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Research Article
THE SHEAR STRENGTH BEHAVIOUR OF YAMUNA SAND-A PRELIMINARY STUDY

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Abstract: To describe the strength parameter in the loaded soil mass are the cohesion and internal frictional angle of the soil. The shear strength determination to study the shear strength after tillage a schematic study on Yamuna sand is conducted. Yamuna sand which is present in the banks of river Yamuna in around Delhi is taken for this study. The shear strength behaviour of Yamuna sand was tested through triaxial and direct shear. For this consolidated drained triaxial test (CD) was conducted on Yamuna sand and results are very different from direct shear test results. The angle of internal friction is more in CD triaxial test as compared to direct shear test. Also, some cohesive strength is also find in CD triaxial test which was not found in Direct Shear Test (DST). Direct shear test was conducted for dense and loose state of relative density and saturated state of Yamuna sand. The angle of internal friction was found to be highest in saturated state for Yamuna sand. Among dense and loose, dense state giving higher internal angle of friction.

Keywords: *Yamuna Sand, Shear Strength of Yamuna Sand, Triaxial Test, Direct Shear Test, Consolidated Drained Triaxial Test*

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Introduction
The shear behaviour of the Yamuna sand is observed through consolidated triaxial test and direct shear strength test conducted in dense and loose state of the soil. Results are examined for the shear strength parameter of Yamuna sand in direct shear and triaxial environment. Results are reviewed in terms of tillage research for this soil that is Yamuna sand. The disruption of soil by roto-tilling and compaction significantly decreased soil cohesion as suggested in Bullock, *et al*., (1988) [1] since this disruption also increased as water content increased for soils. Suitability of the Direct shear environment is to assess the shear strength of the top soil when it is in direct contact with the under carriage or influenced by its load. The direct shear test gives higher internal friction angle as compared to triaxial tests as suggested in Stefanow and Dudzinski (2021) [2]. The residual shear strength may be accessed through direct shear test; this residual shear strength exists in the soil after completing the required displacement of the shear box. This residual shear strength causes stability of the top soil during tillage processes.
Yamuna sand is found near the Yamuna river which starts from Yamunotri glacier and flow through Delhi, the National Capital Territory (NCR) of India. Yamuna river sand is widely available in Gurgaon and Delhi NCR. The bearing capacity of the Yamuna sand which is related to shear strength parameter of the Yamuna sand is weak and helpful in piping and erosion [3-5].

Geotechnical Properties and Mineralogy of Yamuna Sand
It is indicated in study of Groeschke *et al*., (2017) [6] that the Yamuna sand is related to contamination of ammonia in ground water table. The suggested particle size distribution for Yamuna sand and its related geotechnical properties is tabulated in [Table-1]. The river stream and river bed of Yamuna from where Yamuna sand is collected is shown in Groeschke *et al*., (2017).

Material and Methods
Traixial Test of Yamuna Sand
The peak effective cohesion and internal friction angle (c' and φ') of the Yamuna sand can be determined from consolidated drained (CD) Traixial compression tests.

Saturation of Yamuna sand samples is normally carried out by leaving the samples to an elevated back pressure so that the air in the pores is dissolved in water. Back Pressure in the form of pore pressure is applied with the help of volume change gauge pressure at the top of specimen. Cell pressure is slightly higher as compared to applied pore pressure. Cell pressure and back pressure increased in increments, allowing for balance at each stage. Degree of saturation can be expressed in terms of Skempton's pore pressure parameter as [7].

$B = \Delta u/(\Delta \sigma^3)$

Where Δu is equal to change in pore pressure for an applied cell pressure change of $\Delta \sigma^3$.

The consolidation stage of an effective stress triaxial test is carried out for two reasons. First, three samples of Yamuna sand are tested and consolidated at three different confining pressures *i.e*., 1 kg/cm^2, 2 kg/cm^2 and 3 kg/cm^2, in order to give samples of Yamuna sand of different strengths which will produce widely spaced effective stress Mohr circles. Secondly, the results of consolidation are used to determine the minimum time to failure in the shear stage.
The effective consolidation pressure in triaxial test is cell pressure minus back pressure which is normally be increased by a factor of two between each sample, with the middle pressure approximating to the vertical effective stress in the ground. When the consolidation cell pressure and back pressure are applied to the sample, readings of volume change are made using a volume change device in the back pressure line. Pore pressure is measured at the sample's base, with drainage to the back pressure line taking place through a porous stone covering the top of the samples.
The consolidated drained triaxial compression test, with volume change measurement during shear and the back pressure remains connected to the samples which is loaded sufficiently slowly to avoid the development of excess pore pressures. Once shearing is complete, the results are presented as graphs of principal stress difference and volume change as a function of strain, and the failure Mohr circles are plotted to give the drained failure envelope defined by the parameters cd' and φd' where as cd' is the effective drained cohesion and φd' effective drained angle of internal friction [8].

Table-1 The Geotechnical Properties of Yamuna Sand

SN	Geotechnical Properties	Values	Std. Deviation
1	Specific Gravity	2.625	0.035
2	Coeff. Of Uniformity C_u	1.315	0.077
3	Coeff. Of Curvature C_c	2.22	0.91
4	Soil Classification	SP-SM	
5	Maximum Dry Densities kN/m^3	17.355	0.58
6	Optimum Moisture Content(OMC)%	10.6	0.84
7	Effective size of particle D_{10}(mm)	0.0845	
8	Sand Content (4.75-0.075 mm)%	92.4	
9	Fine Soil Fraction(<75 micron)%	7.6	

Table-2 The Sample Dimensions and confining pressure in Triaxial Cell

Sample	Post consolidated length in mm	Post consolidated diameter in mm	Post consolidated area in sq.mm	Post consolidated volume in cubic mm	Confining Pressure in kg per sq.cm.
1	81.12	38.05	1137.1	92.242	1
2	83.36	37.36	1096.2	91.38	2
3	81.64	37.71	1116.9	91.18	3

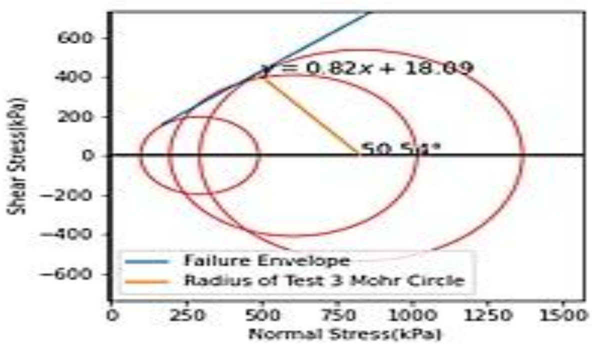

Fig-1 Mohr's Circle of Consolidated Drained Traixial Test of Yamuna Sand

During consolidated drained triaxial test following samples were observed under given confining pressure as given in [Table-2].

Results and Discussion

The Yamuna sand found all along the states of Haryana, Uttar Pradesh and Delhi causing major foundation soil along with other lithological soils of that region. However, this is an effort to minimize the risk of landslides, subsidence during flood and other natural calamities like earthquake. This study augmented those efforts which cause their prevention.

Consolidated Drained Shear Strength Behaviour of Yamuna sand

The result suggests failure strength envelope of Yamuna sand obtained from the consolidated drained triaxial test is shown in [Fig-1]. Yamuna sand's have cd' which is the effective drained cohesion 18.09 kPa and φd' effective drained angle of internal friction angle 39.35 degrees. From [Fig-2] as the confining pressure increases the failure strength of the Yamuna sand also increases. At the confining pressure 0.3 MPa maximum failure strength of the Yamuna sand is obtained in consolidated drained (CD) Triaxial test. This indicates that drained condition in Yamuna sand increases the stability of the Yamuna sand against the sliding and failure due to cave in and subsidence.

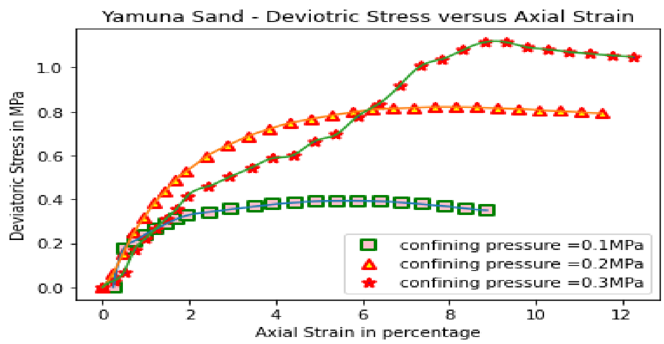

Fig-2 Deviotric Stress versus Axial Strain obtained from consolidated drained triaxial test of Yamuna Sand

The dilation curves obtained from consolidated drained (CD)Triaxial tests of Yamuna sand suggests larger volumetric strain at low confining pressure which results in elastic state during low confining pressure in consolidated drained environment as shown in the [Fig-3].

The pq plot [Fig-4] of the Yamuna sand obtained from consolidated drained triaxial test of Yamuna sand suggest similar results which are given in [Fig-4]. Here effective cohesion is zero and effective angle of internal friction is same as given in [Fig-4]. And also, with increase of confining pressure, failure shear strength of the Yamuna sand also get increased due to consolidated drained environment.

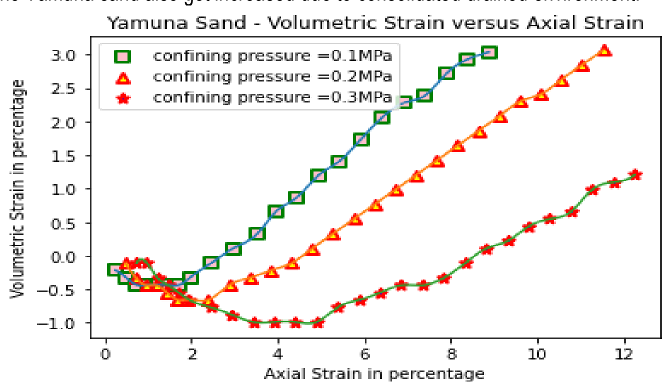

Fig-3 Volumetric Strain versus Axial Strain obtained from consolidated drained triaxial test of Yamuna Sand

As shown in [Fig-5] at confining pressure 0.2 MPa showing fully developed elastic curve of the Yamuna sand under consolidated drained triaxial environment of Yamuna sand.

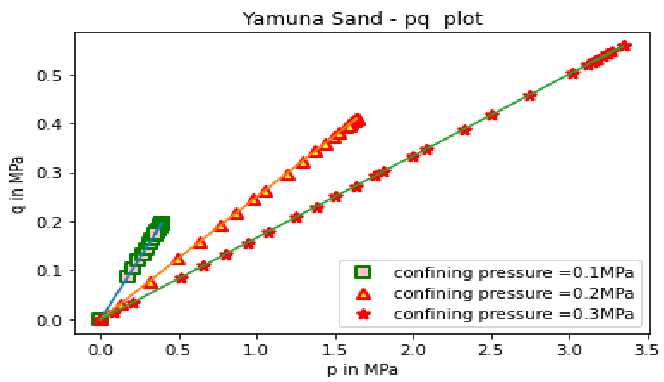

Fig-4 p ((σ1+σ3)/(2)) and q((σ1-σ3)/(2)) obtained from consolidated drained triaxial test of Yamuna Sand

Direct Shear Strength Behaviour of Yamuna Sand

In a direct shear test a constant load is applied normal to the shearing plane and another force is applied parallel to this plane. This later force is increased until the sample fails. The maximum force that the samples resists is divided by the cross-sectional area, is the shearing strength for that soil under that normal loading and

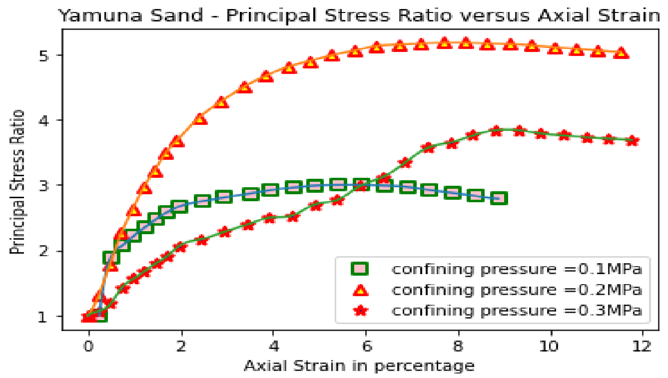

Fig-5 Principal Stress Ratio versus Axial Strain obtained from consolidated drained triaxial test of Yamuna Sand

under that moisture content, density, and degree of consolidation that prevailed throughout the test. By performing a series of these tests under similar conditions, but with different normal load each time, a graph can be constructed with the shearing stress as the ordinate and the normal stress as the abscissa. A shear box of 6 cm by 6 cm is considered for this testing with double and single drainage conditions. Rate of shearing is controlled by strain rate. The effect of rate of shearing on shearing of Yamuna sand is not considered in this testing.Samples that were dried back to water content had a higher strength than samples compacted at that water content; in contrast, samples wetted to achieve that water content had a lower strength. Samples that were dried back to a particular water content had a higher strength than samples compacted at that water content; in contrast, samples wetted to achieve that water content had a lower strength [9]. After this consideration samples of Yamuna sand were tested in two categories dense and loose state with two water content levels dry and saturated.

When Yamuna sand was tested in saturated environment in direct shear with double drainage, as shown in [Fig-6] with increase of normal stress change in thickness of the samples were observed. This shows the dilation behaviour of Yamuna sand with respect to normal stress. At increasing normal stress decrease in the sample thickness is observed as shown in [Fig-6].

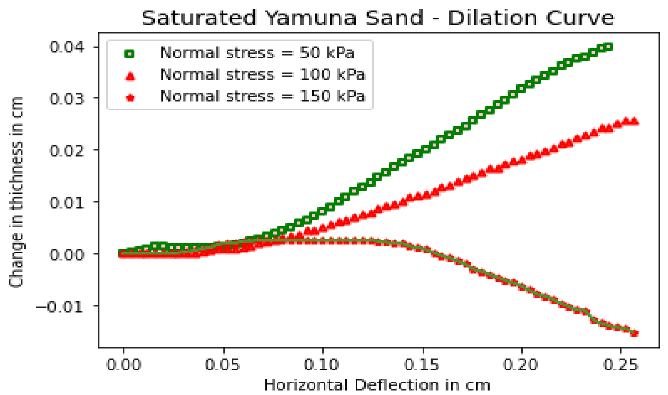

Fig-6 Saturated Yamuna Sand Direct Shear Test-Dilation Curve

With increase of normal stress as shown in [Fig-7] shear strength failure of Yamuna sand in saturated conditions under direct shear environment is achieved at high normal stress. But the peculiar thing is that at low and intermediatory normal stress failure shear strength is very close and near where as at high normal stress failure shear strength is achieved very high as compared to low and intermediatory normal stress.

With increase of normal stress as shown in [Fig-8] shear strength failure of Yamuna sand in dry and dense conditions under direct shear environment is achieved at high normal stress like [Fig-7]. But the peculiar thing is that at low normal stress failure shear strength is low. This is due to compactness of the sand grains is achieved under high normal stress. Where as in dilation curve of dry and dense Yamuna sand under direct shear environment suggests very small change in thickness of the sample with increase of normal stress as shown in [Fig-8].

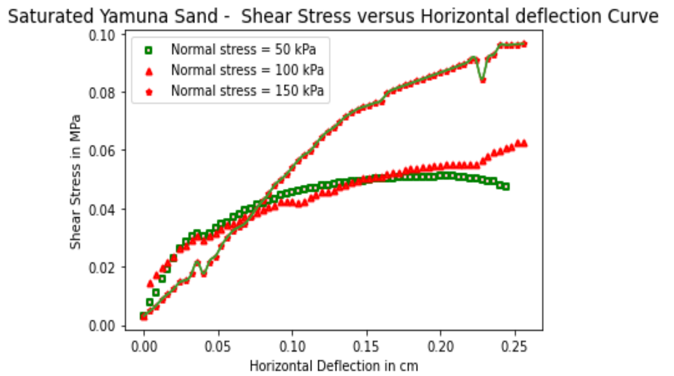

Fig-7 Saturated Yamuna Sand Direct Shear Test-Shear Stress versus Horizontal Deflection Curve

With increase of normal stress as shown in [Fig-8] and [Fig-9] shear strength failure of Yamuna sand in dry and loose conditions under direct shear environment is achieved at high normal stress. But the peculiar thing is that at high normal stress failure shear strength is near and close to each other. This is due to less compactness of the sand grains. Where as in dilation curve of dry and loose Yamuna sand under direct shear environment suggests change in thickness of the sample is decreased with increase of normal stress as shown in [Fig-10] and [Fig-11].

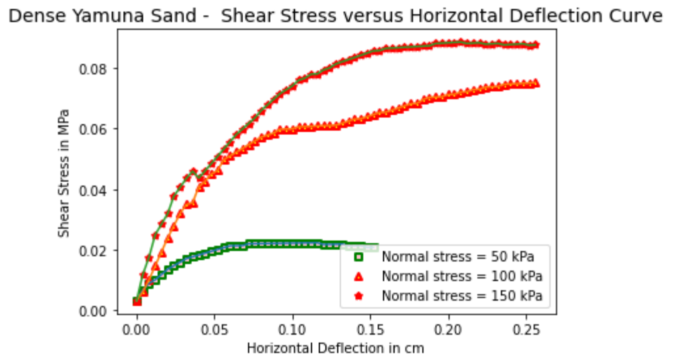

Fig-8 Dry and Dense Yamuna Sand Direct Shear Test-Shear Stress versus Horizontal Deflection Curve

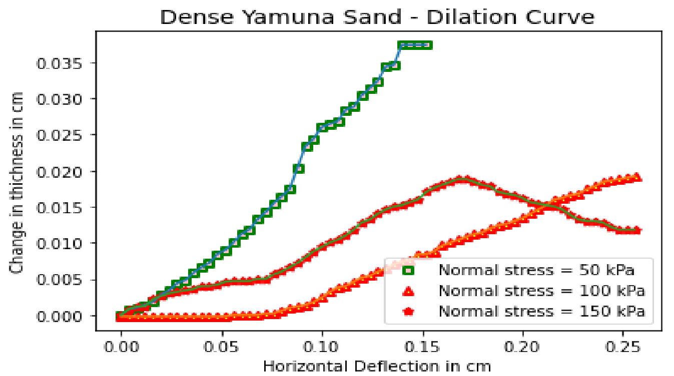

Fig-9 Dry and Dense Yamuna Sand Direct Shear Test-Dilation Curve

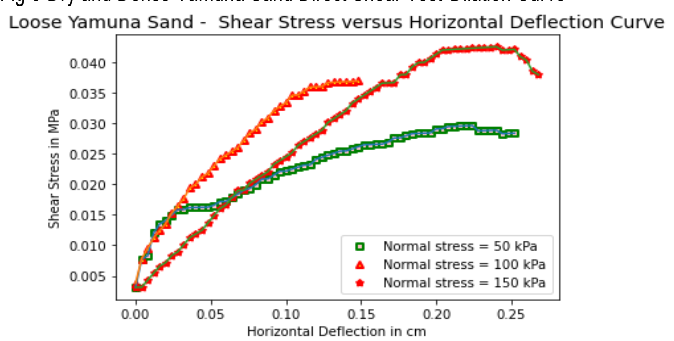

Fig-10 Loose Yamuna Sand Direct Shear Test-Shear Stress versus Horizontal Deflection Curve

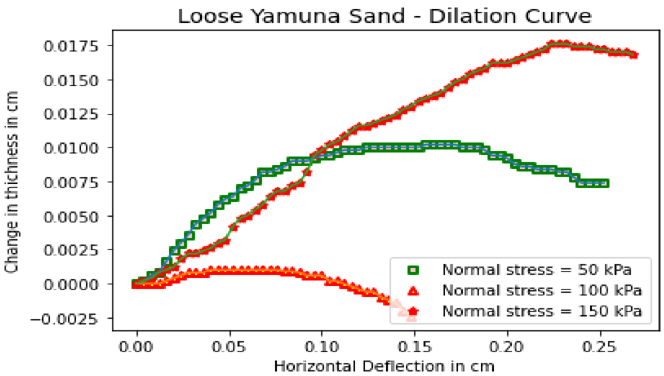

Fig-11 Loose Yamuna Sand Direct Shear Test-Dilation Curve

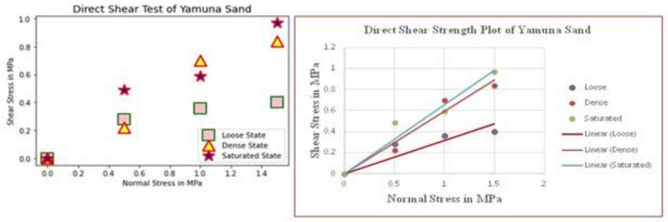

Fig-12 Direct Shear Strength Scatter and Envelope of Yamuna Sand obtained from Direct Shear Test

Direct Shear Strength Scatter and Envelope Behaviour of Yamuna Sand

The scatter and envelope of shear strength of the Yamuna sand under directs shear environment suggesting the failure of the Yamuna sand on a defined plane. As shown in [Fig-12] saturated Yamuna sand shown higher shear strength and Dense Yamuna sand is also slightly less shear as compared to saturated Yamuna sand. However loose Yamuna sand shows considerably lower shear strength as compared to saturated and dense Yamuna sand.

Conclusion

The compactness of sand grains of Yamuna sand has considerable effect on shear strength behaviour of Yamuna sand. Saturated state of Yamuna sand only felicitates the rearrangement of sand grains by the cohesion and adhesion exist between the sand grains, and due to this more compactness is achieved which gives better shear strength behaviour of the Yamuna sand.

Application of research: Soil and tillage action study of the shear strength behaviour of Yamuna sand

Research Category: Soil and Water Engineering, Soil and Tillage

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University: CCS Haryana Agricultural University, Hisar, 125004, Haryana, India
Research project name or number: Research station study

Author Contributions: Sole author

Author statement: Author read, reviewed, agreed and approved the final manuscript. Note-Author agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Yamuna River

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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