Effect of Using Rice Straw Fiber on Slope Stability

Samah M. El kefafy, Mohamed El Gendy, Ahmed M. Mirdan, Gamal Abouelenean

***Abstract*— The objective of this research was to study experimentally the effect of rice straw fibers on slope strength. A sand boxed 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 (x) and percentage of rice straw. Constant water contents were used in all samples. Laboratory results showed that soil stress increases significantly by increasing the percentage of rice straw fibers up to a certain limit.**

***Index Terms*— rice straw, settlement, slope stability, strength.**

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

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II. LITERATURE REVIEW

Prabakar and Siridihar (2002) 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. They concluded that the percentage of fiber content improves the shear strength. Beyond 0.75% fiber content, the shear stress reduces with increase in fiber content. They concluded that fiber length has an effect on shear stress. The shear stress is increased non-linearly with increase in length of fiber up to 20 [7]. Ravishankar and Raghavanthey (2004) used coir fiber to reinforce soil and they 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 (2010) used palm fibers to reinforce silty sand. Specimens with 0.25% and 0.5% content of palm fibers of different lengths were used.

He 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. (2010) 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 (2011) 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 (2011) 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 times with respect to that of unreinforced soil[6].

In this research rice straw fibers were used as soil reinforcement. Rice straw 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 2005/06. The options for disposal of straw are limited and include burning. In-field burning in Egypt has been illegal by law for more than 15 years, but these environmental laws are widely flouted and this results in widespread aerial pollution over neighboring urban areas[12]. Fig.1 shows that Rice straw still burnt in Egypt till now.

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

Fig.2 Rice Straw Pattern

Fig.3 Sand Model

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

III. EXPRIMENTAL WORK

A. *Materials*

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

1) *Soil*

Air dried sand soil was used in this study and its properties are given in Table1.

2) *Rice Straw*

Air dried rice straw to remove moisture was collected from El-Manzala, Ad-Daqahliyah, Egypt as shown in Fig.2. Rice straw properties are given in Table 2.

B. *Preparation of Samples*

The samples were prepared with rice straw fibers of random length added in percentages of 0.25, 0.50, 0.75 and 1%.And 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. And the loading plate 5*5 cm constant.

C. *Placement of Soil*

Mixed soil with straw fiber was put in the sand boxed model in layers .Each layer was 5 cm height to reach a total depth of (**d** = 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.

D. *Testing*

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

Table.1 Sand Properties

Optimum moisture Content (%)	9.00
Maximum dry density (kg.cm^{-3})	1.73*10^{-3}
Minimum density(kg.cm^{-3})	1.48*10^{-3}
Relative density (kg.cm^{-3})	1.62*10^{-3}
Angel of internal friction(˚)	32.49

Table (2) Rice Straw Properties

Average Diameter (cm)	0.25
Average Tensile Strength (kg.cm^{-2})	122.32
Fiber density(kg.cm^{-3})	0.38*10^{-3}

IV. RESULTS AND DISCUSSION

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

Figs. 5 through 8: soil stress increases by adding rice straw to the sandy soil. Generally, whenever rice straw proportion increases the stress increases. For slope1H:1V in Fig.5 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.6 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.7: 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 percentage 1%. Fig.8: 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.

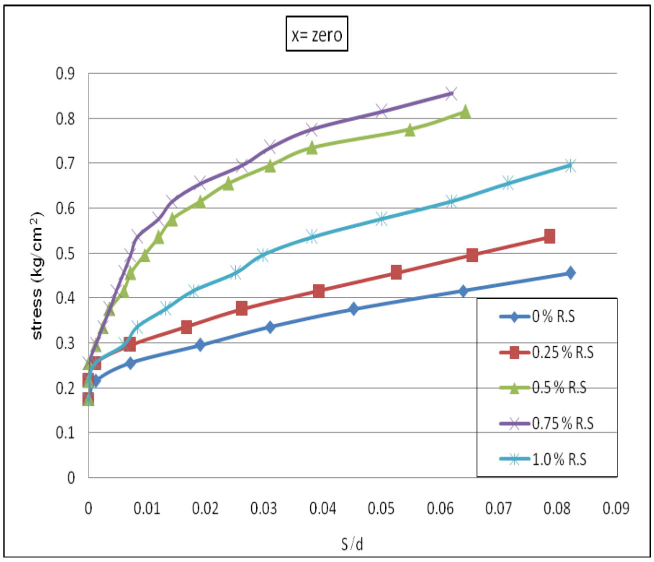

Fig. 5 Stress – Settlement Depth Curves (X= zero, slope 1H:1V)

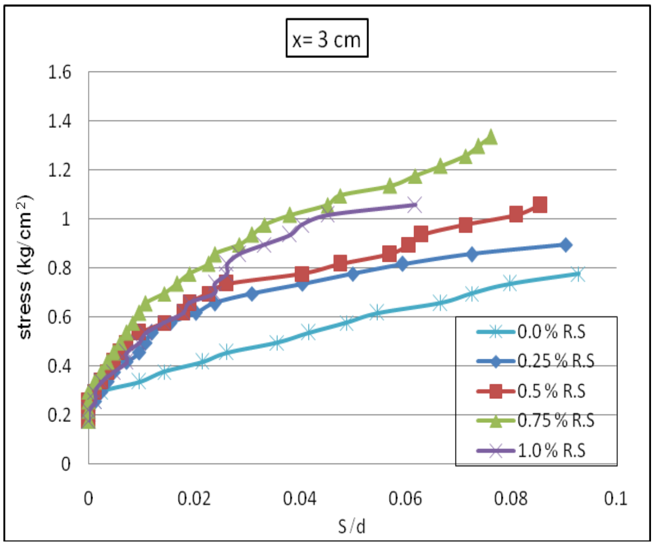

Fig.6 Stress – Settlement Depth Curves (X= 3cm, slope 1H:1V)

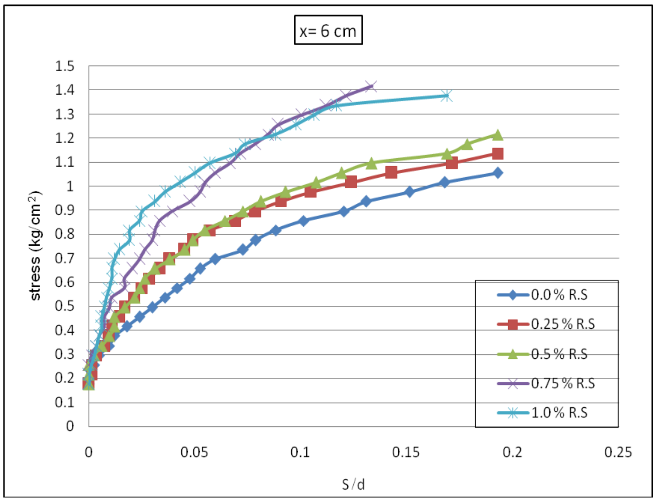

Fig.7 Stress – Settlement Depth Curves (X= 6 cm, slope 1H:1V)

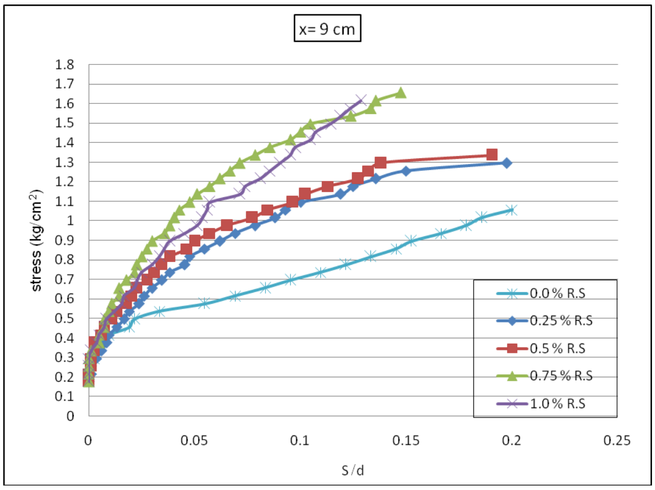

Fig.8 Stress – Settlement Depth Curves (X= 9 cm, slope 1H:1V)

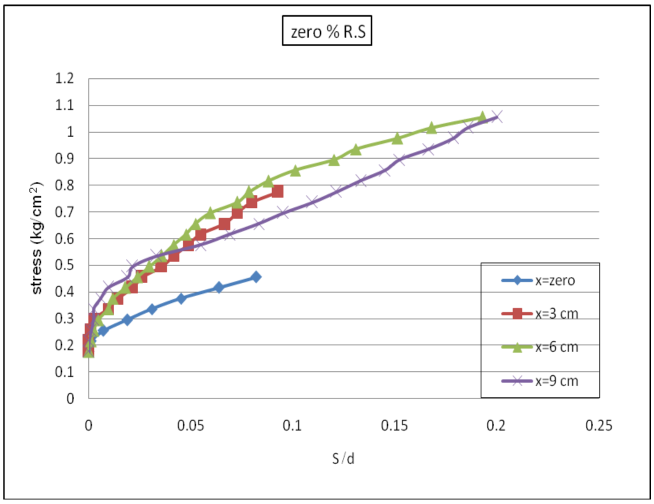

Fig.9 Stress – Settlement Depth Curves (R.S =zero %, slope 1H:1V)

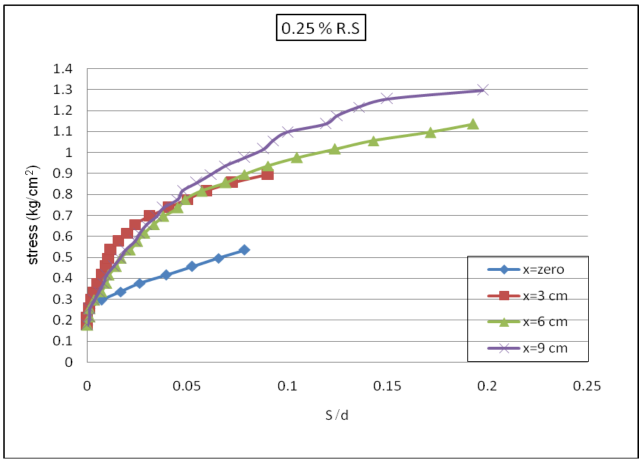

Fig.10 Stress – Settlement Depth Curves (R.S =0.25 %, slope 1H:1V)

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

Figs. 9 through 13: The improvement of Stress - S/d relationship increases by increasing load distance from edge of slope. Soil stress increases on increasing load distance from edge of slope. For slope 1H:1V in Fig.9 with R.S = 0 %, soil stress increases by 131.58 % on increasing load edge distance (X) from 0.0 cm to 9 cm. Fig.10 with R.S = 0.25 %, soil stress increases by 141.79 % on increasing (X) from 0.0 cm to 9 cm. Fig.11 with R.S = 0.5 % , soil stress increases by 63.73 % on increasing (X) from 0.0 cm to 9 cm. Fig.12 with R.S = 0.75 % , soil stress increases by 93.46% on increasing (X) from 0.0 cm to 9 cm. Fig.13 with R.S = 1.0 %, soil stress increases by 132.18 % on increasing (X) from 0.0 cm to 9 cm.

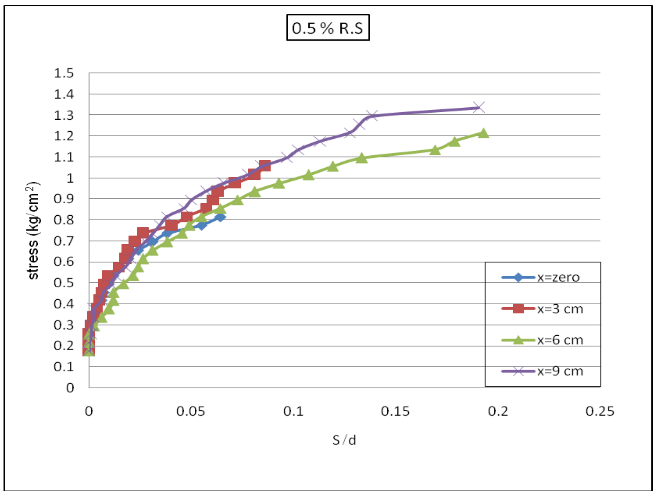

Fig.11 Stress – Settlement Depth curves (R.S = 0.5 %, slope 1H:1V)

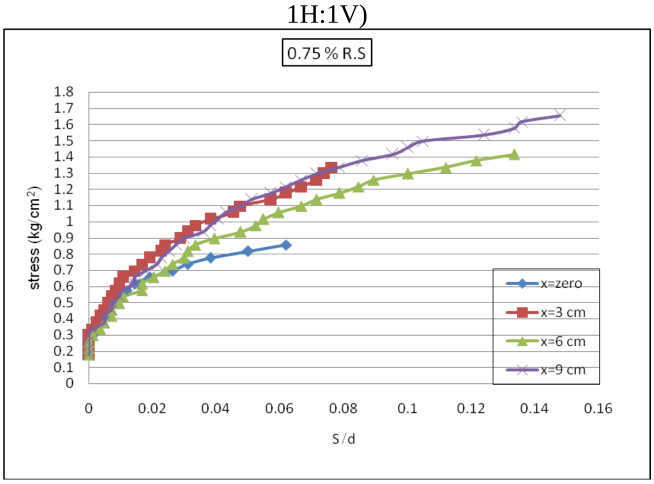

Fig.12 Stress – Settlement Depth curves (R.S = 0.75 %, slope 1H:1V)

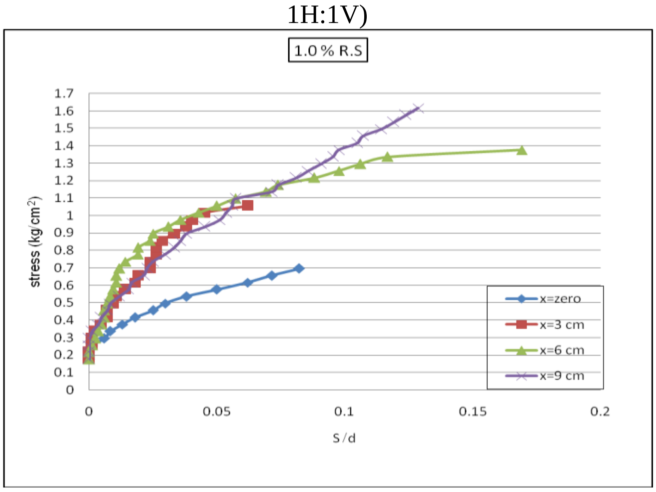

Fig.13 Stress – Settlement Depth curves (R.S =1.0 %, slope 1H:1V)

C. Relationship Between Soil Stress and Rice Straw Content.

Figs. 14 through 16 shows the effect of rice straw fibers on soil stress for slopes (1H:1V, 3H:2V, 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.14 for different load distance from edge of slope, soil reinforced with 0.75 % of rice straw gives the maximum soil stress. For slope 3H:2V in Fig.15 for different load distance from edge of slope, soil reinforced with 1.0 % of rice straw gives the maximum soil stress. For slope 2H:1V in Fig.16 for different load distance from edge of slope, soil reinforced with 0.75 % of rice straw gives the maximum soil stress. Increasing rice straw content more than 0.75 % leads to decreasing in 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.

D. Relationship Between S/d and Rice Straw Content

Figs. 17 through 19 show the effect of rice straw fibers on settlement / depth ratio (S/d) for slopes (1H:1V, 3H:2V , 2H:1V) respectively. (S/d) ratio decreases by adding rice straw reinforcement to the sand. The (S/d) decreases by increasing rice straw proportion.

For slope 1H:1V in Fig.17 for load distance 0.0 cm and 6 cm from edge of slope, soil reinforced with 0.75 % of rice straw gives minimum (S/d) ratio, but for load distance 3 cm and 9 cm from edge of slope soil reinforced with 1.0 % of rice straw gives minimum (S/d). For slope 3H:2V in Fig.18 for load distance 0.0 cm and 6 cm from edge of slope, soil reinforced with0.75 % of rice straw gives minimum (S/d) ratio, but for load distance 3 cm and 9 cm from edge of slope soil reinforced with 1.0 % of rice straw gives minimum (S/d). For slope 2H:1V in Fig.19 for load distance 0.0 cm from edge of slope, soil reinforced with 0.0% of rice straw gives minimum (S/d) ratio, but for load distance 3 cm and 9 cm from edge of slope, soil reinforced with 0.75 % of rice straw gives minimum (S/d) and for load distance 6 cm from edge of slope soil reinforced with1.0 % of rice straw gives minimum (S/d).

E. Effect of Slope Angle on Soil Stress

Tests were made on sand slopes with different proportion of rice straw with slope angles (β) 26.56˚, 33.69˚ and 45˚. Figs. 20 through 24 show that as the load far from the slope crest the soil stress increases. The soil stress decreases with increase 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.

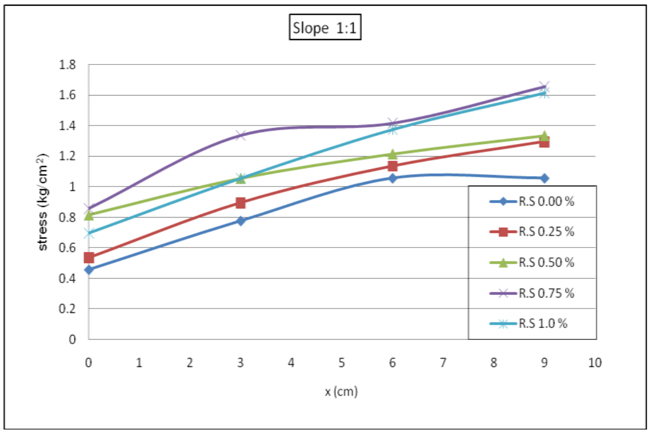

Fig.14 Effect of R.S Content on Soil Stress (slope 1H:1V)

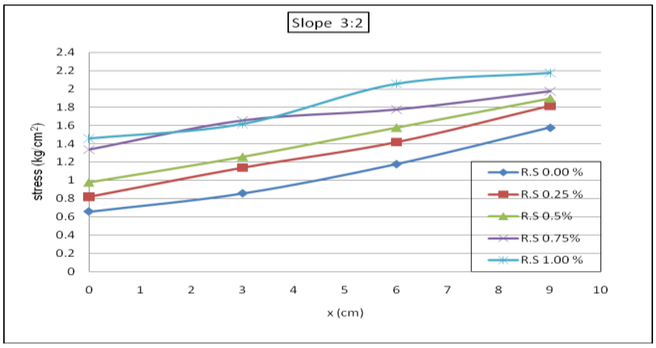

Fig.15 Effect of R.S Content on Soil Stress (slope 3H:2V)

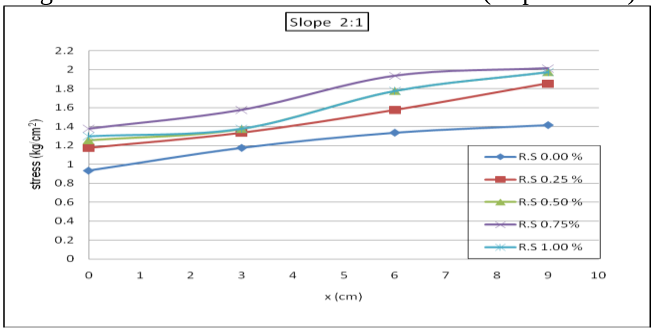

Fig.16 Effect of R.S Content on Soil Stress (slope 2H:1V)

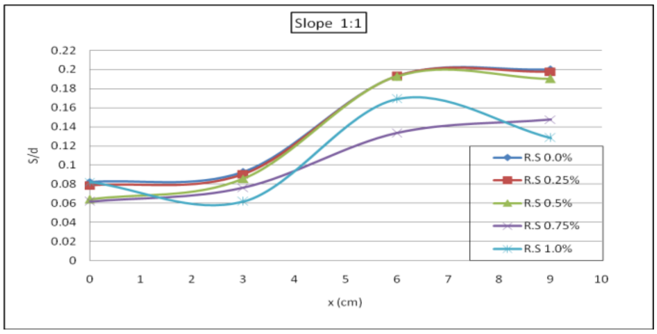

Fig.17 Effect of R.S Content on S/d Ratio (slope 1H:1V)

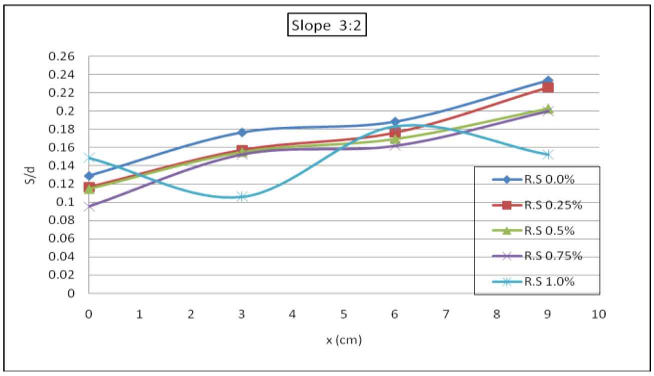

Fig.18 Effect of R.S Content on S/d Ratio (slope 3H:2V)

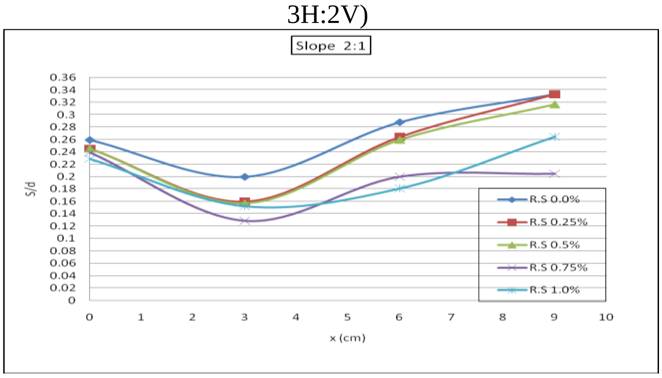

Fig.19 Effect of R.S Content on S/d Ratio (slope 2H:1V)

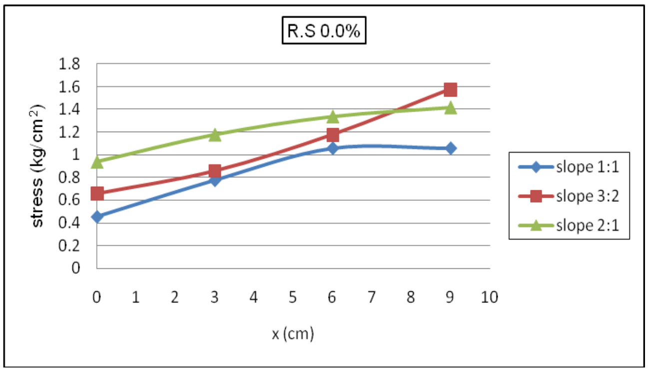

Fig.20 Effect of Slope Angle on Soil Stress (R.S 0.0%)

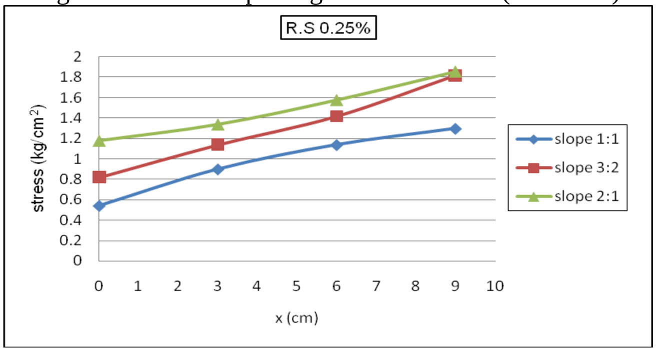

Fig.21 Effect of Slope Angle on Soil Stress (R.S 0.25%)

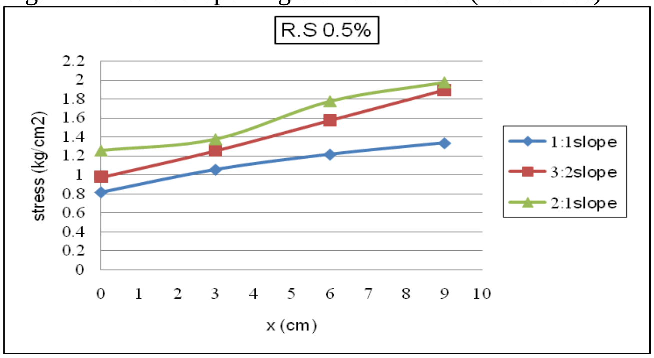

Fig.22 Effect of Slope Angle on Soil Stress (R.S 0.5%)

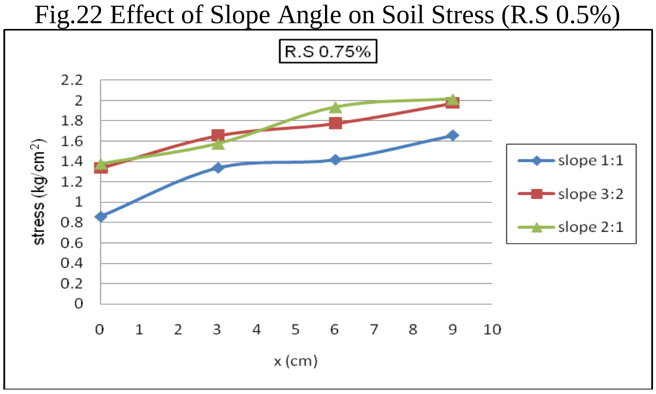

Fig.23 Effect of Slope Angle on Soil Stress (R.S 0.75%)

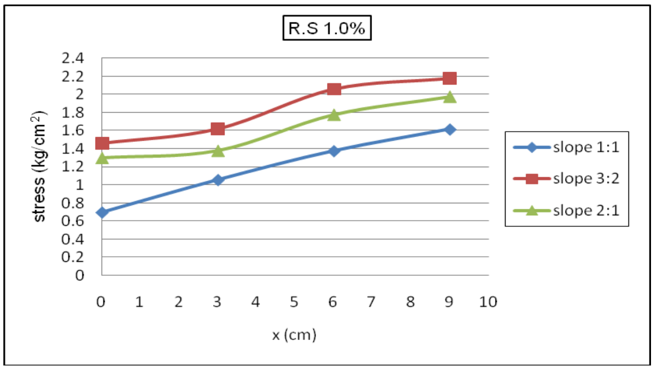

Fig.24 Effect of Slope Angle on Soil Stress (R.S 1.0 %)

V. CONCLUSIONS

1. It can be concluded that Soil stress may increases significantly by adding rice straw to sandy soil. Generally, whenever rice straw proportion increases the stress increases.
2. The optimum rice straw content that gives the maximum stress is in the range of 0.75 percentages by weight.
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 soil stress decreases with increase of the slope angle.
5. Sand mixed with 1.0 % by weight of rice straw leads to increasing the angle of internal friction (Ø) by 46.63%, as compared by sand with rice straw 0.00 % by weight.

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