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Geotechnical Behaviour of soil using Waste Plastics

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Abstract: Availability of sound road aggregates is rare and costly nowadays due to rapid growth in the pavement construction activity to meet the increasing demand due to infrastructure development. Construction of pavement requires large quantity of earth material. India is experiencing tremendous growth in infrastructure including road network and highways. This new technique of soil stabilization can be effectively used to meet the challenges of society, to reduce the quantities of waste, producing useful material from non-useful waste materials. Use of plastic products such as polythene bags, bottles etc. is increasing day by day leading to various environmental concerns. Therefore the disposal of the plastic wastes without causing any ecological hazards has become a real challenge. Thus using plastic bottles as a soil stabilizer is an economical utilization since there is scarcity of good quality soil for embankments. Present research study focus on the evaluation of benefits of stabilization of subgrade soil. Construction of pavement requires large quantity of earth material. Waste plastics can be effectively utilized for improving the engineering properties of the weak soil. In present research was carried out to study the effect of plastic strips on Maximum Dry Density, Optimum Moisture Content, California Bearing Ratio and Standard Proctor Test by using 0.5%, 1%, 1.5% and 2% percentage of plastic waste by dry weight of soil.

Keywords: Maximum dry density, Optimum moisture content, California bearing ratio.

I. INTRODUCTION

Soil Stabilization is the process of blending and mixingmaterials with a soil to improve certain properties of thesoil. The process may include the blending of soils toachieve a desired gradation or the mixing of commerciallyavailable additives that may alter the gradation, texture orplasticity, or act as a binder for cementation of the soil. The long term performance of any construction project depends on the soundness of the under laying soils. Unstable soilscan create significant problems for pavements. Lack ofadequate road network to cater to the increased demand andincrease distress in road leading to frequent maintenancehave always been big problem in our country. Evolving newconstruction materials to suit various traffic and siteconditions for economic and safe design is a challengingtask in road construction. Effective utilization of local weak soils by imparting additional strength using stabilizationmaterials enable reduction in construction cost andimproved performance for roads. Exploring the feasibility ofsuch materials for sub grade and embankment stabilizationwill help the road building sector to evolve a stronger, durable and economic design. Desirable properties ofsubgrade are high compressive and shear strength, permanency of strength under all weather and loadingconditions, ease and permanency of compaction, ease ofdrainage and low susceptibility to volume changes and frostaction.

II. LITERATURE REVIEW

Gray and Ohashi [1] suggested interim designapproach for plastic stabilization of subgrade material. Thelaboratory subgrade CBR is determined using AS1289.6.1.1. It is noted that standard and not modifiedcompaction is used in the preparation of sample. The designsubgrade CBR may be calculated by either using theequivalent CBR approach or using the sub layeringtechniques. Field performance continually showed thatplastic stabilization worked well and shortcuts taken in thespecification or by contractor should be avoided. Setty andRao [2] reported that thickness of soil-cement base/ soilplastic base reduce as modulus of soil- cement base /soil plastic base increases for a particular number ofrepetition and CBR. When CBR increases from 3 to 5/7/10,the thickness of soil cement base/ soil plastic base reducessignificantly for any particular number of repetitions andCBR. Also aggregate consumption is less for the case ofstabilized base compared to that of the conventional method.Moustafa Ahmed Kamel, Mohamed EL- Gray and Al-

Refea[3] conducted a comparative study for optimization andquantification of the beneficial effects of stabilization ofsubgrade soils in flexible pavement system. They selectedsix different groups of stabilizers i.e. cement, plastic, amixture of cement and polystyrene fibers, cement andplastic. Based on the investigated materials withthedetermined optimum amount of stabilizers, the service lifeof the simulated pavement section was increased by 67% to231%. Tom Damion et al [4] studied the cost effectivenessof clayey soil &moorum, treated with fly-ash plastic forconstruction of low volume roads and investigated thatmaximum saving was possible for combination of 70 % soil+ 30 % plastic +2 % plastics. Nafi Abdel Rahman Youssef,S.W. Thakare et al [5] carried out soil investigation withplastic stabilization on high plasticity clay and reported thatthe shear strength of soil increased as plastic concentrationincreased up to 4% CBR was improved when the soil wastreated with plastic. Abhishek Patil et ah [6] performedlaboratory investigation on the stabilization of marine clayusing saw dust and plastic and observed that the CBR valueof marine clay has been increased by 129.76% on additionof 15% sawdust and it has been further improved by283.12% when 4% plastic is added. V. Mallikarjuna et a[7] concluded that dry density of soil decreases with plasticcontent and C.B.R. value of soil increases from 1% to 2.74,3.89 and 6.51% due to stabilization with 2.5, 5 and 7.5%plastic content. There is considerable reduction in layerthicknesses. The thickness of sub-base reduces from 610 to320 mm, where as the DBM thickness is reduced from 215to 130 mm for 7.5 optimum plastic percentages. A.K.Chaudhary et al [8] studied the stability and plasticstabilization requirement of some selected lateritic soilsamples using 2, 4, 6, 8 and 10 % of plastic and reportedthat increase in dry density was as a result of the increasingplastic particles that were ready to perform the exchange of cations with the soil particles, thus filling up the voidsspaces and densely packing the soil particles together.However, the drop in density resulted from the excess waterand plastic remaining after the increasing quantity has beenused up for stabilization process. J. Trivedi, S. Nair and C.Iyyunni [9] carried out experimental studies to investigateoptimum utilization of fly ash for stabilization of subgradesoil and concluded that OMC attains its highest value of29.27 % for 10 % of fly ash as compare to 21.38 % forunstabilized soil whereas, CBR value increases from 5.64 %to 20.53 % for 20 % of fly ash. L. Yadu, R. Tripathi and D.Singh [10] conducted number of experiment for thecomparison of fly ash and rice husk ash stabilized blackcotton soil .Based on the CBR and UCS tests they reportedthe optimum amount of fly ash and rice husk ash was 12%and 9% respectively. Saving in the cost per km length ofroad has been estimated to be approximately 14% and 20%for RHA and FA respectively. B. Phanikumar and R.Sharma [11] studied the effect of fly ash on engineeringproperties of expansive soils and stated that optimummoisture content decreased and maximum dry unit weightincreased with an increase in fly ash content. There issubstantial history of use of soil stabilization admixture toimprove poor subgrade soil performance by controllingvolume change and increasing strength. V. Pasupuleti, S.Kolluru and T. Blessingstone [12] conducted experimentalstudy on effect of fiber and fly ash stabilized subgrade andstated that optimum CBR value was obtained at 15% of fly ash with 1.5 % fiber content. E. Geliga and D. Ismail [13] investigated geotechnical properties of fly ash and itsapplication on soil stabilization and reported that shearstrength observed of sample mixture cured for 7 days weredecreasing when amount of fly ash was 80% of the totalweight of the mixture. R. Sharma [14] studied the sub gradecharacteristics of locally available expansive soil mixedwith fly ash and randomly distributed fibers. As per theresults of investigation, it was reported that proportion of 70% soil and 30 % fly ash was the best proportion havingmaximum dry density and maximum CBR value.

Available literature shows that most of the researchworks on cement, fiber, saw dust, plastic and fly ashstabilization is related to geotechnical aspects only. Veryfew attempts have been made on use of plastic or fly ash inhighway subgrade. Conflicting results have been reported inliterature regarding optimum percentage of plastic and flyash required for soil stabilization. Actual benefits ofstabilizing the subgrade soil with plastic and fly ash alsofinding out its optimum dosage and which one (plastic or flyash) is most suitable in terms of economy and layerthickness reduction has not been reported anywhere in theprevious literature.

III. EXPERIMENTAL PROGRAMME

A. Material Selection

Locally available soil namely Soil A collected from Borivali site was collected. The property of soil used in present studyare given in Table I. As per the AASHTO soil classification system, Soil A is A-7-5. Similarly, hydrated plastic is used in the present investigation; its properties are listed in Table II. The index properties; liquid limit, Plastic limit and plasticity index were determined as per [IS 2720-Part (5)- 1985]. The Standard Proctor's tests were conducted as per [IS 2720-Part (7)-1980] for deciding the Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) for soil. Hydrated Plastic is mixed with dry soil in different percentages varying from0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, and 5 percent by dry weight of soil.

TABLE I. PHYSICAL PROPERTIES OF SOILS USED IN PRESENT STUDY

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Sr. No.	Property	Soil-A
1.	Liquid Limit (%)	96
2.	Plastic Limit (%)	35
3.	Plasticity Index (%)	61
4.	MDD (kN/m3)	12.164
5.	OMC (%)	28
6.	CBR (%)	1.45
7.	UCS (kg/cm2)	2.084
8.	Soil Classification as per AASHTO	A 7-5
9.	Typical name	Clayey soil

B. Determination of soil

1) Standard Proctor's Test

Standard Proctor Tests were carried out on both unstabilized and stabilized soils as per [IS 2720-Part (7)-1980]. Both subgrade soil-A mixed with different percentages of plastic vary from 0.5 to6 percent at the steps of 1.5 percent by dry weight of soil. The mixture was transferred in proctor mould in three equal layers and each layer compacted by giving 25 numbers of uniformly distributed blow. The dry density - moisture content relations were plotted for each test. Then optimum moisture content and maximum dry density at each percentage of plastic were evaluated. Fig. 1 give typical plot showing variation of dry density with moisture content for neat soil and soil stabilized with 1.5 percent plastic for subgrade soil. The results show that, in plastic, for subgrade soil-A, the value of both maximum dry density and optimum moisture content goes on increasing with increase in percentage of plastic. The maximum dry density of unstabilized subgrade soil-A is found to be 12.164 kN/m^3. This value increases to 13.45 kN/m^3 at 3 % of plastic content. Thereafter, these values drop down. Increase in density was as a result of the increasing plastic particles that were ready to perform the exchange of cat ions with the soil particles, thus filling up the voids spaces and densely packing the soil particles together. However, the drop in density resulted from the excess water and plastic remaining after the increasing quantity has been used up for stabilization process. For soil-A, the optimum moisture content increase from 28 % at 0 % plastic to 32 % at 3 % plastic with corresponding increase in MDD from 12.164 kN/m^3 to 13.45 kN/m^3 thereafter it decreases to 12.75 kN/m^3 at 6 % plastic content. The decrease in the MDD is due to light weight of the plastic replacing the soil particles and some of the applied energy of compaction absorbed by the plastic. The change in OMC was quite marginal. Table 3 shows the variation of maximum dry density and optimum moisture content for the subgrade soil-A mixed with different percentage of plastic

2) California Bearing Ratio test

Four days soaked CBR tests were conducted on unstabilized and stabilized soil with different percent of plastic as per [IS 2720 (part 16)-1987]. The maximum limit of plastic content was 6 percent. The dry weight of soil required for filling CBR mould estimated from corresponding dry density and water content correspondingto optimum moisture content added to it. The mixture transferred to CBR mould and then compacted by static compaction. The compacted CBR mould transfer to water tank for 4 days and that after it is tested in CBR testing machine. The CBR was determined at 2.5 mm and 5.0 mm penetration levels and maximum of this is adopted as CBR value. CBR values at different plastic content and percentage increase in CBR with respect to unstabilized soil A is presented in Table 3.The test result shows that, the CBR value of unstabilized subgrade soil-A is 1.45 %. In case of plastic for soil-A, CBR value increases to 2.04, 6.86, 7.70 and 7.60 % due to addition of 1.5, 3, 4.5 and 6 % plastic respectively. From CBR test, in case of plastic, it is seen that maximum improvement in terms of CBR is observed at 4.5 % plastic for subgrade soil-A. Hence it can be considered as optimum percentage of 4.5 percent plastic required for design the flexible pavement.

WATER CONTENT(%)	0.5	1	1.5	2	2.5	3	3.5	4	4.5
DRY DENSITY	0.068	0.108	0.142	0.162	0.181	0.200	0.211	0.437	0.420

WITHOUT WASTE PLASTIC

WATER CONTENT(%)	0.5	1	1.5	2	2.5	3	3.5	4	4.5

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DRY DENSITY	0.079	0.126	0.156	0.182	0.204	0.217	0.232	0.246	0.220

0.5% WASTE PLASTIC

WATER CONTENT(%)	0.5	1	1.5	2	2.5	3	3.5	4	4.5
DRY DENSITY	0.054	0.093	0.122	0.149	0.167	0.181	0.190	0.224	0.206

1%WASTE
PLASTIC

WATER CONTENT(%)	0.5	1	1.5	2	2.5	3	3.5	4	4.5
DRY DENSITY	0.056	0.100	0.131	0.152	0.177	0.189	0.213	0.203	0.198

1.5% WASTE PLASTUC

WATER CONTENT(%)	0.5	1	1.5	2	2.5	3	3.5	4	4.5
DRY DENSITY	0.067	0.112	0.139	0.168	0.184	0.200	0.211	0.206	0.196

2.0% WASTE PLASTIC

WATER CONTENT(%)	0.5	1	1.5	2	2.5	3	3.5	4	4.5
DRY DENSITY	0.056	0.095	0.122	0.139	0.163	0.186	0.197	0.209	0.202

2.5% WASTE PLASTIC

TABLE II. VARIATION OF MDD AND OMC AND CBR VALUE WITH PLASTIC CONTENT FOR SOIL-A

Sr. No.	**SubgradeSoil-Awith Plastic**	**MDD kN/m^3**	**OMC (%)**	**Max.CBR (%)**	**%increase**
	(%)				
1.	0.5	0.437	4	0.45	-
2.	1.0	0.246	4	1.04	40.68
3.	1.5	0.234	5	3.86	373.10
4.	2.0	0.203	5	3.70	431.03
5.	2.5	0.204	5	4.60	424.14

CALIFORNIA BEARING RATIO

penetration	0	0.5	1	1.5	2	2.5	3	4.5	5
Plain soil	0	21	34.4	43	52.6	61	70.9	128	151
At 0.5%	0	19	33.2	44	53.7	62	72	134	153
At 1%	0	20	37.6	52.6	64.4	73	80	136	154
At 1.5%	0	24	38.7	55.9	69.7	81	92.4	160	175
At 2%	0	14	26.9	37.6	50.5	59	66.9	125	140
At 2.5%	0	17	27.9	37.6	43	48	53.7	81.6	91.3

CBR:= LOAD AT 2.5MM / STANDARD LOAD(kgf)

Whereas, for plastic, in case of soil-A, for a traffic intensity of 150 msa, thickness of DBM is 215 mm; it reduces to 135 due to stabilization of subgrade with 4.5 percent plastic. Decrease in thickness of DBM due to plastic and fly ash stabilization indicates that there may be considerable saving in cost of the pavement.

IV. DESIGN CHARTS AND ECONOMICAL ANALYSIS

A. Response Model (as per IRC 37:2012)
The main object of this research is to evaluate the benefits in terms of Layer Thickness Reduction (LTR) due to stabilizing the sub grade soils with plastic. The thicknesses of different layer of flexible pavement resting on unstabilised and stabilized subgrade for traffic intensity of 50 msa, 100 msa and 150 msa has been evaluated using IRC 37:2012. The thickness of subgrade has been taken 500 mm. These model thicknesses are subsequently used for estimating the quantities and economics of stabilized flexible pavement. Table 4 gives the values of thicknesses of various layers and the total thickness of the pavement for design traffic intensity of 50 msa, 100 msa and 150 msa. In present study, the CBR value of unstabilized subgrade soil-A is 1.45 %. There is no provision in IRC 37:2012, for soil whose CBR is less than 2 percent. Hence the design approach assume as per IRC 37:2001 for unstabilized subgrade soil-A as the CBR is less than 2 percent; capping layer of 150 mm has been provided in addition to the sub-base thickness.

B. Layer Thickness Reduction
The laboratory CBR test conducted on subgrade soil-A at different percentages of plastic. The study has been extended to evaluate the thickness of various layers above the stabilized subgrade soils at different plastic contents and for a traffic intensity of 50 msa, 100msa and 150 msa. For plastic stabilized subgrade, Table 5 for soil-A indicates the thickness of various layers and total thickness of the pavement resting on 4.5 percent plastic stabilized subgrade soil-A for a trafiic intensity of 50 msa, 100 msa and 150 msa. The result show that for a pavement resting on unstabilized subgrade soil-A for traffic intensity of 50 msa, 100 msa and 150 msa, the thickness of sub-base is 610 mm and 300 mm respectively, by plastic stabilization it reduces to 200 mm for subgrade soil A for a plastic content of 4.5 percent. Also, DBM may be the important layer responsible for total cost of construction of pavement. The study shows that, In case of plastic, for traffic intensity of 100 msa, in soil-A, thickness of DBM 195 mm; it reduces to 115 mm and for soil-B, thickness of DBM 130 mm; it reduces to 80 mm due to stabilization of subgrade with 4.5 percent plastic

C. Economic Analysis
The construction costs of flexible pavements resting on unstabilized and stabilized sub grade soils for different strategies and alternatives have been estimated in order to find out the most optimal design section based on the economic aspect. The routine maintenance cost has not beenincluded as the long term data of stabilized flexible pavements is not available. The initial construction cost hasbeen worked out for one km long 7.0 m wide pavement. The Schedule of Rate (2017-18) (SoR) for Maharashtra state only (Pune, Nashik, Aurangabad, Amravati, Nagpur and Kokan Regions) of India was followed to carry out this economic analysis. Various layers included in each design section are as follows:-

a) The sub grade of 500 mm
b) Granular Sub-Base (GSB) of River Bed Material (RBM)
c) Water Bound Macadam (WBM) for sub-base course
d) Dense Bituminous Macadam (DBM)
e) Bituminous Concrete (BC)
f) Cost of Plastic per kilogram
g) Cost of Fly Ash per kilogram

1) Estimation of Initial Constrcution Cost
The initial construction cost of each item was worked out in details and subsequently average unit cost of each item was estimated. Table 6 present the thickness and volume of various layers, and corresponding cost of each layer of flexible pavement resting on unstabilized subgrade soil-A for a designed traffic intensity of 50 msa, 100 msa and 150 msa. Cost of plastic is assumed as Rs.4 /kg. Additional cost due to plastic has been worked out for stabilizing the subgrade soil-A and it was added in the construction cost of the subgrade. Table 7 shows the additional cost of subgrade due to stabilization with 4.5 percent plastic. The total cost of the flexible pavement resting on stabilized subgrade soil-A has been worked out for different alternatives and presented in Table 8 to Table 10

V. CONCLUSION

In case of plastic, for subgrade soil-A, with an increase in plastic content up to 3 % the maximum dry density increases and thereafter it drops down whereas; the optimum moisture content decreases at 1.5 % plastic content and thereafter the increase in OMC is constant up to 6 % of plastic content.In case of plastic, the percentage increase in CBR for soil-A is 40.68, 373.10, 431.03 and 424.14 % for the plastic percentage of 1.5, 3, 4.5 and 6 % respectively.From CBR test, in case of plastic, the maximum improvement in terms of CBR is observed at 4.5 % plastic for subgrade soil-A. Hence it can be considered as optimum percentage of 4.5 percent plastic required for design the flexible pavement.Analysis of

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stabilized flexible pavement shows that there is a considerable reduction in layer thicknesses and it is the function of percentage of plastic also traffic for which pavement is designed.The percentage decrease in cost shows that, in plastic, for a design traffic intensity of 50 msa, 100 msa and 150 msa, the total cost of pavement in soil-A decreases by, 27.63, 26.465 and 25.09 respectively.Percentage decrease in cost indicates that, the designof flexible pavement resting on 4.5 % plastic stabilized subgrade soil-A with traffic intensity of 50 msa will be more economical in terms of saving natural resources as well as initial construction cost of the pavement.

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