

Performance of Randomly Oriented Plastic Waste in Flexible Pavement

Dr. A.I.Dhatrak¹, Sunilkumar D. Konmare², Dr. S.P. Tatewar³

Associate Professor, Department of Civil Engineering, and Dean Academics, Government College of Engineering,
Amravati, Maharashtra, India¹

PG Student, Department of Civil Engineering, Government College of Engineering, Amravati, Maharashtra, India²

Associate Professor, & Head of Department, Department of Civil Engineering, Government College of Engineering,
Amravati, Maharashtra, India³

ABSTRACT: Plastic waste problem has now become very critical issue in aspect of decomposition, which is a challenge to environmental control system. Now, plastic is not only used for particular use, but it has become addiction in daily life of human being as well as in industry. Huge quantity of plastic waste is found in MSW, which includes drinking water bottles, carry bags, packing paper etc. This plastic can be effectively used for improving the performance of flexible pavement; also solve the problem of disposal of plastic waste. The aim of project is to improve engineering properties of soil by using plastic waste strips/ chips. On the basis of various research paper studies, it is observed that the soil improvement using waste plastic bottles chips is an alternative method for improvement of sub grade soil for construction of flexible pavement. This project is based on the experimental work on use of plastic waste in soil used for construction of flexible pavement. Experimental studies have also been conducted to explore the effect of various parameters on the shear strength and compressibility characteristics of soils with randomly distributed plastic waste strips/chips in soil. The results from the literature indicated the increase in shear strength, unconfined compressive strength and tensile strength of the soil. It is evident that the studies presented in literature focus mainly on the strength and deformation characteristics of soil with the reinforcement. Furthermore, the study on the use of plastic waste as a reinforcing material has not been extended to field application. Hence in this project, 'Performance of Randomly Oriented Plastic Waste in Flexible Pavement' was studied, to determine the feasibility and effectiveness of the method in actual field construction. Also the economy of the method was evaluated.

KEYWORDS: Clayey Soil, Plastic Waste Strips/Chips, Model Flexible Pavement, Field CBR test.

I. INTRODUCTION

Huge quantity of plastic waste is found in MSW, such as drinking water bottles, carry bags, packing paper etc. This plastic can be effectively used for improving the performance of flexible pavement, which will also solve the problem of disposal of plastic waste. The aim of project is to improve engineering properties of soil by using plastic waste strips/ chips. On the basis of various research paper studies, it is observed that the soil improvement using waste plastic bottles chips is an alternative method for improvement of sub grade soil for construction of flexible pavement. This project is based on the experimental work on use of plastic waste in soil used for construction of flexible pavement.

II. LITERATURE REVIEW

Based on the literature review study, following are some of the conclusions obtained.

- i) There is a good improvement in the strength of soil with inclusion of plastic waste⁹.
- ii) The compressibility and permeability reduced significantly with addition of a small percentage of plastic waste to the soil⁴.

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- iii) Inclusion of waste HDPE strips in soil with appropriate amounts improves strength and deformation behavior of subgrade soils substantially².
- iv) Using plastic bottles as a soil reinforcement is an economical and gainful utilization, since there is scarcity of good quality soil for embankments and fills¹.
- v) Waste plastics and waste tyre rubber may be used as alternative reinforcement materials in place of conventionally used reinforcing materials³.

It is evident that the studies presented in literature focus mainly on the strength and deformation characteristics of soil with the reinforcement. Furthermore, the studies on the use of plastic waste as a reinforcing material have not been extended to field applications. This is the literature gap for present study.

III. SYSTEM DEVELOPMENT

A. MATERIALS

a. PLASTIC WASTE



Fig.1 Waste Plastic Bottle Strips /Chips Used in the Experimental Investigation

In this project, waste plastic bottles strips/chips were used as a reinforcing material in soil. These are locally available in MIDC Amravati and are produced by Plastic Granulator. The plastic waste strips/chips were used for present study is shown in Figure 1.

b. SOIL

The Soil used in the experimental investigations was obtained from the premises of Govt. Engineering College, Amravati. The properties of the clay soil were determined as MDD = 16.00 kN/m³, OMC = 19.60%, Compressive Strength = 16.25 kN/m², LL = 54.32%, PL = 27.21%, and SL = 13.00%.

B. EXPERIMENT PROGRAM

Various laboratory tests were performed to determine the compaction characteristic, strength characteristic and stress strain, characteristic of soil mixed with varying percentage of randomly oriented plastic bottles strips/chips. This mainly included compaction test to determine OMC and MDD. CBR soaked & unsoaked tests were conducted to determine the effectiveness as well as optimum percentage of plastic waste in the soil. Laboratory CBR tests were performed to determine the optimum percentage of plastic waste strips/chips. Plastic waste strips were mixed with soil in percentage of dry weight of soil. The various percentage of plastic strips/chips were 0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5%.

The flexible pavement was designed for soil without and with plastic waste chips, to determine the thickness of pavement in both cases and also to evaluate the economy of the method. Also the field CBR was conducted on a prototype flexible pavement constructed with soil mixed with optimum percentage of plastic waste, as obtained from laboratory test, to determine the feasibility and effectiveness of the method in actual field construction

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C. CONSTRUCTION OF COMPOSITE SUBGRDE

Artificial Subgrade is an earthbankment constructed using natural subgrade soil with specific thickness. It acts as earthwork for pavement construction and increases formation level of pavement. This helps to avoid submergence of pavement under heavy rainfall. Composite subgrade is an earth embankment of road work improved with randomly oriented plastic waste strips/chips. Optimum percentage of plastic strips is to be mixed in subgrade soil as determined from laboratory test to check effectiveness and feasibility randomly oriented plastic waste strips in flexible pavement. Composite subgrade was constructed in the campus of Government college of Engineering Amravati, as per the provision of IRC: 36 -1970: "Recommended Practice for the Construction of Earth Embankments for Road Works" and IRC: 20-SP-2002: "Rural Roads Manual". For present study 0.30 m thickness was adopted for construction of artificial as well as composite subgrade.

Artificial and Composite Subgrade patches for Model Flexible Pavement were constructed of Dimension = 10 m x 3 m x 0.30 m. Dimension of Artificial Subgrade = 5 m x 3 m x 0.30 m and Dimension of Composite Subgrade = 5 m x 3 m x 0.30 m. The constructed composite and artificial subgrade of model pavement in field is shown in Figure 2.



Fig.2 Constructed Artificial and Composite Subgrade of Model Flexible Pavement in Field for Present Study

D. FIELD CBR TEST ON ARTIFICIAL AND COMPOSITE SUBGRADE OF MODEL FLEXIBLE PAVEMENT.



Fig.3 Typical Setup for Unsoaked Field CBR on Artificial Subgrade

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a. EQUIPMENT

As per IS 2720 (Part 31): 1990 for field CBR, in the present investigation, tractor was used for reaction for loading. 2.5 kN proving ring, dial gauge with least count to 0.01 mm and having a travel of 25 mm for measuring the penetration and standard plunger 50 mm diameter and 100 mm long, and spirit level were used for conducting the field CBR.

b. TEST PROCEDURE

The fields CBR tests were performed as per IS 2720 (Part 31): 1990. In these tests, mechanical screw loading jack was fixed to tractor head and leveled with spirit level. Then the metal connector was fixed to jack and connector to proving ring. The proving ring was connected to standard penetration plunger. Surcharge weight of 2.5 kg was placed on composite/ artificial subgrade of model flexible pavement. Magnetic dial gauge was rested on horizontal plate which was attached to jack. Loads were then applied and dial gauge and proving ring readings noted. The graph was plotted between penetration in mm and load in kN. From this graph, CBR value was determined. Soaked condition was developed by watering the artificial and composite layer for 4 days in regular interval. Plastic Paper was used to cover the pavement in soaked CBR test to maintain water content constant during test and also avoid the mud problem for testing. Typical set up for field unsoaked test conditions are shown in Figure 3.

E. DESIGN OF MODEL FLEXIBLE PAVEMENT

Model Flexible Pavement was designed using IRC: 37-2001 'Guidelines for Design of Flexible Pavement'.

F. ECONOMY OF MODEL FLEXIBLE PAVEMENT

As per PWD CSR 2014-15 (Amravati Region, Maharashtra) estimates were prepared for model flexible pavement with and without optimum plastic strips randomly oriented in subgrade. On the basis of both estimate, comparative statements prepared and the economy of present project work was determined.

IV. PERFORMANCE ANALYSIS

A. COMPACTION CHARACTERISTICS OF SOIL MIXED WITH PLASTIC CHIPS/STRIPS

The maximum dry density and optimum moisture contents of the soil mixed with different percentage of plastic strips contents are reported in the Table 1.

Table 1 MDD & OMC for Different Percentage Plastic Strip Content Randomly Mixed in Soil

Plastic Content (%)	OMC (%)	MDD (kN/m ³)
0.5	19.60	15.90
1.0	18.59	15.85
1.5	18.69	16.00
2.0	18.71	15.41
2.5	18.94	15.20

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B. CALIFORNIA BEARING RATIO (CBR) TEST RESULTS

The laboratory unsoaked and soaked CBR tests were performed with varying percentage of plastic waste strips/chips randomly oriented in soil viz., 0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%. Table 2 summarises the results of CBR tests on soil for varying plastic strips/chips contents.

Table 2 CBR Value with Varying Percentage of Plastic Strips Randomly Oriented in Soil

Plastic Strips/chips randomly oriented in soil (%)	UNSOAKED CBR (%)	SOAKED CBR (%)
0.0	4.5	1.7
0.5	5.1	1.5
1.0	5.4	1.6
1.5	6.4	1.7
2.0	4.8	3.0
2.5	3.6	1.4

C. FIELD CBR TEST RESULTS

a. UNSOAKED FIELD CBR TEST

Figure 4 and 5 shows load penetration curve for unsoaked field CBR test on artificial and composite subgrade respectively.

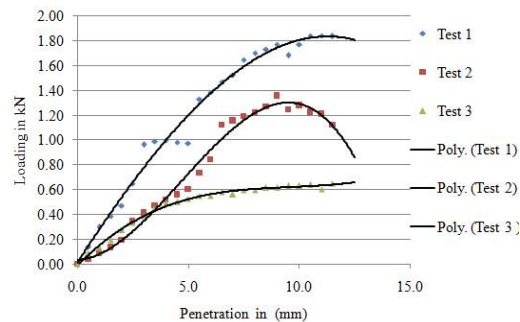


Fig.4 Unsoaked Field CBR Test on Artificial Subgrade (Clayey soil + 0% Plastic Strips)

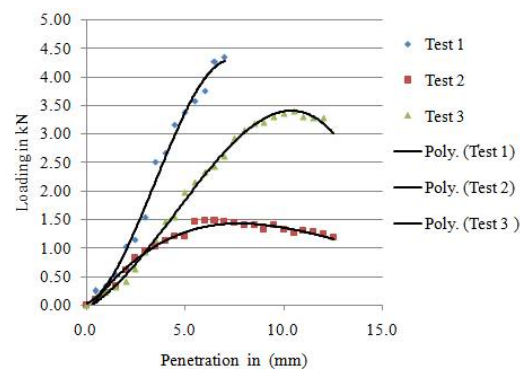


Fig.5 Unsoaked Field CBR Test on Composite Subgrade (Clayey Soil + 2% Plastic Strips)

b. SOAKED FIELD CBR TEST

Figure 6 and 7 shows load penetration curves for soaked field CBR test on artificial and composite subgrade respectively.

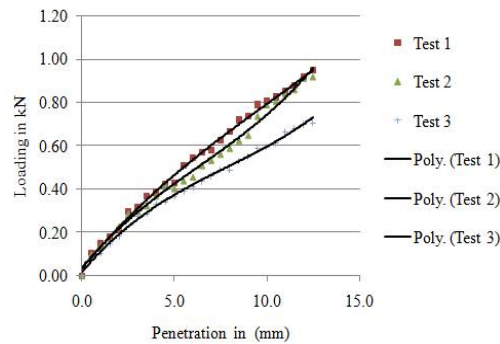


Fig.6 Soaked Field CBR Test on Artificial Subgrade (Clayey Soil + 0% Plastic Strips)

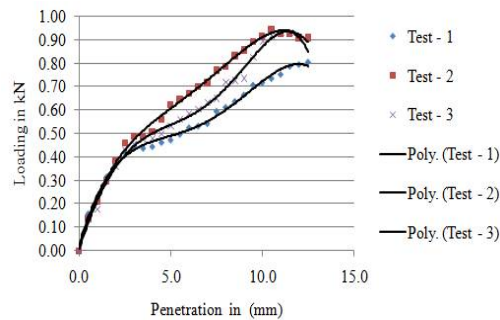


Fig.7 Soaked Field CBR Test on Composite Subgrade (Clayey Soil + 2% Plastic Strips)

D. DISCUSSION OF RESULTS

a. Laboratory Performance of Plastic Strips /Chips mixed soil

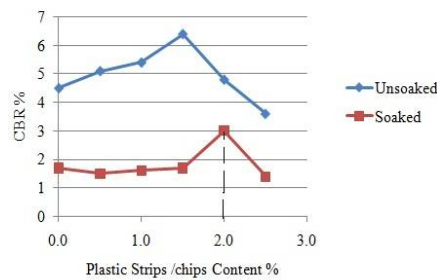


Fig.8 Variation of CBR with Plastic Strips/Chips Content Randomly Oriented in Soil

In present study, the laboratory Compaction and CBR tests were performed with varying percentage of plastic waste strips/chips randomly oriented in soil viz., 0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5%. Compaction properties indicate that the maximum dry density decreases with the increase in the plastic strips/chips content, which is due to

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lower density of plastic strips than the soil particles. Figure 8 summaries the results of CBR tests of soil mixed with varying % of plastic strips/chips contents. The laboratory CBR test results show that, there is an increase in CBR values due to plastic strips reinforcement within a range from 11% to 30% for unsoaked condition and 40% for soaked condition. The maximum soaked CBR value increased by 40 % due to randomly oriented 2% plastic waste in soil. Therefore, optimum percentage of plastic strip to be mixed randomly in subgrade soil was selected as 2.0% for further experimental investigation. Hence the soaked CBR valve soil 3%, and optimum percentage plastic strip 2% were used for design of model flexible pavement.

4.4.2 Field Performance of Plastic Strips /Chips mixed soil

In the present study, field performance of plastic strips /chips mixed soil was studied. Unsoaked and soaked field CBR tests were performed on composite and artificial subgrade of model flexible pavement as per IS 2720 (Part 31): 1990. The results obtained in this analysis are tabulated in Table 3 and 4.

Table 3 Comparison of Unsoaked Field CBR Value for Artificial and Composite Subgrade

Unsoaked Field CBR Strata/Layer	Test No	Unsoaked CBR Value (%)	Avg Unsoaked CBR Value (%)
Artificial Subgrade (Clayey Soil + 0 % Plastic Strip/Chip)	1	4.83	3.28
	2	2.56	
	3	2.45	
Composite Subgrade (Clayey soil + 2% Optimum plastic strips/chip)	1	8.48	6.41
	2	6.11	
	3	4.65	

From the comparison Table 3, it is seen that:

- i) Unsoaked field CBR increased from 3.28 to 6.41% due to addition of optimum % of plastic waste strips/chip,
- ii) Strength of Composite subgrade increased by 48.83 % due to randomly oriented optimum 2% plastic waste in soil.

Table 4 Comparison of Soaked Field CBR values for Artificial and Composite Subgrade

Soaked Field CBR Strata/Layer	Test No	Soaked CBR value (%)	Avg Soaked CBR Value (%)
Artificial Subgrade (Clayey Soil + 0 % Plastic Strip/Chips)	1	2.22	2.11
	2	2.14	
	3	1.96	
Composite Subgrade (Clayey soil + 2% Optimum plastic strips/chips)	1	3.13	3.25
	2	3.44	
	3	3.18	

From the comparison Table 4, it is seen that:

- i) Composite subgrade is more effective in field application than artificial subgrade, as unsoaked field CBR increased from 2.11 to 3.25%.
- ii) Strength of Composite subgrade increased by 35.08 % due to randomly oriented optimum 2% plastic waste in soil. This can be help to develop a new pavement stabilization technique.

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c. DESIGN FOR MODEL FLEXIBLE PAVEMENT FOR CONSTRUCTION OF RURAL ROAD (VR)

For present study, Model pavements were designed for soaked CBR value soil 2 % and 3 % at optimum plastic strips content of 0% and 2% mixed in subgrade soil respectively.

Following data was adopted for the design

- i) Traffic growth rate, $r = 7.5\% = 0.075$ in decimal.
- ii) Design life Period $n = 15$ Yr
- iii) Vehicle damage Factor, $F = 1.5$
- iv) Distribution of Commercial traffic over the carriage way $D = 1$
- v) Number of commercial vehicles as per last count, $P = 90$ CVPD
- vi) Number of Year between the last count and completion of Construction, $x = 0$ Yr
- vii) Single lane Road

$$A = P (1 + r)^x = 90 (1 + 0.075)^0 = 90 \text{ CVPD}$$

($D=1$, $F=1.5$, $r = 0.075$, $n = 15$ Adopted Data)

$$N = \{ 365 \times [(1 + r)^n - 1] / r \} \times A \times D \times F$$

$$N = \{ 365 \times [(1 + 0.075)^{15} - 1] / 0.075 \} \times 90 \times 1 \times 1.5$$

$$N = 1.28698421 \times 10^6 \text{ CVPD}$$

$$N = 1.2869 \text{ msa}$$

$$N = 1.3 \text{ msa}$$

Case I: Soaked CBR value of Artificial Subgrade without Plastic Strips/Chips

Total pavement thickness for CBR 2% and traffic 1.3 msa from IRC: 37-2001 chart1 = 680 mm. Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC: 37 - 2001).

(a) Bituminous surfacing

Wearing course = 20 mm PC –Premix Carpet.

Binder Course = 15 mm BM – Bituminous Macadam.

(b) Granular base = 225 mm WBM

(c) Granular sub-base = 440 mm granular material of CBR not less than 30 %

Case II: Soaked CBR value of Composite Subgrade =3% at Optimum % of Plastic Strips/Chips Content = 2 %

Total pavement thickness for CBR 3% and traffic 1.3 msa from IRC: 37-2001 chart1 = 575 mm. Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC: 37 - 2001).

(a) Bituminous surfacing

Wearing course = 20 mm PC –Premix Carpet.

Binder Course = 15 mm BM – Bituminous Macadam.

(b) Granular base = 225 mm WBM

(c) Granular sub-base = 335 mm granular material of CBR not less than 30 %

Due to randomly oriented optimum 2% plastic strips in soil for composite subgrade, subbase thickness is reduced by 105 mm (23.86%) and soaked CBR value increased by 33.33 %, resulting in saving of 23.86 % of natural sub base material (viz., Murum, Gravel etc).

d. ECONOMY ACHIEVED DUE TO UTILIZATION OF PLASTIC STRIPS IN SOIL

On the basis of comparative analysis of estimated costs of model flexible pavement for 1 km length, net cost of project increased by 0.16% per km for rural road project. This is negligible amount for 1 km length work; therefore the present

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approach of pavement stabilization in the point of economy is feasible. However, this will certainly help towards utilizing the plastic waste and reduce its disposal problem to some extent.

V. CONCLUSION

Following important conclusions may be drawn from the results of the study.

- i) The optimum percentage of plastic strip/chips content corresponding to maximum improvement in soaked CBR value is found to be 2.0 %
- ii) Unsoaked and soaked CBR values increases by about 30 and 40% respectively, due to randomly oriented plastic waste strips in soil as reinforcement.
- iii) Strength of composite subgrade is increased by 35 and 48% in soaked and unsoaked condition respectively.
- iv) On the basis of Model Pavement Design, due to inclusion of 2% plastic strips randomly oriented in subgrade earthwork / composite subgrade, sub base thickness is reduced resulting in the saving of natural sub base construction material.
- v) There is a marginal increase in cost of construction of flexible pavement due to inclusion of plastic waste strips/chips. However, utilization of plastic waste in the road construction may solve its disposal problem to some extent.
- vi) Flexible pavement with randomly oriented plastic waste in composite subgrade may be adopted for rural area development.

REFERENCES

- [1] Ashraf A., Arya S., Dhanya J., Joseph M., and Veena M., "Soil Stabilisation Using Raw Plastic Bottles", *Proceedings of Indian geotechnical Conference-2011*, December 15-17, Kochi (Paper No. H-304)
- [2] Choudhary A.K., Jha J.N., and Gill K.S., "A Study on CBR Behavior of Waste Plastic Strip Reinforced Soil", *Emirates Journal for Engineering Research*, 15 (1), P 51-5, 2010.
- [3] Dr. Prasad D. S. V., Dr. Prasada Raju G V R, Anjan Kumar M, "Utilization of Industrial Waste in Flexible Pavement Construction", *EJGE*, Vol. 13, Bund. D, 2009.
- [4] Geetha M.K., Anoosha G., Pawan Kumar., Chouksey S., and Sivakumar Babu G.L., "Compressibility and Permeability Behaviour of Plastic Waste Mixed Sand", *Proceedings of Indian Geotechnical Conference-2011* December 15-17, 2011, Kochi (Paper No. L-074)
- [5] IRC: 20 SP(2002), *Rural Roads Manual*, Indian Road Congress, New Delhi, India.
- [6] IRC: 37 (2001) *Guidelines for the Design of Flexible Pavement*, Second Revision, Indian Road Congress, New Delhi, India.
- [7] IRC:36 (1970) *Recommended Practice For The Construction Of Earth Embankments For Road Works*, Indian Road Congress, New Delhi, India.
- [8] IS: 2720 (Part 31) (1990) *Method of tests for Soils: Field Determination of California Bearing Ratio*, Bureau of Indian Standards, New Delhi, India.
- [9] Sivakumar Babu, G.L. , Chouksey, Anoosha S., Manjari G., Geetha K., "Strength and Compressibility Response of Plastic Waste Mixed Soil", *Indian Geotechnical Conference – 2010*, GEOTrendz December 16–18, 2010 IGS Mumbai Chapter & IIT Bombay.