Cement Treated Sub-Base For Bituminous Pavement

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Abstract*: In India, due to massive infrastructure construction activities are taking place both in rural and urban area have caused scarcity of construction materials. The pavement industry looks for ways of improving lower quality materials that are readily available for use in road way construction. Cement /lime treatment has become an accepted method for increasing the strength and durability of soils and marginal aggregates, reducing quantity of aggregates. Indian roads congress (IRC) developed a special publication for mix design of base/ subgrade. No pavement design guideline is presently available cement treated sub base. To overcome this problem, the objective of present research work is to develop a pavement design chart using cement and lime stabilized sub base for rural and urban roads with light and medium traffic (up to 50 MSA). It not only saves money but also helps to increase life cycle of roads.*

Index Terms - cement treated sub-base for bituminous pavement.

I. Introduction

For road bases, there is a variety of soils or granular materials available for construction, but they may exhibit insufficient properties (e.g. low bearing capacity, susceptibility for frost action), which then results in substantial pavement distress and reduction of the pavement life [1-5]. However, some addition of a stabilizing agent such as cement, bitumen, lime or some non-traditional agents can improve the properties of soil. Among these different stabilized materials, cement-bound materials develop a quite high stiffness and strength, and exhibit good performance for pavement serviceability and high durability. Stabilized bases can provide cost-effective solutions to many common designs and construction situations. Cement Treated Base (CTB) is a traditional method applied in road bases materials to improve its engineering properties due to the hardening of cement when moisture is present and extends the period of curing times. Bound base materials provide additional strength and support without increasing the total thickness of the pavement layers. Depending on project needs, CTB increases the construction speed, enhances the structural capacity of the pavement, or in some cases reduce the overall time project. In addition, a stiffer base reduces deflections due to heavy traffic loads, thereby extending pavement life. Base thickness of CTB is reduced because of high bearing strength compared to unbound granular base thicknesses [6-10]

II. Methodology

This chapter briefly summarizes the findings of studies performed at the Center for Highway Research and by other investigators in two major areas pertaining to cement-treated materials: factors affecting the tensile strength of cement-treated soil and shrinkage characteristics of cement-treated base materials. In addition, two mix design procedures are reviewed. The findings concerning tensile strengths are evaluated in more details.

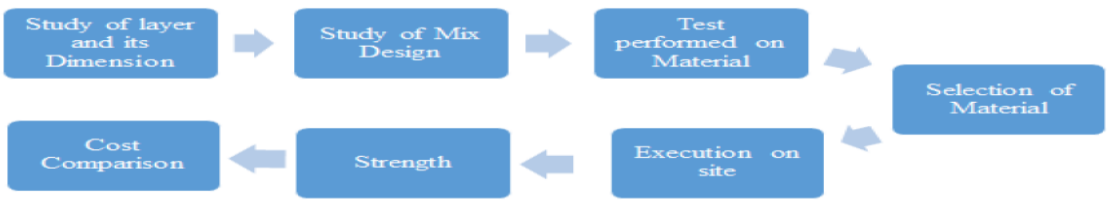


Figure1: Methodology

III. Study Of Pavement Composition.

The sub-base and the base layer can be unbound (e.g. granular) or chemical stabilized with stabilizers such as cement, lime, fly ash and other cementitious stabilizers. In case of pavements with cementitious base, a crack relief layer provided between the bituminous layer and the cementitious base delays considerably the reflection crack in the bituminous course. This may consist of crushed aggregates of thickness 100 mm of WMM conforming to IRC/MORTH Specifications or Stress Absorbing Membrane Interlayer (SAMI) of elastomeric modified binder at the rate of about 2 litre/m^2 covered with light application of 10 mm aggregates to prevent picking up of the binder by construction traffic (AUSTROADS).

- **Unbound sub-base layer**

Sub-base materials may consist of natural sand, moorum, gravel, laterite, kankar, brick metal, crushed stone, crushed slag and reclaimed crushed concrete/reclaimed asphalt pavement or combinations thereof meeting the prescribed grading and physical requirements. When the sub-base material consists of combination of materials, mixing should be done mechanically either using a suitable mixer or adopting mix-in-place method. The sub-base should have sufficient strength and thickness to serve the construction traffic.

- **Specifications of granular sub-base (GSB) materials conforming to MORTH:**

Specifications for Road and Bridge Works are recommended for use. These specifications suggest close and coarse graded granular sub-base materials and specify that the materials passing 425 micron sieve when tested in accordance with IS:2720 (Part 5) should have liquid limit and plasticity index of not more than 25 and 6 respectively. These specifications and the specified grain size distribution of the sub-base material should be strictly enforced in order to meet strength, filter and drainage requirements of the granular sub-base layer. When coarse graded sub-base is used as a drainage layer, Los Angeles abrasion value should be less than 40 so that there is no excessive crushing during the rolling and the required permeability is retained and fines passing 0.075 mm should be less than 2 per cent.

- **Strength parameter**

The relevant design parameter for granular sub-base is resilient modulus (MR), which is given by the following equation:

$$MRgsb = 0.2h^{0.45} \times MR\ subgrade$$

Where h = thickness of sub-base layer in mm

MR value of the sub-base is dependent upon the MR value of the subgrade since weaker subgrade does not permit higher modulus of the upper layer because of deformation under loads.

- **Study of Rut resistance & fatigue resistance**

The design procedures are based on the structural analysis of a multi-layered pavement subject to traffic loading. The design is based on the criteria that strains at three critical locations do not exceed certain values. These limiting strains, shown in Fig. 1, are as follows:

• The horizontal tensile strain ε1 at the bottom of the asphalt layer.

• The horizontal tensile strain ε2 at the bottom of the cemented layer.

• Vertical compressive strain ε3 at the top of the subgrade.

Sr.no	Property	Specified Value
1	Passing 75 mm sieve	100%
2	Passing 26.5 mm sieve	95-100%
3	Passing 75 micron sieve	15-100%
4	Plasticity Index	>10 %
5	Organic Content	2%
6	SO_4 Content	0.2%
7	Minimum Lime	2.5 %
8	Degree of Pulverization	>60%
9	UCS	As per contract specification

- **Mix design procedures**

The procedures used by two agencies, the Portland Cement Association (PCA) and the Texas Highway Department (THD) are summarized below. The PCA method is suggested for use with any type of soil in any part of the country; whereas, the method used by the Texas Highway Department is an example of a simplified mix design developed through experience with the use of locally available materials in the design and construction of cement-treated bases and sub bases within the State of Texas.

- **Standard Requirements for Graded Soil Aggregate Use in Bases or Highways**

ASTM comprises quality-controlled graded aggregates may be expected to provide appropriate stability and load support for use as highway or airport bases or sub-bases. This requirement delineates the aggregate size variety and ranges in mechanical analyses for standard sizes of coarse aggregate and screenings for use in the construction and maintenance of various types of highways. The gradation of the final composite mixture shall conform to an approved job mix formula, within the design range prescribed by ASTM D 448, ASTM D 1241 and ASTM D 2940, subject to the appropriate tolerances.

- **Mix Design of Cement Treated Sub Base (CTSB)**

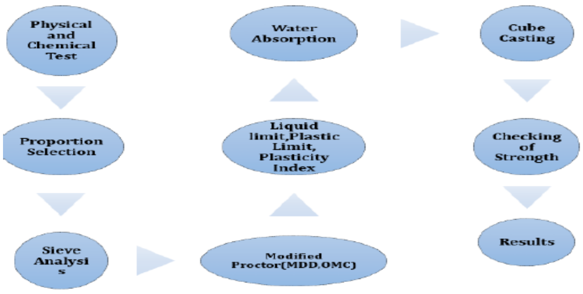


Figure2. Process Cycle for CTB and CTSB

1. Physical and chemical testing of aggregate, cement, water.
2. Selection of Proportion of Material like GSB, dust and cement (% weight) to form CTSB is done with the help of MORTH table 400-4.
3. Sieve Analysis of final CTSB is done and compared with MORTH table 400-4.
4. Then, Modified Proctor test is done to determine Max. Dry Density (MDD) and Optimum Moisture Content of CTSB with min. cement content according to IS 2720 (Part 8).
5. Find Liquid Limit, Plastic Limit and Plasticity Index according to IS 2720 (part 5).
6. Plasticity Modulus and Product are determined according to IS 2720 (part 5).
7. Find Uniformity Coefficient as specified.
8. 10% Fines value is determined according to IS 2386 (Part 4)
9. Water absorption of material larger and less than 10mm in size is found out according to IS 2386 (part 3).
10. Then cubes are casted with the help of Vibro Hammer (DLC).

IV. OBSERVATIONS.

Trials: CTSB - Cubes casted at different moisture contents for Determining OMC & MDD.

Trial No.01 Cement - 2 % and Moisture Content - 2%.

Table 2. Cement 2% and Moisture content 2%

Trial No.	**1**		
Mould No.	1	2	3
Wt. of Mould	12400	12440	12300
Wt. of Mould+Wt. of mix	20100	20100	19890
Weight of Concrete mix	7700	7660	7590
Volume of Mould	3375	3375	3375
Wet Density	2.281	2.270	2.249
Moisture Content (%)	2.00	2.00	2.00
Dry Density (g/cc)	2.237	2.225	2.205
Average Density (g/cc)	**2.222**		
Compressive Strength	0	0	0

i. **Moisture Content - 4.0 %.**

Table 3. Cement 2% and Moisture content 4%

Trial No.	**1**		
Mould No.	4	5	6
Wt. of Mould	11460	12760	11560
Wt. of Mould+Wt. of mix	19150	20460	19360
Weight of Concrete mix	7690	7700	7800
Volume of Mould	3375	3375	3375
Wet Density	2.279	2.281	2.311
Moisture Content (%)	4	4	4
Dry Density (g/cc)	2.191	2.194	2.305
Average Density (g/cc)	**2.230**		
Compressive Strength	0	0	0

ii. **Moisture Content - 6.0 %**

Table 4. Cement 2% and Moisture content 6%

Trial No.	1		
Mould No.	7	8	9
Wt. of Mould	12840	12360	12300
Wt. of Mould+Wt. of mix	20580	20420	20100
Weight of Concrete mix	7740	8060	7800
Volume of Mould	3375	3375	3375
Wet Density	2.293	2.388	2.311
Moisture Content (%)	6	6	6
Dry Density (g/cc)	2.164	2.253	2.305
Average Density (g/cc)	**2.240**		
Compressive Strength	2.133	3.556	2.444
Average	**2.711**		

iii. Moisture Content - 8.0 %.

Table.5 Cement 2% and Moisture content 8%

Trial No.	1		
Mould No.	10	11	12
Wt. of Mould	12600	10620	12500
Wt. of Mould+Wt. of mix	21120	19020	20720
Weight of Concrete mix	8520	8400	8220
Volume of Mould	3375	3375	3375
Wet Density	2.524	2.489	2.436
Moisture Content (%)	8	8	8
Dry Density (g/cc)	2.337	2.305	2.305
Average Density (g/cc)	**2.316**		
Compressive Strength	4.978	4.111	4.089
Average	**4.392**		

iv. Moisture Content - 10.0 %

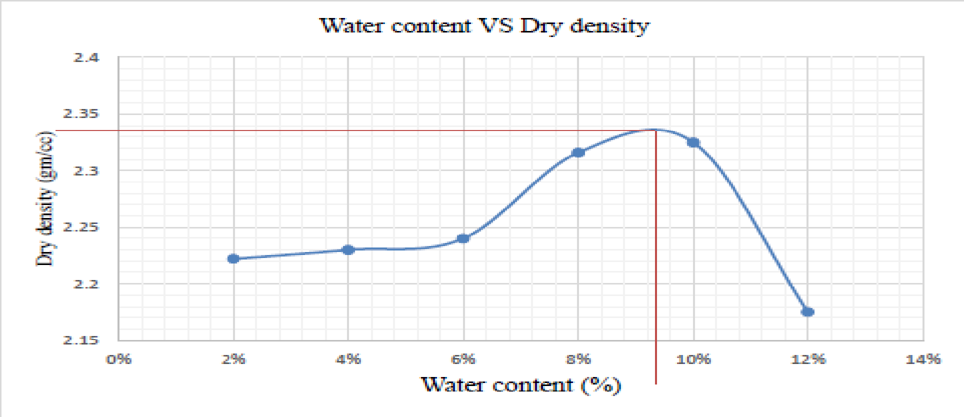
Table 6 Cement 2% and Moisture content 10%.

Trial No.	1		
Mould No.	13	14	15
Wt. of Mould	12600	10600	12500
Wt. of Mould+Wt. of mix	21080	19140	21100
Weight of Concrete mix	8480	8540	8600
Volume of Mould	3375	3375	3375
Wet Density	2.513	2.530	2.548
Moisture Content (%)	8	8	8
Dry Density (g/cc)	2.326	2.343	2.305
Average Density (g/cc)	**2.325**		
Compressive Strength	2.667	2.667	3.556
Average	**2.963**		

v. Moisture Content - 12.0 %.

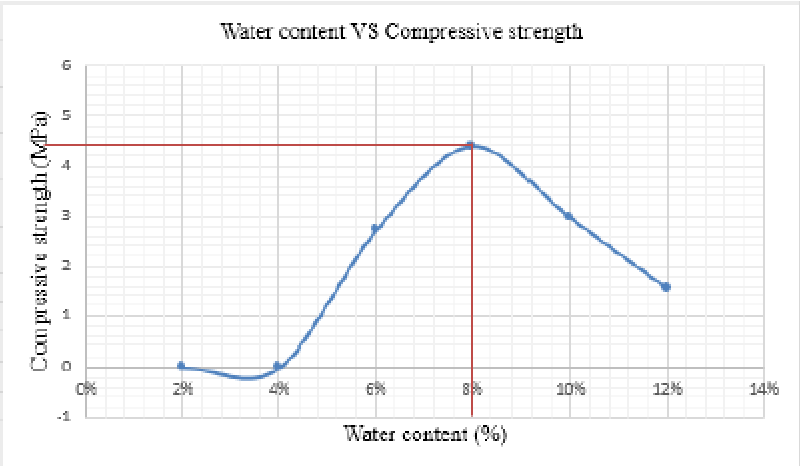
Table7Cement 2% and Moisture content 12%

Trial No.	1
Mould No.	16
Wt. of Mould	12840
Wt. of Mould+Wt. of mix	20620
Weight of Concrete mix	7780
Volume of Mould	3375
Wet Density	2.305
Moisture Content (%)	6
Dry Density (g/cc)	2.175
Average Density (g/cc)	**2.175**
Compressive Strength	**1.568**



Graph 3 DD VS WC- 2% cement content.

OMC=9.4%
MDD=2.34 gm/cc



Graph 4. CS VS WC- 2% cement content

Six numbers of trials were taken for Moisture content 2%, 4%, 6%, 8%, 10%, 12% and in each trail percentage of cement is varied from 2% to 6%. The graphs are plotted for all the combinations. Complete set of tables are not produced here due to limited space.

V. RESULTS.

For 4% cement content and 8% water content, We get,
Maximum Dry Density: 2.388 gm/cc
Optimum moisture content: 8%
Maximum compressive strength: 5.8 MPa.

Table 8 Thickness and width comparison

layer	conventional		layer	treated	
	thickness (mm)	width (m)		thickness (mm)	width (m)
SDBC	50	9	BC	35	9
DBM	100	9	AIL	100	9
WMM	250	10	CTB	150	10
GSB	250	10	CTSB	190	10
Total	650			**475**	

Table 9 Cost of conventional road for 1 km in length.

Layer	Quantity (m^3)	Thickness (mm)	Rates (Rs)	Cost (Rs.)
SDBC	450	50	7832.5	3524625
DBM	900	100	6687.75	6018975
WMM	2500	250	1348.5	3371250
GSB	2500	250	710.95	1777375
Total				**14692225**

Table 10 Cost of treated road for 1 km in length

Layer	Quantity (m^3)	Thickness (mm)	Rates (Rs)	Cost (Rs)
BC	315	35	7832.5	2467237.5
AIC	900	100	1700	1530000
CTB	1500	150	2000	3000000
CTSB	1900	190	1800	3420000
Total				**10417237.5**

Difference= Rs. 1,46,92,225- Rs. 1,04,17,237.5= Rs. 42,74,987.5

VI. CONCLUSION

The following conclusions can be drawn from the study:

- Longer Life of pavements.
- Speed of the Project Completion is accelerated.
- Reduced Use of Aggregates.
- Less local construction traffic due to fast construction.
- Transportation/haulage is reduced.
- Reduced Project Cost (approx. 15 lakhs per KM)
- Reduced thickness of pavement.
- Reduction of bitumen consumption due to strong Sub Base.
- Aggregate consumption is less for the case of stabilized base compared to that of the conventional method.
- Uniform distribution of Load in Cement treated service road as compared to conventional road.
- Resistance against cracking and fatigue cracking.
- Best option in low lying water clogged area.

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