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Experimental Study on Practice of Cement Treated Subbase (CTSB) Layer in Flexible Pavement of National Highways in India

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Abstract. Due to the large number of infrastructure projects taking place in rural and urban areas there has been a shortage of building materials. The road industry is looking at ways to improve low-quality materials that are easily accessible for use in road construction. Cement / lime treatment has become an acceptable way to increase soil strength and consistency with moderate proportions, to reduce the number of compounds. The Indian roads congress (IRC) has developed a special edition for the mixed construction of the base / ground floor. There is no design guide currently available for the under the cement base. To overcome this problem, the aim of the current project is to create a chart of the paved area using concrete and limestone on rural and urban roads with small and medium vehicles. It not only saves money but also helps to increase the life cycle of roads. At the base of the road, there are different soils or granite materials available for construction, but they may indicate insufficient structures and lead to significant road stress and reduced life. However, the addition of a stabilizing agent such as cement, asphalt, lime or other non-traditional materials can improve soil properties. Among these various stable materials, cemented materials improve strength and high strength, and demonstrate the excellent performance of the paved system and high durability. Solid foundations can provide inexpensive solutions to many common designs and building conditions. Cement Treated Sub Base (CTSB) is a common method used on road foundations to improve its engineering properties due to the durability of cement where moisture is present and extends the healing time. The bonded base material provides additional strength and support without increasing the overall thickness of the mortar layers. Depending on the needs of the project, CTB increases construction speed, improves the capacity of the pavement structure, or in some cases reduces the full-time project. In addition, a strong foundation reduces deviation due to heavy traffic loads, thereby extending the life of the pavement. CTB base thickness is reduced due to higher carrying capacity compared to granular base thickness.

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Introduction

In the flexible pavement of bitumen concrete, the use of Cement Treated Sub – base is the new and modern technological method in India. The main reason for the sub base is that it reduces the project cost when compared to Granular sub-Base courses at Flexible pavement of using Grade 2 at Bituminous base and Bituminous Concrete . It increases the speed of the project and extends the major life time of the flexible pavement. It exhibits and results in good performance, High Durability & High bearing strength.[1-2]Sub base treats and helps to subgrade some addition of stabilizing and traditional agents to improve the quality of the soil. The best new method in Indian civil Technology but it may also fail in high embankments at flexible pavement. Main objective is material properties analysis, mix designing procedures, Trail stretch, construction methodology of cement treated sub-base(CTSB) as per control standards as per IRC SP 89-2010.This report is to Conforms / finalize the Design Mix for cement treated sub-base (CTSB) as per the approved pavement design & IRC – 89-2010.

Note : Cholapuram to Thanjavur (NH45C) by laying this technique for **first time in Tamil Nādu**.
Patel Infrastructure Limited, Kumbakonam

Equipments for Lab JMF

- Cube molds. (150 x 150 x 150 mm)
- Sieves (as required)
- Trays, scoop, tape., etc.
- Vibrating Hammer
- Compression testing machine
- CBR testing machine & Molds.
- Proctor Testing equipment.

Acceptance Criteria & QC Checks:

- ✓ Grading shall Satisfies to limit specified in IRC SP 89-2010 Table 8 –Grading III
- ✓ Design JMF Mix should attain the minimum compressive strength of 3 Mpa in 7 days.
- ✓ Properties of stabilizer and stabilizing material shall satisfy the prescribed codal provisions.
- ✓ Confirmatory Test – Durability test prescribed in IRC SP 89-2010

Flowchart Mix Design

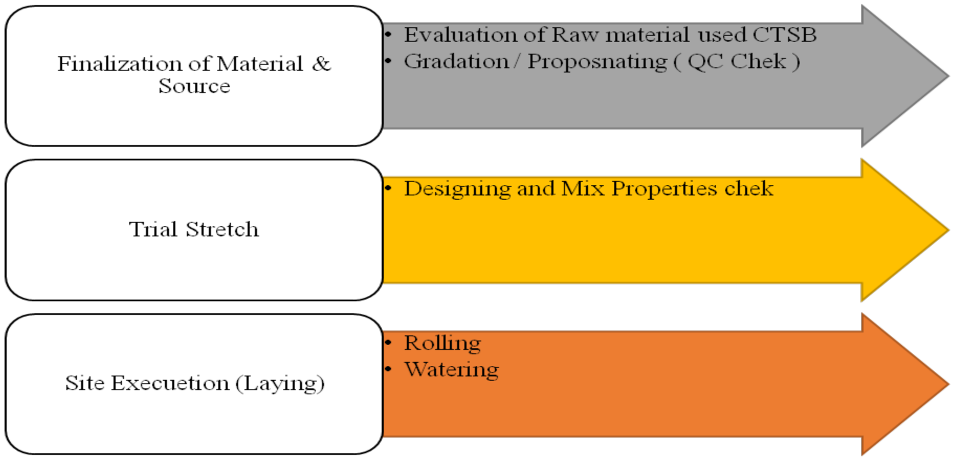


Figure -1 Flow Chart of Mix Design

The chart explains the basic concept from materials collections to site execution with the proportion of mix design based on the principle of MORTH.

Materials & Source

Table -1 *Material Source for Design [3-5]*

S.No	Material Description	Source of Materials
1	CTSB Crushed Material	Ragathampatti Quarry / Crusher
2	40mm Coarse Aggregate	
3	Cement	M/s Dalmia cement , M/s Ultratech Cements, M/s India Cements
4	Water	Borehole @ 138+200 LHS & 162+500 LHS

Evaluation Of Raw Materials Used For CTSB Crushed Materials:
Clean, hard and durable CTSB Crushed Material (53mm down) crushed in 250 TPH Crusher plant (Ragathampatti Quarry / Crusher) has been selected for the Design and Casting mix which is blended with crusher dust to achieve the required grading properties.

Properties of coarse aggregate

Table -2 Properties of Coarse Aggregate

Test Descriptions	Test Result	Specification limit
Aggregate Impact Value	36.22	Max. 35%
10% Fines Value	Test in Progress	Min 50 KN
Organic Content	Test in Progress	Max 2%
Water absorption	0.857	Max. 2%

Fine Aggregate (40MM Aggregate - Crusher Dust)
Clean, hard, durable crusher obtained from crushing of stone boulders crushed by 250 TPH crusher plant (RAGATHAMPATTI) has been selected for the design which complies with the requirement of the MORTH specifications.

Properties of 6MM down. (Crusher Dust)

Table -3 Properties of Fine Aggregate

S.No	Test Descriptions	Test Result	Specifications
1	Liquid Limit	26.6	Max 45%
2	Plasticity Index (PI)	N.P	Max.20%
3	Total SO_4 content	Test in Progress	Max 0.2
4	Organic Content	Test in Progress	Max 2%

Water
Clean water from Bore Hole at 138+200 LHS 162+500 LHS has been selected for the production of design and site mix. The water plays major role in the each and every of construction and the design mix proportions. The properties and characteristics of water are given in table 4.

Table -4 Properties of Water

S.No	DESCRIPTIONS	138+200 LHS	162+500 LHS	Limits
1	Organic	89	32	Max 200
2	Inorganic	165	392	Max 3000
3	Suspended Solids (mg/l)	4.0	10	Max 2000
4	P^H	7.38	7.4	Min 6.0
5	Sulphate ($S0_4$) (mg/l)	10.47	76.3	Max 400
6	Chlorides (Cl) (mg/l)	22.69	195	Max 500
7	Acidity	0.40	0.8	Max 5
8	Alkalinity	7.80	23.2	Max 25

****Note**: If the Mix is produced in any plant and water used for the mix shall be compliance to IRC SP 89 -2010 limits*

Cement
Cement of Ordinary Portland Cement 53 grade from M/s Dalmia, M/s Ultratech Cements, M/s India Cements compliance the requirement of NORTH & IS 269specification is adopted for the design and Casting of mix.

Properties of Cement

The properties of cement for various manufacturers are listed in the table 5

Table -5 Properties of Cement

Descriptions	M/s Dalmia	M/s Ultratech Cements	M/s India Cements	Limits	Remarks
Consistency	30	29.0	29	-	Physical properties (In-House Testing)
Initial Setting time	190	165	170	Min 30 min	
Final setting Time	305	295	280	Max 600 min	
Compressive Strength a) 3 days b) 7 days c) 28 days	 34.63 46.19 TYC	 34.53 44.36 56.04	 35.65 44.41 60.96	a) 27 MPa b) 37 MPa c) 53 MPa	
Fineness	1.73	1.73	1.69	Max 10%	
Soundness by Le-Chatelier	2.78	2.27	2.50	Max 10%	
Total Loss on Ignition(% by Mass)	1.55	2.30	1.82	Not more than 4%	Chemical properties (MTC)
Insoluble Residue(% by mass)	1.07	1.58	2.30	Not more than 5%	
Ratio of Lime to% Slica,Alumina,Iron oxide	0.93	0.91	0.83	Max 1.02% Min 0.80%	
Ratio of % Alumina to Iron oxide	1.00	0.93	1.04	Not less than 0.66%	
Sulphuric Anhydride	2.94	2.37	2.65	Max 3.5% for C3A≤5% Max 3.0% for C3A≤5%	
Magnesia(% by mass)	0.88	1.26	0.84	Not more than 6%	

Gradation of Aggregate and Proposition Finalization

Individual aggregates were tested in CTSB sieves for blending according to IRC SP 89- 2010 Table 8 Grading III.Gradation used for determination of workability, durability, stability, friction resistance, permeability.

Individual Gradation Results

Description	CTSB Crushed Material		
Source of Material	Ragathampatti Quarry / Crusher		Average of **9 Samples**

Table -6 Individual Gradation Results

IS Sieve Size (mm)	Sample No. 01	Sample No. 02	Sample No. 03	Sample No. 04	Sample No. 05	Sample No. 06	Sample No. 07	Sample No. 08	Sample No. 09	Average of 9 samples
53	100	100	100	100	100	100	100	100	100	100
26.5	89.03	89.33	89.16	89.05	89.09	89.18	89.05	89.13	88.59	89.07
9.5	69.02	68.62	68.70	70.16	69.57	69.37	68.56	69.73	69.53	69.25
4.75	55.75	55.34	56.30	56.76	56.93	55.71	55.16	56.18	56.15	56.03
2.36	43.39	44.21	43.14	44.99	44.61	44.18	44.78	44.99	44.51	44.31
0.425	23.07	23.47	23.97	23.59	23.68	23.86	23.98	23.40	24.18	23.69
0.075	0.62	7.81	7.83	7.95	7.02	7.83	7.26	8.45	8.63	7.04

The individual gradation result is based on the California bearing ratio from each sample of mix design for cement treated bases. sieve size according to **IS code** and **IRC037.**

Description	(40mm Aggregate)	
Source of Material	Ragathampatti Quarry / Crusher	Average of **9 Samples**

Table -6.1 Individual Gradation Results

IS Sieve Size (mm)	Sample No. 01	Sample No. 02	Sample No. 03	Sample No. 04	Sample No. 05	Sample No. 06	Sample No. 07	Sample No. 08	Sample No. 09	Average of 9 samples
53	100	100	100	100	100	100	100	100	100	100
26.5	17.58	19.76	17.95	17.93	17.19	17.92	17.66	19.53	18.32	18.20

Individual gradation of coarse aggregate by sieve analysis by conventional cement treated mix design at guidelines for the design of flexible pavement **IRC-37-2018**in a gradation and size analysis a sample of dry aggregate of known weight is separated through a series of sieves with progressively smaller openings.

Theoretical Blending

Theoretical blending is done on various propositions and the proposition which achieves the values nearer to the mid limit of the limits specified in **IRC SP 89- 2010 Table 8 Grading**- III is selected for the practical job mix and design. The cement treated sub base is protective for flexible pavement.

Table -7 Theoretical Blending Results

I.S SIEVE (mm)	**Average % passing of Individual grading**		**THEORETICAL BLENDING AS BELOW PROPORTION**						**Limits as per IRC 89-2010 Table 8-Grading III**
			BLENDING – 01	BLENDING – 02	BLENDING – 03	BLENDING- 04	BLENDING- 05	BLENDING- 06	
	CTSB	**26.5mm Aggregate**	70%	75%	80%	85%	90%	95%	
		40mm Aggregate	30%	25%	20%	15%	10%	5%	
53	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	**100**
26.5	89.07	18.7	67.8	71.4	74.9	78.4	82.0	85.5	**70-100**
9.5	69.25	0.00	48.5	51.9	55.4	58.9	62.3	65.8	**50-80**
4.75	56.03	0.00	39.2	42.0	44.8	47.6	50.4	53.2	**40-65**
2.36	44.31	0.00	31.0	33.2	35.4	37.7	39.9	42.1	**30-50**
0.425	23.69	0.00	16.6	17.8	19.0	20.1	21.3	22.5	**15-25**
0.075	7.04	0.00	4.9	5.3	5.6	6.0	6.3	6.7	**3-10**

The graph defines that theoretical bending by observing IRC-37-2012 via code book analysis while preparation of mix design at flexible pavement by using sieve gradation.

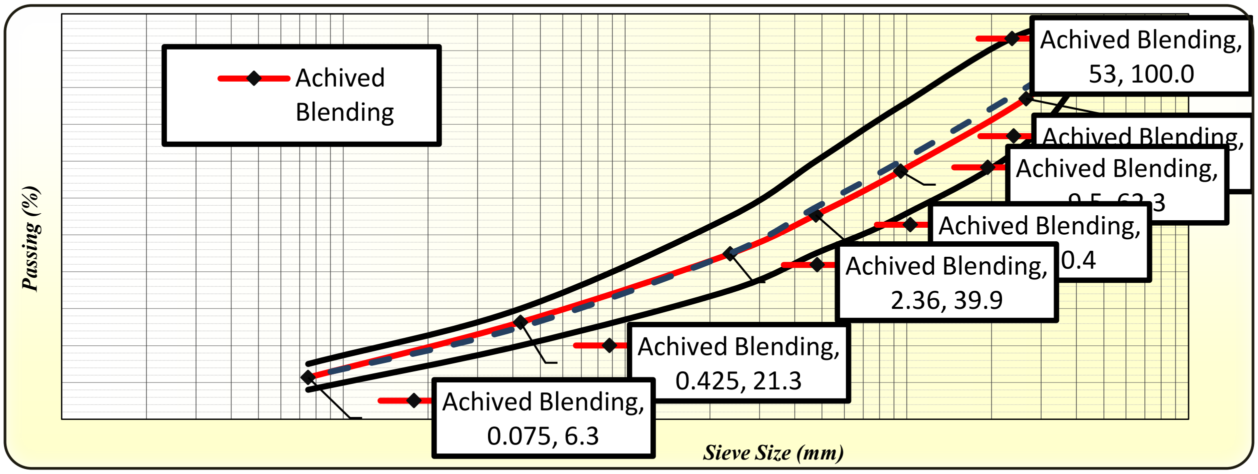


Figure -2 Theoretical Blending Graph

In the graph x and y axis shows the sieve sizes and passing percentage of our sample, The effect of fine percentage on the properties of subbase material.

Practical Blending for CTSB

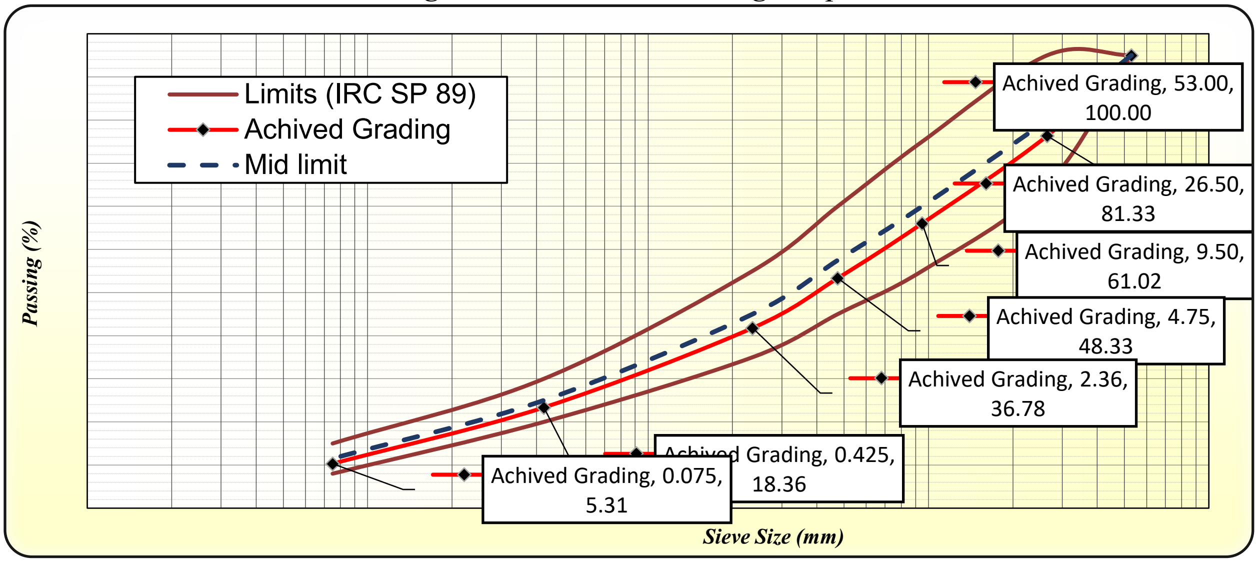
Cement stabilization is one of the new techniques and recycle road base material and helps a durable lifelong pavement.[6 - 9]

Table -8 Practical Blending of Design

IS Sieve Size (mm)	Proposition No-05: 53mm down -90%; 40mm Aggregate-10%						Limits as per IRC 89-2010 Table 8 - Grading III		
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Lower	Upper	Middle
53.000	100.00	100.00	100.00	100.00	100.00	100.00	100	100	100
26.500	80.70	79.47	81.46	82.83	82.21	81.33	70	100	85
9.500	61.40	60.39	60.37	61.74	61.22	61.02	50	80	65
4.750	48.75	48.08	47.81	49.44	47.58	48.33	40	65	52.5
2.360	37.40	36.93	36.32	37.14	36.12	36.78	30	50	40
0.425	18.74	18.84	17.59	18.81	17.81	18.36	15	25	20
0.075	5.61	5.67	5.28	4.77	5.20	5.31	3	10	7

The practical blending and moisture contents for determining optimum moisture content and maximum dry density are explained in figure 3.

Figure -3 Practical Blending Graph



The above graph defines that x axis has sieve size and y axis size passing percentage, the upper and lower line shows the limits of practical blending and the continuous center lines shows that the achieved grading of the mix design. The dotted lines show the mid limit of design .

Design Mix

After finalizing the grading and proposition, CTSB design is conducted in following manner

1. Stabilizing material in the finalized proposition is mixed with cement (2.5%, 3.0%, 3.5%, 4.0%, 4.5%) and optimum moisture content is determined by proctor heavy compaction method is per IS 2720 (Part -8).
2. In accordance with Optimum moisture content results then a set of cubes are casted for (2.5%, 3.0%, 3.5%, 4.0%,4.5%)cement content.
3. Moist curing is done for 7 days and compression test is conducted and strength is obtained for respective cement contents.
4. Graph is plotted for Cement content Vs strength checking and optimum cement content is obtained from the graph.
5. After finalization of Cement content is 7 days strength checking and confirmatory test are conducted to verify the adopted cement content is safe for the mix.[10 - 13]

Determination of Optimum Cement Content For CTSB

The optimum cement content for cement treated sub base has been given in the table.9

Table -9 Design Mix

S.No.	Stabilizer / Cement Content (%)	Stabilizing Material Content (%)		Age Of Test	Average Compressive Strength (Mpa)
		Crushed CTSB Material	40mm Coarse Aggregate		
1	2.5	90%	10%	7 days	2.30
2	3.0	90%	10%	7 days	2.75
3	3.5	90%	10%	7 days	3.20
4	4.0	90%	10%	7 days	3.75
5	4.5	90%	10%	7 days	4.20

The design mix is casted by cube and strength checked by curing as shown in the figure.4.

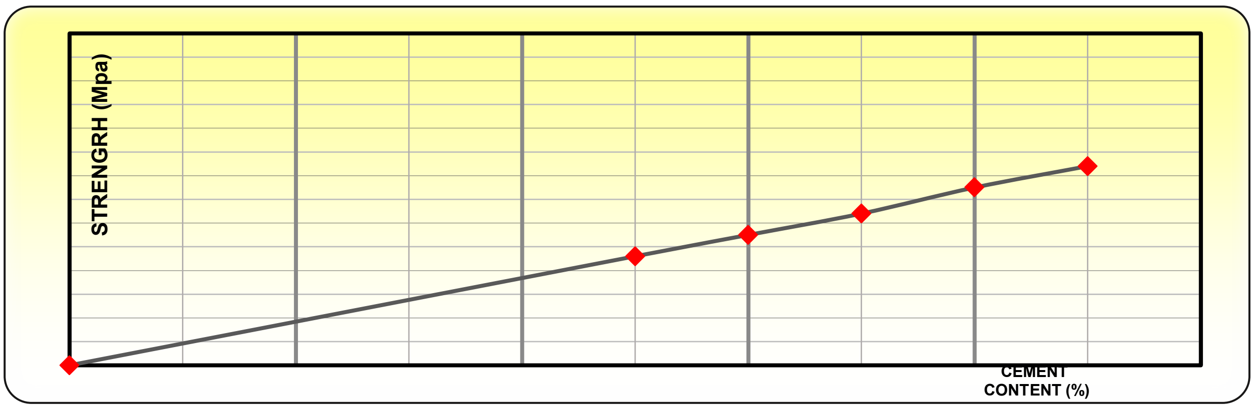


Figure -4 Design Mix Analyzing

The design mix graph defines that cement content has x axis and strength as y axis by using different brand of cement (type-OPC53).[14-15]

Table -10 Cement content for CTSB

S.No.	***Description***	***Results***	
A	Optimum Cement content (From Graph)	3.30	%
B	Considering Factor of Safety of 5% (% of Cement increased by = A*5%)	0.20	%
C	Finalized Cement Content (A+B)	3.50	%

By analyzing the sub base design of flexible pavement optimum cement content used as **4%.**

Confirmatory Tests

A. Confirmatory test set of cubes at Cement content of 3.50% is casted and 7 days compressive strength has been checked with three different sources of cement and found satisfactory on limits of IRC SP 89-2019.

B. Durability Test (Index of resistance to water on strength) is conducted as per IRC SP 89-2010 - Cl.4.7.2-Method -1 and found satisfactory on limits of IRC SP 89-2019.[16]

Table -11 Confirmatory Test

Cement Type / Source	Stabilizer/ Cement Content (%)	Stabilizing Material Content (%)	Confirmatory Test results (MPA) Min 3.0 MPA	Durability Test Results (%) (Min 80%)
OPC 53 Grade / Ultra tech	3.5 %	90% Crushed CTSB Material + 10% 40mm Coarse Aggregate	3.51	86.34
OPC 53 Grade / Dalmia			3.45	87.92
OPC 53 Grade /India Cements			3.25	84.37

As the Job mix Design with 3.50% cement content satisfies all limits specified on IRC SP 89 - 2010 on compressive strength test and durability test. Hence cement content 3.50 % is safer and adopted for laying trails and site execution.

Conclusion

Durable Life of pavement. Thickness of Bitumen Courses will be reduced. Project will be finished at an earlier time. Less traffic problems only faced due to earlier finishing of the project. Mainly reduces the project cost about 18 lakh per/km approx. Uniform distribution of Load in Cement treated service road as compared to conventional road. Aggregate consumption is less for the case of stabilized base compared to that of the conventional method. But in the surface of the high embankment which shows in the metal beam barrier at earthen shoulder which results as a failure of sub base course while high air voids can't rise up in the cement layer it may lead to the crack of the roads. Granular Sub Base will be replaced in the delta region of the project. Depending on the needs of the project, CTB increases construction speed, improves the capacity of the pavement structure, or in some cases reduces the full-time project. Analysis in IRC37-2012 shows that the cement treated sub base naturally produces transverse and longitudinal crack but helps in the thickness of dense bituminous macadam and surface coarse as grade 2.

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