Stabilization of Black Cotton Soil using Ground Granulated Blast Furnace Slag and Plastic Fibres

S. Durga Prasad, D S V Prasad, G V R Prasada Raju

Abstract: Expansive soils cause serious problems and produces damage to many civil engineering structures due swelling and shrinkage. Soil stabilization is the modification of some soil properties by mechanical or chemical methods to improve the engineering properties. Ground Granulated Blast Furnace Slag (GGBS) and Polypropylene Plastic Fibres (PPF), are waste produced from industries, which creates environmental pollution. Utilization of waste material in construction of roads and embankments. Reinforced soils have recently attracted increasing attention in geotechnical engineering. The aim of this research is to know the consequence of GGBS (GGBS) and Polypropylene Plastic Fibres (PPF), on expansive soil when blending with identical proportions. From the exploratory outcome, it has been noticed that remarkable improve in strength as compared to the untreated black cotton soil. The values of compaction parameter has expanded enabling rise in CBR and also load carrying capacity which represents that modified in strength. From these outcome , it was observed that maximum percentage of round Granulated Blast Furnace Slag (GGBS) and polypropylene plastic fibres (PPF), are 15% and 1% respectively when compared with all the other combinations tried in this investigation.

Index Terms: Expansive Soil, GGBS, Polypropylene Plastic Fibres, Compaction, California Bearing Ratio, Load Tests.

I. INTRODUCTION

Expansive or swelling soils are soils that, because of their mineralogical composition, experience large volume changes or volumetric strains when subjected to moisture changes. Another effective method for expansive soil is stabilization by the use of additives that helps to minimize the volume change due to swelling. The clay minerals are formed through extensive physical and chemical weathering of parent material. [1-4]. The different additives used for stabilizing expansive soil include lime, cement, cohesion less material like sand and flyash, quarry dust, GGBS etc.. The reinforcement may take the form of strips, grids, sheet materials and other combinations. There are many techniques employed to improve the engineering and mechanical properties of soil. Latest ground improvement techniques in which additives and fibres are added in soil, mixed randomly and laid in the position after compaction. Many research organizations and researchers are doing widespread studies on waste materials concerning the feasibility and environmental aptness. Reinforced earth technique has been attractiveness in the field of civil engineering due to its highly adaptable and flexible nature and has been used in the construction of civil engineering structures on flexible grounds and other applications [5-6]. Laboratory inspections are done on the black cotton soil mixed with small percentage of polypropylene fiber comprise of 0.5%, 1.0%, 1.5% and 2.0% mass of desiccated soil and various trials were carried to know the effect of polypropylene fiber from trial outcome, with the increment of PPF Liquid limit, Plastic limit and plasticity index decline, which makes the soil less plastic and hence plasticity index declines, OMC decreasing while MDD growing, hence compatibility of soil rises and creating the soli dense and hard, both the UCS CBR values rise, recommend its suitability as good stabilizer for, proving the preformation of the soft soil [7]. Laboratory testing was carried out on clay soil reinforced with quarry dust and polypropylene fibre waste by conducting modified Proctor's test on expansive soil and soil mixed with different % of quarry dust and polypropylene fibre. The soil was replaced by 25% of quarry dust and polypropylene fibres of 10 mm, 15 mm and 20 mm length with varying % of 0.25 %, 0.50 % and 0.75 %, OMC does not show significant change where as by MDD reduces with increasing fibre content and the reduction of average unit weight of solids in mixture of fibre and soil [8]. A study carried out to find the suitability of using waste material i.e. stone dust and polypropylene fibers used as stabilizing material with different percentages for improving the engineering properties of black cotton soil and conducted various tests like CBR, UCS. The CBR value of virgin black cotton soil obtained as 1.59 and increased to 5.79 %; unconfined compressive strength black cotton soil was found to be 11.76 N/cm^2 and increased to maximum value of UCS was found to be 25.92 with 10% stone dust and 1.00% polypropylene fibers respectively. On the basis of the test results, that the strength of black cotton soil can be substantially improved by mixing with stone dust and polypropylene fibers as stabilized materials [9]. A good number of tests conducted sequentially for studying the impact of GGBS along with Sisal fibers on strength features of black cotton soil by adding different percentages, the density of BC soil intensified from 13.15 kN/m^3 to 15.4 kN/m^3 and UCS) of BC soil allowed as 132.5936 kN/m^2 raised to 530.712 kN/m^2 by a toying up 20% and 0.75% SF for 60 days curing, UCC strength has multiplied fourfold that of BC soil alone. Further increase in SF entity the CBR value diminishes. The entire study revealed that 0.75% SF and 20% GGBS is the best possible dose for BC soil used in present study [10]. Effect of polypropylene fiber on swelling

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characteristics of expansive soil by conducting compaction, unconfined compressive strength and swelling characteristics of expansive soil and from the test results OMC does not show significant change by addition of polypropylene fiber whereas maximum dry density reduces as fiber content increases in compaction tests because of reduction of average unit weight of solids in the mixture of soil and fiber. Increase in the peak axial stress and decrease the loss of post-peak strength due to increase in fibre percentage. The reinforced soil exhibit further flexible increase in performance than unreinforced soil and differential swell reduced with increase in fiber increased. [11]. Effect of GGBS in expansive soil on engineering properties by conducting various laboratory tests and from the outcome, GGBS is good enough for rising the strength of the soil with addition of GGBS from 0% to 25% by arid weight. With the grow of GGBS proportion OMC reducing while MDD growing, hence compatibility of soil rises and creating the soil more dense and hard, Specific gravity rising, thus creating the soil harder, proportion finer goes on reducing, which strengthens the soil, liquid limit, plastic limit and plasticity index declining, which strengthens the soil, liquid limit, plastic limit and plasticity index decreases, which creates the soil low plastic and plasticity index decreases, compressive strength rises that means positioning of soil particles are very closely, which decreases the voids, CBR value for saturated and unsaturated grows with grow in proportion of GGBS that illustrate the densification of soil takes set and more suitable for pavement thickness and triaxial trial outcome represents that, with the grows of GGBS proportion cohesion(C) reduces while angle of internal friction (Ø) rises considerably ,thus creating the soil less cohesive and more opposition too[12]. The present investigation is to evaluate the strength characteristics of stabilized black cotton soil using GGBS and polypropylene plastic fibres mixes. The geotechnical properties like compaction, California Bearing Ratio and load carrying capacity increase which indicates the improvement in strength. From these results, it was found that optimum percentage of GGBS is 15% and of polypropylene plastic fibres is 1% which attained maximum strength as compared with all the other combinations.

II. MATERIALS USED

The materials used for this study are Expansive soil, Ground Granulated Blast Furnace Slag (GGBS) and Polypropylene Plastic Fibres .The properties are mentioned below.

A. Expansive Soil

Natural black cotton soil sample was collected from Amalapuram, Andhra Pradesh. The collected soil was air dried , grounded manually and soil transient through 4.75 mm IS sieve was utilized as shown in the Fig. 1. The physical properties of black cotton soil are Liquid Limit (%) = 85.66, Plastic Limit (%) = 36.06, Soil Classification = CH, Specific Gravity = 2.66, Differential Free Swell = 140, OMC = 29.17%, MDD =14kN/m^3, Soaked CBR=1.345.

B. Ground Granulated Blast Furnace Slag (GGBS)

GGBS which is a by-product of iron (obtained from steel factory) slag collected from the blast. The glass content of GGBS blending with cement varies between 90-100% based on the cooling method and structure depends on Si, Al Ca, Mg. (Fig. 2). This unwanted matter comfortably accessible and also cost friendly. The GGBS collected from Visakhapatnam, Andhra Pradesh used in this work and the compositions of GGBS Cao = 30% – 38%; Sio_2 = 30% – 40%; Al_2O_3 = 15%–22%; MgO = 8% – 11%; FeO = 5% (maximum) and MnO = 2% (maximum) and the physical characteristics are Specific Gravity=2.52, % Gravel=0.1, % Sand=1.8, % Silt = 97.3, % Clay = 0.8, Optimum Moisture Content (%) =13, Maximum Dry Density (kN/m^3) =11.56.

C Polypropylene Plastic Fibres (PPF)

Polypropylene (PP) is a thermoplastic made from the combination of propylene monomers. Plastic fibres were obtained from waste plastic cover as shown in the Fig.3. The average thickness of 2 mm.

Fig .1 Expansive Soil (ES)

Fig. 2: Ground Granulated Blast Furnace Slag (GGBS)

Fig. 3: Polypropylene Plastic Fibres (PPF)

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III. LABORATORY EXPERIMENTATION

Laboratory tests were carried by mixing various percentages of Ground Granulated Blast Furnace Slag (GGBS) and Polypropylene Plastic Fibres (PPF) in the expansive soil during the study with a view to determine optimum percentages. All the tests are carried out as per IS Code procedures [13].

A. Compaction Properties: Optimum Moisture Content and Maximum Dry Density of expansive soil with different percentages of GGBS and Polypropylene Plastic Fibres mixes were determined according to IS Heavy compaction test IS: 2720(Part VIII).

B. California Bearing Ratio (CBR) Tests: The CBR tests were conducted in the laboratory for all the samples as per IS Code (IS: 2720 (Part-16)-1979), by blending different percentages of GGBS and PPF with a view to determine the effect on compaction parameters as shown in the Fig.4. All the tests are carried out at soaked condition.

Fig. 4. California Bearing Ratio Test Apparatus

C. Cyclic Plate Load Test Laboratory Cyclic Plate Load Test was carried for determining the ultimate load carrying capacity of soil and the maximum settlement under an applied load. Model flexible pavement is of 25 cm subgrade, 5 cm of gravel cushion as sub base and WBM-III as base course for conducting laboratory cyclic plate load test. The loading was done through a circular metal plate of 10 cm diameter laid on the model flexible pavement system. Circular steel tank was placed on the concrete platform of the load testing machine. Three dial gauges each of sensitivity 0.01 mm accuracy were arranged as shown the Fig.5, for recording the settlements. A 500 kN Ton capacity hydraulic jack was placed on the loading. Cyclic load tests were carried out at OMC state corresponding to tire pressures of 500, 560, 630, 700, 1000 and 1200 kPa. At each pressure increment six cycles of loading and unloading is done until there is no significant change in deformation. Each pressure increment was applied until there was no significant change in deformation between the consecutive cycles. These tests were conducted on all the model flexible pavements prepared. These tests were carried out at saturated states for all the model flexible pavements.

IV. TEST RESULTS AND DISCUSSIONS

Compaction, Soaked CBR and Cyclic load trial were carried by utilizing various proportions of GGBS(Ground Granulated Blast Furnace Slag) and Polypropylene Plastic Fibres (PPF), with a view to find the optimum percentages and its effect on strength properties of expansive soil .The details of these test results presented in the following sections. All the tests were conducted as per IS Code procedures.

Fig. 5 Experimental Cyclic Plate Load Set For Finding Load – Settlement.

A. Effect on Compaction Properties

The OMC and MDD values are presented below form Figs. 6 & 7. From the results the maximum dry density values are varies from 14.01kN/m^3,14.10 kN/m^3, 14.36 kN/m^3, 14.31 kN/m^3 ,14.19 kN/m^3 and 13.37 kN/m^3; most favorable humidity content values are decreasing as 29.17 %, 28.78%, 28.19%, 27.57 %,27.16% and 26.77% respectively when the soil is mixed with 0 %, 10 %, 15% ,20%,25% and 30 % of *Ground Granulated Blast Furnace Slag* mixing in expansive soil respectively shown in the Fig.4. At 15% of GGBS attained maximum dry density. Expansive soil with 15 % optimum GGBS as soil mix, adding different % of plastic fibres 0 %, 0.5 %, 1 %,1.5 % and 2 % the MDD & OMC values are *14.36* kN/m^3,14.53 kN/m^3, 14.87 kN/m^3,14.79 kN/m^3 and 14.06 kN/m$^{3;}$ 28.19%, 28.95%, 29.22 %, 29.44 % and 29.69 % respectively .From the above results 1 % plastic fibres shows maximum increase in dry density when compared to other samples tried in this investigation due to *compatibility of soil increases and making soil more dense and hard.*

B. Effect on California Bearing Ratio (CBR)

Soaked CBR tests were conducted for expansive soil mixed with different percentages of GGBS and Plastic fibres and the results were presented in the Figs. 8 to 11. It is observed from that expansive soil mixed with different percentages of

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GGBS the soaked CBR values are 1.35 %, 2.69 %, 3.59 %, 3.31%, 2.25 % and 1.79 % respectively at 0 %, 10%, 15 %, 20 %, 25 % and 30 % Figs. 8 & 9. From the above results at 15% GGBS attains maximum CBR value. Considering 15% optimum GGBS blending with different percentages of Polypropylene Plastic Fibres ,the soaked CBR values are 3.59 %, 6.72 %, 8.51 %,7.17 % and 5.83% at 0%, 0.5 %, 1 %, 1.5 % and 2 % blending plastic fibres respectively shown in the Figs.10 &11. From the above the maximum CBR attained at 1% plastic fibres is 8.51% compared to other samples tried.

C. Cyclic Plate Load Test

Cyclic plate load tests were carried out on untreated and treated expansive soil flexible pavements in separate model tanks under cyclic pressures 500 kPa, 560 kPa, 630 kPa, 700 kPa, 1000 kPa, 1200 kPa, 1400 kPa as shown in the Figs.12&13. The tests were conducted until the failure of the expansive soil model flexible pavements at OMC conditions. From the laboratory cyclic plate load test results of untreated expansive soil subgrade model flexible pavement has exhibited an ultimate pressure of 630 kPa at 2.61 mm as deformation. Treated expansive soil with 15% GGBS and 1% Polypropylene plastic fibres model flexible pavement has exhibited an ultimate pressure of 1200 kPa at 2.39 mm as deformation.

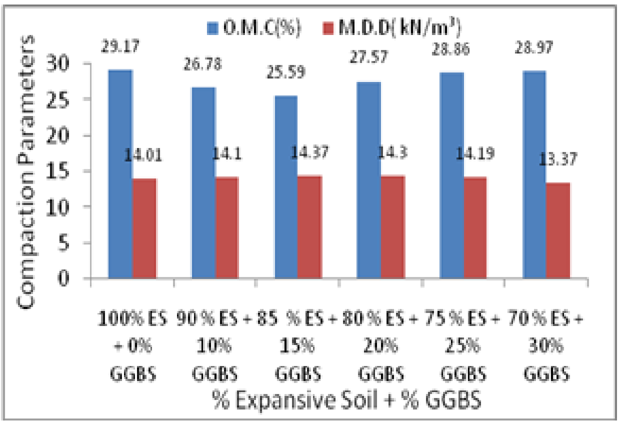

Fig.6 Compaction Specifications for Expansive Soil Treated with Different % GGBS.

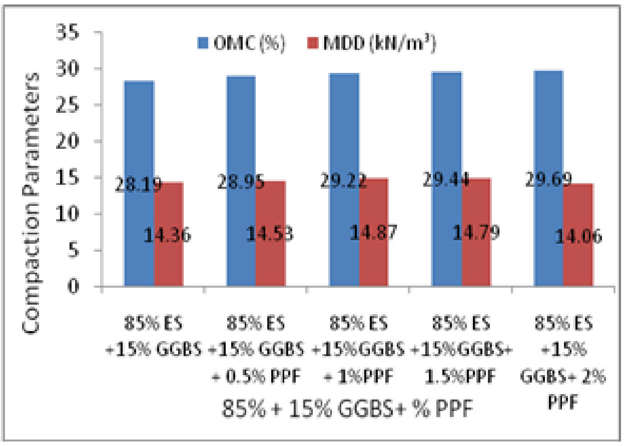

Fig.7 Compaction Specifications for Expansive Soil Treated with 15% of GGBS and different % of PPF

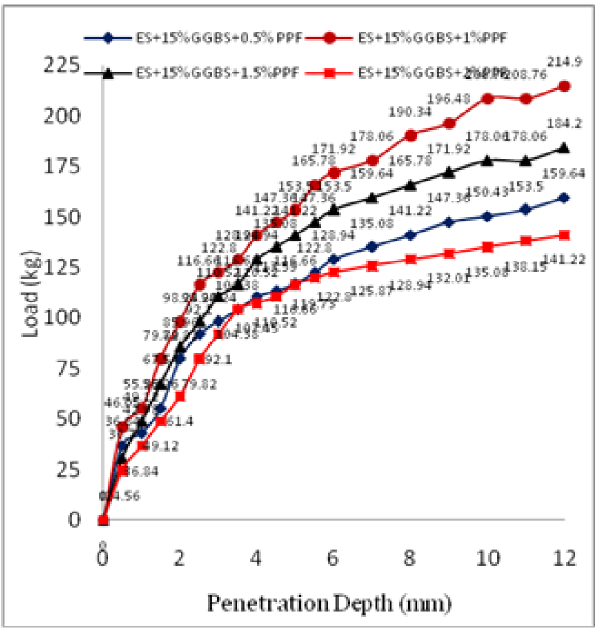

Fig. 8 Load Vs Penetration Values of Soaked CBR for 15% GGBS Treated Expansive Soil with Different % of PPF

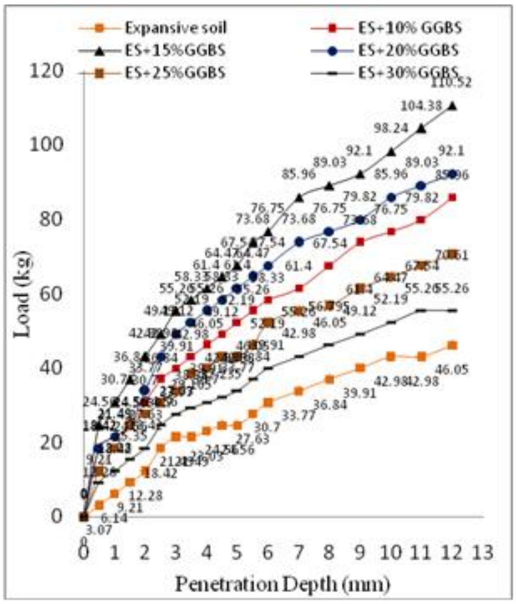

Fig.9 Load Vs Penetration Values of Soaked CBR for Different Percentage of GGBS Treated Expansive Soil

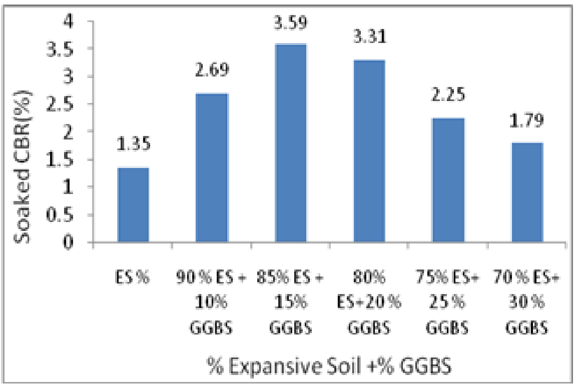

Fig.10 Soaked CBR Values for Expansive Soil Treated with Different Percentages of GGBS

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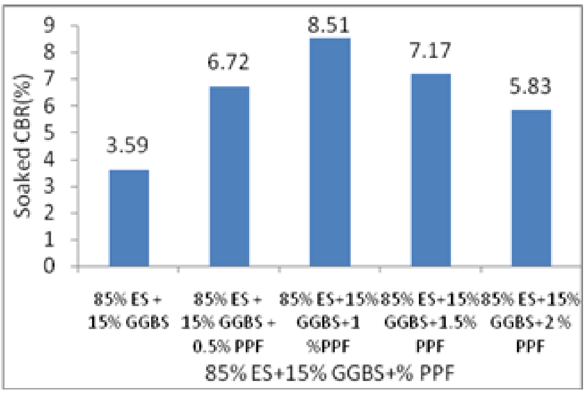

Fig. 11 Soaked CBR Values for Expansive Soil Treated with 15% GGBS and 1% PPF

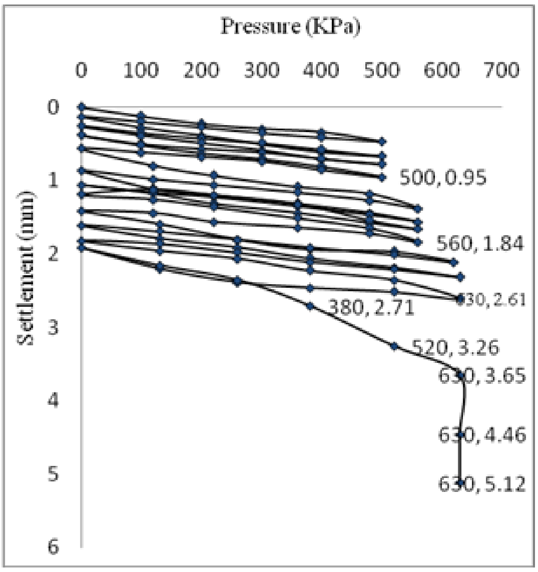

Fig.12 Laboratory Cyclic Plate Load Test Results of the Expansive Soil for Model Flexible Pavement at OMC

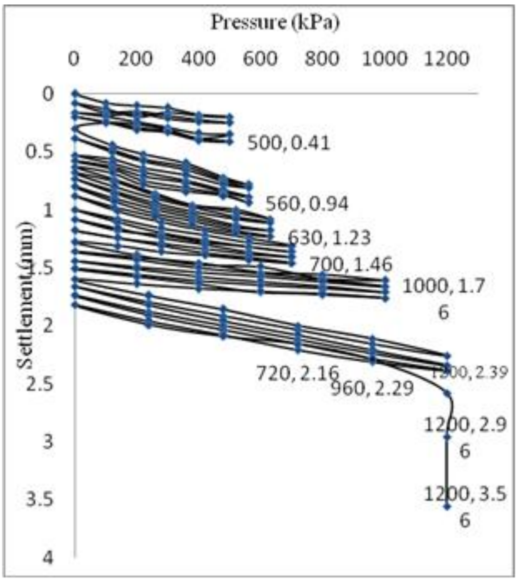

Fig. 13 Laboratory Cyclic Plate Load Test Results of the Expansive Soil Treated with 15% GGBS and 1% PPF for Model Flexible Pavement at OMC

Summary of all the experimental analysis conducted during this study presented in the Table.1 for expansive soil blending with different percentages of GGBS and polypropylene Plastic Fibres (PPF)

Table: 1 Geotechnical properties of Untreated and Treated Expansive soil with 20% GGBS AND 1.5% Polypropylene Plastic Fibres

Property	ES	ES +15 % GGBS	ES + 15 % GGBS + 1% PPF
Liquid limit (%) (W_L))	85.66	68.78	54
Plastic Limit (%)(W_P)	36.06	31.25	34.35
Plasticity Index (%)(I_P)	49.60	37.53	19.65
Soil Classification	CH	CH	CH
Specific Gravity(G)	2.66	2.75	2.8
(OMC) (%)	29.17	25.59	28.42
MDD (g/cc)	1.428	1.464	1.516
CBR (%)	1.345	3.585	8.51
Differential Free Swell (%)(DFS)	140	90	45

V. CONCLUSION

Laboratory experimentation assessed the effect of GGBS as well as Plastic fibres on compaction, soaked CBR and cyclic plate load tests properties of expansive soil. Number of sequential tests was taken up for studying the influence of GGBS and Plastic fibres on strength properties of expansive soil.

GGBS is a dissipate product which is the outcome of that is available copiously from iron manufacturing units, as it has a high specific gravity of 2.52 is used as stabilizing substance.

Addition of 15% GGBS to expansive soil the maximum dry density of expansive soil amplified between 14.01 kN/m^3 and 14.36 kN/m^3 then soaked CBR values augmented within the range 1.39 % to 3.59% which is around 1.6 times more natural expansive soil.

Mixing with 15% GGBS and 1% Polypropylene Plastic Fibres to expansive soil the maximum dry density increased as 14.79 kN/m^3 instead of 14.01 kN/m^3 and soaked CBR values mounted as 8.51 % in place of 1.39% which is around 5.2 times more natural expansive soil.

It was observed from the laboratory cyclic plate test results that the Cyclic Plate Load Test results of the treated expansive soil subgrade flexible pavement has been improved by 90.48% when compared with untreated expansive soil subgrade flexible pavement.

It was noticed from the laboratory investigations of the cyclic plate load test results that, the total deformations of treated expansive soil subgrade flexible pavement have been improved by 2.61mm to 2.39mm when compared with untreated expansive soil.

The soaked CBR value of expansive soil on stabilizing treated with GGBS and Polypropylene plastic fibres is found to be 8.51% and it is satisfying standard specifications. So ultimately it is terminated from the observed outcome that the GGBS can potentially stabilize the expansive soil (or) mixed with Polypropylene fibres.

CBR value for increase in percentage of GGBS and plastic fibres that show the densification of soil takes place

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and more suitable for foundation. The utilization of industrial wastes like GGBS is an alternative to reduce the construction cost of roads particularly in the rural areas of developing countries.

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