Performance Analysis of CTB/CTSB Method over Traditional Method in Flexible Pavements

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Abstract— Countries all over the world are developing rapidly and infrastructure sector plays a vital role in the development of nations. Transportation is the main constituent of infrastructure sector. Most of the countries are dependent on the roads and highways for transportation of all kinds as compare to waterways, railways, airways etc. In many developing countries, crushed rock and murrum is used as a base material for road pavement. These materials are required in large quantities and are not easily available in many regions. Government of India is concentrating on the development of National Highways and State Highways for the fast transportation and conveyance. Hence the requirement of the construction materials is very huge. This report consists of the study of reasons of failure of the flexible pavements. The materials used for the pavement construction in traditional method. The problems associated with these materials. This study explains the mechanism of Cement Treated Base/Sub-base. The quantity of the cementitious material required to be added for stabilization process. The construction process is explained in details. This material is beneficial because it minimizes the crust thickness and hence saves the material required for construction. The cement treated sub-base/base is tested for the unconfined compressive strength and the results are obtained. It proves that, this material gives better strength as per requirement and performance also better as compare to the traditional materials. The construction cost, quantity of material, transportation charges for material, machine requirement, machinery fuel cost are analysed and compared for the cement treated sub-base and traditional material. The result shows the saving in the construction cost for CTB/CTSB method is more. This report shows how it is beneficial to use cement treated sub-base to replace the traditional base material used for construction of highways.

Key words: Cement Treated Base (CTB), Cement Treated Sub-Base (CTSB), Flexible Pavement, Stabilization Performance Analysis

I. INTRODUCTION

India is the fastest growing country in the world at today's date. Infrastructure and construction sector defines a very important role in the development of the country. In this, the connectivity of Capitals, Ports, Industrial areas etc. should be well-connected to ensure the fastest transportation of all goods, materials as well as peoples. Transportation sector includes Highways, railways, waterways etc. In India highways plays vital role for all kinds of transportation. [www.nhai.org]

At present, many highway projects are going on all over country and in future it will increase. The Government of India has planned Rs. 3 Lakh Crore of road projects in current fiscal to meet the target of 30 Km per day highway construction. The transport sector contributes 6% of total GDP out of which 70% shares comes from the road sector. The road pavement costs about 50% of the total cost of construction of the road. For construction of highways many things are taken into account. And the most important is material required for the construction of highway. The cost of the material should be within budget and should be easily available. If it is not easily available and costly then it will affect overall project. For the heavy traffic and heavy rainfall regions the crust thickness in pavement is increased as compared to the other regions. So the material required for the construction of pavement is also increases and it will affect the budget of the project. [www.nhai.org]

To overcome this problem the pavement should be design differently or the materials should be replaced by the better one. In this regards, the Cement treated sub-base seems to be a better one to replace traditional GSB layer. With the use of CTB/CTSB, the GSB & WMM layer thickness can be minimized without affecting the strength criteria of the pavement. It achieves good saving of material, machinery uses and fuel consumption hence results into saving of money.

In this thesis the concept of CTB/CTSB is studied. The effects of using CTB/CTSB rather than the traditional base/sub-base materials are also studied. The comparison of both types of pavements construction methods is done and the factors affecting for performance of pavements of road are also studied.

II. NEED OF THE STUDY

For constructions of Highways in Heavy traffic and Heavy rainfall area the Pavement should be good enough to bear the traffic load or heavy rainfall. To increase the strength of the pavement the crust thickness should be increased as compare to the conventional highways. It increases the material requirement and more consumption of other resources also. It also increases the burden on the contractor and affects the total project cost. The flexible pavements in the heavy rainfall regions getting many problems like surface cracking, rutting, potholes, undulations etc. Thus to achieve desired strength of pavement with limited resources, pavement design needs to be re-engineered.

By considering the current growth in traffic volume, availability of materials, resources & economy, a better & sustainable highway design is the need of our generation. So new pavement design shall fulfill the requirement of less material requirement, more strength and also the future costs like maintenance cost, rehabilitation cost etc. To achieve such pavement design, I would like to introduce Cement Treated Base/Sub-base as a solution for the above problem.

III. PROBLEM STATEMENT

The construction of roads, highways is a big investment. This expenditure can be minimized by using the best suitable and economical materials as well as new methods. The real root cause for introducing CTB/CTSB is the bad health conditions of highways. In heavy traffic areas and heavy rainfall areas, pavement gets heavily damaged within short period. Highways suffers unequal settlements and potholes formation, failure of side-shoulders due to heavy rainfall. The most of the damage is caused due to low strength of foundation layers, permeability and voids present. This happens mainly due to presence of unsuitable material and boulders in foundation layers. So to overcome the failure of unequal settlement, foundation layers must have adequate strength to bear heavy rainfall as well as traffic. Also the maintenance cost of the roads is also high due to the above reasons. The current maintenance practices are subjective in nature. Maintaining the road infrastructure at high level of serviceability with limiting budget is challenge for many agencies. Thus there is a need to find an alternate material for flexible pavement which can be economical, strong enough to bear the loads and also which will require less maintenance in the overall life of the road [7].

IV. OBJECTIVES

1) To study the concept of Cement Treated Sub-base.
2) To study the reasons of failure of flexible pavements.
3) To study the effect of using Cement treated Sub-base/Base on Crust thickness in Highway Pavement. (Reduction in Crust thickness i.e. WMM, DBM layer).
4) To compare the performance, required material quantity, transportation charges, fuel consumption, machineries required for CTB/CTSB method and traditional method of Flexible pavement construction.

V. METHODOLOGY

This report consists of study of the reasons of failure of flexible pavements in India. Also the conventional materials used for the construction of layers in flexible pavements. The cement treated bases and sub-bases is studied. The unconfined compressive strength for the various combinations of cementitious materials to be added in GSB material is checked and its performance is compared with the traditional method of construction of flexible pavements. Comparison is done on the basis of following factors:

1) Quantity of materials required: The quantity of materials required for construction of 1 Km long and 7.5 m wide highway with CTB/CTSB method and traditional method is compared.
2) Transportation charges for material from source to site: Transportation charges for required quantity of material from sources to site is calculated and compared for CTB/CTSB method and traditional method.
3) Machineries required for construction of pavement: Machineries required for construction of pavement with both the methods is calculated and compared. For this study the output of the machineries is taken from the case study of the project.
4) Fuel cost for the machineries: Fuel consumption for the construction of 1 Km long and 7.5 m wide highway with both the methods is calculated and compared. The average fuel consumption of the machineries is taken from the case study of the project and base rate of diesel as Rs.60/- per litre.

VI. DATA COLLECTION

A Highway project "Widening of NH 4B JNPT Phase II Project, PKG IV" is selected. From the study of this Under Construction Project the problems in existing highway, regarding the failure of Flexible pavement due to Heavy rainfall and traffic and other reasons are studied. The mechanism of Cement treated Sub-base is using in the widening of NH 4B Project. For that, the necessary tests are conducted and checked for the performance. Also the machineries required for CTB/CTSB method, output of machineries, fuel requirement, sources of materials etc. is taken from the Project site.

A. Rainfall Intensity

The monthly average intensity of rainfall at the project location is shown in the following table. Heavy rainfall is the main reason of failure of flexible pavements is seen in the background study. Due to the inappropriate drainage of rain water the layers of pavements becomes weak and it affects on the surface layer of the road.

Sr. No.	Month	Average Rainfall (mm)
1	June (Rain started at 23rd June 2016)	55.66
2	July 2016	42.35
3	August 2016	49.25
4	September 2016	34.62
5	October 2016 (Upto 13th October 2016)	18.20

Table 1: Average rainfall intensity

B. Types of distress seen and their probable reasons

The most occurring distresses on the existing flexible pavements of the Case study are shown in the following table with their probable reasons.

Sr. No.	Type of distress	Reason
1	Cracking	Heavy traffic
2	Potholes	Heavy traffic and rainfall
3	Rutting	Heavy traffic
4	Shoulder failure	Rainfall and poor drainage
5	Bleeding	Heavy traffic
6	Undulated surface	Temperature and heavy traffic

Table 2. Types of distress

C. Unconfined Compressive Strength Tests (CTB/CTSB)

As per the Clause 403.2.6 of MoRTH the quantity of cement added shall not be less than 2% by weight of the dry soil. The design mix shall be done on the basis of 7 day unconfined compressive strength (UCS) and/or durability test under 12 cycles of wet-dry conditions. The laboratory strength values shall be at least 1.5 times the minimum field UCS value. The mix design shall be done to achieve a strength of 1.75 MPa when tested on cylindrical specimens compacted to the density at optimum moisture content, tested in accordance with IS: 2720 after 7 days moist curing.

Following are the combinations of Cement and Fly ash used for trials with results achieved:

1) Manually Casting

Sr. No.	Percentage of Cement	Percentage of Fly Ash	Unconfined Compressive Strength for 7 days of Curing (MPa)
1	2	0	2.07
2	4	0	3.69
3	6	0	4.61
4	2	2	3.22
5	2	3	3.72

Table 3: Combinations used for trials by manual casting

2) DLC Hammer Casting

Sr. No.	Percentage of Cement	Percentage of Fly Ash	Unconfined Compressive Strength for 7 days of Curing (MPa)
1	2	0	4.03
2	4	0	4.41
3	6	0	5.06
4	2	2	3.97
5	2	3	4.63

Table 4: Combinations used for trials by DLC hammer casting

VII. RESULTS

A. Use of CTB/CTSB method in construction of Flexible pavement results in minimizing crust thickness, hence it reduces the requirement of material

Following graph shows the comparison of crust thickness for CTB/CTSB method and traditional method. It shows the thickness of WMM and DBM layer is reduced by CTB/CTSB method.

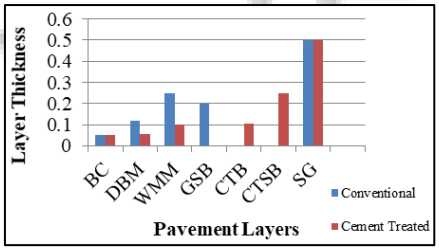

Fig. 1: Layer thickness

The CTSB and CTB for gives the required strength for the combination as per follows:

As per MoRTH it is recommended that the Strength should not be less than 1.75 MPa and the addition of cementitious material should be 2% or more than 2% of the weight of soil or the material which is using for stabilizing.

Sr. No.	Percentage of Cement	Percentage of Fly Ash	Unconfined Compressive Strength for 7 days of Curing (MPa)
1	2	2	3.22 (Manual Casting)
2	2	2	3.97 (DLC Hammer Casting)

Table 5: Compressive strength for the Percentage addition of cementitious material

B. Required Quantity of Material

The required quantity of material for each layer in both the methods is different. Following figure shows the difference of quantity of material required for both methods in each layer.

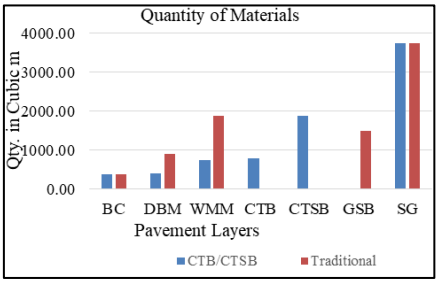

Fig. 2: Quantity of materials

Above figure shows that, GSB layer is present in traditional method. The CTB and CTSB layer is present in only CTB/CTSB method. So the quantity of materials required is different. The thickness of WMM and DBM layer is less in CTB/CTSB method than the traditional method. It reduces the material requirement.

C. Transportation Cost of Materials

The difference in the transportation charges for material used for construction of Flexible pavement by both the methods is shown if following graph.

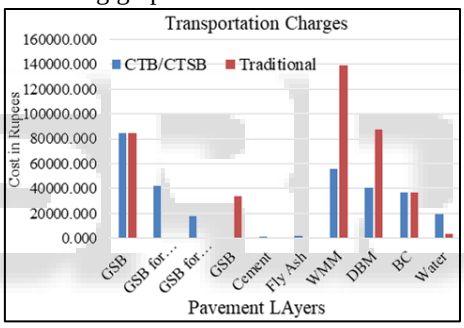

Fig. 3: Transportation charges

The graph shows that the transportation charges are more for WMM, DBM material in traditional method. Water required is more in CTB/CTSB method and it increases the charges of water transportation. CTB/CTSB method also includes the transportation of cement and fly ash from the source which is very less. The overall charges of transportation of material is less for CTB/CTSB method than the traditional method. Rs.86014/- can be saved per Km for the transportation of material required for CTB/CTSB method.

D. Fuel Consumption

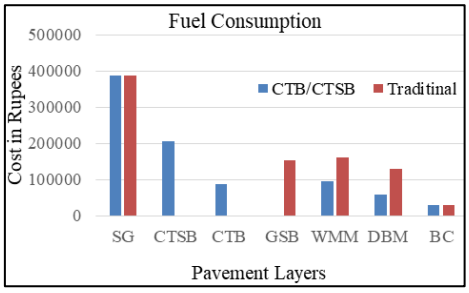

Fig. 4: Fuel Consumption

Fuel consumption for construction of Flexible pavement of 1 Km length and 7.5 m width is calculated for both the methods.

Following graph shows the difference in fuel consumption. There is no big difference in saving of fuel in CTB/CTSB method seen in this graph.

Fuel consumption for laying WMM, DBM and GSB layer is more in traditional method. A big amount of fuel is saved in the WMM plant. As the WMM quantity required is less in CTB/CTSB method, it affects the fuel consumption. Rs.32886/- can be saved for the WMM production for 1 Km, if we use the CTB/CTSB method instead of traditional method.

E. The Construction Cost

Overall construction cost of flexible pavement with CTSB/CTB method is less than the traditional material, because the saving in material, required machineries, fuel consumption and material transportation charges etc.

For Example, we consider a patch of 1 Km (1000 m) length and 7.5 m width for both methods. The quantity and cost of materials required for Main Carriageway will be as follows:

1) Using CTSB/CTB Method

	Depth	Quantity	Unit Cost	Amount
BC	0.050	375.00	8346	3129750
DBM	0.055	412.50	7082	2921325
WMM	0.100	750.00	1237	927750
CTB	0.105	787.50	1510	1189125
CTSB	0.250	1875.0	1382	2591250
SG	0.500	3750.0	425	1593750
Total	1.060			1,23,52,950

Table 6: Quantity and Cost of material by using CTSB/CTB method.

2) Using Conventional Method

	Depth	Quantity	Unit Cost	Amount
BC	0.050	375	8346	3129750
DBM	0.120	900	7082	6373800
WMM	0.250	1875	1237	2319375
GSB	0.200	1500	884	1326000
SG	0.500	3750	425	1593750
Total	1.110			1,47,42,975

Table 7: Quantity and Cost of material by using Conventional method.

Note: The unit cost for the material is approximate and including dumping, grading, pulverizing, watering and rolling etc.

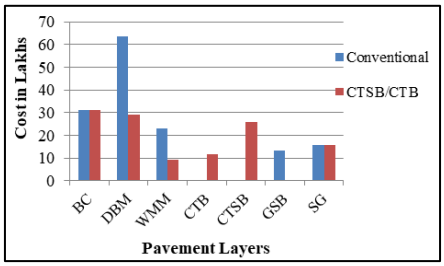

Fig. 5: Cost of construction

Above graph shows the cost comparison for traditional method and CTB/CTSB method. (On Y axis- Cost in Lakhs). It shows that CTB/CTSB method saves upto Rs.2390024/- per Km.

VIII. CONCLUSIONS

In this study, the reasons of failure of flexible pavement are studied. It is seen that most of the failures in flexible pavements are due to high rainfall and heavy traffic load. Also the material using for the base course and sub-base course in traditional method is having low strength as well as poor drainage capacity and hence causing the failure problems. The characteristics of Cement Treated Sub-Base/Base are studied in this study. The concept, mechanism and requirements of CTB/CTSB are studied from the literature review. The mechanical properties and characteristics of this material are tested in laboratory. The experiments for the combinations of cementitious materials to be added in soil are performed and the result for unconfined compressive strength is checked. The results obtained are acceptable as per MoRTH.

The use of CTB/CTSB saves the material required for the construction of flexible pavement. The transportation charges, fuel consumption, machineries required is less for CTB/CTSB method than the traditional method. Hence the initial cost of construction is less for CTB/CTSB method. The CTB/CTSB is having more strength as compare to the traditional material. So the maintenance work required for CTB/CTSB will be less. It will save the maintenance cost and affects the life cycle cost of the project.

In this study, the quantity of different materials used in each layer for flexible pavements is calculated for both the methods. The transportation charges for the material from source to the site is calculated and compared. This comparison shows that the total transportation cost for CTB/CTSB method is Rs.299056/- whereas for traditional method it is about Rs.385069/-. CTB/CTSB method saves about Rs.86014/- per Km (Table 5.12 and Table 5.13). Requirement of machineries for construction of 1 Km long and 7.5 m wide highway is computed and the fuel consumption is calculated (Table 5.15 and Table 5.16). The CTB/CTSB methods saves the fuels consumption, results into minimization of construction cost. Total fuel required for construction of 1 Km long and 7.5 m wide road is Rs.838849/- for CTB/CTSB method and Rs.857835/- for traditional method (Table 5.17 and Table 5.18). Actual fuel is saved in the WMM plant for production of WMM material and it is about Rs.32886/-. As the WMM required for CTB/CTSB method is less than traditional method, fuel consumption will be less. The overall construction cost of 1 km long and for 7.5 m wide road with both the methods is calculated. The difference of cost of construction by traditional method and CTB/CTSB method is about Rs.2390024/- for 1 Km (Table 6.2 and Table 6.3). CTB/CTSB method gives better results than the traditional method of construction of flexible pavement. Hence it is recommended that to use this material for the construction of Base for road pavement. As it reduces the material requirement, minimizes the initial cost of construction, gives better strength than the traditional materials and reduces the maintenance work of the project which affects the life cycle cost of the entire project. It also has environmental benefits.

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