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Effect of Using Rice Straw Fiber on Slope Stability of sand soil

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ABSTRACT

The objective of this research is to study experimentally the effect of rice straw fibers on slope stability. A sand box model was used to simulate the slope failure mechanism under reinforced and unreinforced soil using rice straw fibers. Analysis takes into account three factors; Slope angle (β), load edge distance from loading plate edge (X), and percentage of rice straw. Constant water contents were used in all experiments. Laboratory results showed that soil stress increases significantly by increasing the percentage of rice straw fibers up to 0.75% by weight of sand soil.

KEYWORDS: rice straw, settlement, slope stability, soil reinforcement.

1. INTRODUCTION

Slope resistance to failure due to loading on soil has become a problem threatening watercourses due to the weak nature of soil. Soil can often be regarded as a combination of four basic types: gravel, sand, clay, and silt. Soil has no tensile strength and has significant shear strength. Reinforcement of soil by incorporating materials such as fibers increases strength of soil [1]. Therefore, soil reinforcement is defined as a technique to improve the engineering characteristics of soil in order to develop the parameters such as shear strength, compressibility, density, and hydraulic conductivity [2].

The primary purpose of reinforcing soil is to improve its stability, to increase its bearing capacity, and to reduce settlement and lateral deformation [3-5]. The concept of earth reinforcement with natural fiber materials has been originated in the past. Date palm fibers, wood, bamboo and animal's skin have been used for improvement of bricks mechanical properties and increase in foundation bearing capacity. Natural fibers such as Kenaf, Coir, Banana, Jute, Flax, Sisal, Palm, Reed, Bamboo and Wood fibers have been used for improvement of soil mechanical properties.

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Fibers have been used to increase tensile, compression, and shear strength of soil. Fibers have been also used to prevent soil erosion in canal's slope and shorelines and to reinforce embankment. Fiber reinforcement helps grow plant on slopes, application in asphalt covers, increase of bearing in clay soil, application in unpaved roads …. etc. The advantages of natural fibers in comparison with metal and polymer materials are unpollution, availability, and cost-effectiveness [6].

Prabakar and Siridihar used 0.25%, 0.5%, 0.75%, and 1% of sisal fibers by weight of raw soil with four different lengths of 10, 15, 20, and 25 mm to reinforce soil. It was observed that, As sisal fiber content increase, The shear strength increase till 0.75% then decrease. It was concluded that fiber length has an effect on shear stress. The shear stress is increased nonlinearly with the increase in length of fiber up to 20 mm [7]. Ravishankar and Raghavanthey used coir fiber to reinforce soil and it was found that the compressive strength of the composite soil increases up to 1% of coir content and further increase in coir quantity results in reduction of the values [8]. Ahmad et al used palm fibers to reinforce silty sand. Specimens with 0.25% and 0.5% content of palm fibers of different lengths were used. It was concluded that silty sand with 0.5% coated fibers of 30 mm length gives 25% increase in friction angle and 35% in cohesion compared to those of unreinforced silty sand [9]. Abtahi et al. found that barley straw fibers are most effective on the shear strength of the soil than Kenaf fibers and the optimum content of barley straw was 1% [10]. Anusha R., Emmanual C. Kindo found that using bamboo as soil reinforcement increased unconfined compressive strength by 175% compared with the unreinforced soil [11]. P.G. Greeshma and Mariamma Joseph used samples prepared with rice straw fibers of random length added in percentages of 0.25, 0.50, 0.75 and 1%. They concluded that the unconfined compressive strength of soil reinforced with 0.5% rice straw of random length gave an increase of 1.94 that of unreinforced soil [6].

In this research, Rice straw fibers were used as soil reinforcement. Rice straw (R.S) was chosen because of its availability in Egypt. Egypt is a highly successful producer of rice with average yield of more than 9.5 t ha-1 in

Fig. 1 Burning Rice Straw in Ad-Daqahliyah, Egypt September 2014

2005/06 [12]. Fig. 1 shows that Rice straw is still burnt in Egypt till now.

2. EXPRIMENTAL WORK

2.1. Materials

The materials used for this study were sand soil and rice straw fibers.

2.1.1. Soil

Air dried sand soil was used in this study and its properties are given in Table 1.

Optimum moisture Content (%)	9.00
Maximum dry density ($kg.cm^{-3}$)	$1.73x10^{-3}$
Minimum density($kg.cm^{-3}$)	$1.48x10^{-3}$
Relative density ($kg.cm^{-3}$)	$1.62x10^{-3}$
Angel of internal friction	32.49˚

2.1.2. Rice Straw

Air dried rice straw to remove moisture was collected

Average Diameter (cm)	0.25
Average Tensile Strength ($kg.cm^{-2}$)	122.32
Fiber density($kg.cm^{-3}$)	$0.38x10^{-3}$
Average length (cm)	1 - 5

from El-Manzala, Ad-Daqahliyah, Egypt as shown in Fig. 2. Rice straw properties are given in Table 2.

Table 1 Sand Properties

Table 2 Rice Straw Properties

Fig. 2 Rice Straw Pattern

2.2. Preparation of Samples

The samples were prepared with rice straw fibers added in percentages of 0.25, 0.50, 0.75 and 1% by weight. Water content added was constant 3 % by weight of soil. Sand was mixed with straw fibers and water. The slopes used were 1H:1V, 3H:2V, 2H:1V, and 5H:2V. The dimensions of the loading plate were 5x5 cm.

2.3. Placement of Soil

Mixed soil with straw fiber was put in the sand box model in layers. Each layer was 5 cm height to reach (d) total depth of 21 cm. Each layer was compacted with a tamper consisting of a circular steel plate (6 cm in diameter) connected to the end of steel rod. A sand model used for experiments is shown in Fig. 3 and the slope failure is shown in Fig. 4.

2.4. Testing

Experiment on sand mixed with rice straw was carried on by loading soil with static load 1 kg per minute. The load acted at the edge of slope, 3cm, 6cm, and 9 cm from edge of slope as shown in Fig. 5. Settlement (S) was recorded for each load.

3. RESULTS and DISCUSSION

3.1. Effect of Rice Straw Proportion on Stress - S/d Relationship

The soil stress increases by adding rice straw to the sandy soil as shown in Figs. 6 to 9. Generally, whenever rice straw proportion increases, the stress increases.

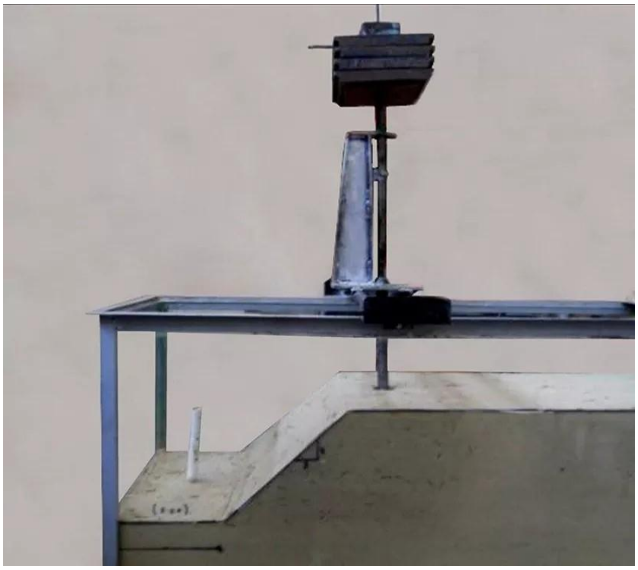

Fig. 3 Sand box Model

Fig. 4 Slope Failure (Slope 1H: 1V, R.S = 0. 5% and X = 6 cm)

For slope1H:1V in Fig. 6 for load distance X = 0.0 cm, soil stress increases by increasing R.S percentage from 0.0% to 0.75% by 87.72% and decreases for R.S percentage 1% consequently. The ratio S/d decreases by 24.64 % on increasing R.S percentage from 0.0% to 0.75% and increases for R.S percentage 1%. Fig. 7 shows that for load distance X = 3.0 cm, soil stress increases by increasing R.S percentage from 0.0% to 0.75% by 72.16% and decreases for R.S percentage 1%. The ratio S/d decreases by 33.33% on increasing R.S from 0.0% to 1.0%.

Fig. 8 shows that for load distance X = 6.0 cm, soil stress increases by increasing R.S percentage from 0.0% to 0.75% by 34.09% and decreases for R.S percentage 1%. The ratio S/d also decreases by 30.86% on increasing R.S percentage from 0.0% to 0.75% and increases for R.S

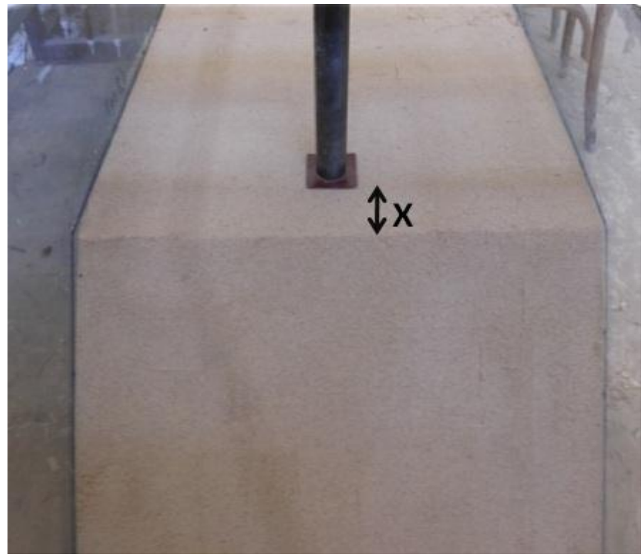

Fig. 5 Load Edge Distance from Loading Plate Edge (X)

percentage 1%. Fig. 9 shows that for load distance X = 9.0 cm, soil stress increases by increasing R.S percentage from 0.0% to 0.75% by 56.82% and decreases for R.S percentage 1%. The ratio S/d decreases by 35.71% on increasing R.S percentage from 0.0 % to 1.0%.

The increase in soil stress attributed to the distributed rice straw fibers behaves as a spatial network. Soil particles mixed with fibers interlocks to form a unified matrix. This mixture of sandy soil and straw fibers makes a coherent structure that can resist settlement of soil. This is attributed to the combination of the friction generated between soil particles and the tensile strength of confined straw fibers mobilized by the relative movements of soil particles.

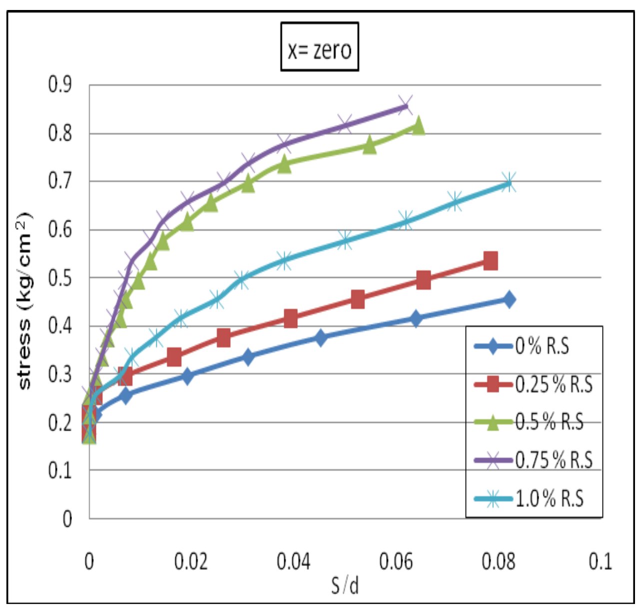

Fig. 6 Stress–Settlement Depth Curves (X = zero, slope 1H:1V)

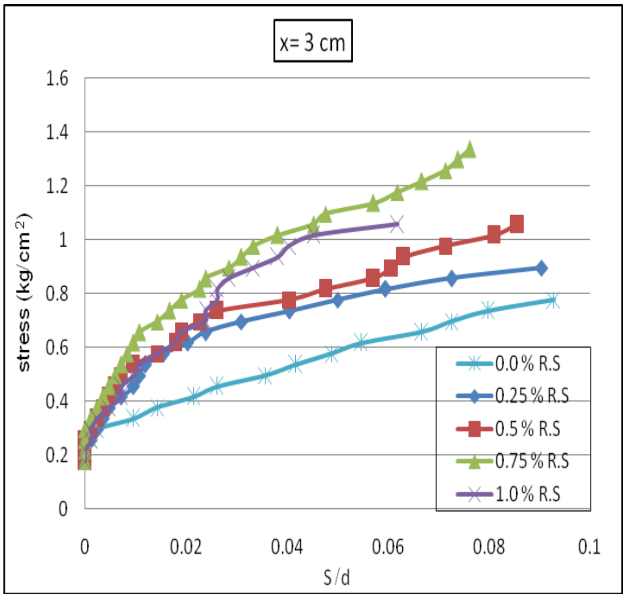

Fig. 7 Stress–Settlement Depth Curves(X = 3 cm, slope 1H:1V)

3.2. Load Edge Distance Effect on Stress - S/d Relationship

Figs. 10 to 14 show that the soil stress increases with increasing load distance from edge of slope. For slope 1H:1V in Fig. 10 shows that with R.S = 0%, soil stress increases by 131.58% on increasing load edge distance (X) from 0.0 cm to 9 cm. Fig. 11 shows that with R.S = 0.25%, soil stress increases by 141.79% on increasing (X) from 0.0 cm to 9 cm. Fig. 12 shows that with R.S = 0.5 % , soil stress increases by 63.73% on increasing (X) from 0.0 cm to 9 cm. Fig. 13 shows that with R.S = 0.75% , soil stress increases by 93.46% on increasing (X) from 0.0 cm to 9 cm. Fig. 14 shows that with R.S = 1.0 %, soil stress increases by 132.18% on increasing (X) from 0.0 cm to 9 cm.

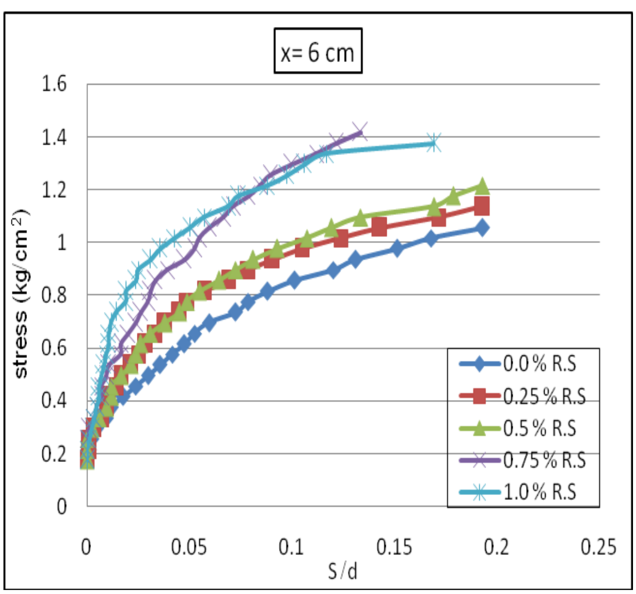

Fig. 8 Stress–Settlement Depth Curves (X = 6 cm, slope 1H:1V)

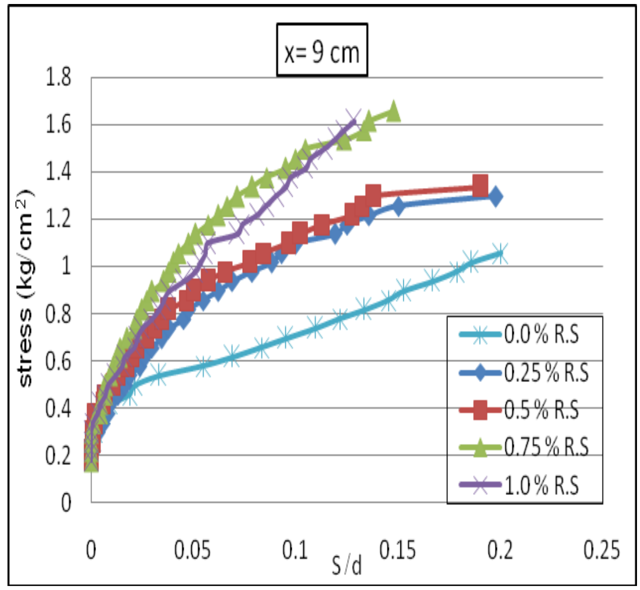

Fig. 9 Stress–Settlement Depth Curves (X = 9 cm, slope 1H:1V)

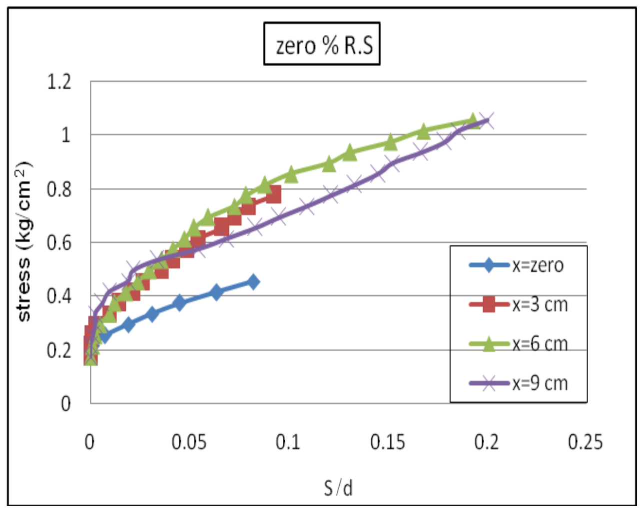

Fig. 10 Stress–Settlement Depth Curves (R.S = zero%, slope 1H:1V)

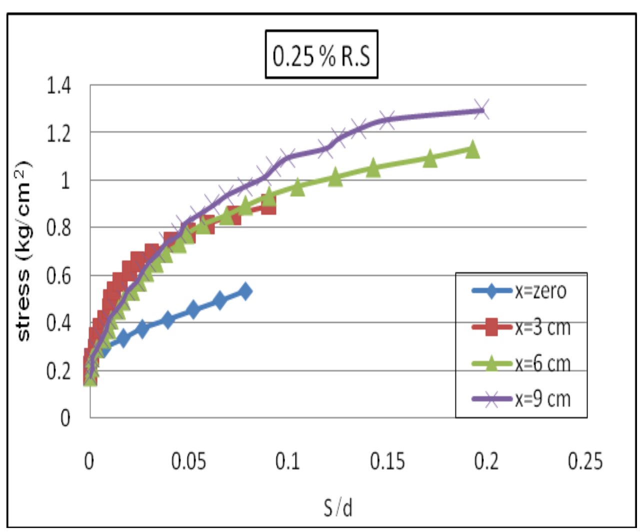

Fig. 11 Stress–Settlement Depth Curves (R.S = 0.25%, slope 1H:1V)

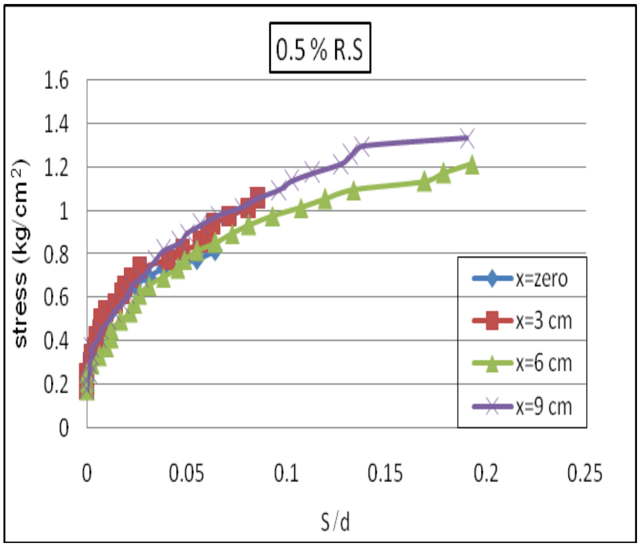

Fig. 12 Stress–Settlement Depth curves (R.S = 0.5%, slope 1H:1V)

3.3. Relationship between Soil Stress and Rice Straw Content

Figs. 15 to 17 show that the effect of rice straw fibers on soil stress for slopes 1H:1V, 3H:2V, and 2H:1V respectively. Soil stress increases by adding rice straw to the sandy soil. Whenever rice straw proportion increases the stress increases. For slope 1H:1V in Fig. 15, soil reinforced with 0.75% of rice straw gives the maximum soil stress. For slope 3H:2V in Fig. 16, soil reinforced with 1.0% of rice straw gives the maximum soil stress. For slope 2H:1V in Fig. 17, soil reinforced with 0.75% of rice straw gives the maximum soil stress. Increasing rice straw content more than 0.75% leads to decreasing soil stress. This decrease in soil stress when using 1% rice straw content may be attributed to the decrease of the degree of homogeneity causing irregularity in soil arrangement.

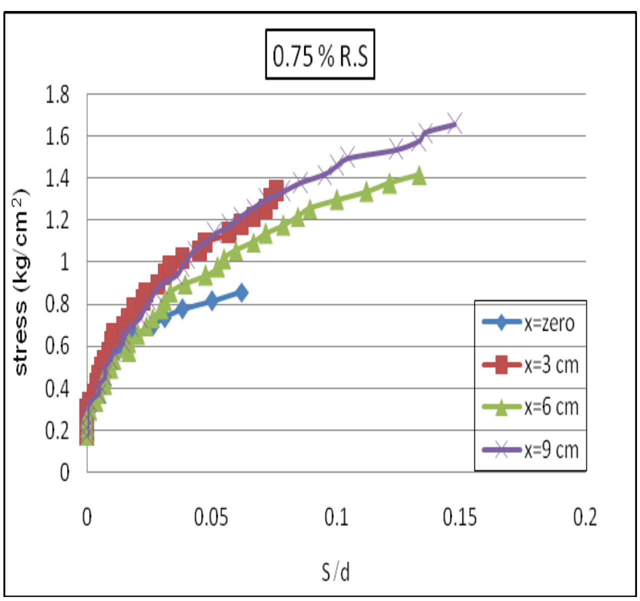

Fig. 13 Stress–Settlement Depth curves (R.S = 0.75%, slope 1H:1V)

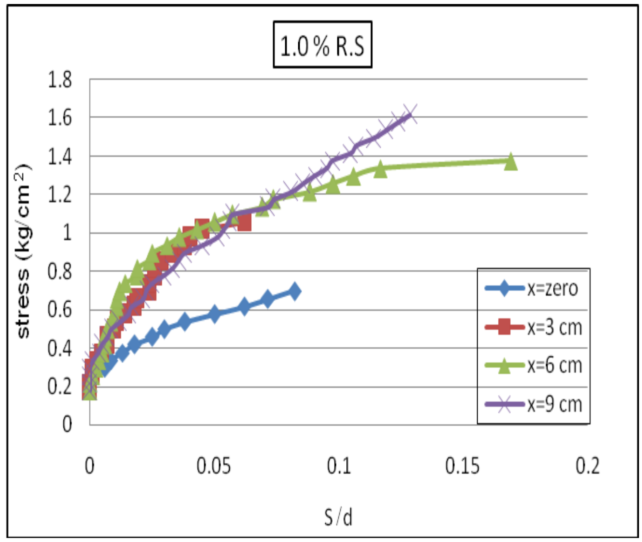

Fig. 14 Stress–Settlement Depth curves (R.S = 1.0%, slope 1H:1V)

3.4. Relationship between S/d and Rice Straw Content

Figs. 18 to 20 show the effect of rice straw fibers on settlement / depth ratio (S/d) for slopes 1H:1V, 3H:2V , and 2H:1V respectively. (S/d) ratio decreases by adding rice straw reinforcement to the sand soil. The (S/d) decreases by increasing rice straw proportion. For slope 1H:1V in Fig. 18 for load edge distance 0.0 cm and 6 cm, soil reinforced with 0.75% of rice straw gives minimum (S/d) ratio, and for load edge distance 3 cm and 9 cm, soil reinforced with 1.0% of rice straw gives minimum (S/d). For slope 3H:2V in Fig. 19 for load edge distance 0.0 cm and 6 cm, soil reinforced with 0.75% of rice straw gives minimum (S/d) ratio, and for load edge distance 3 cm and 9 cm, soil reinforced with 1.0% of rice straw gives minimum (S/d). For slope 2H:1V in Fig. 20 for load edge distance 0.0 cm, soil reinforced with 0.0% of rice straw gives minimum (S/d) ratio, and for load edge distance 3 cm and 9 cm, soil reinforced with 0.75% of rice straw gives minimum (S/d) and for load edge distance 6 cm, soil reinforced with1.0% of rice straw gives minimum (S/d).

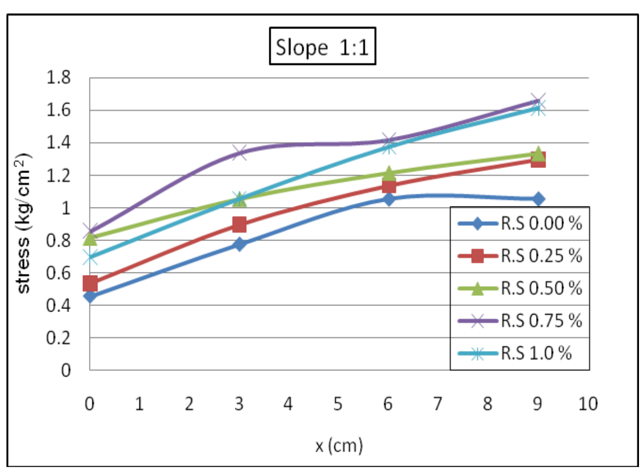

Fig. 15 Effect of R.S Content on Soil Stress (slope 1H:1V)

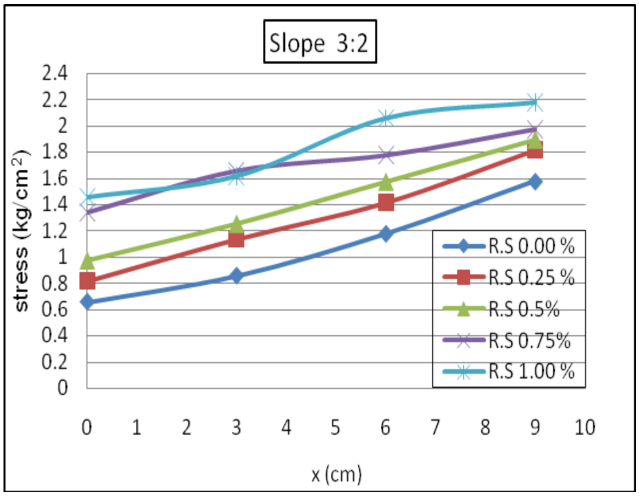

Fig. 16 Effect of RS Content on Soil Stress (slope 3H:2V)

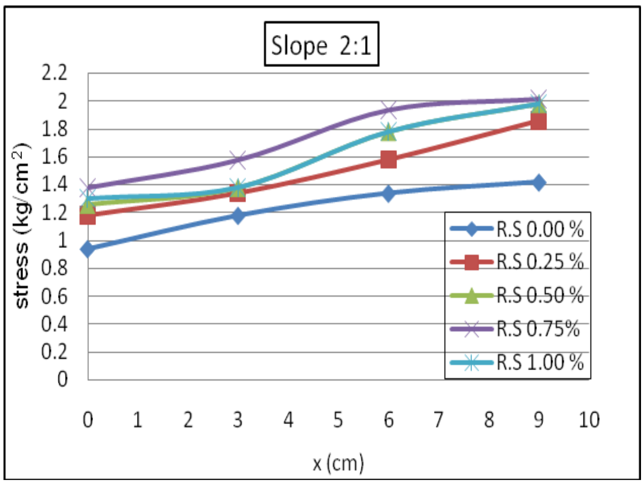

Fig. 17 Effect of R.S Content on Soil Stress (slope 2H:1V)

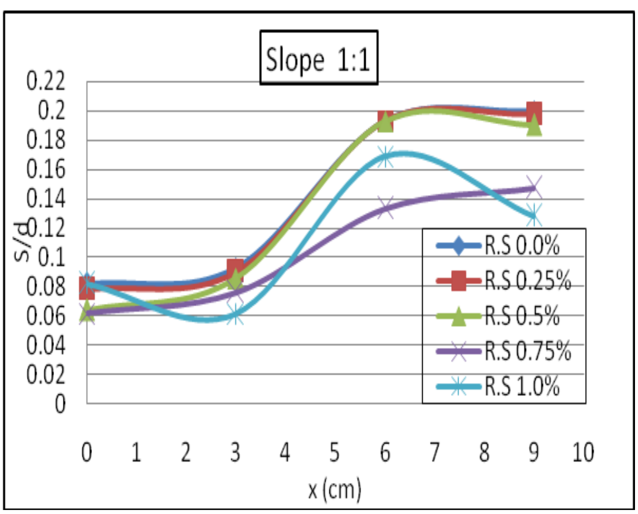

Fig. 18 Effect of R.S Content on S/d Ratio (slope 1H:1V)

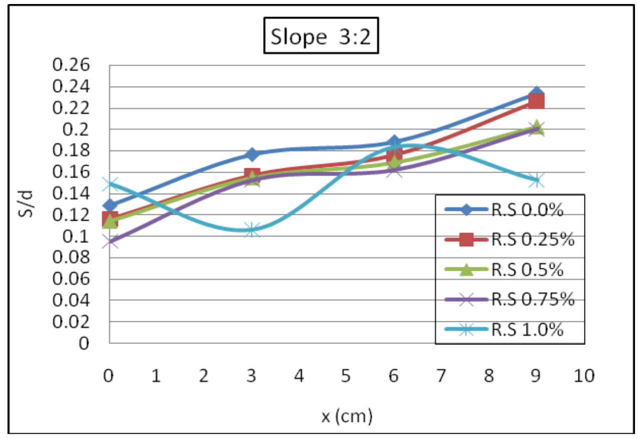

Fig. 19 Effect of R.S Content on S/d Ratio (slope 3H:2V)

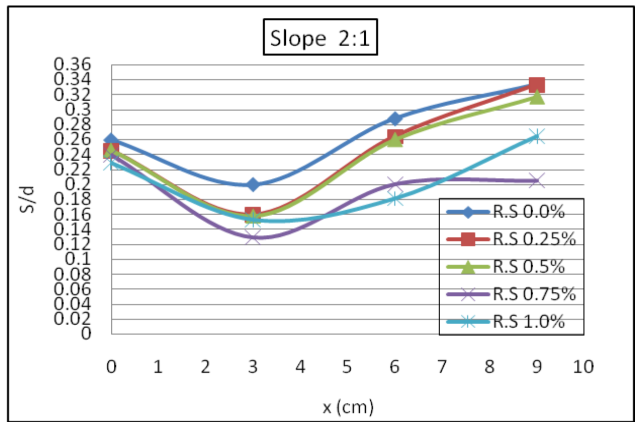

Fig. 20 Effect of R.S Content on S/d Ratio (slope 2H:1V)

3.5. Effect of Slope Angle on Soil Stress

Tests were made on sand slopes with different proportions of rice straw with slope angles (β) 26.56˚, 33.69˚, and 45˚. Figs. 21 to 25 show that as the load far from the slope crest, The soil stress increases. The soil stress decreases with the increase of the angle of slope. This can be attributed to the decrease in shear resistance of supporting soil adjacent to slope face due to boundary confinement effect with increasing slope angle.

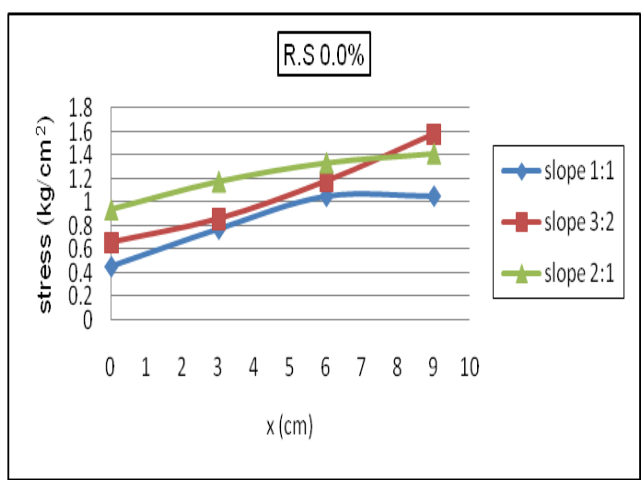

Fig. 21 Effect of Slope Angle on Soil Stress (R.S 0.0%)

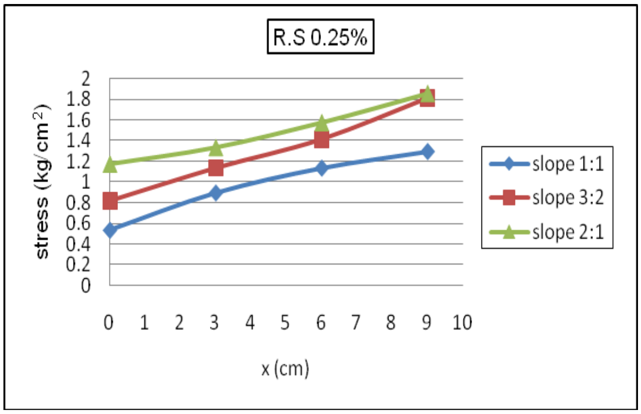

Fig. 22 Effect of Slope Angle on Soil Stress (R.S 0.25%)

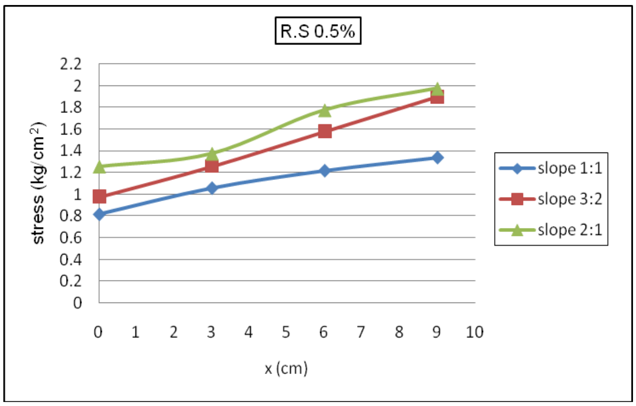

Fig. 23 Effect of Slope Angle on Soil Stress (R.S 0.5%)

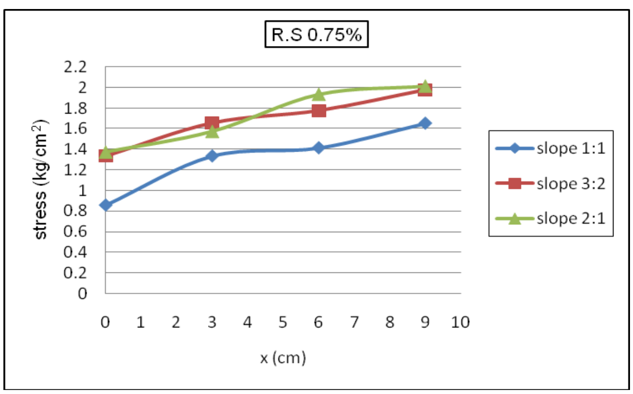

Fig. 24 Effect of Slope Angle on Soil Stress (R.S 0.75%)

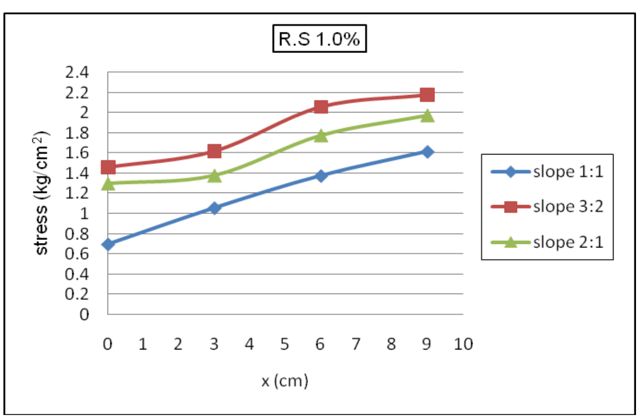

Fig. 25 Effect of Slope Angle on Soil Stress (R.S 1.0 %)

4. CONCLUSIONS

The following points can be concluded from this paper:

1. The soil stress may increase significantly by adding rice straw to sandy soil. Generally, whenever rice straw proportion increases the stress increases.
2. The rice straw content that gives the maximum stress is in the range of 0.75% by weight. The stress of reinforced sand increased by 63.40% as compared by unreinforced sand.
3. The (S/d) ratio decreases by adding rice straw reinforcement to sandy soil and decreases by increasing rice straw proportion.
4. The minimum (S/d) ratio has been noticed at rice straw percentage of 0.75% by weight. The ratio (S/d) of reinforced soil decreases by 27.68% as compared by unreinforced sand. The soil stress decreases with increase of the slope angle.

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