

TRIAXIAL COMPRESSION BEHAVIOUR OF COHESIVE SOIL MIXED WITH FLY ASH AND WASTE TYRE FIBRES

Tapas Das,

Former PG Student, Department of Civil Engineering, Indian Institute of Technology Guwahati,
Guwahati - 781039, Assam, INDIA

Email: d.tapas@alumni.iitg.ernet.in

Baleshwar Singh,

Associate Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati,
Guwahati - 781039, Assam, INDIA

Email: baleshwar@iitg.ernet.in

Abstract

Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. Tyre buffing is a by-product of waste auto tyres and is elongated in shape and can be utilised as fibre reinforcement elements. They can be mixed with local soils available near the construction sites to create a new soil mix, as an effective means of disposal and utilization without adversely affecting the environment. Laboratory investigation is necessary to determine the engineering properties of the new soil mixes.

In the present investigation, the influence of randomly oriented tyre buffings on the triaxial compression behaviour of clayey soil-fly ash mixes has been studied. A Class F fly ash and waste car tyre fibres were added as additive and reinforcement material to a clayey silt soil. Compacted specimens were prepared at the corresponding optimum moisture content and maximum dry density, and then cured for different durations.

The results indicate that the stress-strain relationship and ductility of the specimens are substantially affected by the inclusion of the two waste materials. When fly ash alone is added to the soil, the stiffness and peak strength increase whereas ductility is reduced. When tyre fibres are added to the soil-fly ash mixes, strength decreases and the behaviour changes to a ductile one. A mass of 35% fly ash content and 10% tyre fibres content are considered to be the optimum for blending with the soil. The use of fly ash and waste tyres along with fine-grained soils in geotechnical projects will increase the recycled volume, and will reduce the environmental impact.

Keywords: Soil modification, fly ash, tyre buffings, triaxial compression

1. Introduction

The characteristics of soft ground are low shear 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 methods.

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 (Joshi and Nagaraj 1985). The advantages of using fly ash in geotechnical applications are its low unit weight, high shear strength (Sridharan et al. 1998), low compressibility, low specific gravity (Pandian et al. 1998), insensitivity to moisture variation and pozzolanic nature (Sivapullaiah et al. 1998), 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 (Cetin et al. 2006; Ozkul and Baykal 2006; Akbulut et al. 2007; Edinçliler and Ayhan 2010).

In this study, fly ash and waste tyre rubber fibres were used to modify a cohesive soil at four different percentages of fly ash content (0%, 20%, 35%, 50% by total weight of dry mix) and at three different percentages of fiber content (0%, 5%, 10% by total weight of dry mix). The main objective of this study is to evaluate the effects of waste tyre rubber fibres on the strength parameters of a cohesive soil mixed with fly ash. The data of shear strength parameters were obtained from the laboratory triaxial compression tests on compacted specimens.

2. Methodology

2.1 Materials

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

The cohesive soil is a reddish clayey silt (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% silts 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 16.7 kN/m^3 and the optimum water content (OMC) is 20.6%.

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 ($\approx 1\%$ 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 13.6 kN/m^3 and the OMC is 19.4%.

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 (Figure 1). In addition, tire buffings retained between these sieves were visually inspected prior to sample preparation and fibres with lengths greater than 25 mm (which were few in number) were removed. Hereafter, these tire buffings are referred to as “rubber fibres”.



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

2.2 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 fibres were chosen as 0, 5 and 10% by total weight of dry mix. The dry mix was mixed with the required amount of water based on OMC, considerable care and time required to get a

homogeneous distribution of the fibres 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 diameter and 76 mm length) was extracted from the cylindrical samplers, it was wrapped in plastic to prevent water loss. The specimens were kept in the desiccators at room temperature and constant relative humidity during the curing periods (14 and 28 days).

In order to determine the shear strength parameters, total cohesion (c) and total angle of shearing resistance (ϕ) of the as compacted (unsaturated) specimens of soil, soil-fly ash mixes and soil-fly ash-rubber fibres mixes, several series of triaxial compression tests at confining stresses (σ_3) of 100, 200, 300 and 400 kPa and axial strain rate of 0.316% per min were carried out in accordance with Indian Standards (IS 2720 (Part XII)-1981). The specimens were not saturated before testing. The specimens were isotropically consolidated to the desired confining stresses for a period of time ranging from 30 to 35 min. Triaxial compression (shearing) was then performed on each unsaturated specimen keeping drainage valve open. Deviatoric stresses ($\sigma_1 - \sigma_3$) were recorded as a function of axial deformation up to a total deformation of 16 mm.

3. Results

The deviatoric stress with axial strain curves were obtained from the tests for clayey soil and clayey soil-fly ash mixes with the rubber fibre contents of 0, 5 and 10% at confining stresses of 100-400 kPa. Figure 2 shows the deviatoric stress-axial strain plots for RS at 0 days curing period i.e. immediately after preparation of specimens. The deviatoric stress-axial strain plots for RS+35FA mix at 0 days curing period, with different rubber fibre contents are shown in Figures 3-5. It is seen that the initial stiffness at the same confining stress for soil-fly ash mix is higher than the soil and the soil-fly ash mix is less ductile. On the other hand, the initial stiffness at the same confining stress for soil-fly ash-rubber fibre mix is less than the soil-fly ash mix and the soil-fly ash-rubber fibre mix is more ductile. Therefore addition of rubber fibre to clayey soil-fly ash mix affects the initial stiffness and ductility of the clayey soil mix.

It is also observed that the peak shear stresses are affected by the fibre contents. The variations of peak deviatoric stress with confining stress for RS+fly ash+rubber fibres mixes at 0, 14 and 28 days curing are shown in Figures 6-8 respectively. The peak deviatoric stress of soil increases significantly with the addition of fly ash. On the other hand, the peak deviatoric stress of soil-fly ash mix decreases with the addition of rubber fibres and continues to decrease with increase in fibre content. Figure 9 shows the p-q [$p = (\sigma_1 + \sigma_3)/2$, $q = (\sigma_1 - \sigma_3)/2$] plots for RS and RS+35FA+rubber fibres mixes at 0 days, where $(\sigma_1 - \sigma_3)_f$ represents peak deviatoric stress. The values of total cohesion and internal friction angle, (c and ϕ) were obtained from the p-q plots.

The variation of c and ϕ with curing in triaxial compression tests for RS+ fly ash+rubber fibres mixes are shown in Figures 10 and 11 respectively. The values of c and ϕ for clayey soil-fly ash mix with the rubber fibre contents obtained from tests show that the addition of amount of

rubber fibre has the significant influence on the development of cohesion and internal friction angle. Table 1 refers the c and ϕ values of RS and RS+35FA+ rubber fibres at different curing periods. The cohesion of the rubber fibre added mixes are higher than that of soil-fly ash mix. The internal friction angle decreases with increase in percentage of rubber fibre content. The increase in cohesion and decrease in internal friction angle of clayey silt-fly ash-rubber fibres mixes are due to the compressibility (and/or extensibility) characteristics of rubber fibres and non uniform distribution of soil-fly ash-rubber fibre interfaces respectively.

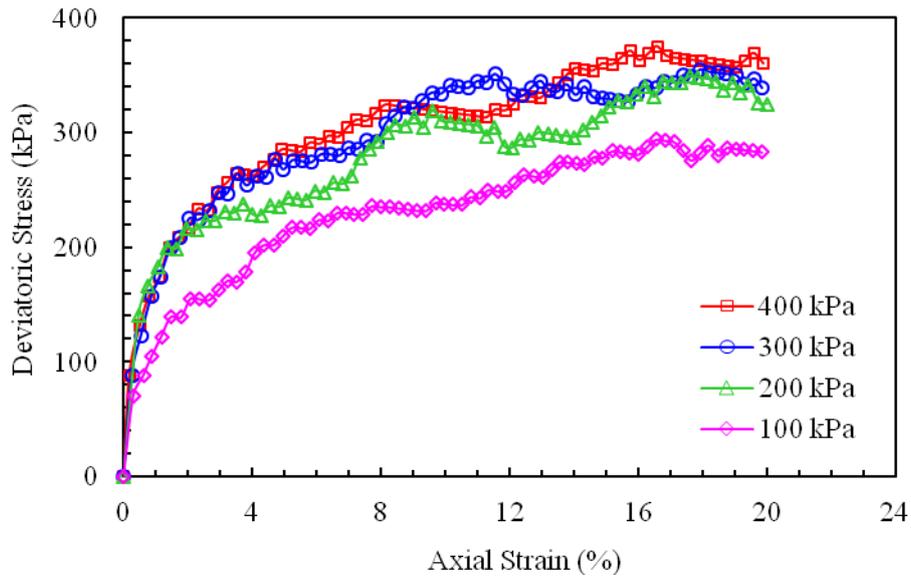


Figure 2: Deviatoric stress-axial strain plots for RS at 0 day curing

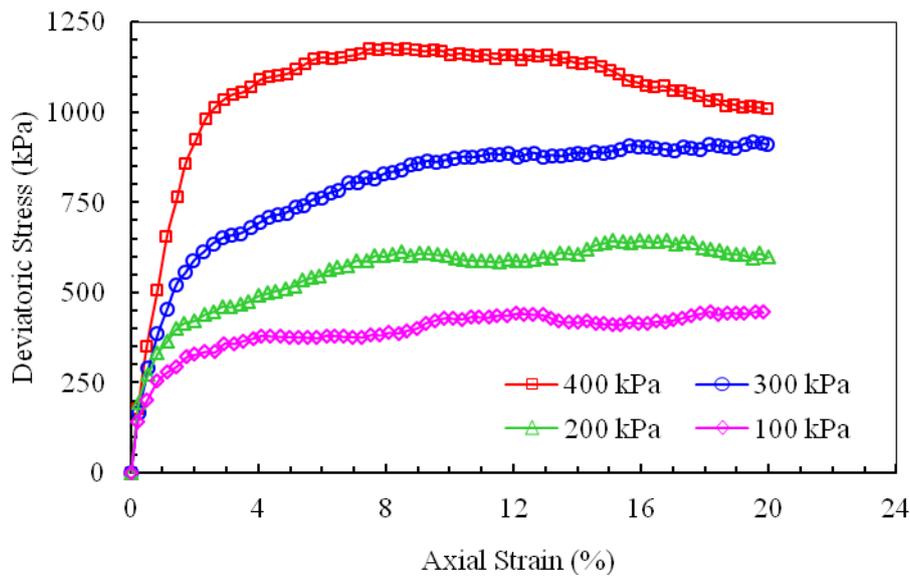


Figure 3: Deviatoric stress-axial strain plots for RS+35FA mix at 0 day curing

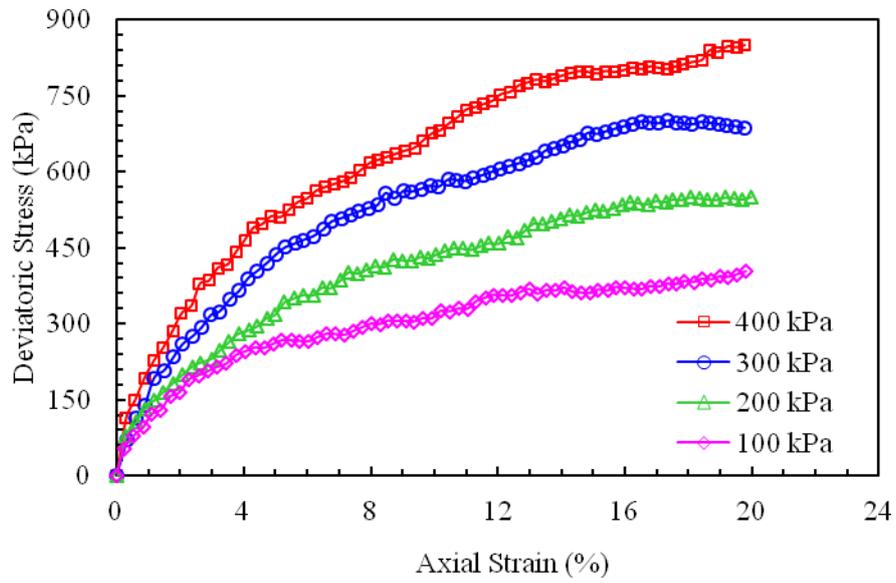


Figure 4: Deviatoric stress-axial strain plots for RS+35FA+5TB mix at 0 day curing

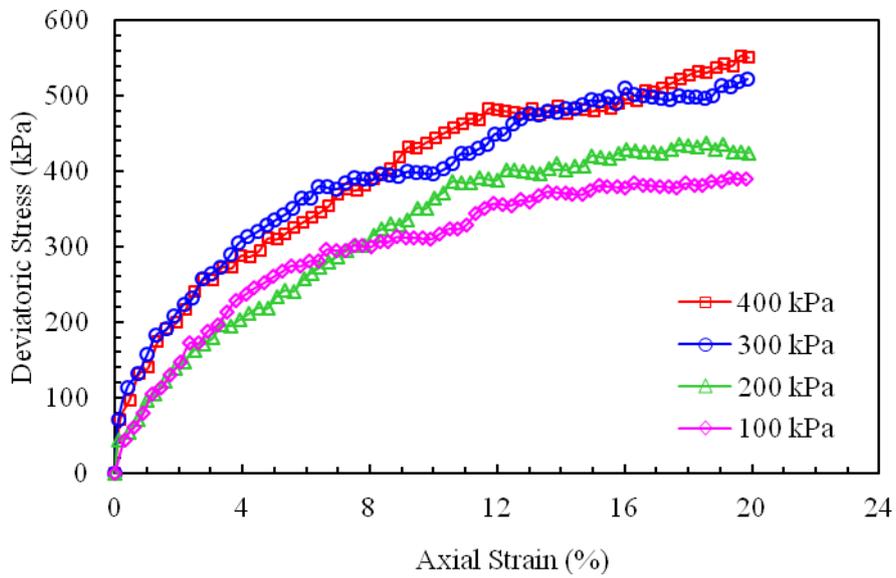


Figure 5: Deviatoric stress-axial strain plots for RS+35FA+10TB mix at 0 day curing

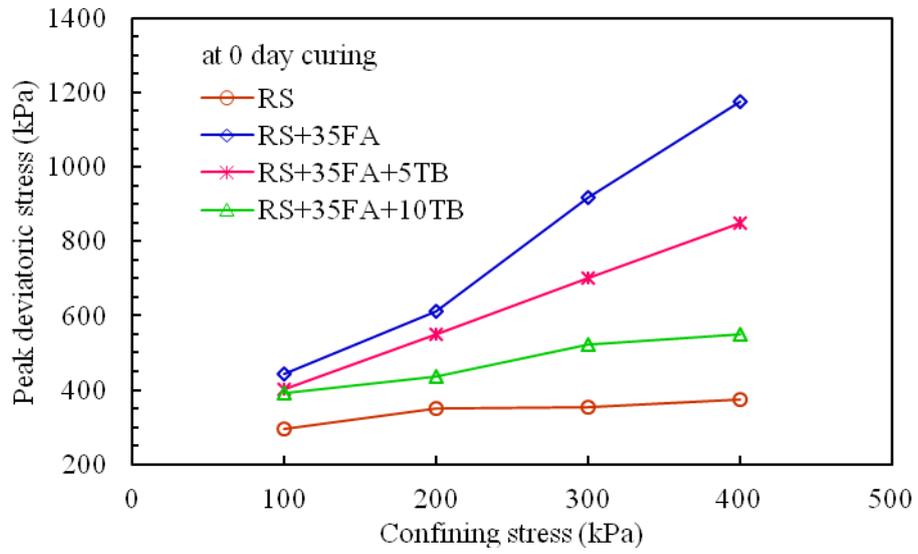


Figure 6: Peak deviatoric stress-confining stress plots for soil mixes at 0 day curing

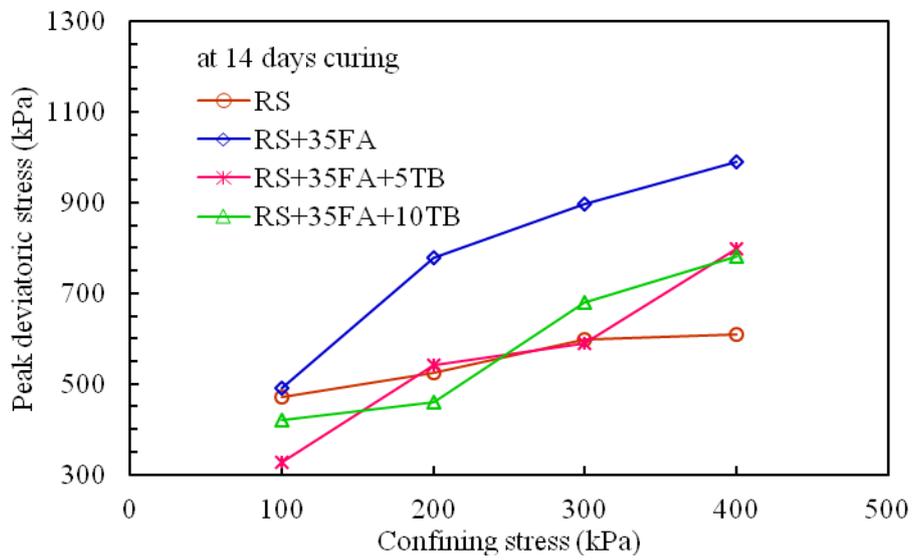


Figure 7: Peak deviatoric stress-confining stress plots for soil mixes at 14 day curing

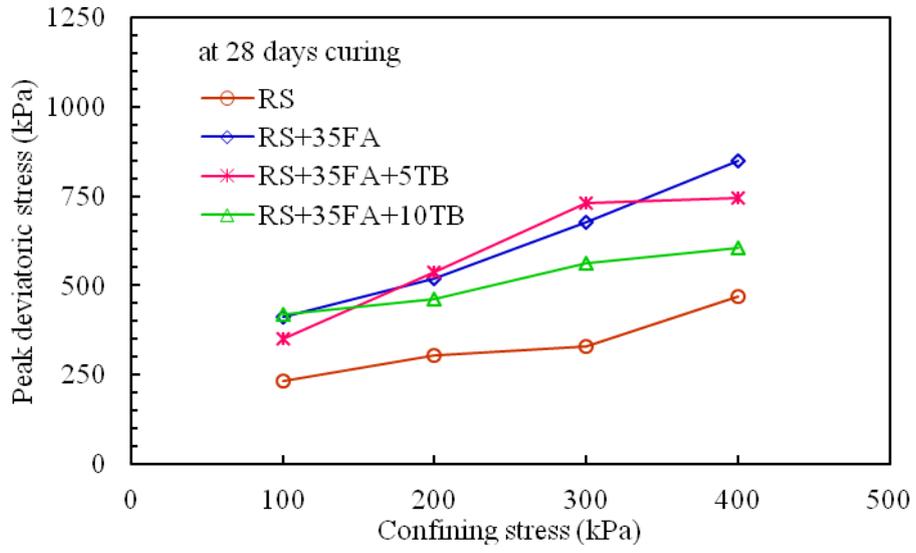


Figure 8: Peak deviatoric stress-confining stress plots for soil mixes at 28 day curing

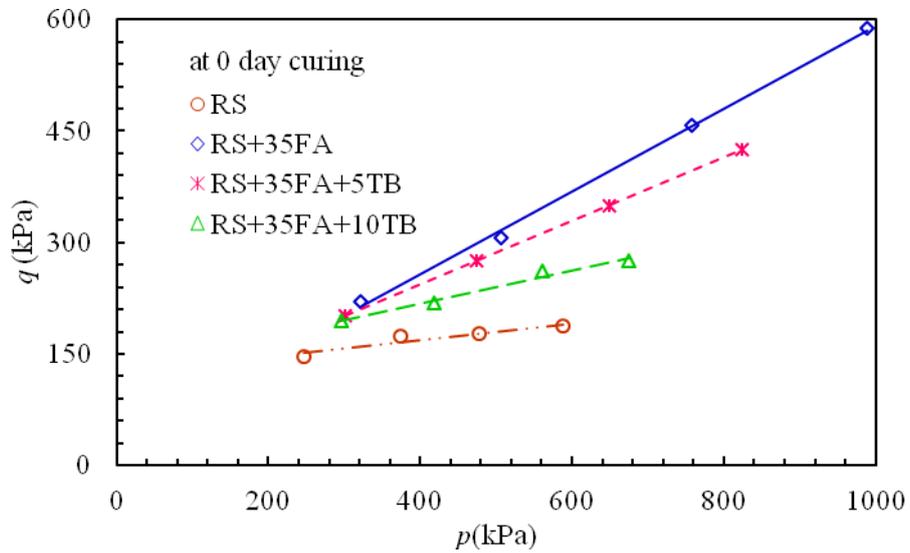


Figure 9: p-q plots for soil mixes at 0 day curing

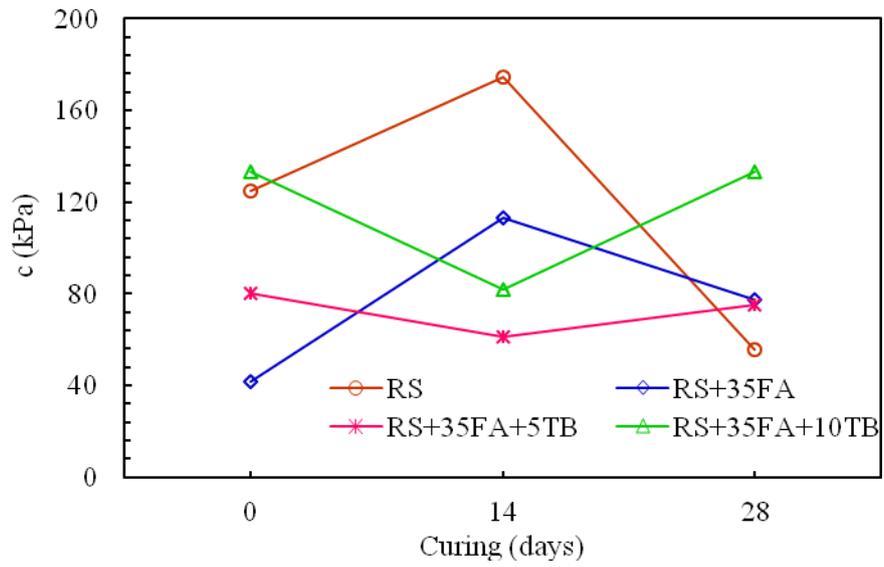


Figure 10: Variation of c with curing for soil mixes

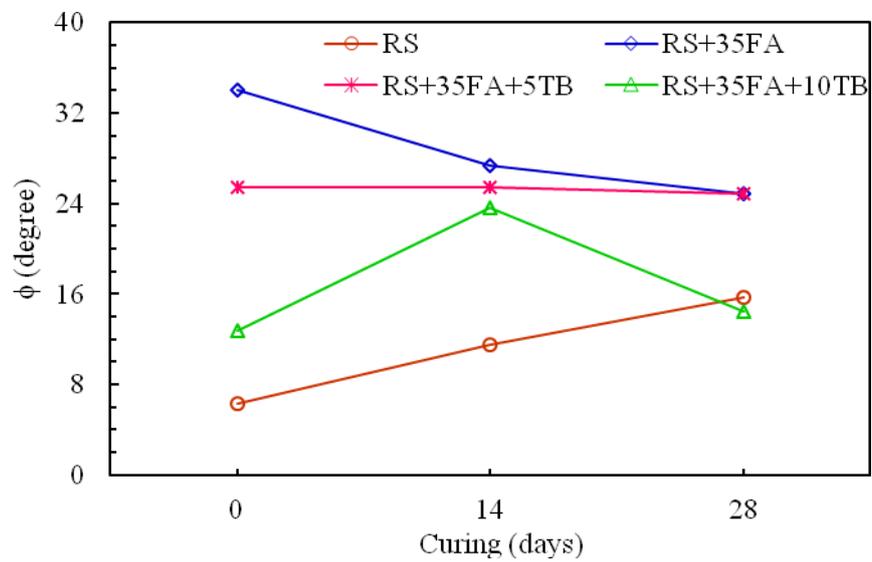


Figure 11: Variation of ϕ with curing for soil mixes

Table 1: Shear strength parameters (c and ϕ) of various mixes

Mix	c in kPa			ϕ in degree		
	0 day curing	14 days curing	28 days curing	0 day curing	14 days curing	28 days curing
RS	125	175	56	6.3	11.5	15.7
RS+35FA	42	113	77	34.1	27.4	24.8
RS+35FA+5TB	80	61	75	25.5	25.4	24.8
RS+35FA+10TB	133	82	133	12.7	23.6	14.5

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 scattered. The study reveals that the fly ash lacks in cementitious property and has not contributed to pozzolanic reactions. When clayey silts-fly ash-rubber fibres mixes were cured, no hardening took place during curing and did not result in strength gain.

4. Conclusions

On the basis of the experimental results, the following conclusions can be drawn.

Due to addition of rubber fibres, the deformation behaviour of the clayey soil-fly ash mix changes significantly and becomes ductile. The results indicate that the presence of rubber fibres reduces the shear strength of clayey soil-fly ash mix. The rubber fibres added clayey soil-fly ash mixes possess greater peak deviatoric stress at higher confining stress i.e. at 300 and 400 kPa.

At MDD and no curing (at 0 day curing), for inclusion of 5% rubber fibres content to the clayey soil mixed with 35% fly ash content, c increases by 190% and ϕ decreases by 75%. Whereas for inclusion of 10% rubber fibres content to the same mix, c increases by 317% and ϕ decreases by 37%. For addition of 35% fly ash content to clayey soil, there are a decrease in 66% of cohesion and an increase in 440% of angle of internal friction. The effect of curing on shear strength parameters (c and ϕ) is insignificant due to the noncementitious property of the fly ash.

Clayey soil-fly ash-rubber fibres mixes are lighter, but the strength is lower than that of the clayey soil-fly ash mix. These mixes can be used in landfills as daily covers and in trench filling for various utility lines. The results indicate that a mass of 10% rubber fibres is the best possible for blending with clayey silts mixed with 35% fly ash content.

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