10Cm 15Cm

5.60	9.70
9.70	13.80
13.15	17.30
16.60	20.80
18.70	24.25
20.80	27.70
23.13	32.37
25.47	37.03
27.80	41.70
30.02	41.70
32.24	41.70
34.46	41.70
36.68	41.70
38.90	41.70
38.90	41.70
38.90	41.70
38.90	41.70
38.90	41.70
38.90	41.70
38.90	41.70
38.90	41.70

KSUB	KDLC10	KSUB	KDLC15
2.10	5.60	2.10	9.70
2.80	9.70	2.80	13.80
3.50	13.15	3.50	17.30
4.20	16.60	4.20	20.80
4.50	18.70	4.50	24.25
4.80	20.80	4.80	27.70
5.03	23.13	5.03	32.37
5.27	25.47	5.27	37.03
5.50	27.80	5.50	41.70
5.64	30.02	5.64	41.70
5.78	32.24	5.78	41.70
5.92	34.46	5.92	41.70
6.06	36.68	6.06	41.70
6.20	38.90	6.20	41.70
6.34	38.90	6.34	41.70
6.48	38.90	6.48	41.70
6.62	38.90	6.62	41.70
6.76	38.90	6.76	41.70
6.90	38.90	6.90	41.70

Typical Axle Load Distribution

Single Axle Loads		Equivalent Single	Tandem Axle Loads		Equivalent Single
Axle Load	Distribution	Axle Load	Axle Load	Distribution	Axle Load
19-21	0.20%	20T	34-38	0.30%	18T
17-19	0.50%	18T	30-34	0.30%	16T
15-17	5.20%	16T	26-30	0.60%	14T
13-15	11.80%	14T	22-26	1.80%	12T
11-13	22.00%	12T	18-22	1.50%	10T
9-11	23.30%	10T	14-18	0.50%	8T
<9	30.00%	8T	<14	2.00%	6T

Distribution on Equivalent Single Axle Load

ESAL	Distribution				
20T	0.20%	100.00%	100	0	98 Percentile Axle Load 14
18T	0.80%	99.80%	100	0	
16T	5.50%	99.00%	99	0	
14T	12.40%	93.50%	94	14	
12T	23.80%	81.10%	81	12	
10T	24.80%	57.30%	57	10	
8T	30.50%	32.50%	33	8	
6T	2.00%	2.00%	2	6	