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Performance Assessment of In-House Soil to be used as Sub grade with Lime Stabilization

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Abstract: The performance of soil stabilization using lime to improve the existing in-house (or in-place) soil of the 'Dasna–Hapur Road Project' in Ghaziabad & Hapur districts of Western Uttar Pradesh, India is assessed. This study is conducted on existing soil within Right of Way (ROW) using lime content in various proportions. Geotechnical laboratory tests on modified soil are conducted for soil characterization and mechanical strength. The results show that lime content significantly changed the mechanical performance of natural soil, increasing its mechanical strength and load-carrying capacity and the in-house soil to be used as sub grade. Compaction effort and curing time provided different responses in the California Bearing Ratio (CBR) tests. The best CBR value of 26.3% for the soil-lime mixture with 2% lime is achieved out of existing in-house soil CBR value of 4.38 %. It is concluded that instead of replacing of existing soil strata with borrow earth (from 35-60 Km of borrow area) for preparation of sub grade layer, the existing soil can be modified and stabilized to be used as sub grade. This will reduce the environmental load and reduction in terms of cost of transportation of borrowed soil and removal & disposal of existing poor soil.

Keywords: flexible pavements, soil stabilization, lime stabilization, sub grade.

Introduction

India is geologically active and had a wide variety of soil types across the country. The highway construction is done with the combination of soil, metal (aggregate) and binders. The bottom layers, namely embankment, and sub grade are constructed of soil. The upper layers are aggregate layers of GSB (Granular Sub Base), WMM (Wet Mix Macadam), DBM (Dense Bituminous Macadam) and BC (Bituminous Concrete) done with or without binders. The thickness of the aggregate layer is dependent on strength of sub grade, i.e. CBR (California Bearing Ratio) value. The pavements are engineered to distribute stresses imposed by traffic to the sub grade, thus sub grade conditions have a significant influence on the choice and thickness of pavement structure and the way it is designed. Depending on the existing in-house soils and project design, the properties of the sub grade may need to be improved or replaced. Improvement in sub grade can be done either mechanically, chemically, or both, to provide a strong platform for the construction of subsequent layers.

Pavement performance can be largely attributed to the performance of its foundation, which is comprised of the sub grade and base layers. Base and sub grade layers provide Shear Strength, Modulus (stiffness), resistance to Moisture, Stability, & Durability

To enhance the performance of subgrade the in-house (existing) poor soil is been replaced with high performing nearby available soil (borrow areas). Remove and Replace technique is widely used in construction practices and people in India treat it as most effective & easy technique. This attracts environmental problems for local habitations, via transportation, excavation, disposal of poor soil, and other environmental impacts related to land use, water, air, noise, etc.

To overcome these problems, soil stabilization of the existing in-place soil with lime is considered. Cement and lime are traditional stabilizers that are used for stabilizing the soils. Cement and lime are traditional stabilizers and have been investigated by many researchers (Miura *et al.,* 2002; Al-Tabbaa, 2003; Raoul, *et al.,* 2010; Farouk and Shahien, 2013; Kitazume and Terashi 2013 and Önal, 2014). Soil modifications with a moderate rate of additives (3% quicklime) cause improvements such as drying and swelling reduction. Soil stabilization from higher rates of application is the focus (Beeghly, 2003).

The objective of the present study is to investigate, the technical potential of the use of lime in the improvement of in-place soil engineering properties.

Material and methods

Location of study and materials used:

The experimental study was performed at 'Dasna –Hapur Road Project', a section of NH 24, plying in the Ghaziabad & Hapur districts of Western U. P., India. The soil properties varied drastically within the district, as well as within the project. Most importantly the existing soil alone is unsuitable to be used as subgrade. As per specifications, the minimum effective CBR for subgrade shall be 8%. The experimental study of existing ground CBR lies in the range 4.38% to 6.34% hence considered as marginal soil and is not unsuitable soil. It is suitable for embankment purpose.

The first option explored is to get the nearest borrow area to the road project of effective CBR more than 8%. It is recognized that Western Uttar Pradesh has diverse geology and consequently a wide variety of soil types throughout the stretch, ranging from fine, alluvial, silty materials clays, fine sand, sandy material and sometimes peat in the floodplains. The project is the link road between the Yamuna and Ganga Rivers, flowing 100 Km apart. The road project is east-west, where the Yamuna is at west and Ganga is at east. The requisite subgrade soil (of minimum 8% effective CBR) available in nearby areas is between 35 to 60 Km from the project site.

It is accessed that transportation of subgrade soil from borrows areas from distance is uneconomical and had a huge environmental impact, like:

- Excavation of existing in-place soil and disposal location for marginal soil (land fill area, mining plan, etc)
- Excavation of subgrade soil at borrows area (excavation, transportation, and compaction, etc).

To overcome these problems, alternatives of soil modification and soil stabilization of the existing in-place soil with lime is considered for experimentation. Lime is traditional stabilizer that is widely been used for stabilizing the soils in many developed countries for centuries. Lime is one of the oldest road construction materials (Dash & Hussain, 2012), whose technological characterization as a soil stabilizing agent was referenced in studies by Machado *et al.* (2006), Consoli *et al.* (2009), and Cristelo *et al.* (2009).

Use of small percentage of lime in existing soil will improve the properties of existing materials, thereby providing a good platform for the overlying pavement layers.

Laboratory experimental setup:

In the laboratory, two types of soil experimental programs are taken simultaneously, namely one of existing in-place soil within ROW and secondly with lime stabilized soil in various proportions (the soil sample considered is of weakest soil obtained in the ROW, which is marginal soil and not unsuitable for embankment)

The soil samples of existing in-place soil within ROW (Right of Way of the road):

The soil samples were collected from various locations and were oven dried for 72 hrs for determination of the following parameters required as per IRC codes in practice:

MDD- Maximum Dry Density (gm/cc),

OMC- Optimum Moisture Content (%),

FSI- Free Swelling Index (%),

GSA- Grain Size Analysis (%),

LL- Liquid Limit (%),

PL- Plastic Limit (%),

PI- Plasticity Index (%),

CBR (California Bearing Ratio) Soaked 2.5 mm (%), and CBR Soaked 5 mm (%).

The modified or stabilized soil samples with lime:

Similarly, the marginally weakest soil is identified and sufficient quantity is collected and is oven dried for 72 hrs. Thereby it was homogeneously mixed with lime for determination of the physical parameters according to the norms and standards.

Data analysis:

The results of soil samples of existing in-place soil within ROW (Right of Way of the road) varies between 4.38% to 6.34%. Tests conducted on every 200 m on both sides (LHS & RHS), as only lowest CBR is considered, hence not reflected here.

The results of modified or stabilized soil samples with lime are tabulated as below:

Type of materials	MDD (gm/cc)	OMC (%)	FSI (%)	GSA			Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	CBR Soaked (%)	
				Gravel (%)	Sand (%)	Silt & Clay (%)				2.5 mm	5 mm
Soil (38+100)	2.025	10.6	16.66	0.072	28.74	71.18	22.4	18.74	3.66	4.38	6.87
Soil+0.5% Lime	1.916	11.35	15.4	0.1	6.64	93.26	23.9	21.03	2.87	7.73	9.99
Soil+1% Lime	1.92	11.8	14.65	0.28	6.49	93.23	23.8	19.57	4.23	14.92	16.42
Soil+1.5% Lime	1.898	11.62	12.5	0.12	6.49	93.39	24.15	21.93	2.22	20.24	23.98
Soil+2% Lime	1.891	11.48	11.44	0.18	6.91	92.91	24.56	21.52	3.04	26.3	27.51

Result and Discussion

The results of soil samples of existing in-place soil within ROW (Right of Way of the road) are analyzed as below:

Results of the physical characterization of local soil shows a predominance of the silt average 65% (91% to 32%), the sand fraction in the samples (> 24%), with a sandy-clayey-silty texture. This soil does not fit into any of the particle size ranges, for use as grain base for subgrade in pavements. The mean value for the specific gravity was recorded as 1.99 gm/cc in RHS and 1.969 gm/cc in LHS. The mean value for the Plasticity Index was recorded as 13.78 % in RHS and 12.53 % in LHS. The CBR value varied between 4.38% and 6.34%, mostly on the lower side. From the results of current study it is clear that these soils cannot be used as subgrade. For the purpose of this study only lowest value soil of CBR 4.38% is used for experimentation.

Results of the physical characterization of modified local soil (Table 2.3.2)

The CBR has increased from 7.73 %, 14.92%, 20.24% and 26.6%, when soil is combined with 0.5%, 1%, 1.5% and 2% respectively. The soil samples with 1%, 1.5% and 2% lime can be used as subgrade.

The density is reduced from 2.025 to 1.89 (average) in combination with lime, however, it will have no materialistic effect on subgrade selection.

1% increase in OMC has been observed, and FSC also reduced from 16.6% to 11.4%, however it will also not affect the selection of subgrade.

The finer particle increased from 71% to 93%, which is the point of concern, however, can be overlooked looking to the increasing value of CBR.

The LL, PL, and PI remained within the required parameters. The maximum excepted limits established for base materials used in flexible pavements are LL = 25% and PI = 6%.

The results are in line with the Pereira *et al.* (2018) work . They assessed the mechanical performance of soil stabilization using lime content of 2% with lateritic soil in the municipality of Niquelândia, Brazil. Geotechnical tests of soil characterization showed that lime content significantly changed the mechanical performance of natural soil, increasing its mechanical strength and load-carrying capacity. In the CBR test, soil-lime mixtures compacted at intermediate and modified efforts were considered for application as subbase material of flexible road pavements. The results are also following the change in pattern observed by Kulkarni *et al*. (2017) in Indian soil. It showed that, when lime & fly ash are mixed with the expansive soil, the Plastic limit increases by mixing lime and liquid limit decreases by mixing fly ash, which decreases plasticity index. As the amount of fly ash & lime increases there is apparent reduction in modified dry density & free swell index and increase in optimum moisture content

Conclusions

Analysis of the results clearly led to the following conclusions:

Strengthening the existing soil by lime has resulted in an increase in 5 times the initial strength which will help in reducing the conventional aggregate layers, thus saving aggregate and the quantity of bitumen. The treated subgrade soil in more impermeable, thereby increasing water resistance and hence increases strength to the road foundation. The durability has increased thus the need for regular maintenance will also be reduced.

Reengineering of marginal soil and stabilizes has increased strength and hence it eliminates the need of transport of good soil and, thereby helps in saving carbon footprint.

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