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Effect of Ground Granulated Blast Furnace Slag and Plastic Fibres on Geotechnical Properties of Black Cotton Soil

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Abstract. Disposal of waste materials is a big problem with exceptionally growing up country like India. Rapid industrialization, population explosion, an extensive repletion of natural resources produce large quantities of waste materials which cause serious Geo-Environmental problems. An expansive soil is a weak soil because it has high swelling and shrinkage in wet and dry condition. Many techniques are available for increasing the strength of the soil and to make better foundation for structures. Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the intended purpose. Adding up admixtures from Industrial wastes such as Ground granulated blast furnace slag (GGBS) which is the waste of iron ore i.e., in powder form and plastic fibers which will increase the bearing strength of the soil. In this examination, an attempt has been made to study the possibility of utilizing GGBS & plastic fibers which are the hazardous industrial waste for stabilization of soil to improve the physical and strength property of black cotton soil blend with varying percentages of GGBS and plastic fibres in the present paper. As a result of stabilization, the strength properties of natural soil have increased and safe disposal of industrial wastes.

Keywords: Black Cotton Soil, Ground Granulated Blast Furnace Slag, Plastic Fibres, Compaction, CBR.

1 Introduction

The expansive soils are particular type of soils which are almost clayey soils. When they absorb the process of expansion takes place and they shrink when they dry out. Soil is the major and most commonly used material in the field of civil engineering. Safe and Economic disposal of industrial wastes and development of economically feasible ground improvement techniques are the important challenges being faced by the engineering community. Soil stabilization is necessary to increase the bearing capacity of foundation soil. Soil stabilization is the most significant for the construction which is broadly used in connection with road pavement and foundation construction because it improves the engineering properties of soil such as strength. However, the main use of stabilization is to improve the natural soils. Utilization of industrial waste materials in the improvement of soils is a cost efficient and environment friendly method. Industrial waste GGBS which is available in a little cost combine by a range of percentage in expansive soil and conduct different laboratory experiments in order to improved strength of the soil and from the conclusion of tests while GGBS and lime are independently mixed with B.C soil, 14.2% water content and 1.68% dry density for 30% of GGBS and 4% lime for 13.6% water content and 1.48% dry density and lime gives higher liquid limit and which is improved with GGBS than lime and also lime gives higher plastic limit [1]. Effective utilize of basalt fiber and ground granulated blast furnace slag (GGBS) added in varying proportions and conducted compaction and unconfined compressive strength test (UCS) in the laboratory. Based on the experimental outcome, it is found that OMC increases and MDD decreases as well as unconfined compression increases with best proportion of 2% basalt fiber and 6% GGBS, the maximum compressive strength attained ($183kN/m^2$). The basalt fiber act as a reinforcement to increase the strength properties and GGBS acts as cementitious it reduces the permeability and increase the shear strength of the soil [2]**.** Influence of GGBS and lime on the strength characteristics and durability of soil were investigated by conducting Atterberg's limits, Standard Proctor test, UCS, and Wetting-Drying test be performed on the clayey soil at curative period of 7,14 and 28 days and found that Liquid Limit and Plastic Limit of the treated soil decreased by 41.8% and 26% respectively as compared to virgin soil, UCS of soil enlarged about 100% with 7% lime alone and 347.5% by adding up of 7% lime + 15% GGBS, OMC improved from 15.7% to 17.8% even as MDD decreased to 1.68 gram /cm^3 from 1.75 gram/cm^3 by addition 7% and strength decrease observed in the UCS test of soil after subjecting to 12(W-D) cycles as compare to their initial state (0 W-D cycle). The best possible amount of lime and GGBS suggested to be used for stabilizing the clayey soil is 7% and 15% respectively[3] **.** Experimentations carried by combinations of GGBS 0.3%, 0.6%, 0.9% and 1.2%; Ordinary Portland Cement 0.25%, 0.5%, 0.75% and Glass Fibre 1% were respectively used with black cotton soil to know their effects on Compaction and UCS at 3,7 and 14 days of curing period. The outcome of the research work, black cotton soil blended with GGBS, GF & OPC shows higher MDD values than the soil mixed with GGBS & GF alone and MDD value for black cotton soil alone was 1.430g/cc with 32.3% OMC, on addition of 25% GGBS+0.5%GF+0.9% OPC, MDD value increases to 1.653 and OMC reduces to 21.1% ; the % of GF increases the value of MDD also increases up to 0.5% further increase in % of glass fiber reduces the value, this is because of the workability property of the soil. UCS strength increases with increase in the % of GF up to 0.75%, further increase of GF reduces the UCS strength and highest UCS strength is achieved the soil blended with 25% GGBS+0.75% GF+0.6% OPC at 14 days of curing. The value reaches to $5.911kg/cm^2$ which is around 6 times the strength of B.C. soil alone tested at zero days [4]**.** Stabilization of clay soil treated with constant percentage of

GGBS with different percentage of natural fibers like human hair combinations are evaluated by using laboratory experiment. Experimental results showed that GGBS & human hair treated soil can increase the index properties and compressive strength of the soil and increase the maximum dry density and compressive strength is obtained by clay soil with 25% of GGBS and 2% of hair is optimum[5]**.** Experimental work carried by blending coconut coir fibre by dry weight of soil is taken as 0.5%, 1%, 1.5%, 2%, 2.5% and GGBS powder varied from 10%, 20%, 30%, 40% respectively to the soil. The Maximum dry density increased and the optimum moisture content decreased with increasing due to compatibility of soil increases and making soil more dense and hard and percentage finer particles goes on decreases, which strengthens the soil and liquid limit increase and plastic limit decreases, which makes the soil less plastic and hence plasticity index reduced and also CBR value for increase due to densification of soil takes place and more suitable for foundation at 40% GGBS and 1% Coir fibres content[6]**.** An attempt has been made to study the possibility of utilizing lime & plastic fibers for stabilization of soil blending various proportions at different curing periods. Experimental results found that strength of BC soil increased with addition of GGBS up to 40% for the curing periods of 7 and 28 days and further addition of GGBS decreased the strength, reduced the swell percent from 25 % to 12.1 %.The strength of BC soil blended with 40 % of GGBS increased with addition of 0.75 % of Polypropylene fibers for the curing periods of 7 and 28 days. Further addition of polypropylene fibers decreased the strength of Soil – 40 % GGBS mixture blended with polypropylene fibers. 4. The addition of 0.75 % Polypropylene fibers to the GGBS blended BC soil reduced the swell percent from 25 % to 2.5 %. Further additions of polypropylene fibers to the GGBS blended BC soil do not have significant reduction in swell percentage [7]**.** The present investigation is to evaluate the compaction and CBR values of stabilized black cotton soil using varying percentages of GGBS and plastic fibre mixes in the laboratory. From these results, it was found that optimum percentage of GGBS is 15% and of plastic fibres is 1% which gives the maximum improvement in geotechnical properties as compared with all the other combinations tried in this investigation.

2 Study Design

The present study has planned in a three stages. In the first stage, it is proposed to carry out individual geotechnical properties in laboratory of the materials used during the study. In the second phase, stabilization method tried in the laboratory carried out blending with different proportions of GGBS to calculate the optimum percentage as shown in Fig. 1. In the third phase, different percentages of plastic fibres as a reinforcement material to the optimum soil – GGBS sample as shown in Fig. 2. Based on the assessment of results, optimum percentages of plastic fibres find out from the laboratory experimentation and comparison will be made with a view to know the improvement in geotechnical properties. The details of each of stages are explained in the following articles.

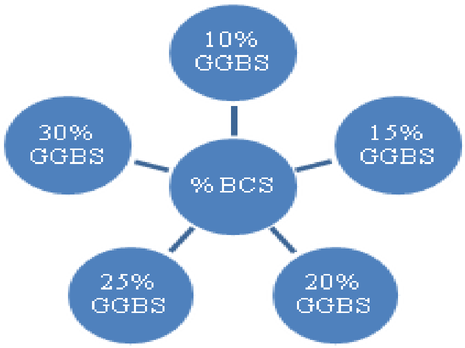

Fig. 1. Flow Chart Shows Different Percentages of GGBS Blend with Black Cotton Soil

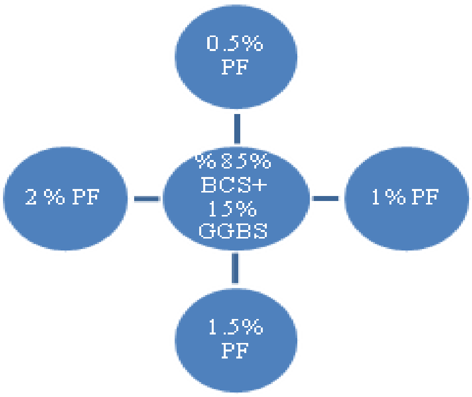

Fig. 2. Flow Chart Shows Various Mix Proportions of Black Cotton Soil Blend with 15% GGBS and % of Plastic Fibres.

3 Materials Used

Details of assorted materials used throughout the laboratory testing are presented in the succeeding segment

3.1 Black cotton soil (BCS): Natural black cotton soil was obtained from local village in Amalapuram, East Godavari district, Andhra Pradesh. The soil is dark grey to black in color with light clay content. The obtained soil was air dried, pulverized manually and soil passing through 4.75 mm IS sieve was used during this study. The physical properties of black cotton soil are, Liquid Limit (%) = 85.66, Plastic Limit (%) = 36.06, Plasticity Index (%) = 49.60, Soil Classification = CH, Specific Gravity = 2.66, Free Swell (%) = 140, Optimum Moisture Content (%) = 29.17, Maximum Dry Density (g/cc) = 1.428 and CBR (%) = 1.62 respectively.

3.2 Ground granulated blast furnace slag (GGBS): A by-product from the blast-furnaces used to make iron. It is a result of use of water during quenching process. This waste material is easily available and also cost efficient. It has a cementitious property which acts as binding material for the soil. The GGBS used this research work is collected from Visakhapatnam. The chemical compositions of GGBS Calcium oxide:40%, Silica:35%, Alumina:13%, Magnesia:8% and the physical properties are Specific Gravity = 2.52, % of Gravel = 0.1, % of Sand = 1.8, % of Silt = 97.3,% of Clay = 0.8, Optimum Moisture Content (%) = 13, Maximum Dry Density =11.56 kN/m^3 respectively.

3.3 Plastic fibres: Plastic covers were shred into fibers each of average thickness of 2 mm. These plastic covers are usually considered to be waste materials. Therefore, a rising need to discover alternative use of reclaimed plastic bag waste to lengthen the usage time of the plastic material and thereby save the degrading environment.

4 Laboratory Experimentation

Various tests were carried out in the laboratory for finding the index and other important properties of the black cotton soil used during the study. Index Properties, Compaction, and soaked CBR tests were conducted by using different percentages of GGBS and Plastic Fibres mixed with black cotton soil materials for finding optimum percentages

4.1 Index properties

Standard procedures recommended in the respective I.S. Codes of practice [IS:2720 (Part-5)-1985; IS:2720 (Part-6)-1972], were followed while finding the Index properties viz. Liquid Limit and Plastic Limit of the samples tried in this investigation.

4.2 Compaction properties

Optimum Moisture Content and Maximum Dry Density of Black Cotton Soil with different percentages of GGBS and plastic fibre mixes were determined according to IS Heavy compaction test IS: 2720 (Part VIII).

4.3 California bearing ratio (CBR) tests

Different samples were prepared for CBR test using expansive soil material mixing with different percentages of GGBS and plastic fibres with a view to determine optimum percentages. The CBR tests were conducted in the laboratory for all the samples as per IS Code (IS: 2720 (Part-16)-1979).

Fig. 3. California Bearing Ratio Test Apparatus

5 Results and Discussions

Laboratory tests were conducted for finding the index and other important geotechnical properties of the materials used during the study. Compaction and soaked CBR tests were conducted by using different percentages of GGBS and Plastic Fibres were mixed with black cotton soil for finding optimum percentages and its effect on geotechnical properties.

5.1 Variation of liquid & plastic limit properties

The liquid limit and plastic limit values are declining as amalgamation of GGBS proportion increasing as shown in the Fig. 4.The liquid limit values are lessening from 85.66%, 73%, 68.78%, 63.54% and 58.26%; plastic limit values are also decreasing from 36.06%, 33.25%, 31.25%, 30.24% and 29.14% when the percentage of GGBS varies from 0% to 25% correspondingly. The liquid and plastic limit values are falling when the stabilized black cotton soil treat with 15% GGBS and addition of dissimilar percentage of plastic fibres 0% to 2% the liquid limit values are 85.66%, 68.78%, 58.56%, 52,46% and 41.55%;plastic limit values are 36.06%,31.25%, 28.78%, 24.34%, 22.36% and 19.62% in that order presented in the Fig. 5.

5.2 Effect on compaction parameters

The maximum dry density of black cotton soil is 14.1 kN/m^3 with optimum moisture content 27.78%. While GGBS blend with black cotton soil the maximum dry density values are augmented upto 15 % adding of GGBS and additional adding it decreases where as the optimum moisture content values are continuously decreases as represented in the Fig. 6. Black cotton soil combines with best possible percentage (15%) GGBS and addition of plastic fibres the density attains a maximum value 15.11 kN/m^3 at 1% plastic fibres and extra adding up it decreases where as the optimum moisture content continuously increases as present in the Fig.7. Thus 15% of GGBS and 1% Plastic Fibres attain a maximum dry density as shown in the Figs.6 and 7 respectively.

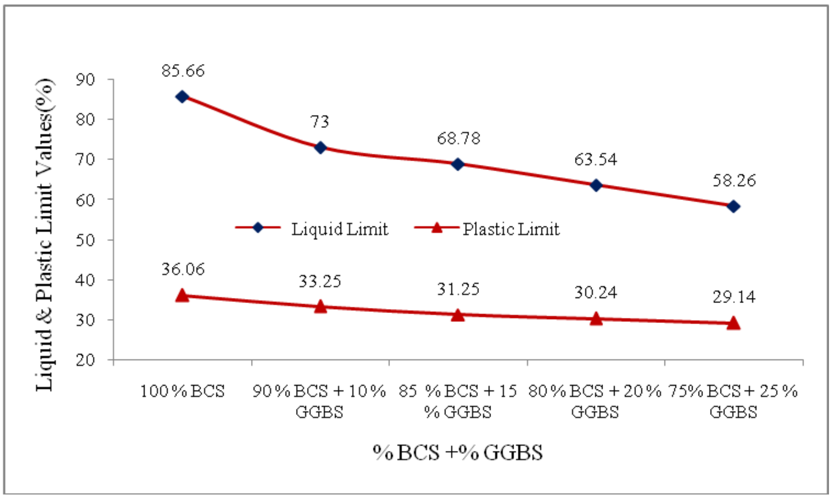

Fig.4. Variation in Liquid and Plastic Limit Values of Black Cotton Soil Treated with Different Percentages of GGBS.

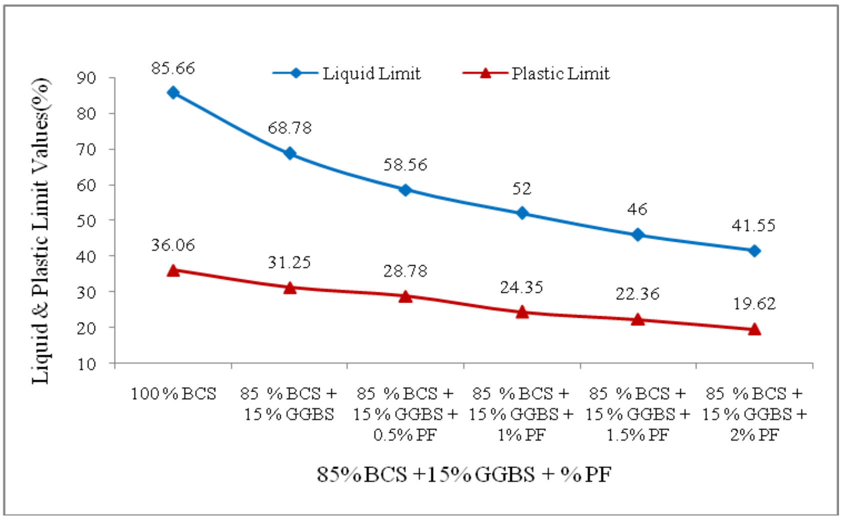

Fig.5. Variation in Liquid and Plastic Limit Values of Black Cotton Soil Treated with Optimum Percentage of GGBS and Various Percentage of Plastic Fibres.

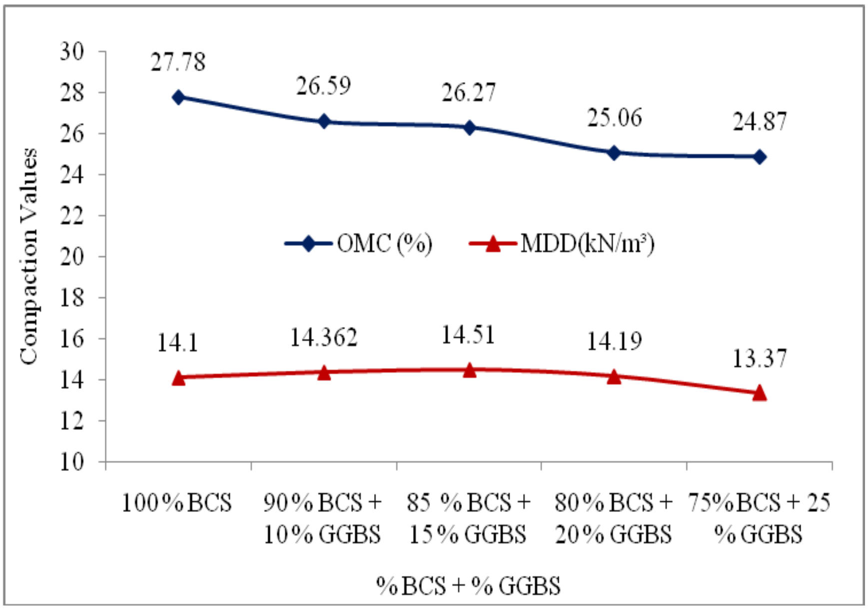

Fig.6. Variation in Compaction Parameters of Black Cotton Soil Treated with Different Percentages of GGBS.

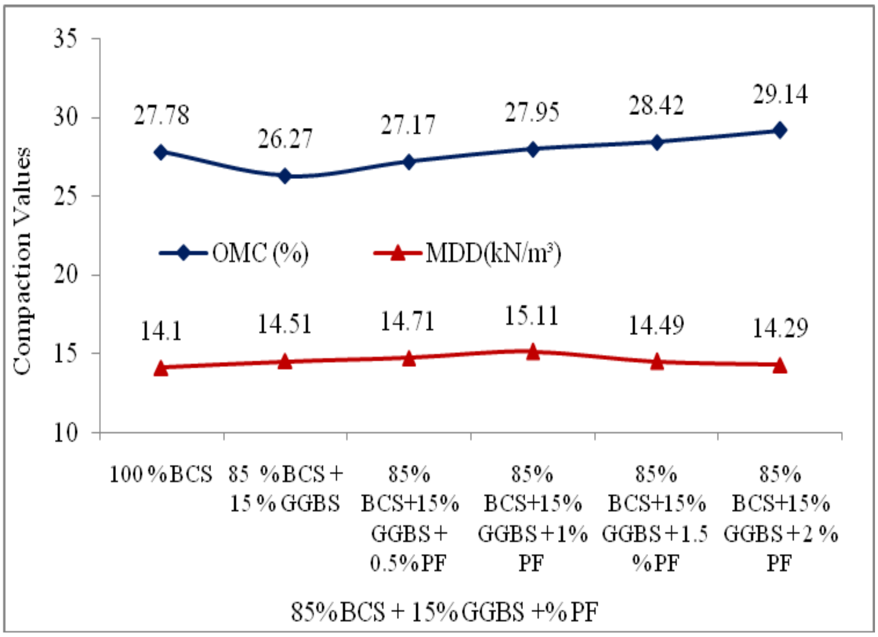

Fig.7. Variation in Compaction Parameters of Black Cotton Soil Treated with Optimum Percentage of GGBS and Various Percentages of Plastic Fibres.

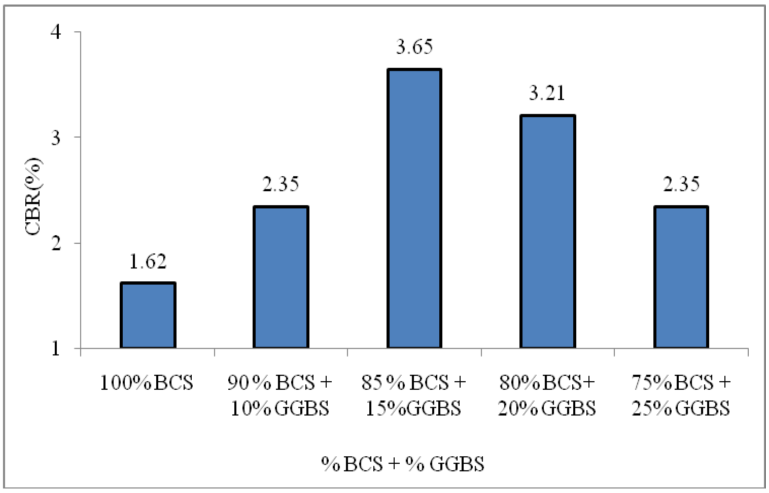

Fig.8. Variation in Soaked CBR Values of Black Cotton Soil Treated with Different Percentages of GGBS.

5.3 Effect on soaked CBR

Addition of percentage of GGBS to black cotton soil, the soaked CBR values varies from 1.62 %, 2.35 %, 3.65 %, 3.21% and 3.35% with an increment 5 % increments sown in the Fig. 8. Soaked CBR values also increase from 3.65%, 4.64%, 6.31%, 4.11% and 3.85 % with the addition to 0%, 0.5%, 1%, 1.5% and 2% plastic fibres to optimum soil mix as shown in the Fig. 9. From the above Figures at 15 % blending GGBS to black cotton soil attained maximum CBR value 3.65% and blending 1% Plastic Fibres attained 6.31 respectively presented in the Figs. 8 and 9.

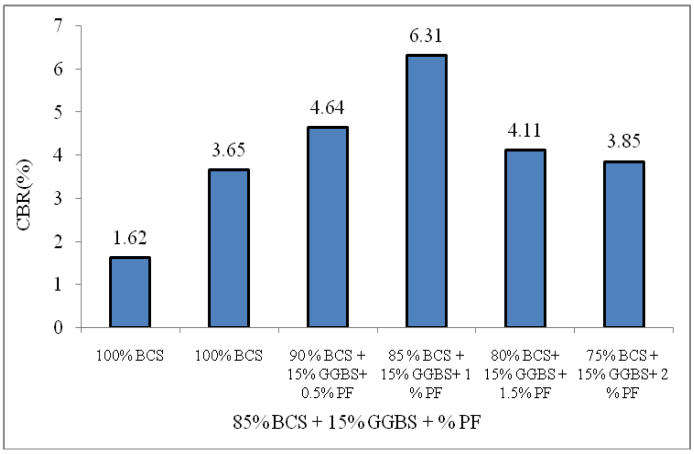

Fig.9. Variation in Soaked CBR Values of Black Cotton Soil Treated with Optimum Percentage of GGBS and Various Percentage of Plastic Fibres.

6 Conclusions

The following conclusions were prepared based on the experiments carried out in this examination.
Adding up of GGBS and plastic fibres to the black cotton soil significantly decreases the liquid and plastic limits due to modify in soil structure which makes the soil less plastic and plasticity index reduces.

Maximum dry density greater than before from 14.11 kN/m^3 to 14.51 kN/m^3 when 15% GGBS combine to black cotton soil and greater than before to 15.11 kN/m^3 when 1 % Plastic Fibres to optimum soil mix respectively. Increase in the MDD of the soil is due to the decrease in the number of voids with the adding up of GGBS and plastic fibres which leads to the successful compaction.

The Optimum Moisture Content decrease continuously while blend with GGBS to black cotton soil and adding up of plastic fibres to optimum soil mix continuously increases.
The soaked CBR value of black cotton soil treated with 15% GGBS and 1% Plastic Fibres is found to be 3.65 % and 6.31 % which increases 125 % and 290 % and also it is satisfying standard specifications. CBR value increases with increases in percentage of GGBS and plastic fibers which shows that densification of soil takes place which is suitable for reduction in pavement thickness.

From the present research it may be accomplished that GGBS and plastic fibres waste materials from industry can be efficiently used to improve the strength behaviour of black cotton soil which can reduce environmental pollution. The use of industrial wastes is another way to reduce the construction cost of rural roads mostly in the rural areas of developing countries.

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