Techno-Economical Design of Flexible Pavement based on the Stabilization of Soil using stone dust as an additive

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Abstract - Due to rapid urbanization, industrialization and growth of population there is tremendous increase in construction activities, has led to scarcity of land with good bearing capacities thus forcing the construction over sites deemed unsuitable for such activities. To improve the geotechnical properties of soil of such sites soil stabilization methods are adopted. Stabilization is an effective alternative for improving soil properties, the engineering properties derived from stabilization vary widely due to heterogeneity in soil composition. The technical modification of soil is carried out by addition of stone dust to original expansive soils in the range of 0 to 60% with an increment of 10% viz. 10%, 20%, 30%, 40%, 50% and 60%. The effect of stone dust on liquid limit, plastic limit, plasticity index, dry density, optimum moisture content and their CBR values are computed. The economics is computed for the different percentages of stone dust added to the soil and their cost arrived for these percentages are computed.

Index Terms: CBR, Liquid limit,msa, Plastic limit, Stone dust, Techno-economics.

1.0 INTRODUCTION

The Greater Hyderabad Municipal Corporation (GHMC) was created in 2007 to oversee the civic infrastructure of the 18 "circles" of the city. This increased the area of Hyderabad from 175 square kilometers to 650 square kilometers, and the population grew by 87%. The GHMC has a population of 10 million, which makes it the 6th most populous urban agglomeration in India. GHMC's population has grown from 7.7 million in 2011, showing substantial growth. Hyderabad has an estimated population of 8.7 million with a population density of 18,480 people per square kilometer (47,000/sq mi).

The rapid urban and industrial developments pose an increasing demand for the construction of highways embankments and many other civil engineering structures. Hence barren lands and problematic soils, waterlogged areas, landfills, damping yards are to be brought to use for construction activities. The problematic soils such as soft clays, black cotton soils, barren lands, waterlogged lands are to be treated for improving their bearing capacity and settlement behaviour. The construction of roads, highways, runways over these soils affect its stability. The embankment laid on these soils will not be stable. Due to shrinkage and swelling nature of sub soil the pavement gets damaged it will cost heavy expenditure for repair.

In recent year's lot of experimental studies have been carried out on improvement of sub-grade soil, increasing the strength of the pavements and embankments to take heavier loads as well as widening and renewal of roads. The present work is aimed to assess the improvement in gradation. Atterbergs limits, compaction characteristics, specific gravity, CBR values on different samples with varying percentage of stone dust to original soil. The stone dust is added by percentage of weight to the dry soil sample for this properties of soils and properties of stone dust available from the nearby stone crushing plant are found out.

For successful soil stabilizer applications it is imperative to understand the mechanism of stabilization of each additive. A basic understanding of stabilization mechanisms assists the user agency in selecting the stabilizer or additive best suited for a specific soil not only from the standpoint of developing the engineering properties desired for the pavement sub-layers but also to minimize the risk of long-term deleterious reactions that might compromise pavement structural capacity oreven induce disruptive volumetric changes such as sulphate-induced heave. In order to determine an appropriate soil-additive combination and to reduce the risk of deleterious reactions for a specific soil-stabilizer combination field exploration is required. For soil stabilization operations, the exploration process is less complex than for structural foundations as the depth of the influence zone is less. Therefore, although geological data are valuable, the most important data come from pedagogical profiles that are available, for example, in the National Resources Conservation Service (NRCS) County Soil Surveys.

Over the years engineers have tried different methods to stabilize soils that are subject to fluctuations in strength and stiffness properties as a function of fluctuation in moisture content. Stabilization can be derived from thermal, electrical, mechanical or chemical means. The first two options are rarely used. Mechanical stabilization, or compaction, is the densification of soil by application of mechanical energy. Densification occurs as air is expelled from soil voids without much change in water content. This method is particularly effective for cohesion less soils where compaction energy can cause particle rearrangement and particle interlocking. But, the technique may not be effective if these soils are subjected to significant moisture fluctuations.

2.0 LITERATURE REVIEW

The authors have stabilized the subgrade expansive soil with different materials as stabilizer viz. quarry dust or stone dust, fly ash, brick powder, marble powder, waste plastic, iron ore, silica powder etc., with different proportions of the stabilizer to find the OMC, MDD, CBR etc., of the stabilized soil. They found only the technical properties of the stabilized soils. They inferred that highest CBR for the specific msa lower the thickness of pavement.

It's absolutely true that the higher the CBR the lower the pavement thickness.

3.0 EXPERIMENTAL WORK

The sieve analysis for expansive soil, stone dust, for different proportions of stone dust stabilized viz. 10%, 20%, 30%, 40%, 50%, 60%, of stone dust added to the expansive soils and are presented in the below Figure1 as per IS:2720 (part 4)1985[1].

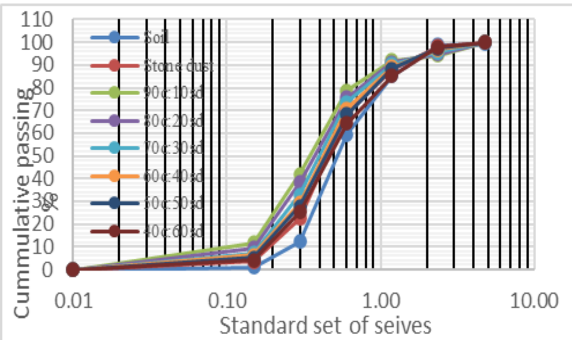

Fig. 1 The sieve analysis of stone dust, expansive soil, and different percentages of stone dust added to soil.

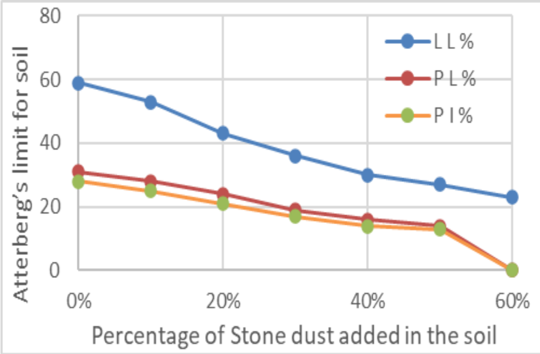

Fig.2 Effect of stone dust on Atterberg's limit for soil

Table 1: Effect of stone dust on Atterberg's limit

Sl. No.	% of stone dust to soil	Soil (S), Stone Dust (SD)						
		S	SD10	SD20	SD30	SD40	SD50	SD60
		100:0	90:10	80:20	70:30	60:40	50:50	40:60
1	L L	59	53	43	36	30	27	23
2	P L	31	28	24	19	16	14	*N P
3	P I	28	25	21	17	14	13	*N P

*N P – Non plastic

From the Table 1 it is seen that on addition of stone dust the liquid limit varies from 59 to 27 and is in the decreasing order and the same trend is seen for plastic limit also which varies from 31 to 14this may be due to the stabilizer added is non-plastic.

The below Figure 3 shows the variation of MDD, OMC as per IS:2720 (part VII) 1980 [2], CBR as per IS:2720 (part 16) 1987 [3] and A.S. Bshara, Y.K. Bind, and P.K. Sinha [6], N. Agarwal, A. Murari, A. Kumar [7], when different % of stone dust added to the soil

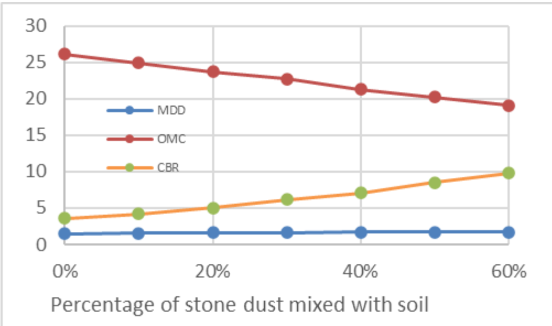

Fig.3 Variation of MDD, OMC, CBR corresponding to the % of stone dust added to soil.

Table 2 Variation of MDD, OMS, and CBR

Sl. No.	% of stone dust to soil	Soil (S), Stone Dust (SD)						
		S	SD10	SD20	SD30	SD40	SD50	SD60

		100:0	90:10	80:20	70:30	60:40	50:50	40:60
1	MDD	1.47	1.55	1.60	1.64	1.67	1.70	1.73
2	OMC	26.10	24.90	23.70	22.70	21.30	20.20	19.10
3	CBR	3.27	4.21	5.01	6.12	7.08	8.51	9.78

From the Table 2 it is seen that the value of MDD increases from 1.47 to 1.73 due to addition of stone dust to the soil in different percentages. This may be due to the resistance offered by the stone dust when mixed in different percentages in the soil. The same trend is seen while computing the CBR also and the value varies from 3.27 to 9.78. There is a decreasing trend in OMC, this may be because the stone dust is non-plastic and the water required only for the soil. This parameter is very important and useful, because while stabilizing the soil less water can be used.

3.1 COMPUTATION OF TRAFFIC DESIGN

The following data is collected and the traffic volume in msa is computed as per IRC 37 2001[5] and 2018[4]

Table 3 Data required for computing the traffic volume in msa

Particulars	Symbol	Value	Unit
Length of the road		5.00	km
No of lanes of the road		2.00	
Average number of vehicles in both lanes	P	1600.00	Nos. CVPD
Annual growth rate of commercial vehicles	r	7.50	%
Total period of construction	x	4.00	months
Design period of the road	n	10.00	years
Vehicle damage factor (table 1 of IRC 37 2001)	F	4.50	VDF
Lane distribution factor (3.3.5.1 (ii)) IRC 37	D	75.00	LDF %

Cumulative number of standard axles to be catered for in the design

$$N = \frac{365 * \{(1+r)^n - 1\}}{r} * A * D * F \qquad \text{EQ 1}$$

Where

N - Cumulative number of standard vehicles

A - Initial traffic in the year of completion of construction in terms of the number of commercial vehicles

D - Lane distribution factor (as per IRC 3.3.5.1 (ii))

F - Vehicle damage factor

n – Design life in years

r - Annual growth rate of commercial vehicles (for 7.5% r = 0.075)

The traffic in a year of completion is estimated using the formula

$$A = P * (1 + r)^x \qquad \text{EQ 2}$$

A = 2140.00 CVPD in both lanes

Substituting the value of a in equation 1

N = 20.00 msa (million standard axles)

As per latest IRC 37 2018 the thickness of pavement is given from 5% CBR. Hence, IRC 37 2001 is also taken to compute the thickness below 5% CBR.

Figure 4 shows the pavement thickness corresponding to CBR and msa as per IRC 37 2001[5]

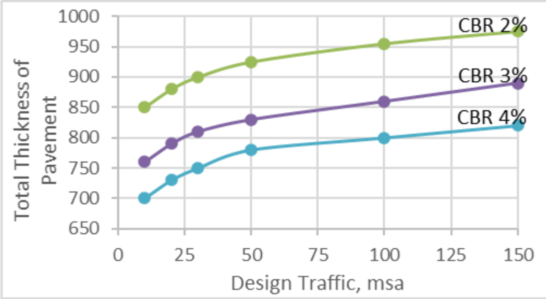

Fig. 4 Pavement thickness design chart as per IRC 37, 2001

Figure 5 shows the pavement thickness corresponding to CBR and msa as per IRC 37 2018

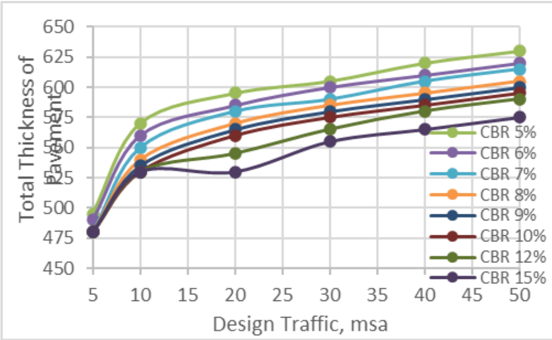

Fig. 5 Pavement thickness design chart as per IRC 37, 2018

3.2 COMPUTATION OF PAVEMENT COST

Table 4 Consolidated thickness of pavement at different CBR percentages for different percentages of stone dust added to sub grade soil for 20msa

Sl. No.	% of Stone dust	CBR value	Rounded CDR value	Thickness of road	BC	DBM	Base WMM	Sub base GSB
	SD	%	%	mm	mm	mm	mm	mm
1.	0.00	3.27	3.00	790	40	120	250	380
2.	10.00	4.22	4.00	730	40	110	250	330
3.	20.00	5.01	5.00	595	40	105	250	200
4.	30.00	6.12	6.00	585	40	95	250	200
5.	40.00	7.08	7.00	580	30	100	250	200
6.	50.00	8.51	9.00	565	40	75	250	200
7.	60.00	9.78	10.00	560	40	70	250	200

The Table 4 depicts the values for the thickness of pavement corresponding to the values computed for CBR for different percentages of stone dust added to the soil as per IRC 37 2001 and 2018.

The cost is computed for two lane, 1.0km stretch of a road and the depth of consolidation of subgrade is taken as 600mm, the rates are taken from the market.

Table 5 Cost of pavement for different CBR values

Sl. No.	addition of Stone dust	CBR value	Thickness of pavement	Cost of Pavement
	%	%	mm	Rs.
1	0.00	3	790	2,78,68,418.00
2	10.00	4	730	2,68,18,481.00
3	20.00	5	595	2,45,15,503.00
4	30.00	6	585	2,45,09,567.00
5	40.00	7	580	2,48,46,240.00
6	50.00	9	565	2,44,97,694.00
7	60.00	10	560	2,49,09,116.00

Table 5 shows the cost of the pavement for different thickness for the corresponding CBR.

Figure 6 shows the cost of the pavement corresponding to thickness of pavement and CBR

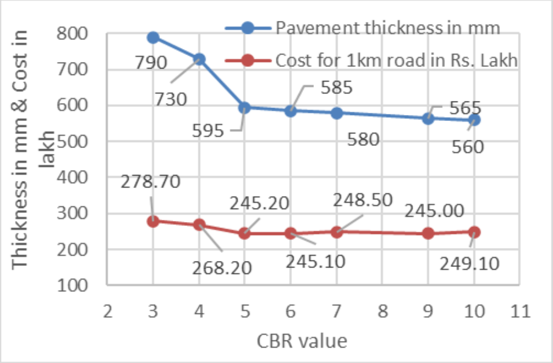

Fig. 6 Cost and thickness of pavement Vs CBR value.

From the figure 6 it is seen that the thickness of pavement is decreasing corresponding the CBR value, at the same time it can also be seen that the cost is reducing as the thickness reduces but the cost starts increasing from 9% CBR, there is an increase of Rs.3.77 lakh between 9% and 10% CBR.

4.0 CONCLUSIONS

The main objective of this study is to improve the Engineering (technical) properties of expansive soil for road construction. This strategy of improving properties of expansive soil is developed by mixing stone dust to expansive soil in different proportions and observing the improvement in properties. The following conclusions may be drawn from the study.

- It is been observed from the study that as the percentage of stone dust is increased, the CBR value is increasing and the OMC is reducing.
- Adding stone dust is effective in decreasing OMC of soils which is advantageous in decreasing quantity of water required during compaction.
- While considering the only the technical properties, the pavement thickness for the existing soil is 790 mm while the thickness of pavement for soil stabilized with 60% stone dust is 560 mm. A significant reduction of thickness is observed and the reduced thickness is 230mm.
- The cost analysis when 60% of stone dust is added to the existing soil with a CBR value of 10% works out to be Rs.2,68,18,481.00
- The cost analysis when 50% of stone dust is added to the existing soil with a CBR value of 9 works out to be Rs.2,44,97,694.00
- While considering the techno-economical properties the CBR value is 9 for the addition of 50% stone dust to the existing soil for cost of pavement is Rs.2,44,97,694.00.

There is a reduction of cost of Rs.3.77 lakh for 1.0km stretch of two lane road.

5.0 ACKNOWLEDGEMENT

I express my sincere gratitude to my supervisor Dr. D RAJASHEKAR REDDY, Associate Professor, Department of Civil Engineering, University College of Engineering (Autonomous), Osmania University, Hyderabad who offered me the valuable guidance, motivation and encouragement throughout the study.

I would also like to thank V VRaghunandan for helping in conducting the experiments.

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