A STUDY OF THE CBR BEHAVIOUR OF LOW DENSITY POLYETHYLENE WASTE PLASTIC STRIP

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ABSTRACT: The paper presents a study of the CBR behaviour of waste plastic strip reinforced-stone dust overlying soft clay. The Low Density Polyethylene (LDPE) waste plastic strips of three different lengths (12 mm, 24 mm and 36 mm) were used in this study. The effect of strip content (0.10, 0.20, 0.40) by weight of stone dust and strip length on the CBR and secant modulus of strip reinforced-stone dust overlying soft clay has been investigated. The test results indicated that addition of waste plastic LDPE strip-reinforced stone dust overlying soft clay results in marginal increase in the CBR and the secant modulus. The reinforcement benefit increased with an increase in LDPE waste plastic strip content and strip length. The material can be used in base courses in constructing the rural roads over soft clay thereby leading to safe disposal of these waste materials in an environmental friendly manner. Further study is recommended to estimate the cost economics of the use of waste materials in base courses in rural roads.

1. INTRODUCTION
Most developed and developing countries all over the world have huge resources of waste materials such as LDPE plastic and stone dust etc. The quantities of wastes that are accumulating in developed and developing countries are causing disposal problems that are both financially and environmentally expensive. One method to reduce some portion of the waste disposal problem is by utilizing these waste materials for engineering purposes. This paper presents the study of the effect of LDPE waste plastic strip content and strip length on the CBR behaviour and secant modulus of stone dust overlying soft clay. A series of laboratory California Bearing Ratio (CBR) tests were carried out with varying strip content and lengths. The results obtained from the tests are presented, compared and discussed in this paper.

2. BACKGROUND
Several researchers have conducted investigations using different types of reinforcement and materials. Gray & Ohashi (1983), based on the direct shear test results, indicated that fiber reinforcement increased the peak shear strength and limited post peak reductions in shear resistance. However, no increase in stiffness of the fiber–sand composite was observed. Freitag (1986) reported that randomly distributed fibers in a compacted fine-grained soil could result in greater stiffness. Gray & Al-Refai (1986), conducted triaxial compression tests on sand and found that randomly distributed discrete fibers resulted in a loss of compressive stiffness at low strains (less than 1%). Benson & Khire (1994) used cut pieces of waste milk jugs and shown that there is an increase in CBR by a factor of 5. The secant modulus of the sand also improved with the addition of cut pieces of waste milk jugs in to the sand. Bauer & Oancea (1996), based on their triaxial test results, indicated that the secant modulus as an indicator of the stiffness within the initial vertical strain of 2% decreased with increasing polypropylene fiber contents up to 0.5%. They also reported that beyond this vertical strain the secant modulus remained fairly constant. Michalowski & Zhao (1996), based on triaxial test results, indicated that the steel fibers led to an increase in the stiffness prior to reaching failure. Bueno (1997) conducted laboratory study on mechanically stabilized soils with short thin plastic strips of different lengths and contents. They found an enhancement in load bearing capacity. Consoli et al. (1998), conducting triaxial compression tests, showed that fiber reinforcement decreased the stiffness. Kumar et al. (1999), based on their laboratory investigations conducted on silty sand specimens reinforced with randomly distributed polyester fibers, concluded that the fibers increased the CBR value and ductility of the specimens. They also reported that the optimum fiber content for both silty sand and pond ash was approximately 0.3–0.4% of dry unit weight. Yetimoglu & Salbas (2003) indicated that initial stiffness of the sand was not affected significantly by the randomly
distributed discrete fibers. Venkatappa Rao & Dutta (2004a) reported a theoretical analysis on the basis of triaxial results to assess the improvement in bearing capacity of a footing on waste plastic strip reinforced sand bed resting on clay soil. Their analysis revealed that waste plastic strips in sand were found to improve only the bearing capacity. Venkatappa Rao & Dutta (2004b) reported a theoretical analysis on the basis of triaxial results to assess the overall influence of waste plastic strip reinforced sand on the bearing capacity improvement of granular trench. Their analysis revealed that inclusion of waste plastic strips in sand improved the bearing capacity of granular trench. Yetimoglu et al. (2005) conducted CBR tests on sand fills reinforced with randomly distributed discrete fibers overlying soft clay. Their study reveals that adding fiber in sand fill resulted in an appreciable increase in the peak piston load. However, the initial stiffness of load–penetration curves was not significantly affected by fiber reinforcement. The test results further showed that increasing fiber reinforcement content could increase the brittleness of the fiber-reinforced sand fill–soft clay layer. The disagreement among the reported results is attributed to the difference in the material properties and testing conditions. The literature presented above clearly indicates that the study of the influence of LDPE waste plastic strip reinforcement on the CBR behaviour of strip-reinforced stone dust overlying soft clay has not yet been investigated so far.

3. EXPERIMENTAL WORK

A brief description of the material used in this investigation along with CBR tests conducted in the present study is as follows.

3.1 Stone Dust

The investigation was carried out on locally available stone dust in Hamirpur, Himachal Pradesh, India. It contains a sand fraction of about 88.7%, silt and clay fraction of about 11.3%. It had a specific gravity of 2.65, mean particle diameter ($D_{50}$) of 0.40 mm, coefficient of uniformity ($C_u$) of 7.66, coefficient of curvature ($C_c$) of 0.85. The stone dust was classified gap graded as per Indian Standard Soil Classification System. The maximum dry unit weight and optimum water content obtained from standard proctor test for the stone dust is 18.64 kN/m$^3$ and 12% respectively.

3.2 Soft Clay

The soft clay used in this study was of commercial grade kaolinite. It contains a sand content of about 3.2%, silt content of about 12.2% and clay content of about 84.6%. It had a specific gravity of 2.65, liquid limit of 61.8% and plastic limit of 21.2% respectively. The clay was classified as per Indian Standard Soil Classification System as high plasticity clay. The maximum dry unit weight and optimum water content obtained from standard proctor test for the kaolinite clay is 18 kN/m$^3$ and 22% respectively.

3.3 Waste Plastic Strip

Used plastic carry bags of LDPE having a mass per unit area of 30 gsm and a thickness of 0.05 mm were chosen. From these, 12 mm wide strips were cut. Further these were cut into lengths of 12 mm (designated as Type A), 24 mm (designated as Type B) and 36 mm (designated as Type C). In the absence of standards for testing strips, the standards used for wide width tensile strength test (ASTM D 4885) for geosynthetics were used. The tensile strength of 100 mm long waste plastic strip was determined at a deformation rate of 10 mm/min in a computer controlled Hounsfield machine. The average ultimate tensile strength of LDPE strips was 0.011 kN and percent elongation at failure was 20%. The load versus percent elongation curve is shown in Figure 1.

![Fig. 1: Load versus Percent Elongation Curve for LDPE Plastic Strip](image)

3.4 Parameters Varied

The LDPE waste plastic strips to be added to the stone dust were considered as a part of solids fraction in the void–solid matrix of the soil. The content of strips is defined herein as the ratio of weight of strips to weight of dry stone dust. The tests were conducted at a strip content of 0.10%, 0.20%, 0.40% and 0.80% with respect to weight of stone dust.

3.5 CBR Tests

The experimental study involves performing a series of laboratory CBR tests on the unreinforced and randomly distributed strip-reinforced stone dust overlying soft clay. A thin layer of grease was applied on the internal surfaces of the CBR mould to minimize the wall friction. A typical test model consisted of soft clay subgrade overlain by a waste plastic strip-reinforced stone dust, as the base course, was prepared as shown in Figure 2. The stone dust with and without strips were compacted in two layers of thickness 20 mm each on the top of the CBR mould (rigid metal cylinder with an inside diameter of 152 mm and a height of 178 mm) at optimum moisture content of 12% by the standard
compaction procedure by giving 56 blows of a 25.5 N rammer dropped from a distance of 310 mm. Soft clay as subgrade of thickness 88 mm was prepared at water content of 36% (between plastic limit and liquid limit, the condition which can occur during rainy season and to make a paste of workable consistency) and was made by hand kneading by pasting the soft clay, layer by layer in order to avoid the development of negative pore pressure (matric suction) or trapped air in the subgrade soil. The placement dry unit weight of the clay in the CBR mould was 12.35 kN/m$^3$ at a water content of 36%. The CBR value of the soft clay is 0.32% at a water content of 36%. The secant modulus of soft clay at a penetration of 2.5 mm is 8.80 MPa. A manual loading machine equipped with a movable base that travelled at a uniform rate of 1.25 mm/min and a calibrated load-indicating device was used to force the penetration piston of diameter of 50 mm into the specimen. A surcharge plate of 2.44 kPa was placed on the specimen prior to testing. The loads were carefully recorded as a function of penetration up to a total penetration of 12.5 mm.

4. TEST RESULTS AND DISCUSSION

4.1 Load Penetration Behaviour of LDPE Reinforced Stone Dust over Soft Clay

The load-penetration curves obtained from the CBR tests for waste plastic strip (content varying from 0.10 to 0.80% of Type A) reinforced stone dust overlying soft clay is shown in Figure 3. It is seen that LDPE waste plastic strip-reinforced stone dust overlying soft clay marginally increased the CBR value. For example, the CBR value of the unreinforced stone dust overlying soft clay corresponding to 2.5 mm and 5.0 mm penetration were found to be 0.93% and 0.69% respectively. These values of CBR for the stone dust reinforced with 0.10% waste plastic strips of Type A overlying soft clay increased to 0.96% and 0.72% respectively corresponding to the above penetrations. Further, for a stone dust with 0.80% waste plastic strips of Type A overlying soft clay, the CBR values increased to 1.10% and 0.81% respectively corresponding to 2.5 mm and 5.0 mm penetration. Figure 3 reveals that the initial slope of the load–penetration curve is marginally improved by incorporation of LDPE strips in stone dust overlying soft clay. Similar study has been carried out in respect of stone dust with strip Types B and C overlying soft clay and the results are shown in Figures 4 and 5.

The marginal increase in CBR can be noticeably attributed to strip inclusion in the stone dust overlying soft clay and strip length. For example, the CBR of the unreinforced stone dust overlying soft clay was 0.93%. This value of CBR increased to 0.97% when 0.10% waste plastic strip of Type A is added to stone dust. Further, for a stone dust with 0.80% waste plastic strips of Type A overlying soft clay, the CBR value increased to 1.10%. Figure 6 further reveals that for a stone dust with waste plastic strip content of 0.40% and strip length of 12 mm, the value of CBR was 1.06%. This value increased to 1.10% when the strip length is increased from 12 mm to 24 mm at the same strip content. Similar trend can also be noticed at other strip content.

The variation of CBR of strip-reinforced stone dust overlying soft clay with strip content and strip length is shown in Figure 6. The variation of secant modulus (defined as ratio of load in kPa at a penetration of 2.5 mm to the penetration of 0.0025 m) of strip-reinforced stone dust overlying soft clay with waste plastic strip content and strip length is shown in Figure 7. As expected, the marginal increase in secant modulus is noticeably attributed to strip inclusion in the stone dust overlying soft clay and strip length. For example,
the secant modulus of the unreinforced stone dust overlying soft clay was 25.44 MPa. This value of secant modulus increased to 26.64 MPa when 0.10% waste plastic strip of Type A is added to stone dust. Further, for a stone dust with 0.80% waste plastic strips of Type A overlying soft clay, the secant modulus value increased to 30.24 MPa. Figure 7 further reveals that for a stone dust with waste plastic strip content of 0.40% and strip length of 12 mm, the value of secant modulus was 29.04 MPa. This value increased to 30.24 MPa when the strip length is increased from 12 mm to 24 mm at the same strip content. Similar trend can also be noticed at other strip content. The cost economics of using the waste materials in base or sub-base courses is beyond the scope of the present study, which requires a separate detailed investigation. However the authors of this paper are of the opinion that the solution may be economical in those areas where the waste materials are available in the nearby places.

5. CONCLUSIONS

An experimental study is carried out to investigate the CBR behaviour of stone dust reinforced with three different sizes of LDPE waste plastic strips overlying soft clay. The effect of waste plastic strips content on CBR and secant modulus of strip reinforced-stone dust overlying soft clay was investigated. The study brings forth the following conclusions.

(a) Addition of LDPE waste plastic strip inclusions in stone dust overlying soft clay subgrade results in marginal increase in the CBR and the secant modulus.

(b) The reinforcement benefits increased with an increase in LDPE waste plastic strip content in the stone dust overlying soft clay.

(c) The CBR and the secant modulus of stone dust reinforced with LDPE waste plastic strips overlying soft clay increased marginally with the increase in length of the strips.
Further study is recommended to study the cost economics of the use of waste materials in base courses in rural roads over soft clay.

On the whole, this study has attempted to provide an insight into the CBR behaviour of stone dust reinforced with different sizes and types of waste plastic strips overlying soft clay for use in base course in constructing the rural roads over soft clay. Utilizing some portion of the waste in this way will reduce the quantity of the waste-requiring disposal. More so the disposal in this way will be in an environmental friendly manner.

REFERENCES


