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Strength Behavior of Polypropylene Fiber Reinforced GGBS Based Geopolymer Clay Blends

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Abstract. Geopolymers are alternative binders to cement and lime blended expansive clays and also utilize industrial by-products as precursors for the effective blends. This paper presents the experimental investigation on the influence of polypropylene fibers on the strength behaviour of the GGBS based geopolymer expansive clays. The geopolymer soil is embedded with varying percentages of polypropylene fibers such as 0.2%, 0.4%, 0.6%, 0.8% and 1.0% by dry weight of soil. Unconfined compressive strength increased with increase in GGBS content from 0% to 25% by dry weight of soil. UCS and split tensile strength of the GGBS based geopolymer clay blends increased with increase in polypropylene fibers for a given precursor content. Scanning electron microscopy (SEM) analysis was carried for understanding the texture and microstructure of the geopolymer blends for an addition of different precursor's contents. The micrographs of the geopolymer blends showed that formation of Si-O-Si bonds, and micro-cracks observed for the blends having higher percentage of precusor content.

Keywords: Expansive Clays, GGBS, Geopolymers, Tensile Structure

1 Introduction

In the last few decades, green materials and their applications in the civil engineering infrastructure have been gaining significant attention. Geopolymers are the emerging green materials comprises of silica and alumina for development of geopolymerization products. In general, sodium silicate gel and sodium hydroxide or potassium hydroxide pellets are used to prepare the alkali-activator (Davidovits, 1989). The alkali-activators were reacted with the Al and Si ions present in the precursor and form three dimensional Si-Al chains with strong bonds. And also, the formation of Si-O-Al bonds leads to dense geopolymer matrix with mild brittle behavior when exposed to thermal curing specimens (Davidovits, 1989; Pan et al. 2011). Fly ash based geopolymers are commonly used blends because of fly ash consists rich aluminum trioxide and silicon dioxide, which helps in the formation of N-A-S-H compounds (Phummiphan et al. 2016). Moreover, other precursors such as ground granulated blast furnace slag (GGBS), silica fume and rice husk ash (RHA) are also useful for acceleration of condensation and geopolymerization process (Zhang et al. 2013; Suksiripattanapong et al. 2017). Moreover, in geopolymer soils, the minerals present within the soil contributes pozzolanic reactions when Ca^{2+} ions in the pozzolanic material reacts with Si^{4+} and Al^{3+} ions in the clay form cementitious compounds of calcium silica hydrate (C-S-H), calcium alumina hydrate (C-A-H) and C-A-S-H (Suksiripattanapong et al. 2017). Both geopolymerization products and cementatious products results in high stiffness and moderate brittle behavior.

At present, in geopolymers research there is a shift towards the necessity or potential of fibers imbedded in the geopolymer blends in order to improve flexural resistance. This can be helpful for wide range of geopolymer applications in civil infrastructure. Utilization of fibers embedded in cement concrete have been in vogue, and since many studies related to fibers reinforced soils also increased tremendously (Kumar et al. 2006; Tang et al. 2007; Kumar and Gupta, 2016). The strength characteristic of the fiber reinforced soils depends on the type of fiber, amount of fiber and aspect ratio of fiber. The fiber inclusion in expansive clays shows significant enhancement in swell-shrink behavior, i.e. rate of heave and swelling pressure. Moreover, during swell-shrink behavior, the contact area of fibers exposed to soil blends allows greater internal friction between the soil and fibers. Further, increases the greater resistance against the swelling and shrinkage. Friction resistance of fiber reinforced soil mainly depends on the aspect ratio, i.e. when length is more interlocking performance is high, and when width is more there is an improvement in contact area, thereby swelling resistance increases (Soltani et al. 2018). And also, inclusion of fibers such as natural fibers or synthetic fibers shows significant enhancement in shear strength, permeability, compressibility and bearing capacity (Prabakar and Sridhar, 2002; Kumar et al. 2006; Soltani et al. 2018).

The objective of this paper is fiber embedded in the geopolymer clays is to date limited and the tensile behavior of the geopolymer blends reinforced with fibers is focused in this research work. Unconfined compressive strength and split tensile strength tests were conducted on the geopolymer soil blends with varying precursor and fiber content. SEM analysis was carried to characterize the GGBS, clay and treated geopolymer clays.

2 Experimental Investigation

2.1 Materials

The expansive clay used in this study is a locally available in Bhimavaram, India. The expansive clay consists of montmorillonite material and having high swelling and shrinkage behaviour. GGBS used in this study as a precursor for effective condensation and geopolymerization process, which is collected at local market in Vijayawada, India. Other raw materials used in this investigation were sodium hydroxide pellets and sodium silicate gel. Moreover, for determining split tensile strength, polypropylene fibers were used as a reinforcement material embedded in geopolymer soil blends. The index properties of expansive clay are shown in Table 1.

Table 1. Index properties of expansive clay

Properties	Liquid limit, %	Plastic limit, %	Soil Classi-fication (IS)	Specific gravity	Fines, %	Free swell index, %
Value	86	24	CH	2.66	94	180

2.2 Sample preparation

Geopolymer solution was prepared using 10 molar NaOH solution and Na_2SiO_3 gel, and ratio of Na_2SiO_3/NaOH is maintained as 2.5. Flat expansive clay used in this study was powdered into smaller sizes using mechanical tampers and then sieved into 4.75mm I.S. sieve. Pulverized soil sample was oven-dried for 24hours at a temperature of 110°C. It was mixed with prefixed amount of geopolymer solution and precursor content was mixed homogeneously and compacted in a standard cylindrical mould of size 38 mm diameter and 76mm height using manual static compactor.

2.3 Methods

Many researchers have suggested different approaches to evaluate mechanical behaviour of soils using unconfined compressive strength (UCS), direct tensile strength test, split tensile strength test (STS) and flexural strength test. This study was comprised of UCS and STS on geopolymer blended expansive clays. The specimens for the UCS and STS were prepared in the standard cylindrical moulds of dimensions 38mm diameter and 76mm height. UCS test was conducted on geopolymer soil blends by varying amount of precursor as 0%, 5%, 10%, 15%, 20% and 25% by dry of soil. The specimens were loading at a rate of 1mm/min until the specimen failed.
For determining split tensile strength of geopolymer soil blends, cylindrical specimens of same dimensions used in the UCS were prepared. The load is applied on the surface center line on each side of support. Split tensile strength test was conducted for cylindrical soil specimens placed horizontally in between the compressed blocks in the compression test in accordance with the Kumar et al 2007.

Scanning electron microscopy (SEM) tests were carried out on the GGBS based geopolymer blends to know about surface texture and developed geopolymer products.

3 Results and Discussion

3.1 Effect of GGBS based geopolymers on unconfined compressive strength

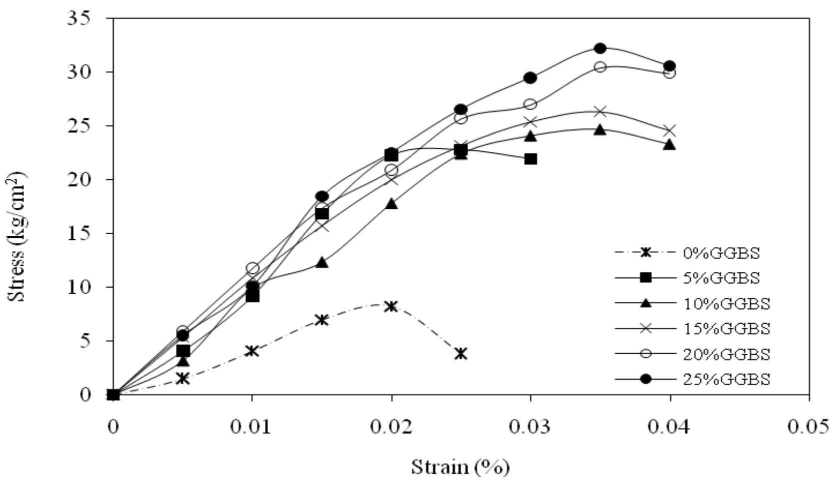


Fig. 1. Stress strain behavior of untreated clay and GGBS based geopolymer clays

The stress strain curves of the GGBS based geopolymer clay blends for different percentages of GGBS content in the blends are shown in Figure 1. It shows that, for a given strain, maximum axial compression stress increases with increasing precursor content. UCS values (kg/cm^2) of GGBS based geopolymer clay blends were 8.1, 22.8, 24.71, 26.33, 30.45 and 32.24 when GGBS content varied as 0%, 5%, 10%, 15%, 20% and 25% by dry weight of soil respectively. The results showed the enhancement of strength is due to the increasing precursor content, i.e. increasing Si/Al ratio.

3.2 Effect of GGBS based geopolymers and polypropylene fibers on split tensile strength

Table 2. Effect of GGBS and polypropylene on the split tensile strength

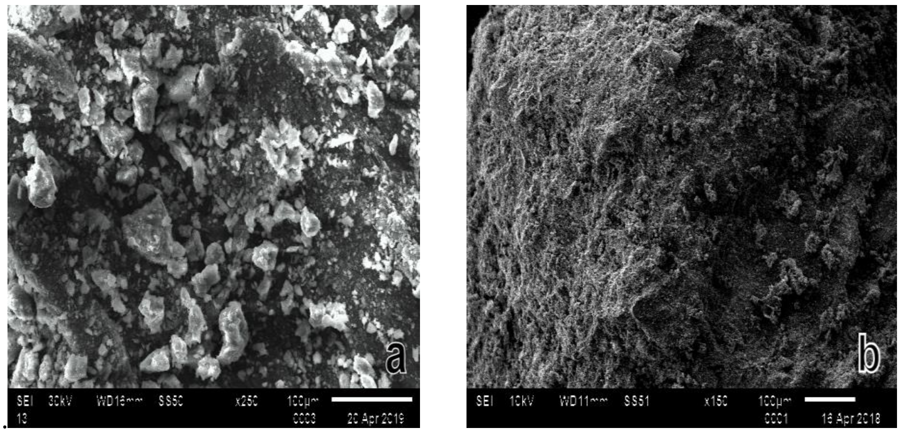
GGBS content	Split tensile strength (kg/cm^2) of geopolymer soil blends with varying polypropylene fiber content as					
	0%	0.2%	0.4%	0.6%	0.8%	1.0%
0%	0.58	0.65	2.15	3.08	4.75	3.65
15%	0.63	2.85	5.45	6.18	9.24	7.20
20%	0.88	3.20	7.22	8.64	11.18	9.15
25%	1.05	4.55	9.85	11.20	13.26	10.85

Split tensile strength results of the GGBS based geopolymer mixtures, with and without polypropylene fiber inclusion are shown in Table 2. It can be seen that, for a given precursor content, inclusion of polypropylene shows significant improvement in the tensile behavior. This effect is more evident in the higher percentage precursor 920% and 25% GGBS) blends. The fibers embedded in the dense geopolyme matrix contribute adhesion or internal friction between the fibers and geopolymer blends. The higher percentage of fines presence in the GGBS enhances dispersion of fibers in the geopolymer matrix.

3.3 Micro-analysis

Micrographs of GGBS based geopolymers shows that alkali-activators react with precursor, when GGBS was activated with 10M of NaOH. The micro-structure of the GGBS geopolymer clay blends at higher GGBS content (20% and 25%) clearly shows micro cracks and pockets on the surface does not effective on strength characteristics due to strong Si-O-Si bonds. Moreover, pockets on the surface are formed due to the higher concentration leaching of Al and Si oxides from GGBS by alkali dissolution (vide Figures 2c and 2d).

Figure 2a and 2b, by comparison, it was clearly evident that dense matrix was found when precursor is added (vide Figure 2b). Addition of precursor content to the geopolymer soils contributes the effective condensation and geopolymerization process. Further, allows formation of geopolymerization products (hydrates of Na-S-Al).



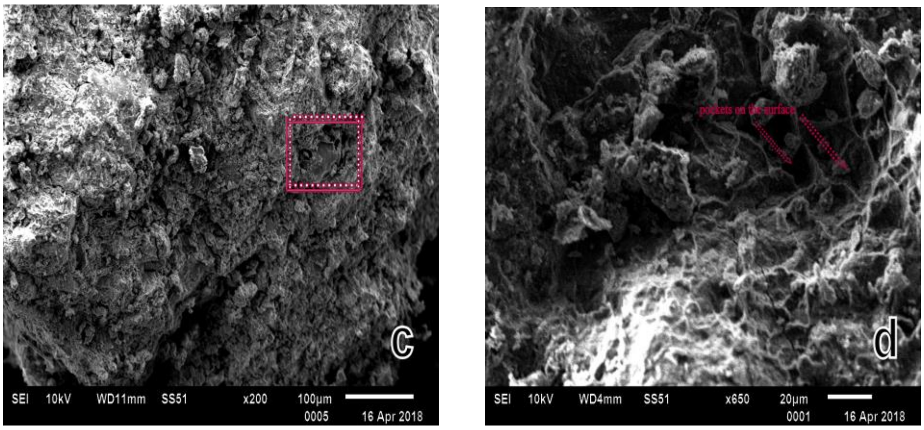


Fig. 2. SEM micrographs of GGBS geopolymer clay blends with varying GGBS content: a) 0% GGBS, b) 15% GGBS c) 20% GGBS d) 25% GGBS

4 Conclusions

Utilization of geopolymer soils in civil engineering infrastructure presents a sustainable opportunity by bulk utilization of industrial by-products. Previous studies on strength characteristics of geopolymer soils show positive results. Moreover, studies on flexural and tensile behavior of geopolymer soils were limited. This study provides effect of fibers on tensile behavior of expansive clays. The following conclusions were drawn from this work:

The UCS values of GGBS based geopolymers increased with increasing precursor content. Results also suggested that bulk utilization of GGBS is possible while using geopolymers (up to 25%).

Split tensile strength of the geopolymer clay blends were improved with increasing polypropylene fibers content up to 0.8%. SEM micrographs are helpful to explain the formation of geopolymer products.

Finally it can be concluded that inclusion of polypropylene fibers into the geopolymer clays can give scope for wide range of applicability.

References

1. Davidovits, J. (1989). Geopolymers and geopolymeric materials. *Journal of thermal analysis*, *35*(2), 429-441.
2. Kumar, A., & Gupta, D. (2016). Behavior of cement-stabilized fiber-reinforced pond ash, rice husk ash–soil mixtures. *Geotextiles and Geomembranes*, *44*(3), 466-474.
3. Kumar, A., Walia, B. S., & Bajaj, A.: Influence of fly ash, lime, and polyester fibers on compaction and strength properties of expansive soil. *Journal of materials in civil engineering*, *19*(3), 242-248 (2007).
4. Kumar, A., Walia, B. S., & Mohan, J. (2006). Compressive strength of fiber reinforced highly compressible clay. *Construction and building materials*, *20*(10), 1063-1068.

5. Pan, Z., Sanjayan, J. G., & Rangan, B. V. (2011). Fracture properties of geopolymer paste and concrete. *Magazine of concrete research*, *63*(10), 763-771.
6. Prabakar, J., & Sridhar, R. S. (2002). Effect of random inclusion of sisal fibre on strength behaviour of soil. *Construction and Building materials*, *16*(2), 123-131.
7. Phummiphan, I., Horpibulsuk, S., Sukmak, P., Chinkulkijniwat, A., Arulrajah, A., & Shen, S. L. (2016). Stabilisation of marginal lateritic soil using high calcium fly ash-based geopolymer. *Road Materials and Pavement Design*, *17*(4), 877-891.
8. Soltani, A., Deng, A., & Taheri, A. (2018). Swell–compression characteristics of a fiber–reinforced expansive soil. *Geotextiles and Geomembranes*, *46*(2), 183-189.
9. Suksiripattanapong, C., Kua, T. A., Arulrajah, A., Maghool, F., & Horpibulsuk, S. (2017). Strength and microstructure properties of spent coffee grounds stabilized with rice husk ash and slag geopolymers. *Construction and Building Materials*, *146*, 312-320.
10. Tang, C., Shi, B., Gao, W., Chen, F., & Cai, Y. (2007). Strength and mechanical behavior of short polypropylene fiber reinforced and cement stabilized clayey soil. *Geotextiles and Geomembranes*, *25*(3), 194-202.
11. Zhang, M., Guo, H., El-Korchi, T., Zhang, G., & Tao, M. (2013). Experimental feasibility study of geopolymer as the next-generation soil stabilizer. *Construction and Building Materials*, *47*, 1468-1478.