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A Study on Shear Strength for Dune Sand Reinforced With Shredded Waste Tyres

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Abstract: *This paper presents the general study on shear strength for dune sand reinforced with shredded waste tyre. The reuse of tyres shreds may not only address growing environmental and economic concerns, but also help solve geotechnical problems associated with low soil shear strength. Laboratory tests were conducted in large scale direct shear test apparatus to investigate the feasibility of using shredded waste tyres to reinforce dune sand. In tests were conducted on a matrix of dry dune sand mixed with waste of shredded tyres. Tyre shreds were randomly mixed with dune sand. Tyre shred contents were varied from 2%, 6% and 8%.The effect of factors such as shred length was also studied.*

A number of identical samples were tested under increasing normal loads and the required maximum shear force was recorded. The results of these tests are plotted with normal stress along horizontal axis and shear stress that produced failure of the specimen along vertical axis. A straight line, called strength envelope is drawn connecting the points and is extended to intersect vertical axis.

Key Words: *Dune Sand, Shred Length, Shear strength, Shredded Waste Tyre*

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I. INTRODUCTION

Rajasthan is covered by a vast sandy desert known as the **Thar Desert**. It covered about 60% an area of Rajasthan. Dune sand is a wind deposited, non-plastic, uniformly graded fine sand. The construction of any structure on dune sand is a challenging job for Geo-technical Engineers i.e. immense shifting nature, high permeability, low shear strength and poor bearing capacity. Lime, Cement , Bitumen, Chemicals, Heavy tamping, Vibro-floating, Mud, Reinforcing element, Natural fibres, Geo-textiles, Geo- membrane are various ground improvement techniques for dune sand. .Tyre shreds and tyre shred soil mixture can be used as alternative back fill material for retaining structure and many Geo-technical applications. The proposed study work is an initiative to develop methodology for improvement of the bearing capacity of dune sand in presence of shredded waste tyres for benefited in embankment, pavement designs, roads, and foundation .

II. ANALYSIS AND DISCUSSION OF TEST RESULTS

Laboratory tests observations obtained from the shear-box test apparatus on un-reinforced and reinforced dune sand have been presented in the form of graphs and tables. Test observation obtained for dune sand in terms of normal stress and shear stress has been presented in Table (2.1).

TABLE (2.1): Normal Stress V/S Shear Stress (Kg/cm²) of Un-reinforced Dune Sand At

Density Υ_m = 1.62 g/cm³		Density Υ_m = 1.52 g/cm³	
Normal Stress	Shear stress	Normal Stress	Shear stress
0.5	0.318	0.5	0.240
1.0	0.629	1.0	0.489
1.5	0.945	1.5	0.751
2.0	1.268	2.0	1.011
2.5	1.561	2.5	1.261
Ø = 32°		Ø = 27.1°	

The strength envelopes of unreinforced dune sand have been shown in Figure (2.1). It may be observed that the strength envelopes are straight lines passing through origin. The angles of internal friction (ø) have been observed to be 32° and 27.1° for tests conducted at densities of 1.62 gm/cm³ and 1.52 gm/cm³ respectively. These values of ø are in agreement with those determined by previous investigators. Shear tests were conducted in a small scale direct shear box also. It has been found that the angle of internal friction of dune sand is not affected by the size of test apparatus.

TABLE (2.2): Normal Stress V/S Shear Stress (Kg/cm²)

Shred Length (0-3) cm, Matrix Density Υ_m= 1.62 g/cm³

Shred content					
2%		**6%**		**8%**	
Normal Stress	**Shear stress**	**Normal Stress**	**Shear stress**	**Normal Stress**	**Shear stress**
0.5	0.3565	0.5	0.3965	0.5	0.4165
1.0	0.7245	1.0	0.8065	1.0	0.8425
1.5	1.0785	1.5	1.1850	1.5	1.2615
2.0	1.4632	2.0	1.5795	2.0	1.6895
2.5	1.8365	2.5	1.9985	2.5	2.1425
Ø = 36.50°		**Ø = 38.69°**		**Ø = 40.79°**	

Direct shear tests were conducted on dune sand reinforced with tyre shreds. The normal stresses applied and the corresponding shear stress observations for dune sand reinforced with varying shred content 2%, 6% and 8% for shred length (0-3) cm at a sand matrix density of 1.62gm/cm³ have been given in Table (2.2). Corresponding observations for shred length (3-6) cm and (6-9) cm are given in table (2.3 to 2.4). At least two and sometimes three tests were conducted to check the reproducibility of the tests results. The strength envelopes were linear the range of normal stress applied.

TABLE (2.3): Normal Stress V/S Shear Stress (Kg/cm²)

Shred Length (3-6) cm, Matrix Density Υ_m = 1.62 g/cm³

Shred content					
2%		**6%**		**8%**	
Normal Stress	**Shear stress**	**Normal Stress**	**Shear stress**	**Normal Stress**	**Shear stress**
0.5	0.3685	0.5	0.4000	0.5	0.4250
1.0	0.7875	1.0	0.8250	1.0	0.8625
1.5	1.1875	1.5	1.2500	1.5	1.2875
2.0	1.5720	2.0	1.6625	2.0	1.7250
2.5	1.9525	2.5	2.0875	2.5	2.1625
Ø = 38.65°		**Ø = 40.06°**		**Ø = 40.94°**	

TABLE (2.4): Normal Stress V/S Shear Stress (Kg/cm²)

Shred Length (6-9) cm, Matrix Density Υ_m = 1.62 g/cm³

Shred content					
2%		**6%**		**8%**	
Normal Stress	**Shear stress**	**Normal Stress**	**Shear stress**	**Normal Stress**	**Shear stress**
0.5	0.4165	0.5	0.4485	0.5	0.4655
1.0	0.8125	1.0	0.8575	1.0	0.9065
1.5	1.225	1.5	1.2985	1.5	1.3640
2.0	1.6515	2.0	1.7395	2.0	1.8150
2.5	2.0475	2.5	2.1570	2.5	2.2650
Ø = 39.10°		**Ø = 40.38°**		**Ø = 41.58°**	

2.1 INFLUENCE OF SHRED CONTENT ON SHEAR STRENGTH

Direct shear strength were conducted with dune sand mixed with different amount of shred contents varying from 2%, 6% and 8%. The shear strength envelopes for dune sand reinforced with shred content are plotted for shred length (0-3) cm, (3-6) cm and (6-9) cm compacted at sand matrix density of 1.62gm/cm³. All the strength envelopes are found to be straight lines passing through the origin. The strength envelopes show an increase in internal friction angle with the increase in the shred content for the three shred lengths of (0-3) cm, (3-6) cm and (6-9) cm. Internal friction angle for dune sand reinforced with varying shred contents at matrix density of 1.62gm/cm³ is shown in Table (2.5).

TABLE (2.5): Internal Friction Angle at Matrix Density = 1.62gm/cm³

Shred Length	**Internal Friction Angle (ø°)**		
	Shred Content		
	2%	**6%**	**8%**
(0-3) cm	36.50	38.69	40.79
(3-6) cm	38.65	40.06	40.94
(6-9) cm	39.10	40.38	41.58

(Internal Friction Angle for Un-reinforced sand = 32°)

It may be observed from Table (2.5), that increase in the shred content increases the angle of internal friction and thus increases the strength of dune sand. The angle of internal friction, ø increases from 32° (unreinforced dune sand) to about 41.58° when dune sand is reinforced with shred length (6-9) cm for 8% shred content. However there is a variation when even 2% shred content have been added to dune sand. The angle of internal friction increases from 32° to about 39.10° when dune sand is reinforced with shred length (6-9) cm for 2% shreds content have been added to dune sand. Increase in angle of internal friction due to reinforcement of sand has also been reported by others investigators also. It may be observed in general that maximum angle of internal friction is much higher for dune sand reinforced with tyre shreds. The increase in internal friction angle, lead to an increase in the overall shear strength of reinforced dune sand. For sake of comparison the shear strength of unreinforced and reinforced dune sand has been calculated from Coulomb's relationship.

$$\tau_f = \sigma \tan\phi \qquad (2.1)$$

Where τ_f = Shear strength of soil
ø = Internal friction angle
σ = Normal stress on failure plane

The shear strength has been determined for an arbitrarily chosen value of normal stress, σ = 1.25kg/cm². The computed values of shear strength are given in table (3.6) and percentage increase in strength in table (2.7). A graph between shred content and percentage increase in shear strength for all the three shred length is shown in Figure (2.2). The Figure shows that the shear strength of dune sand reinforced with shreds increases as the shred content increase. An increase in shear strength to as high as 41.58% was observed when dune sand is reinforced with shred length (6-9) cm for 8% shred content. The strength of dune sand increases by 1.38 times, when dune sand is reinforced with shred length (3-6) cm for 2% shred content.

TABLE (2.6): Observed Shear Strength of Sand Reinforced with Varying Shred Content for different Shred Lengths

Normal Stress σ = 1.25 kg/cm², Matrix Density = 1.62 g/cm³

Shred content (%)	Shear Strength (Kg/cm²)		
	Shred Length		
	(0-3) cm	(3-6) cm	(6-9)cm
2	0.9250	0.9997	1.0158
6	1.0010	1.0511	1.0630
8	1.0786	1.0843	1.1090

(Shear Strength of Un-reinforced sand = 0.78125 kg/cm²)

TABLE (2.7): Percentage Increase in Shear Strength of Sand Reinforced with Varying Shred Content for different Shred Lengths

Normal Stress σ = 1.25 kg/cm², Matrix Density = 1.62 g/cm³

Shred content (%)	Shear Strength (%)		
	Shred Length		
	(0-3) cm	(3-6) cm	(6-9)cm
2	18.40	28.00	30.05
6	28.16	34.58	36.10
8	38.04	38.85	41.99

2.2 INFLUENCE OF SHRED LENGTH ON SHEAR STRENGTH

The data presented in table (2.5) has been utilised for depicting the influence of shred length on angle of internal friction. The increase in angle of internal friction which in turn leads to increase in shear strength for different shred lengths has been tabulated in table (2.5). It was observed angle of internal friction, ø is not significantly affected with the variation of shred length if the same amount of shred content has been mixed in dune sand. For 2% shred content, ø varies from 36.50, 38.65 and 39.10 for shred length of (0-3) cm, (3-6) cm and (6-9) cm. Table (2.6) shows that the shear strength of dune sand reinforced with shred length (0-3) cm, (3-6) cm and (6-9) cm for 2% shreds content are 0.925, 0.9997 and 1.0158 respectively. The percentage increase in shear strength for different shred lengths has been calculated and tabulated in table (2.7). Figure (2.2) shows the variation in increase in shear strength (%) with shred length for different shred contents. It was observed that shear strength increases as the shred length increases up to 8% shred content. Shred content higher than 8% for higher shred lengths causes little influence on shear strength due to problem of mixing and preparation of specimen i.e. boundary effects.

III. CONCLUSIONS

The laboratory investigations were carried out to study the use of tyre shred as a reinforcing material to increase the shear strength. Based on the experimental investigations and the test results obtained the following conclusions are made as follows:

1. The angle of internal friction of dune sand increases with addition of tyres shreds. The angle of internal friction of unreinforced dune sand at a density of 1.62gm/cm^3 is 32^o; it increases to as large as 41.58°on addition of 8% tyre shreds at the above density of matrix.
2. Addition of tyre shreds to dune sand causes an increase in its shear strength. Shear strength increases by 41.99% on addition of 8% tyre shreds at matrix density of 1.62gm/cm³.
3. The increase in shear strength is a function of shred length. Shear strength increases as the shred length increases. The shear strength of dune sand at tyre shred = 8% are increases to 38.04% , 38.85% and 41.99 %, when tyre shred length were increased as (0-3) cm , (3-6) cm and (6-9) cm respectively at matrix density of 1.62gm/cm³.

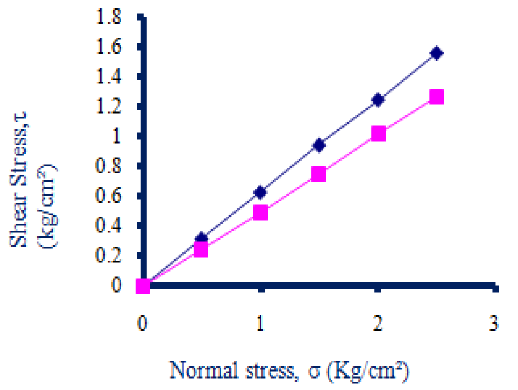

Figure (2.1)
Strength Envelopes for Unreinfored Dune Sand

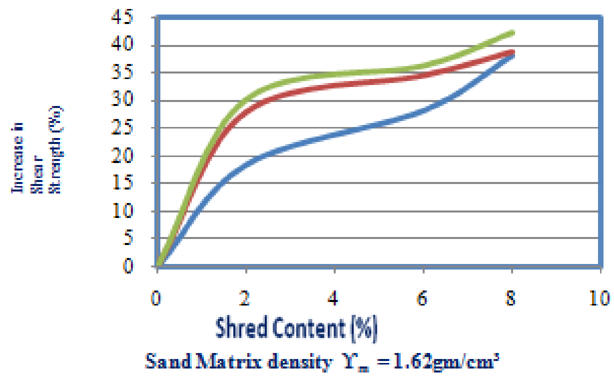

Figure (2.2)
Effect of Shred Content on Shear Strength of Sand

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