CONSULTING ENGINEERING SERVICES (I) PVT.LTD.

DPR of Roads in Nanded Waghala City- Road NO.3

DESIGN OF PLAIN JOINTED RIGID PAVEMENT *(FOR THICKNESS = 30cm)*

SHEET: 1 of 2

STEP 1: DESIGN DATA

Sr.No.	CRITERIA		VALUE ADOPTED
1	Compessive Strength of Concrete **(F_{ck})**	=	**350** Kg/cm^2 **=35 mpa**
2	Flexural Strength of Concrete = **0.7** $\sqrt{F_{ck}}$	=	**41.41** Kg/cm^2 **=4.14 mpa**
3	Elastic Modulus of Concrete **(E)**	=	**300,000** Kg/cm^2 **(Cl.4.7.2- IRC-58)**
4	Poission's Ratio (μ)	=	**0.15** **(Cl.4.7.2- IRC-58)**
5	Coefficient of Thermal Expansion of Concrete **(α)**	=	**1.0E-05** /^{o}C **(Cl.4.7.3- IRC-58)**
6	Tyre Pressure **(q)**	=	**8** Kg/cm^2 **(Cl.4.2- IRC-58)**
7	Rate of Increase of Traffic for every 5 year **(r)**	=	**4%** **3%** **3%** **2%**
8	Spacing of Contraction Joints **(L)**	=	**450 Cm**
9	Width of Slab **(B)**	=	**232 Cm**
10	Present Traffic Volume	=	**812 ESAL/Day**
11	Design Life of Pavement	=	**20 Years**
12	Number of Lanes/ Carriageway	=	**2**
13	Dual Carriageway (Y/N)	=	**Y**
14	Type of Subgrade	=	**S** (R for Rocky & S for Soil)
15	If Soil Subgrade, CBR of Subgrade (%)	=	**3**
16	Temperature Differential **(t)**	=	**21** ^{o}**C** **(Table-1- IRC-58)**
17	Load Safety Factor **(LSF)**	=	**1.2** **(Cl.4.2- IRC-58)**
18	c/c distance of two tyres in dual wheel assembly, **(S)**	=	**31 cm**

STEP 2: DESIGN TRAFFIC CALCULATION (EQUIVALENT STANDARD AXLE LOADS):-

	Present Traffic	=	232	Commercial Veh.per day.		
	Weighted average of Vehicle Damage Factor	=	3.500	(refer enclosed Traffic Data)		
∴	Equvalent Std.Axles/Day (ESAL) = 3.5X345	=	812			
	Direction Distribution Factor **(D_f)**	=	25%			
	No. of Repetitions per lane:-'=365 x 812 x 0.25 x [(1+0.04)5 - 1]/0.04+365 x 812 x 0.25 x [(1+0.03)5 - 1]/0.03+					
	365 x 812 x 0.25 x [(1+0.03)5 - 1]/0.03+	=	**1573677**	**ESAL**		
	365 x 812 x 0.25 x [(1+0.02)5 - 1]/0.02	=	**1.5737**	**MSAL**	(Million std.axles)	

STEP 3: CALCULATIONS FOR MODULUS OF SUBGRADE REACTION "K"

For CBR 5.0 % , K value of DLC of 150 mm Thick- from Table 4,

Therefore K Value of the DLC = **20.8**

STEP 4: CALCULATION OF REPETITIONS OF AXLE LOADS FOR DIFFERENT MAGNITUDES DURING DESIGN LIFE

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)
19-21	0.00%	34-38	0.00%	20	0	36	0
17-19	0.00%	30-34	0.00%	18	0	32	0
15-17	0.00%	26-30	0.00%	16	0	28	0
13-15	0.00%	22-26	0.00%	14	0	24	0
11-13	2.12%	18-22	0.00%	12	33,362	20	0
9-11	10.11%	14-18	0.00%	10	159,099	16	0
<9	87.77%	<14	100.00%	<10	1,381,216	<16	1,573,677
Total	100.00%	**Total**	100.00%				

ITERATIONS FOR STRESS CALCULATIONS :-

STEP 5: TEMPERATURE (WARPING) STRESS CALCULATION

$S_{te} = \frac{E \alpha t C}{2}$ =temperature stresses in the edge region, Kg/cm^2

h = Assumed Thickness of PQC Slab= **30 cm.**

$l = \frac{(E h^3)^{1/4}}{(12(1-\mu^2) K)^{1/4}}$ **= radius of relative stiff ness, cm.**

= 75.907 cm

therefore

L/l = 5.928
B/l = 3.056

} rounded largest Value= **5.9**

C = Bradbury's Coefficient, which can be ascertained directly from Bradbury's Chart against values of L/l and B/l (Fig.2 of IRC:58 - 2002)

C = 0.90 For L/l and B/l = 5.9,

S_{te}= 28.350 Kg/cm^2

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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/cm^2)**

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

$$= \left[\frac{0.8521\,P_d}{q\,\pi} + S\left(\frac{P_d}{\pi\left(0.5227\,q\right)}\right)^{0.5}\right]^{0.5}$$ 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/cm^2

STRESS RATIO, SR = (EdgeStress **'σ'** calculated as above) / (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	18.000	46.35	UNSAFE	0.56	0	399108	0.00
2	18	21.6	10800	23.188	21.706	17.000	45.35	UNSAFE	0.51	0	8633591	0.00
3	16	19.2	9600	22.295	20.924	15.500	43.85	UNSAFE	0.46	0	INFINITE	0.00
4	14	16.8	8400	21.334	20.101	13.500	41.85	OK	0.41	0	INFINITE	0.00
5	12	14.4	7200	20.288	19.228	12.000	40.35	OK	0.36	33,362	INFINITE	0.00
6	10	12	6000	19.132	18.294	10.500	38.85	OK	0.31	159,099	INFINITE	0.00
7	<8	9.6	4800	17.826	17.279	8.000	36.35	OK	0.25	1,381,216	INFINITE	0.00
Tandem Axle												0.00
8	36	43.2	10800	23.188	21.706	13.000	41.35	OK	0.51	0	399,108	0.00
9	32	38.4	9600	22.295	20.924	12.500	40.85	OK	0.46	0	8,633,591	0.00
10	28	33.6	8400	21.334	20.101	11.500	39.85	OK	0.41	0	INFINITE	0.00
11	24	28.8	7200	20.288	19.228	9.500	37.85	OK	0.36	0	INFINITE	0.00
12	20	24	6000	19.132	18.294	8.000	36.35	OK	0.31	0	INFINITE	0.00
13	16	19.2	4800	17.826	17.279	7.500	35.85	OK	0.25	0	INFINITE	0.00
14	<16	19.2	4800	17.826	17.279	5.500	33.85	OK	0.25	1,573,677	INFINITE	0.00
									Factor of Safety <1 hence safe			0.00
Overall Average Distribution							**4.78**	OK	0.04	**3,147,353**	**INFINITE**	**0.00**

*** = Total Stress = Temperature Stress + Edge Stress.**
**** = Check whether Total Stress is < 43 Kg/cm^2 (Flexural Strength of Concrete)**

STEP 8: CALCULATION OF CORNER STRESS

Check For Corner Stress

98 Percentile Axle Load	=	8 Tonnes
98 Percentile Wheel Load	=	4000 Kg
Radius of load contact area (a	=	17.826 Cm
Radius of Relative Stiffness (	=	75.91 Cm
Depth of Slab	=	30 Cm
Corner Stress	**=**	**10.8966 kg/Cm^2**

therefore ***OK***

98th PERCENTILE LOAD CALCULATION

Typical Axle Load Distribution

Single Axle Loads		Equivalent Single Axle Load	Tandem Axle Loads		Equivalent Single Axle Load
Axle Load	Distribution		Axle Load	Distribution	
19-21	0.00%	20T	34-38	0.00%	18T
17-19	0.00%	18T	30-34	0.00%	16T
15-17	0.00%	16T	26-30	0.00%	14T
13-15	0.00%	14T	22-26	0.00%	12T
11-13	2.12%	12T	18-22	0.00%	10T
9-11	10.11%	10T	14-18	0.00%	8T
<9	87.77%	8T	<14	100.00%	6T

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	0.00%	200.00%	say=200	NA
12T	2.12%	200.00%	say=200	NA
10T	10.11%	197.88%	say=198	NA
8T	87.77%	187.77%	say=188	NA
6T	100.00%	100.00%	say=100	NA

Therefore, 98 Percentile Axle Load = 8 T

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Bradbury's Coeff (C)

L/l	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	K Value for DLC 10Cm	15Cm
1	0		
2	2.10	5.60	9.70
3	2.80	9.70	13.80
4	3.50	13.15	17.30
5	4.20	16.60	20.80
6	4.50	18.70	24.25
7	4.80	20.80	27.70
8	5.03	23.13	32.37
9	5.27	25.47	37.03
10	5.50	27.80	41.70
11	5.64	30.02	41.70
12	5.78	32.24	41.70
13	5.92	34.46	41.70
14	6.06	36.68	41.70
15	6.20	38.90	41.70
16	6.34	38.90	41.70
17	6.48	38.90	41.70
18	6.62	38.90	41.70
19	6.76	38.90	41.70
20	6.90	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	
Axle Load	Distribution	Axle Load	Axle Load	Distribution
19-21	0.20%	20T	34-38	0.30%
17-19	0.50%	18T	30-34	0.30%
15-17	5.20%	16T	26-30	0.60%
13-15	11.80%	14T	22-26	1.80%
11-13	22.00%	12T	18-22	1.50%
9-11	23.30%	10T	14-18	0.50%
<9	30.00%	8T	<14	2.00%

Distribution on Equivalent Single Axle Load

ESAL	Distribution			
20T	0.20%	100.00%	100	0
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

Equivalent Single Axle Load
18T
16T
14T
12T
10T
8T
6T

98 Percentile Axle Load
14