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IMPROVEMENT OF BLACK COTTON SOIL USING GGBS AND POLYPROPYLENE FIBRES

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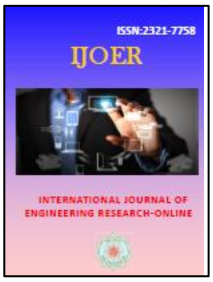


ABSTRACT
Safe and Economic disposal of industrial wastes and development of economically feasible ground improvement techniques are among the important challenges being faced by the engineering community.

In this investigation, an attempt has been made to study the possibility of utilizing lime & plastic fibers these are the hazardous industrial waste for stabilization of soil, since bulk utilization of lime & plastic fibers is feasible in the case of geotechnical applications like construction of embankments, earth dams, and highway and air field pavements. 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. In its broadest senses, stabilization includes compaction, pre-consolidation, drainage and much other such process. However, the term stabilization is generally restricted to the process which alters the soil material itself for improvement of its properties. A cementing material or a chemical is added to a natural soil for the purpose of stabilization.

Soil stabilization is used to reduce the permeability and compressibility of the soil mass in earth structures and to increase its shear strength. Soil stabilization is required to increase the bearing capacity of foundation soils. However, the main use of stabilization is to improve the natural soils for the construction of highways and airfields. The principles of soil stabilization are used to control the grading of soils and aggregates in the construction of bases and sub bases of the highways and airfields.

Keywords — Polypropylene Fibres, GGBS, Geotechnical Properties, Laboratory Tests.

1. INTRODUCTION

Expansive soils are a worldwide problem posing many challenges to civil engineers, construction firms and owners. Black cotton soils of India are well known for their expansive nature. In India, the black cotton soil covers 7 lakh square kilometres approximately 20-25 % land area and are found in the states of Maharashtra, Gujarat, Rajasthan, Madhya Pradesh, Uttar Pradesh, Karnataka, Andhra Pradesh and Tamil Nadu. These are derived from the weathering action of Basalts and traps of Deccan plateau. However, their occurrence on granite gneiss, shales, sandstones, slates and limestone is also recognised.

They are highly fertile for agricultural purposes but pose severe problems to the pavements, embankments and light to medium loaded residential buildings resting on them due to cyclic volumetric changes caused by moisture fluctuation. This volume change behaviour is the reason for cracking to the overlying structures. The reason for this behaviour is due to presence of clay mineral such as montomorillonite that has an expanding lattice structure. During monsoon's, soils containing this mineral will imbibe water, swell, become soft and their capacity to bear water is reduced, while in drier seasons, these soils shrinks and become harder due to evaporation of water. These types of soils are generally found in arid and semi-arid regions.

These types of soils are to be stabilized in order to rectify its deficiencies in engineering properties especially to use as pavement material. Pavement design is based on the preface that minimum specified structural tone will be achieved for each layer of material in the pavement system. Each layer should resist shearing, avoid excessive deformations that cause fatigue cracking within the layer or in overlying layers, and prevent excessive permanent deflection through densification. As the quality of a soil layer is enhanced, the ability of that layer to spread the load over a greater area is generally increased so that a reduction in the required thickness of the soil sub-grade and surface layers may be allowed.

Figure.1.1: Regions covered by Black cotton soil in India

2. LITERATURE REVIEW

Since ancient times, mankind has used the natural earth surface for transportation. These road surfaces were transformed in to masses of mud by the spring and rain, where as in the summer season the carts created clouds of dust. Several attempts were made to take care of these problems. Some researchers tried to modify the engineering properties of soil using certain stabilization technique. At the same time various waste products are created by several industrial plants. These waste products could be used in the road construction projects after following certain treatment procedure. By treating natural soil or fly-ash, or by addition of certain materials to it, new road construction materials can be developed. One such natural soil that covers many parts of India is black cotton soil. The main problem with this soil is their expansive nature.

Expansive soils, which usually contain the clay mineral Montmorillonite, include sedimentary and residual soils, clay stones and shales. The change in volume can exert enough force on a building or other structure to cause damage to them. Expansive soils will also shrink when they dry out. This shrinkage can remove support from buildings or other structures and result in damaging subsidence and fissures. Geotechnical engineers did not recognize damages associated with buildings on expansive soils until the late 1930s. The U.S. Bureau of reclamation made the first recorded observation about soil heaving in 1938 (Chen, 1975). Since then a number of researchers have pioneered researches into expansive soils. The expansive nature of soil is most obvious near ground surface where the profile is subject to seasonal, environmental changes (Terzaghi, Peck and Mesri, 1996; Fredlund and Rahardjo, 1993).

2.2 CLAY MINERALOGY

The term clay can refer both to a size and to a class of minerals. As a size term, it refers to all constituents of a soil smaller than a particular size, usually 0.002 mm in engineering classifications. As a mineral term, it refers to specific clay minerals that are distinguished by (1) small particle size, (2) a net electrical charge, (3) plasticity when mixed with water and (4) high weathering resistance (Mitchell and Soga, 2005).

The basic idealized crystalline structural unit of a clay mineral is composed of a silica tetrahedron block and an aluminium octahedron block. Aluminium octahedron block may have Aluminium (Al^{3+}) or magnesium (Mg^{2+}). If only aluminium is present, it is called gibbsite [$Al_2(OH)_6$]; if only magnesium is present, it is called brucite [$Mg_3(OH)_6$]. Various clay minerals are formed as these sheets stack on top of each other with different ions bonding them together (Oweis and

Khera, 1998). A silica tetrahedron and a silica sheet, also an octahedron and an octahedron sheet are presented in Figure 2.1 and Figure 2.2, respectively. Also, these figures consist of schematic representations of silica and octahedron sheets.

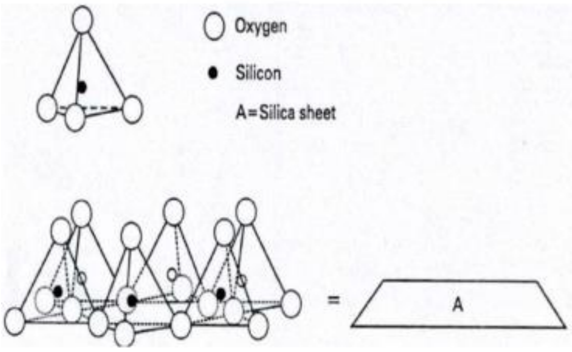


Figure 2.1

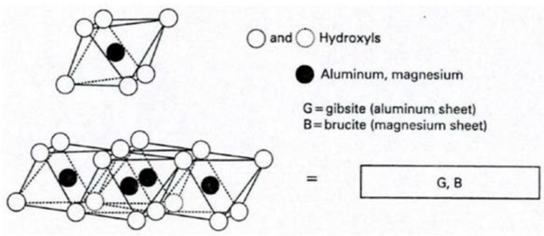


Figure 2.2

The term 'clay minerals' refers to hydrous aluminium phyllosilicates minerals that are fine grained (<0.002 mm) with sheet-like structures and very high surface areas (Cameron, 1992). The clay minerals consist of silcon-oxygen tetrahedral ((Si4O16)2-) layer and aluminium (Al2 (OH)6) or magnesium (Mg3(OH)6), the brucite or gibbsite sheet in the octahedral layer (Wu, 1978). The most common clay minerals include kaolinite group minerals (kaolinite, dickite, halloysite and nactrite), chlorite group, illite group (clay-micas), and smectite (pyrophyllite, talc, vermiculite, sauconite, saponite, nontronite and montmorrillonite) and mixed layer phases.

The common clay minerals usually found in soil are Kaolinite, Illite and Montmorillonite. Kaolinite is a common phyllosilicate mineral in sub grades; it is most abundant in soils of warm moist climates. Illite is essentially a group name non-expanding, clay-sized minerals. Smectites commonly result from the weathering of basic rocks. These minerals have a very small size and are concentrated in the fine clay fraction of soils. Figure 2.3 presents a systematic manner in which synthesis of different clay minerals takes place.

Because clay minerals are composed of only two types of structural units (octahedral and tetrahedral sheets), they can be classified according to the way that tetrahedral and octahedral sheets are packed into layers as well as isomorphous substitution effect, and types and amount of the interlayer cations. If one tetrahedral combines with one octahedral a two layers structure of the 1:1 (individual planar unit) clay minerals is formed. Otherwise, a three layers structure of 2:1 (silica-alumina-silica) clay minerals results when one aluminium octahedral sheet is sandwiched between two silicon tetrahedral sheets.

The 1:1 clay units are bonded together by hydrogen bonding between hydroxyl groups, thus they have no charge (i.e. they are electrically neutral) and therefore they do not attract positively or negatively charged solutions such as water. Consequently, the 1:1 minerals have stable structure and they neither shrink nor swell with alternate cyclic episodes of wetting and drying. Kaolinite and chlorite are examples of 1:1 clay minerals with silicon in the tetrahedral and aluminium in the octahedral.

Unlike the 1:1 type mineral, most of the 2:1 clays are weakly bonded to each other thus they easily separate and allow water and contaminants to enter between the sheets. Accordingly, these minerals expand by adsorption of water adjacent to 2:1 units. Usually, water gets attracted to the oxygen surface of the clay and to the neutralizing cations in the interlayer's (Burden and Sims, 1999). Smectite (e.g. Montmorillonite) is an example of 2:1 minerals. In some cases, it is possible to find larger cations such Na+ and K+ between the 2:1 layers in which expansion is constrained thus forming the illites and chlorite groups which are non-expansive.

EXPERIMENTAL STUDY

Materials:

SOIL: Black-cotton soil (BC soil) is obtained from the brick manufacturing site located 10 km away from SSCET, MACHILIPATNAM, ANDHRA PRADESH.

GGBS: Ground granulated blast furnace slag is a non-metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material when further ground to less than 45micron will have specific surface about 400 to 600 m2/kg. The chemical composition of ground granulated blast furnace slag (GGBS) is shown in table

Polypropylene fibers: The Polypropylene fibers are procured from Panjagutta, Hyderabad. The polypropylene fibers of length 12 mm are chosen for inclusion in various percentages (0.25, 0.5, 0.75 and 1%). The properties of the Polypropylene fibers .

Atterberg Limits: The tests were performed according to IS 2720-Part 15, (1985) on soil passing 425µ sieve. For saline water, this test was performed at different concentrations.

Specific Gravity: The Specific gravity (G) of the soil has been determined by exploited some density bottle and pycnometer as per the guidelines provided by IS 2720-Part 3, (1980). The average value has been taken from the three trials was obtained and the result as shown in the table.

Standard Proctor Compaction Test: The soil sample was oven dried at 110OC for about 24 hours. Later, as per standards, the soil is mixed with the various concentrations (0.001 M, 0.01 M and 0.05M) of salt in weight and then this mix has been compacted in three equal layers with each set of experiments with increasing the water content. Later, based on the compaction curves plotted for the different mix, optimum moisture content (OMC) and maximum dry density (MDD) for each test specimens were obtained.

UCC Test: The unconfined compressive strength of the cylindrical shaped specimens (38 mm diameter and 76 mm length) was determined according to IS: 2720-Part 10, (1991). The cylindrical specimen was placed on the base plate and the load frame has been fixed without any stress application upon the specimen. Set the dial gauge reading and proving ring to zero. Axial load increment was applied at a strain rate of 1.5 mm/min. Noted the proving reading value at regular intervals of the dial gauge reading.

Index Properties:

Table 1: Properties of the selected material

S.NO	Properties	BC Soil
1	Specific gravity	2.65
2	Grain size analysis	
	Gravel (%)	47
	Sand (%)	29
	Silt (%)	40
	Clay (%	27
3	Liquid limit	63
4	Plastic limit	21
5	Plasticity index	42
6	IS Soil classification	CH
7	Compaction properties Optimum moisture content (%)	19
	Maximum dry density (g/cm^3)	1.45
8	Unconfined compressive strength (kg/cm^2)	1.65

PROPERTIES OF POLYPROPYLENE FIBERS:

S. No	Type of Fiber	Polypropylene
1	Length (mm)	12 mm
2	Specific gravity	0.90 – 0.91
3	Diameter (mm)	0.04 mm
4	Tensile strength (Mpa)	450
5	Shape	Triangular
6	Melting point (Oc)	165
7	Heat resistance (Oc)	< 130

PROPERTIES OF GGBS:

S.No	Chemical composition	GGBS (%)
1	SiO_2	34.06
2	MgO	7.89
3	Fe_2O_3	0.8
4	SO3	0.9
5	CaO	32.6
6	MnO	0.31
7	Na2O	0.22
8	Al_2O_3	20
9	LOI	0

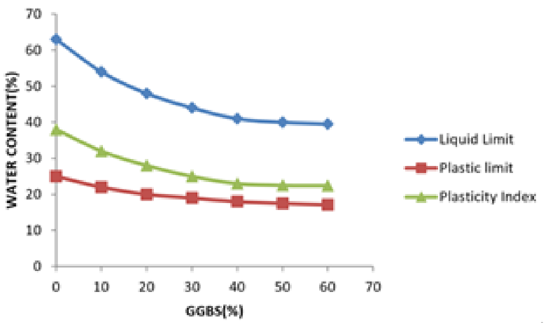
TESTS CONDUCTED:

The series of Tests conducted for determination of Compaction Characteristics (Optimum Moisture Content & Maximum Dry Density) and UCC (Unsoaked) for different proportions of GGBS, plastic Fibers mixed with soil.

RESULTS AND DISCUSSIONS

ATTERBERG LIMITS:

The test results from figure 4.1 shows that LL, PL and PI decreased when BC Soil mixed with GGBS. It is known by addition of GGBS to BC Soil can, (1) Reduce the thickness of the diffuse double layer, (2) Cause flocculation of clay particles, and (3) increases the coarser particles content by substituting finer soil particles with coarser GGBS particles. These reasons all together cause the decrease in LL and PI, and the increase in PL. Mitchell (1993) indicated that PI is a good indicator of swell potential, the lower PI is, and the lower swell potential will be. Addition of GGBS to BC soil decreased the plasticity index of expansive soil significantly. This implies there is a significant reduction in swell potential by addition of GGBS to BC Soil.

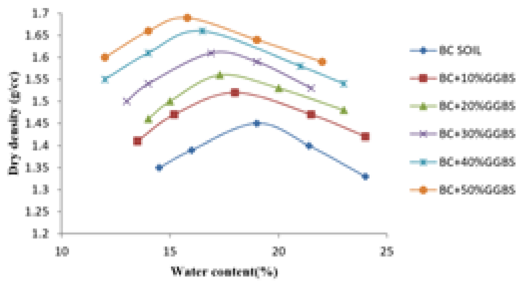


COMPACTION TEST

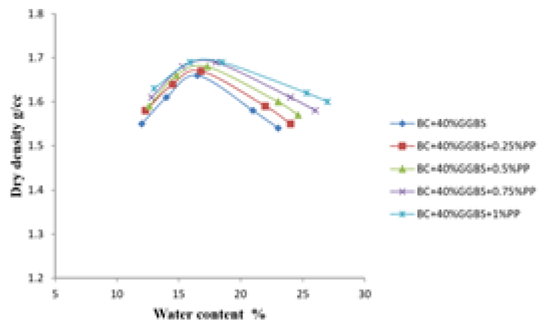
The standard proctor tests were conducted by mixing different percentages of GGBS and GGBS-Polypropylene fibers to the Black cotton soil. BC soil is mixed with GGBS by varying its percentage from 0 % to 50 % in increments of 10 % and Mini Compaction tests are conducted. After selecting suitable proportion of GGBS, Polypropylene fiber content was varied from 0.25 % to 1 % in increments of 0.25 % and mini compaction tests are conducted on these mixes.

The variation of OMC Vs. MDD with addition of GGBS to BC soil is shown in figure 4.2. It is observed that there is an decrease in the optimum water content and increase in maximum dry unit weight when GGBS is added to BC Soil, this can be explained as follows: The increase of the maximum dry unit weight by adding GGBS to BC Soil is mainly due to its higher specific gravity and reduction in the repulsive forces between the soil particles. This results in increase in the density. The pozzolanic reaction between BC soil and GGBS is responsible for decrease in OMC

The variation of OMC Vs. MDD with addition of 40% GGBS and PP fibers to BC soil is shown in the figure 4.3. It is observed from the figure that the maximum dry density of GGBS + PP fibers blended BC soil is slightly higher than that of blended GGBS stabilized BC soil. Hence it can be inferred that there is no significant increase in the value of maximum dry density due to the inclusion of PP fibers.



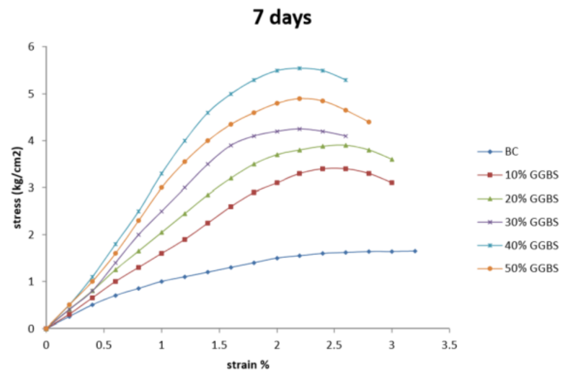
Variation of OMC vs. MDD with addition of GGBS to BC soil.



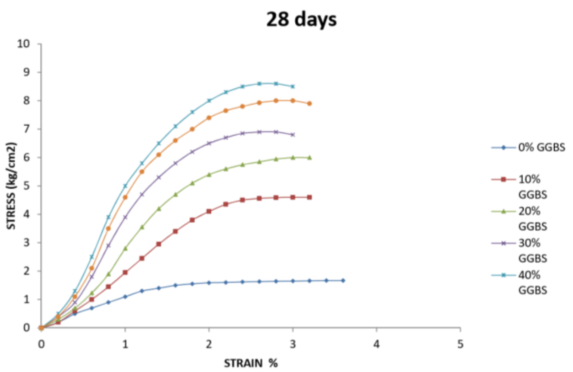
Variation of OMC vs. MDD with addition of 40% GGBS and PP fibers to BC soil

UNCONFINED COMPRESSIVE STRENGTH

The unconfined compressive strength tests were conducted on the optimum mixes which are selected from Mini compaction test. The unconfined compressive strength tests were carried out for 2 curing periods 7 and 28 days. The stress-strain behaviour of different composites with corresponding curing periods is shown in the following figures 4.4, 4.5 and 4.6. From the stress strain behaviour of BC soil, it was observed that BC soil reached its maximum stress at low strain only whereas strain absorption rate at same loading intensity is increased. With the addition of GGBS to the BC soil, it is absorbing higher stresses than BC soil at similar strains. However, with increase in curing period the stress absorption rate is increased at higher strains than BC soil, but brittle nature is observed. The unconfined compressive strength of GGBS stabilized soil improved up to 40 % of GGBS content and slight decrease in strength is observed for later percentages. All the input CaO is consumed by the natural pozzolanic material in the soil to produce a pozzolanic reaction. Strength development in the inert zone tends to slow down; the incremental gradient becomes nearly zero and does not make any further significant improvement. A decrease in strength, which appears when the GGBS content is in the deterioration zone.

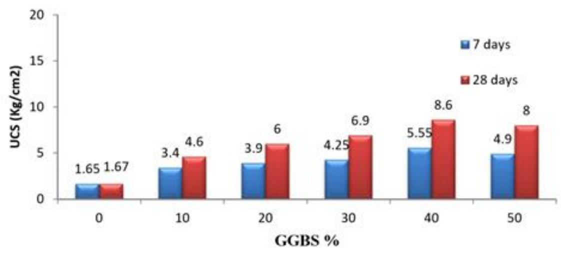


Stress-Strain behaviour of BC soil treated with GGBS for a curing period of 7 days

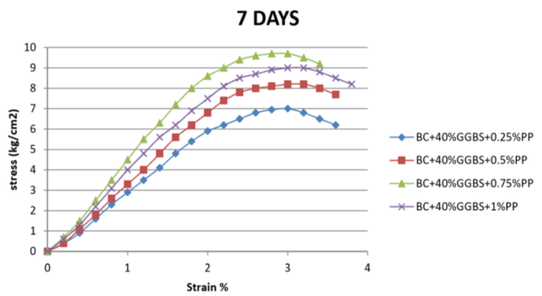


Stress-Strain behaviour of BC soil treated with GGBS for a curing period of 28 days

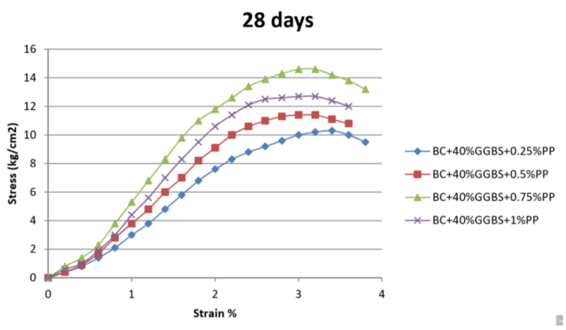
The UCS samples with optimum GGBS content of 40 % and varying percentages of PP fibers (0.25 %, 0.5 %, 0.75 % and 1 %) are prepared and cured for 7 days and 28 days. The stress-strain behaviour of different composites with corresponding curing periods is shown in the following figures 4.7, 4.8 and 4.9. From the stress strain behaviour, it was observed that BC soil reached its maximum stress at low strain only whereas strain absorption rate at same loading intensity is increased. With the addition of GGBS to the BC soil, it is absorbing higher stresses than BC soil at similar strains. The unconfined compressive strength of GGBS stabilized soil with PP fibers improved up to 0.75 % of PP fibers content and slight decrease in strength is observed for later percentages. However, with increase in curing period the stress absorption rate is increased at higher strains than BC soil.



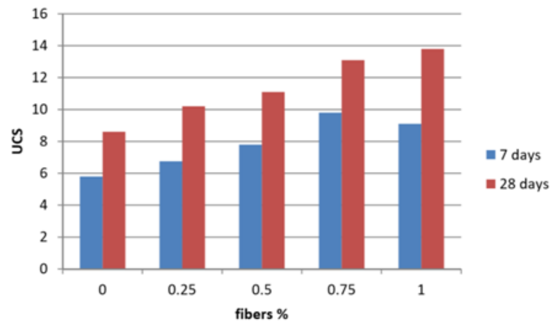
Unconfined compressive strength of BC soil treated with GGBS for curing periods of 7 and 28 days respectively



Stress-Strain behaviour of BC soil treated with 40% GGBS with varying percentages of PP fibres for a curing period of 7 days

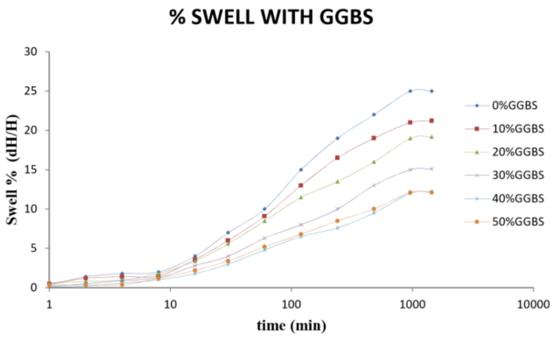


Stress-Strain behaviour of BC soil treated with 40% GGBS with varying percentages of PP fibres for a curing period of 28 days

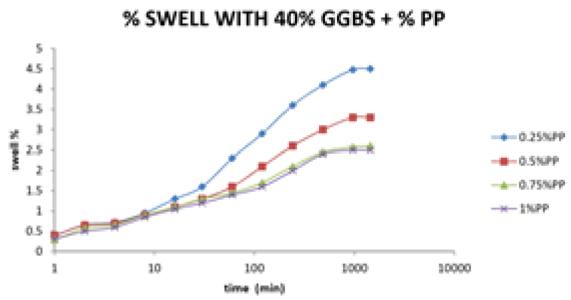


Comparative graph for UCS vs. % fibers with 40% GGBS at 7 and 28 days curing

Test samples are prepared as per the specifications with varying contents of GGBS with BC soil and 40 % GGBS with PP fibers blended with BC soil. One dimensional swell tests are conducted on the samples. The variation of Swell % with time is shown in the figures 4.10 and 4.11. It can be observed that swell % decreases with increase in GGBS content due to cation exchange reaction. With the addition of PP fibers to BC soil blended with 40 % of GGBS, swell % decreases. It can be inferred that no significant decrease in the swell % is achieved with the addition of PP fibers beyond 0.75 %.



Variation of % swell vs. Time for different GGBS proportions

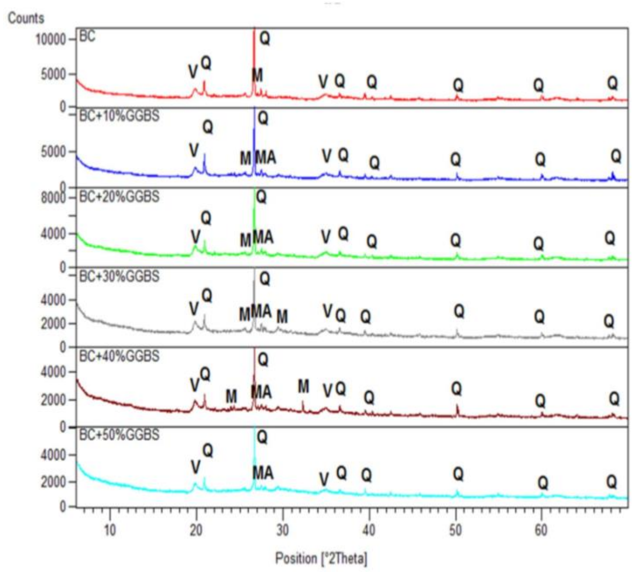


Variation of % swell vs. Time for 40% GGBS and different PP fibers proportions

MINERALOGICAL STUDIES

Mineralogical studies are conducted using PAN analytical X-pert powder diffractometer. Samples were scan from 6º (2θ) and 70º (2θ) angle using copper K alpha radiation at a scanning rate of 2 degrees per minute. The data obtained is analysed using X- pert high score plus software, to identify minerals by comparing the standard diffraction patterns of minerals.

The X-ray diffraction analysis is carried out on samples cured for a period of 28 days. Prior to testing all the samples were oven dried for a period of 24 hours. Then the oven dried samples were powdered and passed through 75 micron sieve. This powder is used for X-ray diffraction analysis. X-ray diffraction patterns of BC soil and BC soil treated with different percentages of GGBS are shown in figure 4.12. In X-ray diffraction pattern of soil with respect to water shows that the natural black cotton soil contains Volkonskoite (Peaks at 4.49, 2.56 and 1.50 [Å]) along with Quartz (Peaks at 3.34, 2.45, 1.81 and 1.67 [Å]) and microcline (Peaks at 3.24, 2.90 and 1.98 [Å]) as their major minerals. The black cotton soil treated with GGBS showed peaks pertaining to Anorthite (peaks at 3.20, 3.03 and 2.13[Å]), a new mineral, which is a calcium aluminium silicate mineral



X-ray diffraction patterns of BC soil and BC soil treated with different percentages of GGBS

CONCLUSIONS

The following conclusions can be drawn from the experimental results:

1. The strength of BC soil increased with addition of GGBS up to 40% for the curing periods of 7

and 28 days. Further addition of GGBS decreased the strength of Soil – GGBS mixture.

2. The addition of 40% GGBS to the BC soil reduced the swell percent from 25 % to 12.1 %. Further additions of GGBS to the BC soil do not have significant reduction in swell percentage.
3. 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.

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