Performance Evaluation of Very Low-Volume –Low CBR Flexible Pavements With Stone Dust Stabilized Sub Grades

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Abstract— **Many rural areas in developing countries like India lack adequate and affordable access to transport infrastructure and services. The problem is more persistent in low volume and low CBR value sub-grades. The objective of this project is to evaluate the required flexible pavement for very low volume traffic roads with very low CBR values with practically very low traffic of not more than 30-40 vehicles mostly comprising passenger cars where the level of serviceability is very high. The IRC recommended pavement composition is for unpaved gravel roads in rural areas with low volume traffic. There are various disadvantages associated with construction of the road using gravel like dust generation, and gravel loss over a period of time due to passage of vehicles and inaccessibility during rains and the quality of serviceability is unsatisfactory. Problems with sub grade having low CBR values are stability and large deformations or settlements. A project has been taken up where the CBR of sub grade soil is 1.5 or less, the soil is improved by mechanical stabilization with an additive of stone dust. The emphasis of the project is 'Performance evaluation of very low-low-CBRFlexible pavements with stone dust stabilized sub-grades '. The addition of stone dust has improved the sub soil condition in achieving higher CBR value. Locally available soils mixed with crushed stone dust serve as effective reinforcement in soft soils for different sub-grade resulting in technically better sub-grade as well cost economy in savings of aggregate material and also reducing carbon foot print.**
Keywords: Soil stabilization with stone dust, improved sub-grade strength, CBR value, UCS, FSI., etc.

I. Introduction

Rural road connectivity is a key component of rural development, since it promotes access to economic and social services, thereby generating increased agricultural productivity, non- agriculture employment as well as nonagricultural productivity, which in turn expand rural growth opportunities and real income through which poverty can be reduced. The Ministry of Rural Development (MoRD), Government of India has decided to develop various rural roads under Pradhan Mantri Gram Sadak Yojana (PMGSY). The PMGSY has set up a programme to achieve all weather connectivity to all the habitations with population more than 500 (250 for hilly areas) by the end of tenth five year plan i.e. by 2007. Gravel roads are important components of the road transportation network throughout the world which have not yet been paved. In many developing countries, more than 75% of the road network consists of gravel and earth roads. Aggregate surfaced roads are referred to as unpaved roads. Gravel pavement will not only carry traffic loads but will also be resistant to shear deformation and wear i.e. they have to be of sufficient strength and durable (Cygas and Zilioniene, 2002). The CBR test is a way of putting a figure on the inherent strength, the test is done in a standard manner to compare the strengths of different sub-grade materials, and the CBR values are used as a means of designing the road pavement required for a particular strength of sub-grade. The stronger the sub-grade (the higher the CBR reading) the less thick it is necessary to design and construct the road pavement, this gives a considerable cost saving. Conversely if CBR testing indicates the sub-grade is weak (a low CBR reading) a suitable thicker road pavement is to be adopted to spread the wheel load over a greater area of the weak sub-grade in order that the weak sub-grade material is not deformed, causing the road pavement to fail. The CBR in spite of its limited accuracy still remains the most generally accepted method of determining sub-grade strength, and as such this information, along with information on traffic flows and traffic growth is used to design road pavements.

1.1 Pavement Materials

Gravel: Gravel is a naturally occurring material consisting of small pebbles, stones, or fragments of stone intermixed with finer materials such as powdered rock, sand, loam, silt, or clay. Sometimes the term gravel is also meant to represent rounded or water-borne stones or pebbles which have no fine material in them, and is known more popularly as shingle. (IRC: SP: 72:2007)

1.2 Factors Affecting Pavement Performance

In general, pavement performance depends on several factors. These factors can be grouped into following categories.

1. Traffic loading associated factors,
2. Material properties and composition,
3. Environmental associated factors, and
4. Other factors.

1.3 Study Area

The proposed road falls at Gollagudem in Sadasivpet Mandal, district of Medak in Telangana State. Medak district coordinates are between 17°27'and 17°79' Northern latitude and 78°27' and 79°35' Eastern longitude. Geologically the District is covered by Classified Granite Rocks, the district has a mean maximum temperature of 40˚C and a mean minimum temperature of 26˚C. The average annual rain fall is 873 mm. Manjira, a perennial tributary of River Godavari with its tributaries of Haldi (Pasupuyeru) and Kundlair drains the district. The important rock types are Peninsular Gneissic complex, Dharwar super group associated with Younger intrusives of Achaean age separated unconformably with overlying Basaltic flows of late Cretaceous to early Eocene age with sub-Recent to Recent alluvium along the stream courses

1.4 Objectives of the Study

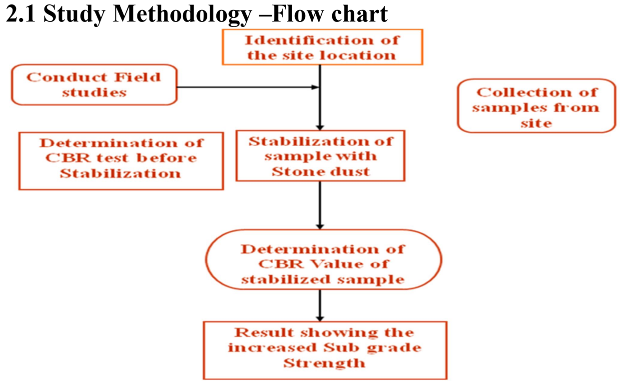
The main objectives of the study are listed below:

1. To improve the sub-grade strength by stabilizing the subsoils with soil-stone dust in low CBR conditions.
2. To evaluate and compare the performance of the stabilized sub-grade

II. REVIEW OF LITERATURE

The rural road connectivity in India, the background information of the gravel roads, types of sealing coat and functions of sealing techniques of the gravel roads have been discussed. In this chapter, attempts have been made to review the literature on gravel roads, various stabilization techniques available for sub-grades, performance evaluation. Sridharan and soosan et.al (2005) identified that quarry dust manifest high shear strength and is beneficial for its use as a geotechnical material. Sabat et.al (2012) conducted compaction, tri-axial and durability tests on lime stabilized expansive soil-quarry dust mixes. Satyanarayana, et al compacted crusher dust and Crushed Stone mixes through a series of CBR tests by varying the crusher dust. Ramadas and Kumar et.al (2010) reported that the combination of fly ash and stone dust found to be suitable to reduce swelling and increase the strength of expansive soil. Onyelowe Ken et.al (2012) exposes the qualities and applications of quarry dust as admixture during soil improvement and for a more economic approach. Agrawal and gupta et.al (2011) reported that the potential use of marble dust as stabilizing additive to expansive soil, which involves the determination of the swelling potential of expansive soil in its natural state as well as when mixed with varying proportion of marble dust Rock flour can be advantageously used in construction of reinforced soil construction such as reinforced earth retaining walls, reinforced soil beds and reinforced flexible pavements as a fill material due to its stability, free draining nature and good frictional characteristics with synthetic reinforcement. Moorthy N.V.R. et al (2002) have studied the interaction of usage of rock flour with Geotextiles and reported the potential areas of application. Soosan et.al (2001) identified that crusher dust exhibits high shear strength and is beneficial for its use as a geotechnical material. Sridharan et.al. (2005) studied the effect of quarry Dust in highway construction that CBR and angle of shearing resistance values are steadily increased with increase the percentage of Quarry Dust. Praveen Kumar et.al(2006) conducted CBR and tri-axial tests on fly ash, coarse sand, stone dust and river bed materials for their use in the sub base materials of the flexible pavements. Shanker and Ali(1992) have studied engineering properties of rock flour and reported that the rock flour can be used as alternative material in place of sand in concrete based on grain size data. Rao, et al (1996) have reported that sand can be replaced fully with rock flour. Nagaraj T.S and Bhanu et al (2000) have studied the effect of rock dust and pebble as aggregate in cement and concrete. Wood S.A et.al reported that the quality of crushed stone dust depends on the type of parent materials. In this an attempt is made to study the effect of Crusher Dust and Crushed Stone Mixes in studying their Strength, Gradation and Compaction Characteristics.

2.1 Study Methodology –Flow chart



III. DETERMINATION OF FREE SWELL INDEX OF SOILS

To determine the free swell index of soil as per IS: 2720 (Part XL) – 1977. Free swell or differential free swell, also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water. Free swell tests are commonly used for identifying expansive clays and to predict the swelling potential. The free swell test is one of the most commonly used simple tests in the field of geotechnical engineering for getting an estimate of soil swelling potential . This test is performed by pouring 10 cm3 of dry soil through a sieve or aperture size 0.42 mm into a 100 cm3 graduated jar filled with water and noting the swelled volume or the soil after it comes to rest.

3.1.Determination of Unconfined Compressive Strength

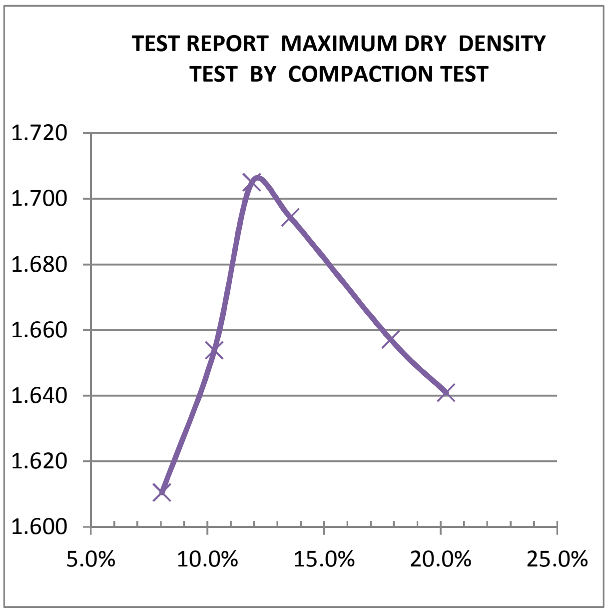
Determination of the unconfined compressive strength of clayey soils, undisturbed, remoulded or compacted, using controlled rate of strain as per IS 2720 – Part X – 1991. The objective of the unconfined compression test is to determine the UU (unconsolidated, undrained) strength of a cohesive soil in an inexpensive manner. Fine-grained soil is tested in compression. Undisturbed specimens cut from tube samples and disturbed specimens are loaded in compression, recording load and deflection measurements. Laboratory strength tests of soil are similar to testing concrete cylinders, but can be performed with or without lateral confining pressures. The unconfined test uses axial loading without lateral confining pressures, making it the simplest and easiest laboratory method of estimating strength. To more accurately simulate actual loading conditions in the field, lateral confining pressures can be applied using a triaxial test, which is a completely different apparatus.

IV.RESULTS AND OBSERVATIONS

The parameters affecting pavement performance and the methods, equipments used to evaluate the sub-grade strength and other related materials are discussed.

4.1 Compaction Test MDD & OMC

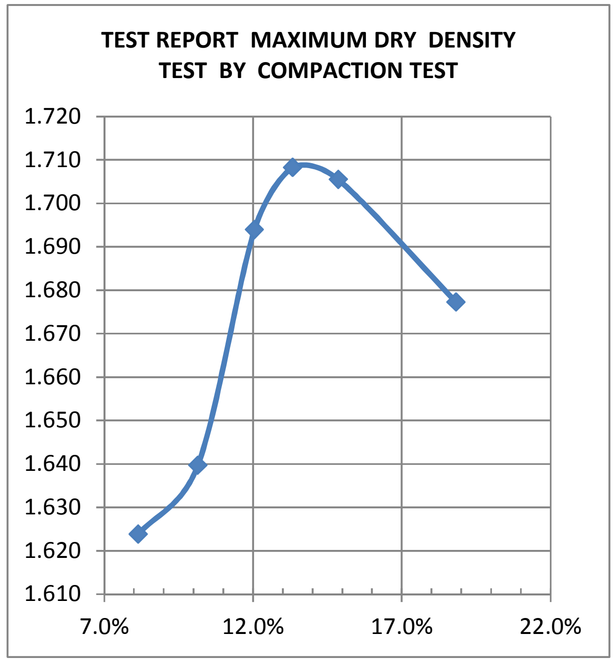
DRY DENSITY	MOISTURE CONTENT
1.610	8.046%
1.654	10.294%
1.705	11.905%
1.694	13.559%
1.657	17.857%
1.641	20.238%



MAXIMUM DRY DENSITY	1.705
OPTIMUM MOISTURE CONTENT	11.905%

COMPACTION TEST MDD & OMC

DRY DENSITY	MOISTURE CONTENT
1.624	8.140%
1.640	10.145%
1.694	12.048%
1.708	13.333%
1.705	14.865%
1.677	18.824%



MAXIMUM DRY DENSITY	1.708
OPTIMUM MOISTURE CONTENT	13.333%

4.2 Determination of Liquid and Plastic Limit

SOIL SAMPLE

	LIQUID LIMIT			**PLASTIC LIMIT**	
	Test 1	Test 2	Test 3	Test 4	Test 5
Container I.D.	R	24	H	S	A
Mass of Empty Container (grams)	37	32	38	38	39
Mass of Wet Soil + Container (grams)	79	71	78	75	79
Mass of Dry Soil + Container (grams)	64	59	66	68	72
Mass of Water (grams)	15	12	12	7	7
Mass of Dry Soil (grams)	27	27	28	30	33
% Moisture	55.56	44.44	42.86	23.33	21.21
No. of Blows	20	24	29		
Liquid Limit from Flow Curve	**46.15**				
Plastic Limit	**22.27**				
Plasticity Index (Liquid Limit - Plastic Limit)	**23.88**				

4.3 Determination of Free Swell Index

Readings on the Glass Jar	Sample 1	Sample 2	Sample 3
V_d = volume of soil specimen read from the graduated cylinder containing distilled water.	20	17	23
V_k = volume of soil specimen read from the graduated cylinder containing kerosene	11	9	12
Free swell index= [Vd - Vk] / Vk x 100%	82%	89%	92%
Average Free Swell index	88%		

V.SUMMARY

The main objective of this study is to use the locally available gravels/ soils with mixing stone dust instead of using borrowed gravels in the sub-grade of internal road at Sadasivpet and also to check the performance of the sub-grade. Based on the traffic and the CBR value and also in view of the requirement to provide a sub-grade depth of about 0.90 M with good gravel to meet requirement of table 300-2 of MoRT&H, the sub-grade is proposed to be improved by mechanical stabilization with an additive of stone dust in the locally available poor black cotton soils which are highly expansive in nature. The reduction in the cost is emphasized below where an overall savings of Rs.42, 84,000.00 are projected against the original estimated cost of Rs. 1, 94, 68,800.00 by using the soil & stone dust mixtures in sub-grades. This savings of approximately 22.00% is a commendable savings in the cost of construction. The original estimate is for providing sub-grade with good gravel from an approved quarry located at a lead distance of 8KMS from the work site for a length of 4 KMs and for the entire width of the right of the way. With the advent of the use of the locally available gravels/ soils with mixing stone dust and mechanically stabilizing the sub-grade layer over which a capping layer of 150 mm thick good gravel to achieve CBR 10% has been very promising as the savings achieved in terms of money, time reduction, green rating and carbon points etc. The technical parameters and the specification for the sub-grade have been taken care of well in suggesting the usage of mechanically stabilized locally available gravels/ soils with mixing stone dust in the sub-grades. A sample stretch of the road pavement has been proposed with the above methodology where the CBR value is improved from 1.4% to 2.5% by using mechanically stabilized-locally available gravels/ soils mixed with stone dust in the sub-grades.

5.1 Conclusions

Following conclusions are drawn from this study:

- To determine the Unconsolidated, Undrained strength of a cohesive soil the Unconfined Compressive Strength test was carried out for all the 5%, 10%, 15% and 20% fraction mixtures of stone dust and the strength is ranging between 140.233 KPa to 149.06 KPa.
- The free swell index FSI was determined and found to be ranging between 86.33% to 72.33% for the fractions of stone dust mixtures between 10% to 20%.
- Similarly the Optimum Moisture Content and Maximum Dry Density test were carried out to determine the degree of compaction and the results varied between 12.9% - 12.50% and 1.779-1.7142 for the fractions of stone dust mixtures between 10% to 20%.
- To assess the sub-grade strength, CBR value of the sub-grade using stabilized soils was tested and found to be ranging between 2.4%-2.6% when tested for a soil & 10% of stone dust mixture, which is found to be most economical. However, the stabilized soil mixture was also tested for 10%, 15% and 20% of the stone dust fractions mixed in the soil sample, the increase in the CBR is observed, but due to economical criteria 25% fraction of stone dust mixture mixed in the local soils was adopted.

5.2 Recommendations for Further Work

- As the proposed road uses only one fraction of stone dust mixture i.e., 10% of stone dust mixed in the locally available soils is adopted for the road section and the evaluation of the other fractions can be made with respect to the mixes. Distresses like pot holes, corrugations, rutting, ravelling, skid resistance, and roughness in the road sub-grade could not be studied as the road section is not completed in full shape.
- The evaluation of sub-grade strength with the composite mixtures such as fly-ash and stone dust in different fractions can be studied in an elaborative manner for more economical and feasible designs.
- This data can be used to develop deterioration models by considering various factors like traffic, pavement distress, and pavement age after continuing this work for few more years. To evaluate the performance of the pavements with proper maintenance, continuous study for successive years is required, for which, this study is to be continued and historical data has to be generated. To develop various distress progression models, continuous data base is required so that it can be incorporated in the further study.

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