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Comparison of Engineering Behavior of Silty Sand and Fibre-Reinforced Pond Ash

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ABSTRACT: This note presents the consequences of lab examinations led on silty sand and pond ash specimens built up with arbitrarily circulated polyester filaments. The test outcomes uncover that the incorporation of filaments in soils expands the pinnacle compressive strength, CBR esteem, top erosion point, and malleability of the examples. It is reasoned that the ideal fiber content for both silty sand and pond ash is approximately 0.3 to 0.4% of the dry unit weight.

1 INTRODUCTION

Reinforcement of soils with natural and synthetic fibres is potentially an effective technique for increasing soil strength. In recent years, this technique has been suggested for a variety of geotechnical applications ranging from retaining structures and earth embankments to subgrade stabilisation beneath footings and pavements (Gray et al. 1983). Inclusion of discrete synthetic fibres in soil is one adaptation of this technique. Mixing a predetermined amount of fibre, at a particular moisture content, gives a mesh- like configuration leading to a mechanical means for reinforcement of the soil matrix (Nataraj and McManis 1997).

Previous studies of sand reinforcement using fibre inclusions has been reported by Gray et al. (1983), Nataraj and McManis (1997), and Maher and Gray (1990). Similar studies for silty clay and clayey soils have been reported by Fletcher and Humphries (1991), Al Wahab and Al Quirma (1995), Nataraj and McManis (1997), and Maher and Ho (1964). However, the influence of fibre reinforcement on the engineering behaviour of pond ash has not yet been reported. Hence, the current note describes aspects of the engineering behaviour of pond ash and a locally available silty sand reinforced with dis- crete fibres.

2 EXPERIMENTAL PROGRAMME

The silty sand was collected locally and the pond ash was obtained from the Indra Prasta Thermal Power Plant, near New Delhi, India. The particle size distribution for each soil type is shown in Figures 1 and 2. The physical properties of the silty sand, pond ash, and fibres are given in Tables 1 and 2.

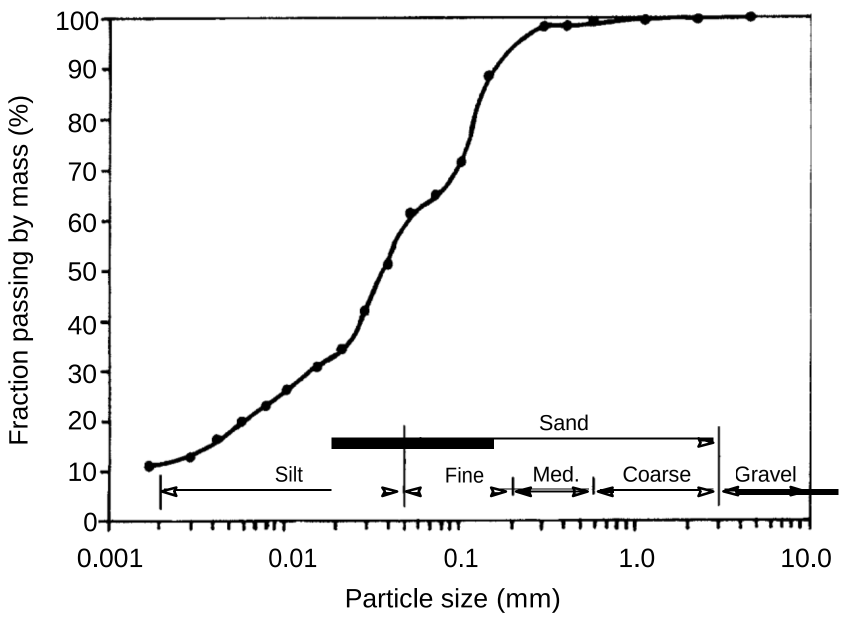

Figure 1. Particle size distribution for the silty sand.

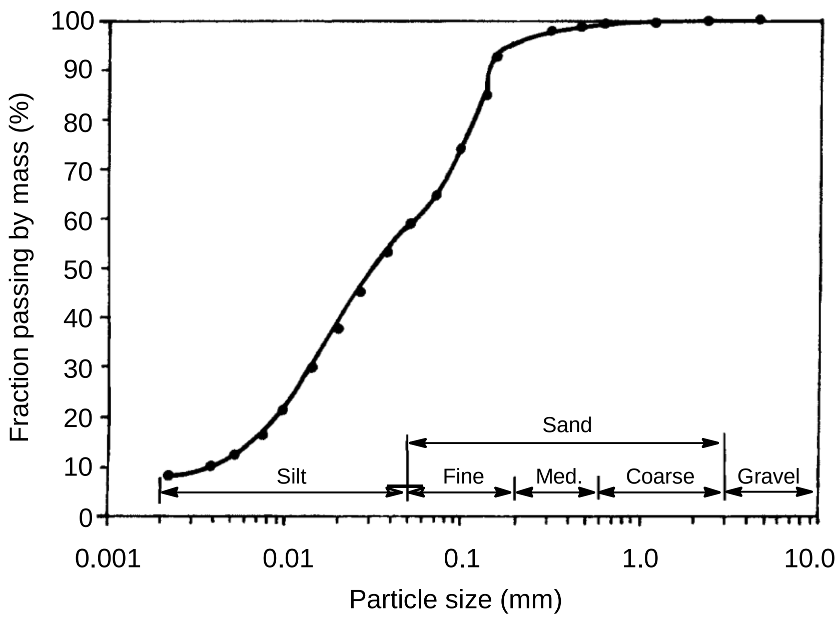

Figure 2. Particle size distribution for the pond ash.

Table 1. Physical properties of the silty sand and pond ash.

Soil	*c* (kPa)	φ (_)	γ_{max} (kN/m^3)	*OMC* (%)
Silty sand	63	32	19.1	9.2
Pond ash	16	37	11.6	26.0

Notes: c = soil cohesion; φ = peak friction angle of the soil; γ_{max} = maximum dry unit weight; *OMC* = optimum moisture content; C_u = coefficient of uniformity; C_c = coefficient of curvature.

Table 2. Physical properties of the polyester fibres.

Property	Value
Young's modulus	10,000 to 17,235 MPa
Specific gravity	1.38
Tensile strength	510 MPa
Water absorption	0
Fibre length	30 mm
Linear density	0.333 tex (3 denier)*

Note: * 1 denier = mass in grams per 9,000 m of fibre = 1.11×10^{-7} kg/m = 0.111 tex (1 tex = 1×10^{-6} kg/m).

The laboratory tests performed on the two soils, both reinforced and unreinforced, include compaction, unconfined compression, direct shear, and CBR tests. The fibre content ranged from 0.1 to 0.4% of the dry unit weight of the soil. With 0.4% fibre con- tent, the problem of balling occurred during soil compaction. The fibres were separated by hand before mixing in the soil. The required water was added to oven-dried soil in small increments and mixed by hand until uniform mixing of the fibres was ensured. All tests were carried out in accordance with the procedures prescribed in Indian Stan- dards (IS:2720). Three specimens were used for each type of test. The averaged results of triplicate specimens were used for the analysis.

3 ANALYSIS OF TEST RESULTS

Silty Sand

Compaction Tests

The relationship between the dry unit weight and moisture content of unreinforced and reinforced soil specimens was investigated using the procedure described in IS:2720 (Part 8). The relationship obtained for unreinforced and reinforced soil speci- mens (with fibre contents of 0.1, 0.2, 0.3, and 0.4%) are shown in Figure 3. Figure 3 indicates that, within the range of fibre content used in the current study, the relationship between the dry unit weight and moisture content does not differ significantly from that of unreinforced soil. However, a slight decrease in dry unit weight is observed with an increase of fibre content. Similar results have been reported by Maher and Ho (1964) Nataraj and McManis (1997).

Unconfined Compression Tests

Unconfined compression tests were performed on unreinforced and reinforced spec- imens according to IS:2720 (Part 2). Cylindrical specimens with a height to diameter ratio of 2 (100 mm high × 50 mm diameter) were compressed until failure. Triplicate specimens were tested for fibre contents of 0.0 to 0.4% and the test results, i.e. stress- strain relationships, are shown in Figure 4. These results show that the reinforcement increases the peak strength, as well as the strain to failure. The maximum increase in strain, approximately 80% higher than that for unreinforced soil, occurred at a fibre content of 0.3%. However, the increase in peak strength of the same soil is approximate- ly 28% higher than that of the unreinforced specimen. The specimens reinforced with 0.4% fibre content show nearly the same peak strength, but with a 35% decrease in stain. This may be due to the higher fibre content causing balling of fibres, resulting in poor mixing of the soil. Although fibre contents of 0.3 and 0.4% showed an increase in strength of approximately 28%, there was a marked difference in failure strains as shown in Figure 4.

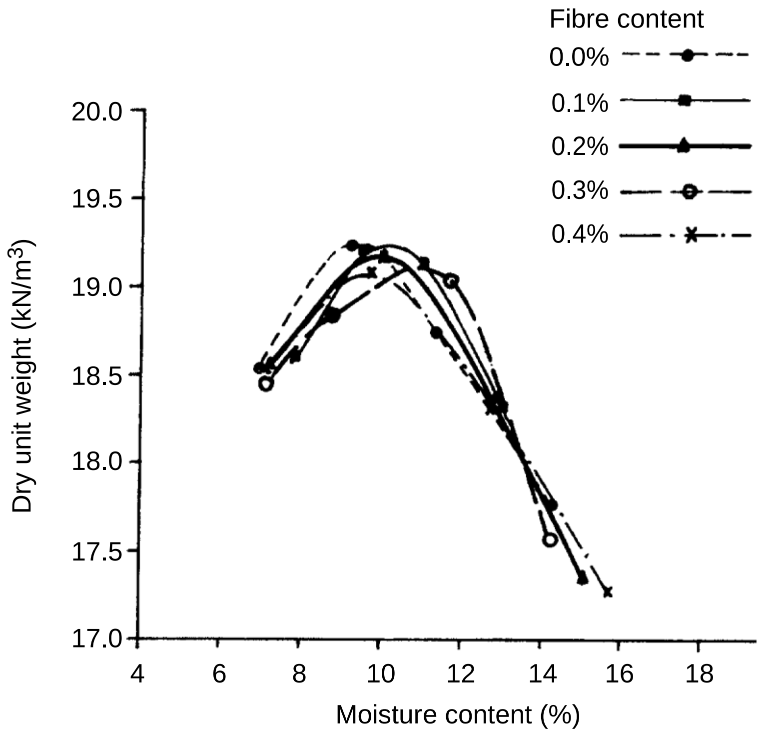

Figure 3. Compaction test results for fibre-reinforced and unreinforced silty sand specimens.

Direct Shear Tests

Specimens were tested in a 60 mm square shear box at normal stresses of 25 to 100 kPa and sheared at a rate of 1.25 mm/minute according to IS:2720 (Part 13). The resulting peak friction angle and cohesion values are given in Table 3.

Table 3. Peak friction angle and cohesion values versus fibre content for fibre-reinforced and unreinforced silty sand specimens.

Fibre content (%)	Peak friction angle (_)	Cohesion (kPa)
0.0	32	15
0.1	36	16
0.2	39	16
0.3	40	17
0.4	41	17

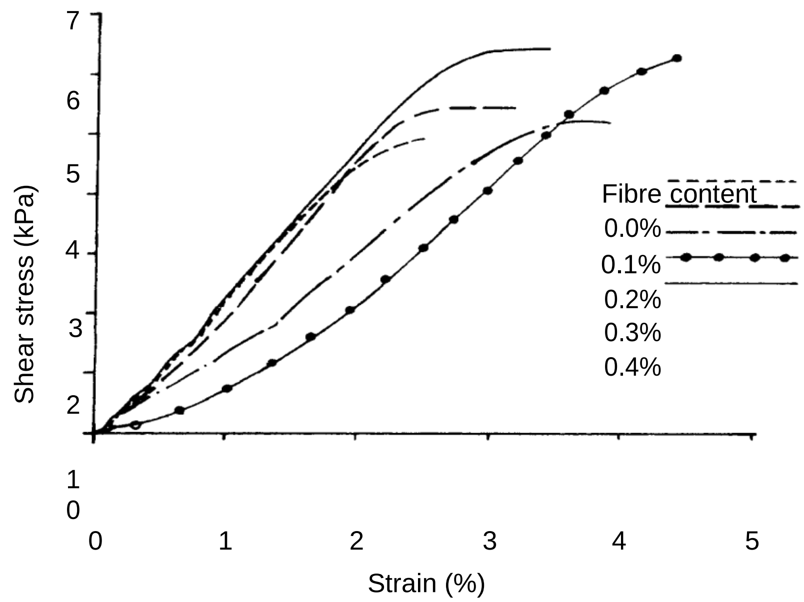

Figure 4. Unconfined compressive strengths for fibre-reinforced and unreinforced silty sand specimens.

The results in Table 3 suggest that both cohesion and friction angle values increase with increasing fibre content. The peak friction angle value is approximately 41_ with a 0.4% fibre content, which again is approximately 28% higher than that for the unreinforced specimens.

CBR Tests

Soaked California Bearing Ratio (CBR) tests were performed as described in IS:2720. The test results are given in Table 4 and indicate that reinforcement increases the CBR values for fibre contents of 0.3 and 0.4% by 28% compared to the unreinforced specimen.

Table 4. CBR values versus fibre content for fibre-reinforced and unreinforced silty sand specimens.

Fibre content (%)	CBR value (%)
0.0	21
0.1	22
0.2	24
0.3	27
0.4	27

Pond Ash

Compaction Tests

The compaction behaviour of pond ash specimens without and with fibre contents of 0.1, 0.2, 0.3, and 0.4% of the dry unit weight of the pond ash is shown in Figure 5. As can been seen, the effect of the reinforcement is insignificant.

Unconfined Compression Tests

The tests were carried out as for the silty sand, and the results are shown in Figure 6. It is apparent from Figure 6 that the reinforcement increases both peak stress and strain with increasing fibre content, consistently increasing the failure strain. The re- sults also show that the peak stress is a maximum for a 0.4% fibre content, with this increasing strength approximately threefold compared with unreinforced specimens.

Direct Shear Tests

The pond ash specimens were tested, as described in Section 3.1.3, and the peak friction angle and cohesion values obtained for the specimens tested are presented in Table 5.

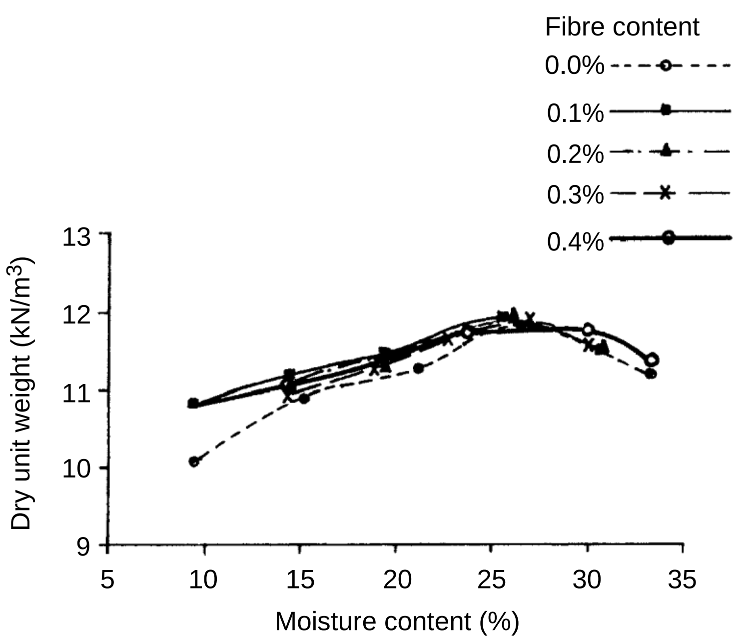

Figure 5. Compaction test results for fibre-reinforced and unreinforced pond ash specimens.

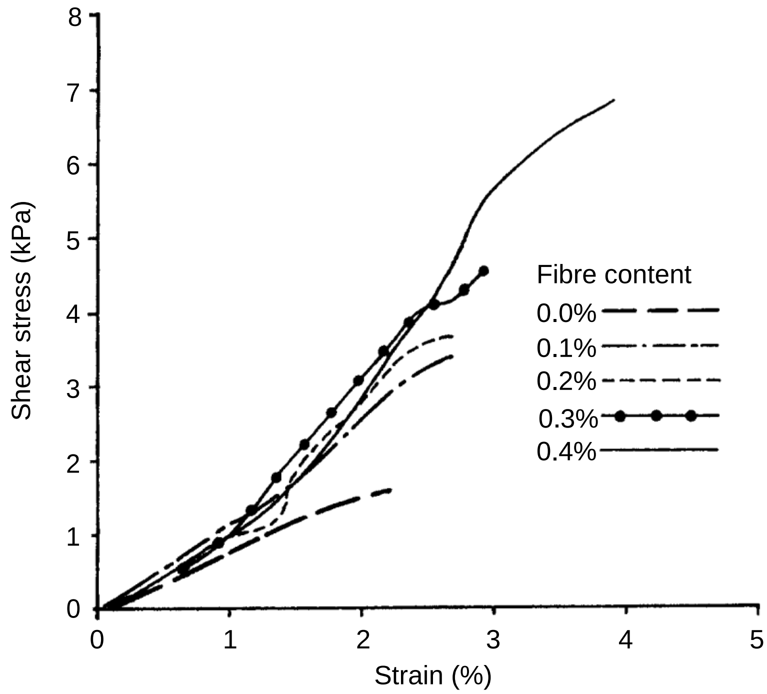

Figure 6. Unconfined compressive strengths for fibre-reinforced and unreinforced pond ash specimens.

Table 5. Peak friction angle and cohesion values versus fibre content for fibre-reinforced and unreinforced pond ash specimens.

Fibre content (%)	Peak friction angle (_)	Cohesion values (kPa)
0.0	37	16
0.1	38	22
0.2	40	25
0.3	43	26
0.4	43	27

The results suggest that peak friction angle and cohesion values increase with increasing fibre content, up to 0.3%, beyond which any increase in strength is insignificant. Hence, the optimum fibre content is between 0.3 and 0.4%.

CBR Tests

CBR tests were conducted as described in Section 3.1.4 and the results are given in Table 6.

Table 6. CBR values versus fibre content for fibre-reinforced and unreinforced pond ash specimens.

Fibre content (%)	CBR value (%)
0.0	5
0.1	6
0.2	6
0.3	6
0.4	9

Increases in measured CBR values were marginal for fibre contents up to 0.3%, how- ever, at 0.4% fibre content, the CBR value increased markedly to give an 80% increase in CBR compared to the unreinforced specimen.

4 CONCLUSIONS

The compaction characteristics of fibre-reinforced silty sand and pond ash do not differ significantly from unreinforced specimens, but fibre reinforcement, particularly at 0.3 to 0.4%, does significantly increase compressive strength and failure strain. Simi- larly, in the range of 0.3 to 0.4%, fibre reinforcement significantly increases peak fric- tion angle, cohesion, and CBR values.

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