



IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

“DESIGN OF RIGID PAVEMENT USING IRC AND CBR METHOD”

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ABSTRACT

Rigid pavements play a crucial role in modern transportation infrastructure due to their high durability, load-carrying capacity, and long service life. This study focuses on the design and analysis of rigid pavement using the California Bearing Ratio (CBR) method and Westergaard's theory. The project includes field surveying, soil testing, and pavement design considerations such as wheel load, temperature stresses, and joint design. The CBR value of the soil was determined to assess subgrade strength, and appropriate slab thickness was evaluated. The analysis considers critical loading conditions including interior, edge, and corner stresses. The results demonstrate that rigid pavements effectively distribute loads over a wider area and are more suitable for heavy traffic conditions. The study also highlights the importance of proper joint spacing and reinforcement in improving pavement performance and durability.

Key Words: Rigid Pavement, CBR, Westergaard, Joint Design, Temperature Stress.

I. INTRODUCTION

Transportation infrastructure plays a crucial role in economic development [1]. In developing regions, efficient road connectivity significantly improves accessibility, reduces travel time, and supports industrial growth [2]. Rigid pavements, constructed using cement concrete, provide higher durability and load distribution capacity compared to flexible pavements [3].

Rigid pavements distribute wheel loads over a wider area due to slab action and are less susceptible to deformation. The Indian Roads Congress (IRC) provides guidelines for pavement design, ensuring standardization and efficiency in construction practices [1].

This study focuses on the design of rigid pavement for a proposed road project, incorporating field survey data, soil testing, and analytical design methods [2].

II. LITERATURE REVIEW

Previous studies emphasize the importance of pavement design in ensuring long-term performance and cost efficiency [2]. The Indian Roads Congress (IRC) provides standard specifications for pavement design, materials, and construction practices [5].

Westergaard developed analytical models for stress analysis in rigid pavements, considering the slab as a thin elastic plate resting on a subgrade. His theory introduced the concept of modulus of subgrade reaction and radius of relative stiffness [4].

Research indicates that rigid pavements offer advantages such as reduced maintenance costs, higher load-carrying capacity, and longer service life compared to flexible pavements. Studies on CBR-based design highlight its effectiveness in determining pavement thickness based on subgrade strength [5].

Surveying techniques such as profile levelling are widely used for alignment design and estimation of cut and fill quantities. Soil strength evaluation through CBR testing remains a fundamental aspect of pavement design [5].

III. METHODOLOGY

The study involves evaluation of subgrade strength using the California Bearing Ratio (CBR) test. The CBR value is determined using the relation:

$$\text{CBR} = (\text{Load Applied} / \text{Standard Load}) \times 100$$

Based on experimental data, the CBR value is found to be approximately 5%, indicating moderate soil strength.

The methodology adopted for this study includes:

1. **Surveying:** Profile levelling was conducted along the proposed road alignment using auto-level instruments to determine ground elevations.
2. **Soil Testing:** CBR tests were performed to evaluate subgrade strength.
3. **Data Collection:** Field data including levels, distances, and soil properties were recorded.
4. **Design Approach:** Pavement thickness was determined using CBR values and IRC guidelines.
5. **Analysis:** Stress analysis was carried out using Westergaard's equations considering different loading conditions.

IV. DESIGN OF RIGID PAVEMENT

Westergaard analyzed rigid pavements as elastic plates resting on a subgrade. The behavior of the pavement system is governed by the modulus of subgrade reaction, which is defined as follows:

$$k = P / \Delta$$

Where:

k = Modulus of subgrade reaction (kN/m³)

P = Applied load or pressure (kN/m²)

Δ = Deflection of subgrade (m)

The radius of relative stiffness (l), an important parameter in rigid pavement analysis, is given by:

$$l = [(E h^3) / (12 (1 - \mu^2) k)]^{(1/4)}$$

Where:

E = Modulus of elasticity of concrete

h = Thickness of slab

μ = Poisson's ratio of concrete

k = Modulus of subgrade reaction

Critical Load Positions

- Interior loading
- Edge loading
- Corner loading

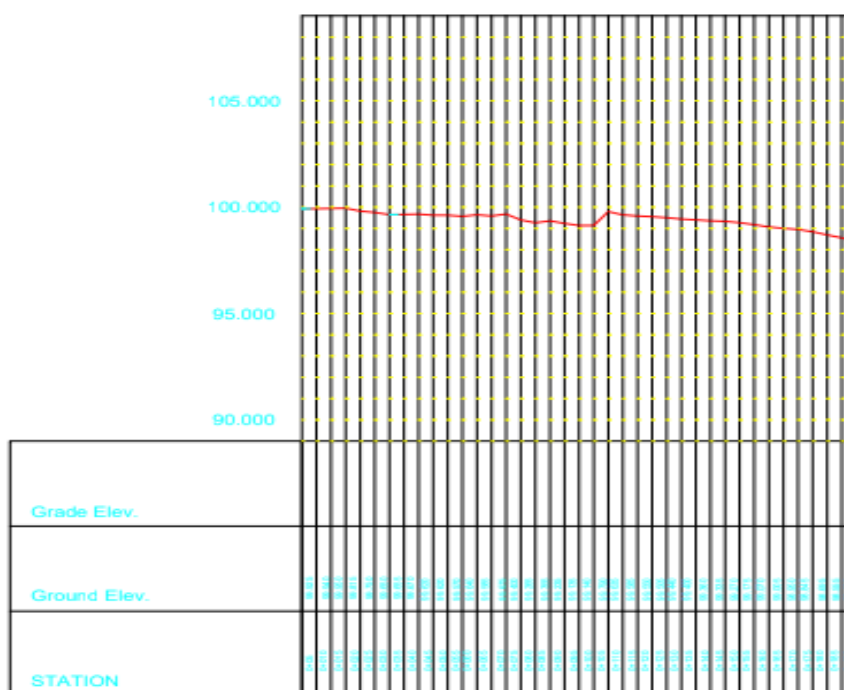
Maximum stress occurs at these locations depending on load position.

Levelling Profile

NO	CHAINAGE	BS	IS	FS	HI	RL	REMARK
1	0	1.015			101.015	100	
2	5		1.09			99.925	
3	10		1.075			99.94	
4	15		1.065			99.95	
5	20		1.2			99.815	
6	25		1.265			99.75	
7	30		1.365			99.65	
8	35		1.36			99.655	
9	40		1.345			99.67	
10	45		1.395			99.62	
11	50		1.395			99.62	
12	55		1.445			99.57	
13	60		1.375			99.64	
14	65		1.43			99.585	
15	70		1.34			99.675	
16	75		1.615			99.4	
17	80		1.75			99.265	
18	85		1.66			99.355	
19	90		1.78			99.235	
20	95	1.735		1.88	100.87	99.135	
21	100		1.875			99.14	
22	105		1.225			99.79	
23	110		1.38			99.635	
24	115		1.43			99.585	
25	120		1.465			99.55	

26	125		1.51			99.505	
27	130		1.575			99.44	
28	135		1.615			99.4	
29	140		1.655			99.36	
30	145		1.68			99.335	
31	150		1.745			99.27	
32	155		1.84			99.175	
33	160		1.945			99.07	
34	165		2.01			99.005	
35	170		2.065			98.95	
36	175		2.17			98.845	
37	180		2.32			98.695	
38	185		2.46			98.555	
39	190		2.61			98.405	

Cross Section



CBR Test Observation table

penetration (in mm)	applied load (in kg)
0.5	235
1	250
1.5	325
2	400
2.5	563
4	756
5	922
7	1032
10	1132
12.5	1475

Penetration /mm	Standard load /Kg	Load applied /Kg
2.5	1370	563
5	2055	922

CBR % for 2.5 penetration = (load applied / standard load) * 100 = (563/1370)*100 = 4.10%

CBR% for 5mm penetration =(load applied /standard load)*100 =(922/2055)*100 = 4.48%

The CBR value is 5%

Dowel bar

Dowel bar of expansion joints are mild steel round of short length . half length of this bar is bonded in one cement concrete slab and the remaining portion is embedded in adjacent slab but is kept free for the movement during expansion and contraction of the slab. The dowel bars allow opening and closing of the joint maintaining the slab edge at the same level and the load transference is effected from one slab to the other this is explained below.

12mm

Spacing = 300mm

No. of bar = 15

Tie bar

Tie bars are used across the longitudinal joints of cement concrete pavement. Tie bars ensure two adjacent slabs to remain firmly together. These bars are not designed to act as load transfer devices. Tie bar are thus designed to with stand tensile stresses the maximum tensile force in tie bars being equal to the force required to overcome frictional force between the bottom of the adjoining pavement slab and the soil sub-grade. The force is considered from the joint location to the subsequent joints or free edge.

Where

Allowable working stress in tension $S_s = 1400 \text{ kg/cm}^2$

Unit weight of concrete $W = 2400 \text{ kg/cm}^3$

Coefficient of friction $f = 1.5$

Allowable bond stress in deformed bars in concrete $S_b = 24.6 \text{ kg/cm}^2$

$b = 4.5 \text{ m}$

$h = 25 \text{ cm}$

allowable of steel per metre of longitudinal joints

$A_s = bfhW/100S_s$

$A_s = 4.5 \times 1.5 \times 25 \times 2400 / (100 \times 1400)$

$A_s = 1.666 \text{ cm}^2/\text{m}$

Using 1.2cm diameter bars having area of cross section

$A_s = 1.130 \text{ cm}^2$

Spacing = $100 \times 1.130 / 1.666$

Spacing = 67 cm

Using 1.2 cm diameter tie bars the length L_t is obtained

$L_t = dS_s / 2S_b$

$L_t = 1.2 \times 1400 / (2 \times 24.6)$

$L_t = 35 \text{ cm}$

Use 1.2 cm diameter tie bars of length 35 cm at 50 to 67 cm c/c

Quantity and cost Estimation for 1 km of road

S.no	Description	No.	Length	Breadth	Height	Quantity	Unit	Rate	Amount
1	Base layer	1	1000	4.5	0.25	1125		Rs	
	Cement					6237	Bag	370	2307690
	Sand					347	Tonnes	1333	462551
	Aggregate (20mm)					1949	Tonnes	111.5	217313.5
	Water					18	Tanks	350	6300
	Labour for spreading and consolidation	1	1000	4.5	0.25	1125		20	22500
2	Dry lean concrete	1	1000	4.5	0.13	585			
	Aggregate (40mm)					1267	Tonnes	121.2	153560.4
	Dust					10	Tonnes	1000	10000
									3179914.9
3	Labour charged	12					30	350	126000
									3305914.9
	contractor							10%	330591.49
									2975323.4
	Rollar charged							5%	89259.702
	Total cost of the project							3064583.112	

V. RESULT AND ANALYSIS

Rigid pavements effectively distribute loads and reduce stress on subgrade. The design based on CBR value ensures adequate thickness and performance. Proper joint spacing improves durability and reduces maintenance. The CBR value of the soil was found to be approximately 5%, indicating moderate subgrade strength. Based on this value, suitable pavement thickness was determined.

The analysis shows that:

- Rigid pavements effectively reduce stress on subgrade.
- Load distribution is wider compared to flexible pavements.
- Temperature stresses significantly influence design.
- Proper joint spacing improves pavement performance.

The estimated cost of construction for 1 km of road was approximately ₹30,64,583.

VI. CONCLUSION

Rigid pavements provide a durable and efficient solution for modern road construction. The study concludes that proper design using CBR values and Westergaard's theory ensures structural stability and long service life. The use of recycled materials can further reduce construction costs and environmental impact. Joint design and temperature stress considerations are critical for preventing pavement failure. Overall, rigid pavements are suitable for high-traffic roads due to their strength, durability, and low maintenance requirements.

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