UPGRADATION OF TWO-LANE ROAD TO FOUR-LANE ROAD

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Abstract**:** The satisfactory performance of the pavement will result in higher savings in terms of vehicle operating costs and travel time, which has a bearing on the overall economic feasibility of the project. This study discuss about the most economical method (CBR) as per IRC for the design of flexible pavement. Flexible pavement are preferred over cement concrete roads as they have a great advantage that these can be strengthened and improved in stages with the growth of traffic and also their surfaces can be milled and recycled for rehabilitation. The flexible pavements are less expensive also with regard to initial investment and maintenance. This total work includes collection of data required (traffic and leveling) and its analysis for flexible pavement design and cost estimation procedure which is very much useful to engineer who deals with highways.

Index Terms— Traffic data analysis, Earth work calculations, Design of flexible pavement, Cost analysis

I. INTRODUCTION

India has one of the largest road networks in the world. Development of road network is considered as one of the most important infrastructure development for economic growth. India has a road network of over 5,472,144 kilometers as on 31 March 2015, the second largest road network in the world. India had completed and placed in use over 25,600 kilometers of recently built 4 or 6-lane highways connecting many of its major manufacturing centers, commercial and cultural centers. With the increase in the road traffic, the design service volume of two lane road is exceeded due to which there is a need to update the road to a four lane road. The widening of road also helps in improving road safety and making driving a hassle-free experience.

II. TYPES OF PAVEMENTS

The pavements can be classified as the following three types:

1. Flexible pavement
2. Rigid pavement
3. Composite pavement

A. Flexible pavement

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure. The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavement normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low quality material can be used.

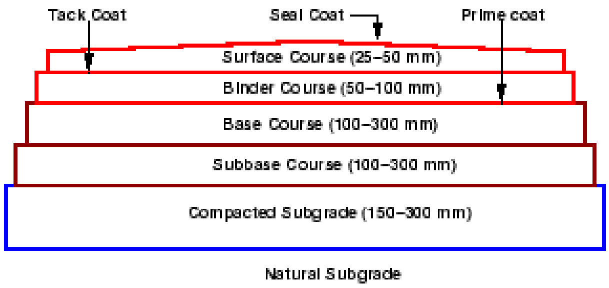


Fig. 2.1 Cross section of Flexible Pavement

III. VARIOUS COMPONENTS OF PAVEMENT

A. Subgrade

It is an integral part of road pavement structure as it provides the support to the pavement from beneath. The subgrade soil and its properties are important in the design of the pavement structure. The desirable properties of subgrade are

- Stability
- Incompressibility
- Permanency of strength
- Good drainage
- Ease of compaction

Subgrade course can be of different types: Stabilized soil sub base, water bound macadam sub base, etc.

B. Base course

The base course in pavements is a layer of material that is located under the surface layer. If there is sub base course, the base course is constructed directly above this layer. Base course can be following types: Granular Base, Macadam Base and Cementous Base.

C. Binder course

The binder shall be an appropriate type of bituminous material and aggregates complying with the relevant indian standards (IS). This layer consists of the following materials:

- *Bitumen:* The bitumen shall be paving bitumen of penetration grade S65 or A65 (60/70). As per IS Specifications for "paving bitumen IS: 73". In case of non-availability of bitumen of this grade, S90(80/100) grade bitumen may be used with the approval of engineer.
- *Coarse aggregate:* The coarse aggregates shall consist of crushed stone, crushed gravel/shingle or other stones. The aggregate shall satisfy the physical requirement set forth in the table:

Table 3.1. Physical requirements of aggregates.

S. no.	Test	Test method	Requirement
1	Los angles abrasion value	IS:2386(Part- 4)	40% maximum
2	Aggregate impact value	IS:2386(Part- 4)	30% maximum
3	Flakiness and elongation indices (total)	IS:2386(Part- 1)	30% maximum
4	Soundness • Loss with sodium sulphate • Loss of magnesium sulphate	IS:2386(Part- 5) 5 cycles 5 cycles	 12% maximum 18% maximum
5	Water absorption	IS:2386(Part- 3)	2% maximum

- *Fine aggregates*: Fine aggregates shall consist of crushed or naturally occurring material or a combination of the two, passing 2.36 mm sieve and retained on the 75 micron sieve.

IV. TRAFFIC DATA ANALYSIS

An accurate estimate of the traffic that is likely to use the project road is very important as it forms the basic input in planning, design, operation and financing. A thorough knowledge of the travel characteristics of the traffic likely to use the project road as well as other major roads in the influence area of the study corridor is, therefore, essential for future traffic estimation. Hence, detailed traffic surveys were carried out to assess the present day traffic and its characteristics. Following information is needed for estimating design traffic:

i. Initial traffic after construction in terms of number of Commercial Vehicles per day (CVPD).
ii. Traffic growth rate during the design life in percentage.
iii. Design life in number of years.
iv. Vehicle Damage Factor (VDF)
v. Distribution of commercial traffic over the carriageway

Table 4.1. Traffic data analysis

DAY	CAR/JEEP	2 WHEELER	MINI TRUCK		TRUCK		AGRICULTURE TRACTOR		BUS	CYCLE	CYCLE RICKSHAW	ANIMAL CART	TOTAL
			LADEN	UNLADEN	LADEN	UNLADEN	LADEN	UNLADEN					
1	7660	5326	536	369	886	287	80	124	214	500	78	42	
2	9066	6476	725	398	1058	247	137	130	236	449	115	47	
3	11065	6323	891	652	1715	258	258	253	349	447	144	54	
4	8569	5799	507	451	865	332	129	93	238	441	139	42	
5	9115	6476	672	451	1014	296	188	76	236	337	173	46	
6	10214	5665	855	665	1670	283	309	214	332	313	186	37	
7	8350	5557	444	483	815	376	170	51	223	273	186	42	
TOTAL	64039	41622	4630	3469	8023	2079	1271	941	1828	2760	1021	310	
VPD	9148	5946	661	495	1146	297	182	134	261	394	146	44	
PCU	1	0.5	1.5	1.5	3	3	1.5	1.5	3	0.5	2	5	
CVPD(in terms of Standard vehical	9148	2973	991	742	3438	891	273	201	783	197	292	220	20149

V. CENTRELINE READINGS

For 1km stretch of road the following natural reduced levels of ground along the central line of the road logitudenally are noted with the help of surveying and the required formation level of the road are also shown in the table below:

A. Longitudinal section readings and graph

Table 5.1. Longitudinal levels at particular intervals.

Reduced distance(m)	RL of ground(m)	Formation level(m)
0	98.625	99.500
150	98.975	99.250
300	99.045	99.000
450	99.110	98.750
600	99.015	98.500
750	98.560	98.250
900	98.250	98.000
1000	98.200	97.833

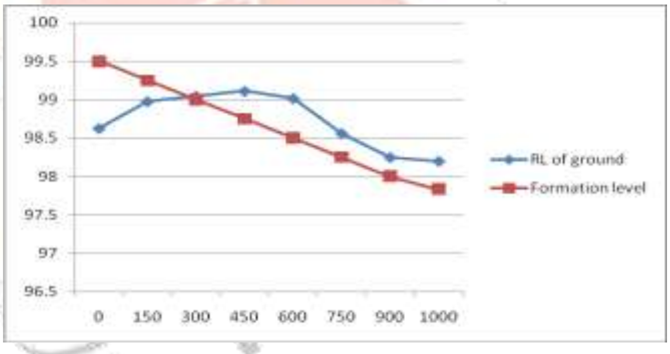


Fig.5.1. Longitudinal section of road

B. Cross section readings and graphs

Table 5.2. RL's at Distance (0 m)

Distance	0	2	4	5	6	7	8
R.L.(g)	98.970	98.680	98.625	98.800	98.760	98.690	98.64
R.L.(f)	99.400	99.450	99.500	99.475	99.450	99.425	99.40

Table 5.3. RL's at Distance (150 m)

Distance	0	2	4	5	6	7	8
R.L.(g)	98.936	98.93	98.975	98.55	98.66	98.83	99.075
R.L.(f)	99.15	99.2	99.25	99.225	99.2	99.175	99.15

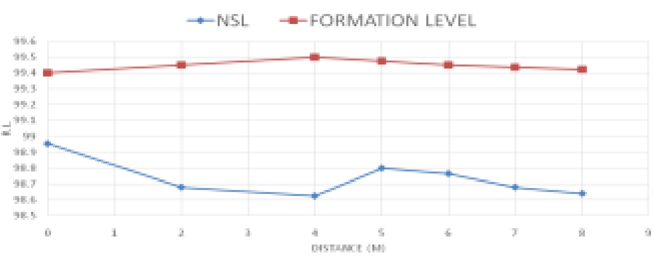


Fig 5.2. Cross Section at (0m)

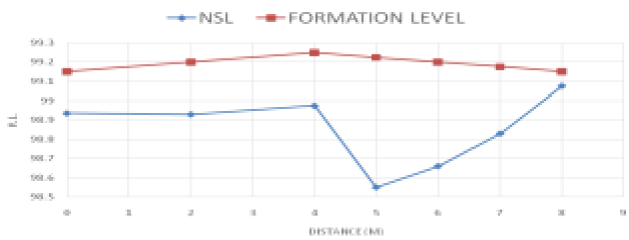


Fig 5.3. Cross Section at (150m)

Table 5.4. RL's at Distance (300 m)

Distance	0	2	4	5	6	7	8
R.L.(g)	99.18	99.185	99.045	99.135	98.925	98.145	98.935
R.L.(f)	98.9	98.95	99	98.975	98.95	98.925	98.9

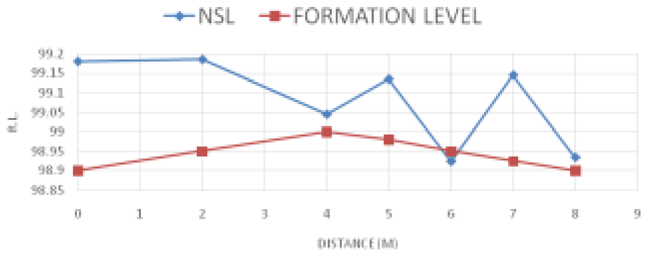


Fig 5.4. Cross Section at (300m)

Table 5.5. RL's at Distance (450 m)

Distance	0	2	4	5	6	7	8
R.L.(g)	99.09	99.09	99.11	99.095	98.875	98.975	98.885
R.L.(f)	98.65	98.7	98.75	98.725	98.7	98.675	98.65

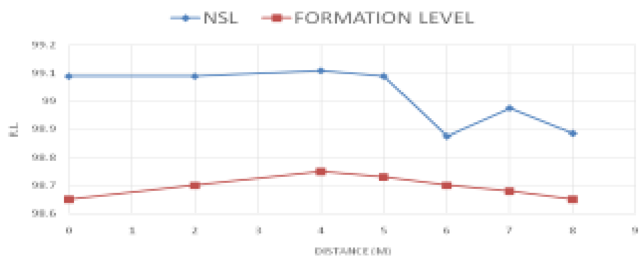


Fig 5.5. Cross Section at (450m)

Table 5.6. RL's at Distance (600m)

Distance	0	2	4	5	6	7	8
R.L.(g)	99.115	99.01	99.015	99.115	9.02	99.105	99.125
R.L.(f)	98.4	98.45	98.5	98.475	98.45	98.425	98.4

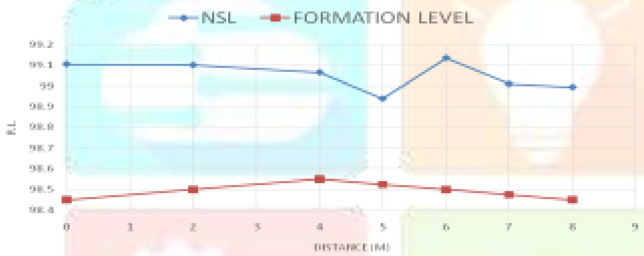


Fig 5.6. Cross Section at (600m)

Table 5.7. RL's at Distance (750m)

Distance	0	2	4	5	6	7	8
R.L.(g)	98.365	98.665	98.560	98.58	98.64	98.605	98.265
R.L.(f)	98.5	98.2	98.25	98.225	98.2	98.175	98.15

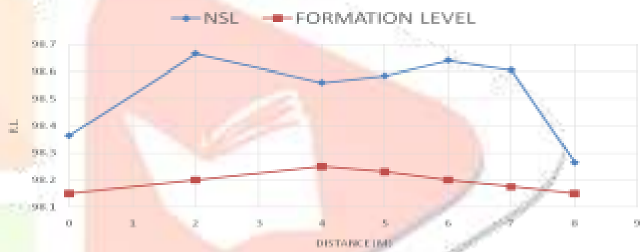


Fig 5.7. Cross Section at (750m)

Table 5.8. RL's at Distance (900m)

Distance	0	2	4	5	6	7	8
R.L.(g)	98.29	98.38	98.25	98.31	98.145	98.095	98.015
R.L.(f)	97.9	97.95	98	97.975	97.95	97.925	97.9

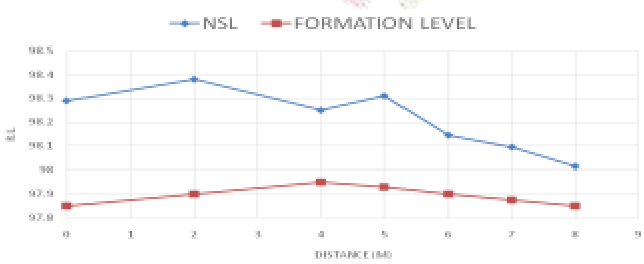


Fig 5.8. Cross Section at (900m)

Table 5.9. RL's at Distance (1000m)

Distance	0	2	4	5	6	7	8
R.L.(g)	98.22	98.065	98.2	98.2	98	98.3	98.31
R.L.(f)	97.973	97.8	97.83	97.805	97.78	97.755	97.773

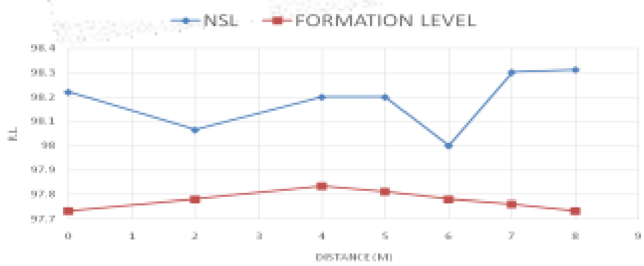


Fig 5.9. Cross Section at (1000m)

VI. EARTH WORK CALCULATIONS

Table no. 6.1. Earth work calculations

Distance	Mean depth (d)	Central area (Bd)	Area of sides ($0.5sd^2$)	Total area ($Bd+0.5sd^2$)	Length (L)	Banking ($Bd+0.5sd^2$)L	Cutting ($Bd+0.5sd^2$)L
0	0.714	7.14	0.51	7.65	150	1147.5	
150	0.342	3.42	0.11	3.53	150	529.5	

300	-0.135	-1.35	0.018	1.388	150		208.2
450	-0.322	-3.22	0.103	3.323	150		498.45
600	-0.556	-5.56	0.31	5.87	150		880.5
750	-0.333	-3.33	0.11	3.44	150		516.0
900	-0.32	-3.2	0.102	3.302	150		495.3
1000	-0.409	-4.09	0.167	4.257	100		425.7

Total excavation work in cutting = 3024.15

Total excavation work in banking = 1677.0

VII. SOIL EXPLORATION

A. Optimum Moisture Content test

The OMC test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort.

1. *OMC at the surface*
   Optimum moisture content = 15.2
   Maximum dry density = 1.733

2. *OMC at 500m depth*
   Optimum moisture content = 14
   Maximum dry density = 1.8

B. California Bearing Ratio test

CBR value at 2.5 mm penetration

$$= \frac{\text{Load at 2.5 mm penetration}}{\text{Standard load at 2.5 mm penetration i.e.1370kg}} * 100$$

CBR value at 5 mm penetration

$$= \frac{\text{Load at 5 mm penetration}}{\text{Standard load at 5 mm penetration i.e.2055kg}} * 100$$

Use the CBR value at the 2.5 mm penetration if it is more than that at 5 mm penetration otherwise, repeat the test. If the value at the 5 mm penetration still comes out to be more, then use it.

- ***Observations***

1. **Table 7.1**. CBR Test of Compacted Borrow Material

Penetration (mm)	Standard load(kg)	Dial Gauge Divisions	Load (kg)
0.0		0.00	0.00
0.5		3.59	35.90
1.0		6.65	66.50
1.5		9.50	95.00
2.0		12.50	125.00
2.5	1370	15.75	157.50
3.0		17.10	
5.0	2055	20.80	208.00
7.5		22.10	221.00
10.0		22.50	225.00
12.5		24.20	242.00

2. **Table 7.2.**.CBR below 500mm of compacted subgrade

Penetration (mm)	Standard load(kg)	Dial Gauge Divisions	Load (kg)
0.0		0.00	0.00
0.5		3.05	30.50
1.0		6.57	65.70
1.5		8.20	82.00
2.0		8.85	88.50
2.5	1370	9.34	93.40
3.0		9.53	95.30
5.0	2055	10.30	103.00
7.5		10.63	106.30
10.0		10.90	109.00
12.5		11.00	110.00

3. Effective CBR Graph (IRC 37)

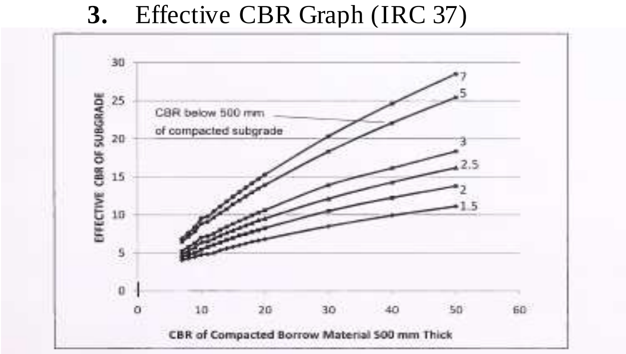


Fig. 7.1. Effective CBR of subgrade

Effective CBR of compacted subgrade 500mm below = 6.81%
Effective CBR of compacted borrow material = 11.5%
From graph, effective CBR of subgrade = 10%

VIII. DESIGN OF FLEXIBLE PAVEMENT BY IRC METHOD

The Indian Road Congress (IRC) has established various standards and codes for the design and construction of pavements in India. The codes mainly used for design of flexible pavements are IRC: 37-2012 and IRC-SP-84.
The flexible pavements are designed by using the two input parameters:
(i) Design traffic in terms of cumulative number of standard axles
(ii) CBR value of sub-grade
The design traffic is calculated by using the following formulae:

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

Where,
N = the cumulative number of standard axles to be catered for design in terms of msa
A= initial traffic in the year of completion of construction in terms of the number of the commercial vehicles per day
D= lane distribution factor
F= vehicle damage factor
n = design life in years
r = annual growth rate of commercial vehicles

- **Design calculations**

Design the pavement for up-gradation of two lane to four lane road with the following data:
- Dual carriage way with divider i.e. 4-lane divided carriageway
- Traffic growth rate per annum, r = 5%
- Design life, n = 15 years
- Lane distribution factor, D = 0.75
- Vehicle damage factor, F = 4.5
- No. of years in completion, x = 1 year
- ADT in both direction = 7118
- ADT in one direction = 3559

$A= P(1+r)^x$

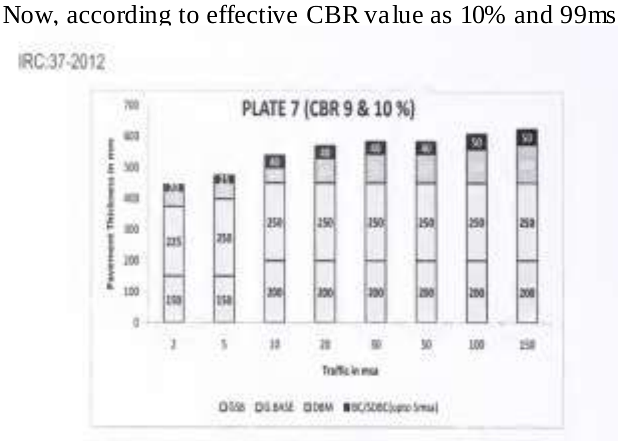
Where,
A= initial traffic after construction in terms of cvpd
P= number of commercial vehicles as per last count
x = number of years between the last count and the year of the completion of construction
r = annual growth rate of commercial vehicles

$A= P(1+r)^x$
$=3559*(1+.05)^1$
=3737cvpd

Now, number of standard axles $N= \frac{(365*3737*\{(1+0.05)15-1\}*0.75*4.5)}{0.05}$

$= 99*10^6$ or 99 million standard axle (msa)

Now, according to effective CBR value as 10% and 99msa thickness of the pavement is taken from PLATE 7 of IRC: 37-2012



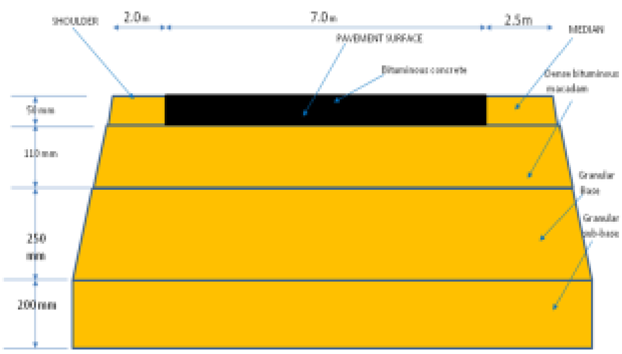


Fig. 8.1. Plate bar graph from IRC:37-2012

Fig. 8.2. Designed Cross-section of flexible pavement

Total pavement thickness = 610mm
Thickness of granular sub-base = 200mm
Thickness of granular base = 250mm
Thickness of dense bitumen macadam = 110mm
Thickness of bitumen concrete = 50mm
Width of shoulder for built up area = 2m

IX. COST ANALYSIS

Total length of road = 1.0 Km
Metalled width of road = 3.75 m
Formation width of road = 6.5m
Bitumen Present Rate (VG 10 Grade) = Rs42020/metric ton

Table 9.1. Cost Analysis of rigid pavement

Sr. no.	Description of item	No.	L(m)	B(m)	D/H(m)	Quantity	Rate	Amount
1	2	3	4	5	6	7	8	9
1.	Earth work from any lead including compaction and preparation of subgrade including loosening ,leveling of earth 225 mm thick top layer ,rough dressing of soil, final dressing of earth to give level, camber, watering, rolling with road roller, compacting the bed to achieve maximum dry density (As per C.S.R 24.5(A))							
	Below the GSB	1	1000	11.5	0.225	2588		
					TOTAL	2588	385.74	998295.12
2.	Providing and fixing brick on end edging as per CSR 24.15							
		2	1000	-	-	2000		
					TOTAL	2000	60.8	121600
3.	Granular subbase(coarse graded material grading 2)							
	Construction of granular sub-base by providing close graded material grading -II, spreading in uniform layers with motor grader on prepared surface, mixing by mix in place method with vibrator at OMC, and compacting with vibratory roller to achieve the desired density, complete as per technical clause 401 of MORT&H specifications							
		1	1000	11.5	0.2	2300		
					TOTAL	2300	1460.7	3359610
4.	Water Bound Macadam Grading II							
	Providing, laying, spreading and compacting stone aggregates of Grading II to water bound macadam specification including spreading in uniform thickness, hand packing, rolling with smooth wheeled roller 8-10 tones in stages to proper grade and camber, applying and brooming Water Bound Macadam Grading II requisite type of screening/ binding Materials to fill up the interstices of coarse aggregate, watering and compacting to the required density complete as per technical clause 404 of MORT&H specifications							
		1	1000	7	0.25	1750		
					TOTAL	1750	1741.8	3048150
5.	Providing and laying tack coat for D.B.M. with bitumen @ 0.25kg per sqm as per CSR 24.18 a							
		1	1000	7	-	7000		
					TOTAL	7000	18.73	131110
6.	Providing and laying Dense Bituminous Macadam 125mm thick using crushed aggregates of specified grading, premixed with bituminous binder G-30 @ 4%, carriage of mixed material to site of work, level and alignment, rolling with smooth wheeled, vibratory and tandem rollers to achieve the desired compaction complete as per technical clause 507 of MORT&H specifications.							
		1	1000	7	0.125	875		
					TOTAL	875	2970	2598750
7.	Providing and laying tack coat for B.C. with bitumen @0.40kg per sqm as per CSR 24.18b							
		1	1000	7	-	7000		
					TOTAL	7000	20.79	145530
8.	Providing and laying Dense Bituminous Macadam 125mm thick using crushed aggregates of specified grading, premixed with bituminous binder G-30 @ 5.5%, carriage of mixed material to site of work, level and alignment, rolling with smooth wheeled, vibratory and tandem rollers to achieve the desired compaction complete as per technical clause 509 of MORT&H specifications.							

		1	1000	7	0.05	350		
					TOTAL	350	4200	1470000
	Total amount							11873045.12
	Contingency charges @1.5%							178095.68
	Grand total							12051140.8
	Amount in Lakhs							120.51 Lakh

X. CONCLUTION

The pavement is designed as a flexible pavement upon a black cotton soil sub grade, the CBR method as per IRC 37-2001 is most appropriate and economical method. It is observed that flexible pavements are more economical for lesser volume of traffic. The life of flexible pavement is near about 15 years whose initial cost is low, needs a periodic maintenance after a certain period and its maintenance costs could be very high.

The CBR method is probably the most widely used method for the design of flexible pavement. The CBR method is based on strength parameter of the material and is therefore, more rational than the any other method. The shortcoming of the method is that it gives the same total thickness above a material irrespective of the quality of the overlying layers.

The thickness of crust varies with the change in the value of C.B.R. With higher value of C.B.R. the crust thickness is less and vice versa. Due to the saving in crust less quantity of material will be applicable so that, huge amount of money can be saved.

Further this research work can be carried with the different soaking conditions of soil with respect to time, and improving the C.B.R values with the stabilization process with the different materials and on different types of soils, also the design analysis can be done with some other suitable methods for betterment in the design and costing of flexible pavement.

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