STRENGTH BEHAVIOUR OF COHESIVE SOIL-FLY ASH-WASTE TYRE MIXES

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ABSTRACT

Fly ash and tyre buffings are industrial waste by-products and can be mixed with local soils available near the construction sites, as an effective means of disposal and utilization without adversely affecting the environment. Due to their widespread availability, they are finding increasing use in geotechnical applications. Laboratory investigation is necessary to determine the engineering properties of the new soil mixes. In the present investigation, fly ash and waste tyre rubber fibers have been chosen as additive and reinforcement materials respectively to modify a cohesive soil at four different percentages of fly ash content and at three different percentages of fiber content. The study focuses on the strength behaviour of the soil mixtures determined through triaxial shear tests.

Key words: Soil modification, Fly ash, Tyre buffing, Strength

1. INTRODUCTION

Rapid urbanization and industrialization requires various types of civil engineering infrastructure and facility services. At present, for various types of constructions, engineers are forced to utilize problematic soft ground sites. The characteristics of soft ground are low strength, instability and high settlement. Soil modification by treating soft soil with various types of industrial waste by-products and a suitable binder is an attractive alternative and often economical compared to other ground improvement method.

The combustion of coal is used throughout the world to raise steam for power generation. About 80-90% of the ash formed from the burnt coal is carried out of the furnace, extracted from the flue gas and is known as fly ash. Bulk use of fly ash or fly ash-soil mixtures is possible in geotechnical engineering applications such as construction of embankments, dams, back-fill material behind retaining walls, base or sub-base material and land fill reclamation [1]**.** The advantages of using fly ash in geotechnical applications are its low unit weight, high shear strength [2], low compressibility, low specific gravity [3], insensitivity to moisture variation and pozzolanic nature [4], which could result in significant engineering benefits in addition to facilitating mass disposal of fly ash. The effectiveness and economy of using fly ash has been explored by researchers.

The volume of used rubber auto tyres in the developing countries is increasing every year and therefore, their disposal becomes a major environmental problem worldwide. Scrap tyres represent one of several special wastes that are difficult for municipalities to handle. Tyre buffings, obtained from waste tyres, are a by-product of the tyre retread process. The fibrous shape of tyre buffings, as well as their high strength and extensibility, make them ideal reinforcement elements for soils. Tyre buffings are used as an additive for the modification of the soil properties [5, 6, 7 and 8]**.**

In this study, fly ash and waste tyre rubber fibers were used to modify the clayey soil at four different percentages of fly ash content (0%, 20%, 35%, 50%) and at three different percentages of fiber content (0%, 5%, 10%). The main objective of this study is to evaluate the effects of waste tyre rubber fibers on the strength parameters of a cohesive soil. The data of shear strength parameters (c and ϕ) were obtained from the laboratory consolidated drained triaxial tests.

2. METHODOLOGY

Materials

Three types of materials were used in this experimental investigation, i.e., cohesive soil, fly ash and tyre buffings.

The cohesive soil is a reddish soil (RS) obtained from a nearby hill. The liquid limit and plastic limit of the soil are 46% and 28% respectively. Grain size distribution test results indicate that only 20% of the soil is clay (finer than 2 μm) with 57% silt and the remainder being sand. It is a normal active clay (activity is 0.9) and has a specific gravity of 2.61. According to Unified Soil Classification System, the soil can be classified as MI-type soil (clayey silts of medium compressibility). At standard compactive effort, the maximum dry unit weight (MDD) is 16.5 kN/m^3 and the optimum water content (OMC) is 20.3%.

The fly ash (FA) was collected from electrostatic precipitator of the Farakka thermal power station in West Bengal. The fly ash obtained from this plant has low free lime (CaO) content (≈1% by weight). It is a class F (siliceous) fly ash and has a specific gravity of 2.13. The fly ash is non-plastic and can be classified as non-plastic silts. At standard compactive effort, the MDD is 13.7 kN/m^3 and the OMC is 19.7%.

Tire buffings (TB) are by-products of the tire retread process. In this study, their specific gravity was found to be 1.05. The water absorption capacity was found to be 4% by weight. In order to prevent size effects, only tire buffings retained between 4.75 mm and 2 mm size sieves were used (see Fig. 1). In addition, tire buffings retained between these sieves were visually inspected prior to sample preparation and fibers with lengths greater than 25 mm (which were few in number) were removed. Hereafter, these tire buffings are referred to as "rubber fibers."

Testing Program

The clayey soil was dried and then ground before using in the mixtures. At first the required amounts of RS, FA and TB were blended together under dry conditions. The contents of fly ash were chosen as 0, 20, 35 and 50% by total weight of dry mix. The contents of waste tyre rubber fibers were chosen as 0, 5 and 10% by total weight of dry mix. As the fibers tended to lump together, considerable care and time were spent to get a homogeneous distribution of the fibers in the mixtures. The mix RS+35FA+5TB represents RS mixed with 35% FA and 5% TB by total weight of dry mix. Then all the test specimens were compacted at their respective MDD and OMC, corresponding to the values obtained in the Standard Proctor Compaction Tests. After each specimen (38 mm dia and 76 mm length) was extracted from the cylindrical samplers, it was wrapped in plastic to prevent from water loss. The specimens were kept in the desiccators at room temperature and constant relative humidity during the curing periods (3, 7, 14 and 28 days).

In order to determine the shear strength parameters (c and ϕ) of the as compacted samples of soil, soil-fly ash mixes and soil-fly ash-rubber fibers mixes, several series of consolidated drained (CD) triaxial shear tests at confining stresses of 100, 200, 300 and 400 kPa and deformation rate of 0.24 mm/min were carried out in accordance with Indian Standards. The specimens were not saturated before testing. Deviatoric stresses were recorded as a function of axial deformation up to total deformation of 16 mm.

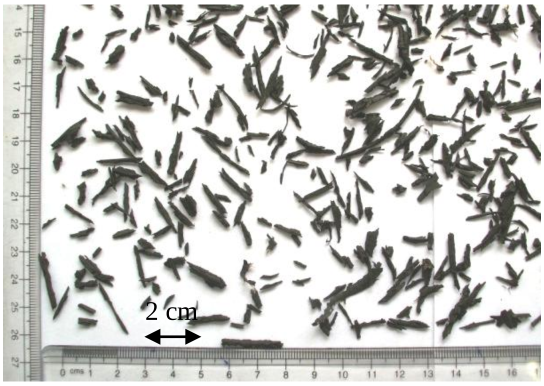

Figure 1: Rubber fibers used (retained between 4.75 and 2 mm size sieves)

3. RESULTS

The deviatoric stress (σ_1-σ_3) with axial strain curves were obtained from the tests for clayey soil, clayey soil-fly ash mixes with the rubber fiber contents of 0, 5 and 10% at confining stresses (σ_3) of 100-400 kPa. The deviatoric stress with axial strain curves for RS+35FA mix at 7 days curing period with different rubber fiber contents are shown in Figures 2-4. It is seen that initial stiffness at the same confining stress for soil-fly ash-fiber mix is less than the soil-fly ash mix. Therefore addition of rubber fiber to soil and soil-fly ash mix affects the initial stiffness of the clayey soil and clayey soil mix.

It is also observed that the peak shear stresses are affected by the fiber contents. The variation of peak deviatoric stress with confining stress for RS+35FA+tyre buffings mixes at 7 days curing is shown in Fig. 5. Fig. 6 shows the p-q [$p=(\sigma_1+\sigma_3)_f/2$, $p=(\sigma_1-\sigma_3)_f/2$] plots for RS+35FA+ tyre buffings mixes at 7 days, where $(\sigma_1-\sigma_3)_f$ represents peak deviatoric stress. The values of drained cohesion (c_d) and drained internal friction angle (ϕ_d) were obtained from the p-q plots.

The variation of c_d and ϕ_d with curing in CD triaxial tests for RS+fly ash+5TB and RS+fly ash +10TB mixes are shown in Figures 7-10 respectively. The values of c_d and ϕ_d for clayey soil, clayey soil-fly ash mixes with the rubber fiber contents obtained from tests showed that the addition of amount of rubber fiber have the significant influence on the development of cohesion and internal friction angle. The variation of cohesion and internal friction angle with percentage of rubber fiber content is random.

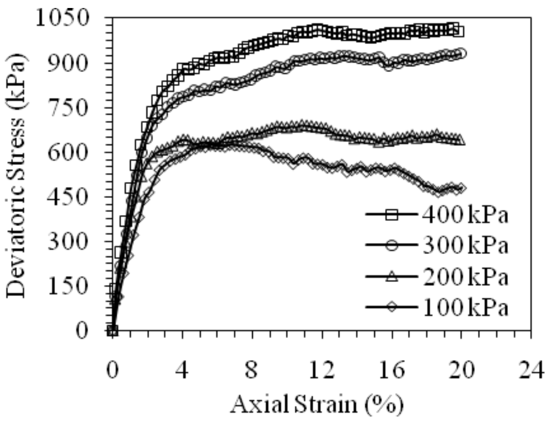

Figure 2: Deviatoric stress-axial strain plots for RS+35FA mix at 7 days curing

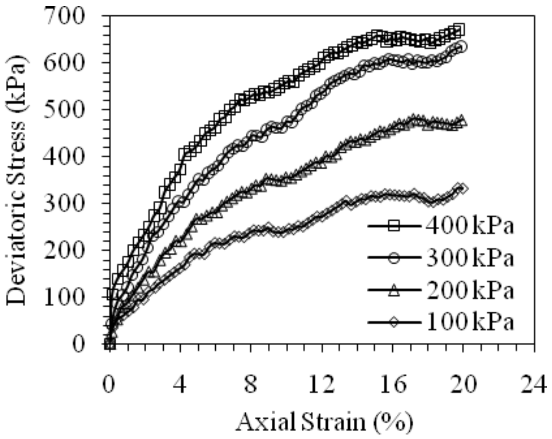

Figure 3: Deviatoric stress-axial strain plots for RS+35FA+5TB mix at 7 days curing

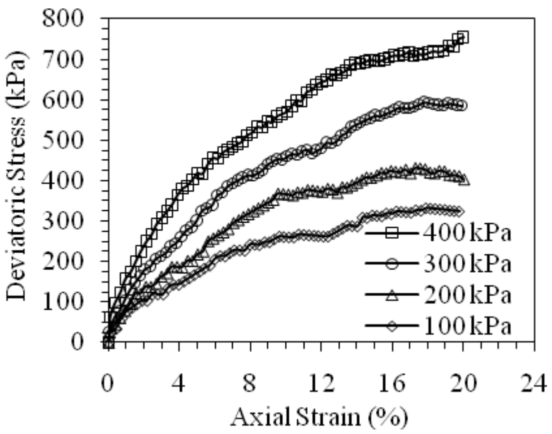

Figure 4: Deviatoric stress-axial strain plots for RS+35FA+10TB mix at 7 days curing

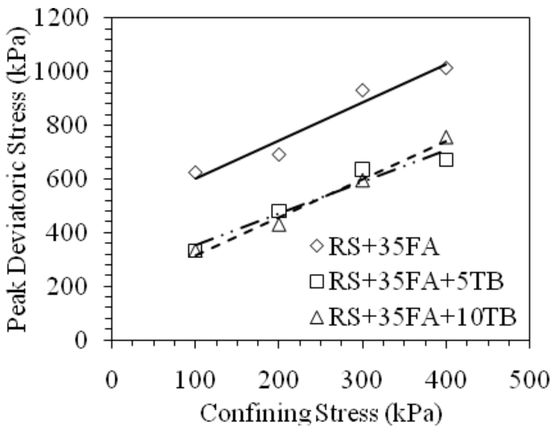

Figure 5: Peak deviatoric stress-confining stress plots for RS+35FA+tyre buffings mixes at 7 days curing

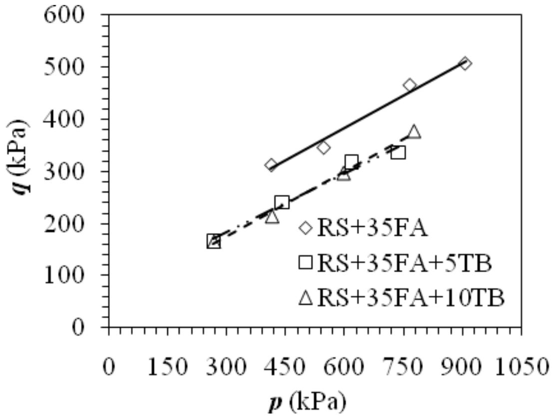

Figure 6: *p*-*q* plots for RS+35FA+tyre buffings mixes at 7 days curing

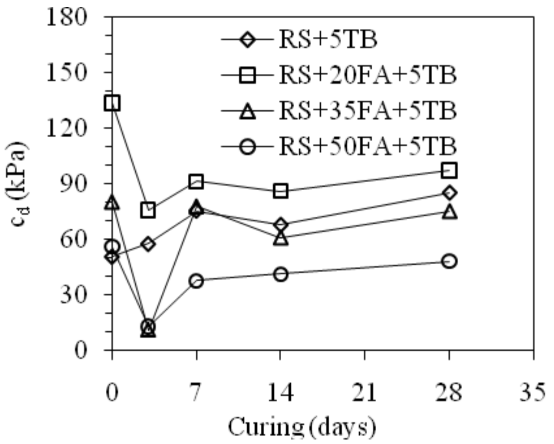

Figure 7: Variation of c_d with curing for RS+fly ash+5TB mixes

Figures 7-10 indicate that with the increase in fly ash content in clayey soil-fly ash and clayey soil-fly ash-fiber mixes, the cohesion decreases and internal friction angle increases. This reveals that rubber fibers have more effect on low plastic soil.

Tests were conducted at different curing periods to study the influence of curing periods on strength development. The results show that the strength variation is random.

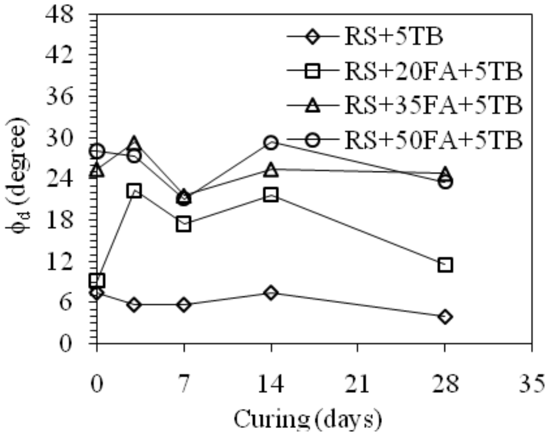

Figure 8: Variation of ϕ_d with curing for RS+fly ash+5TB mixes

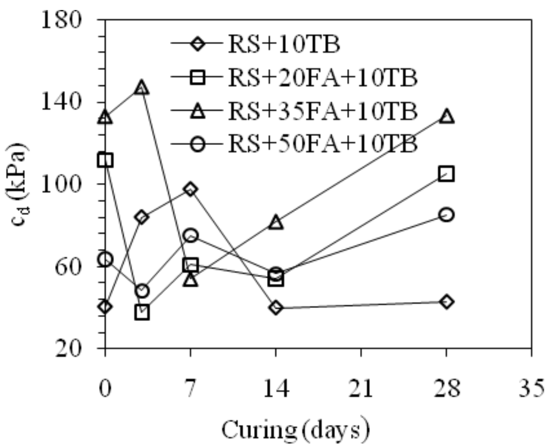

Figure 9: Variation of c_d with curing for RS+fly ash+10TB mixes

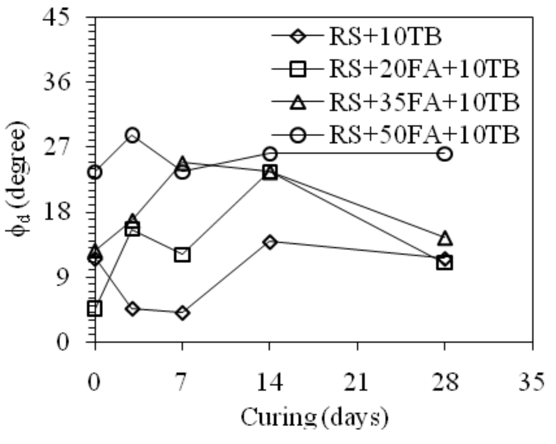

Figure 10: Variation of ϕ_d with curing RS+fly ash+10TB mixes

4. CONCLUSIONS

Due to addition of rubber fibers, the deformation behaviour of the clayey soil-fly ash mix changes significantly and becomes ductile. The dry density of the clayey soil-fly ash-rubber fiber mixtures are less than the dry density of clayey soil and clayey soil-fly ash mixes. The results also indicate that the presence of rubber fibers reduces the strength of clayey soil and clayey soil-fly ash mixes.

Compared to that of the soil, soil-fly ash mixes are lighter and possess higher strength. They can be used for embankments construction and bulk filling applications.

Clayey soil-fly ash-tyre buffings mixes are still lighter, but the strength is lower than that of the clayey soil-fly ash mixes. These mixes can be used in landfills as daily covers and in trench filling for various utility lines.

5. REFERENCES

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