EFFECT OF WHEAT STRAW ON THE DYNAMIC PROPERTIES OF CLAYEY SOILS

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Abstract
Understanding the dynamic behavior of clayey soils is essential for engineering design, construction, and risk assessment to ensure the stability and safety of infrastructure built on or within these soils. To assess the impact of wheat straw on the dynamic properties of clayey soils proper testing and evaluation should be conducted before implementing it in engineering or construction projects. The objectives of the current study are to explore the impact of wheat straw on the dynamic properties of clayey soils; particularly the shear modulus and damping ratio. Prior research has mostly examined how wheat straw affects the physical, mechanical, biological, and index characteristics of soil; little attention has been paid to how wheat straw affects the dynamic features of clayey soils. In the present study, various percentages (0 to 10%) of wheat straw were blended with clayey soil and the testing was conducted on the Resonant Column Apparatus at the four confining pressures (90 kPa, 135 kPa, 180 kPa and 225 kPa). According to the experimental findings, the shear modulus and damping ratio gradually increase as the amount of wheat straw increases. Whereas, The shear modulus increases as the confining pressure increases, but the damping ratio decreases as a result. From the results, it may be concluded that the use of an optimal content of wheat straw increased the shear modulus and damping ratio which results in more resilience against earthquake damages.
Keywords: wheat straw, damping ratio, Shear modulus, resonant column

1. INTRODUCTION

The load varies in their magnitude, direction or position with time called dynamic loading. The dynamic loading on the soil can be experienced directly or indirectly by several sources such as machine foundation, traffic loading, wind loads, sea waves and earthquakes etc. The soil parameters which represent the mechanical response of the soil under dynamic loading are generally named as dynamic soil parameters. The dynamic soil parameters mainly consist of shear modulus, damping ratio, Poisons' ratio and liquefaction potential etc. Apart from several other factors the effect of earthquake loading mainly depends upon the frequency, amplitude, and duration. Moreover, the effect of earthquake loading depends on site conditions either hard strata or soft ground, such as structure built on rock, will be subjected to short-duration excitation while structures founded on soft soils will result in the longer period, causes amplification effect. In case of construction on soft soils conditions such as clayey soils, prior to site utilization ground improvement is made usually by reinforcement and or stabilization otherwise it may result to excessive settlement and subsequent failure of the foundation. The ground improvement which done for the improvement of soft ground conditions may results in the change in the site conditions and subsequently the ground response under dynamic loading (coming from earthquakes).

Numerous investigations have been carried out in the past on soft soil reinforcement [1-10]. Their studies show that the reinforcement increases the dynamic properties. Clayey soils are generally, considered to be soft soil having high compressibility and low shear strength [11, 12]. It is nearly hard to use soft soils as a foundation material without finding a way to change their unfavorable characteristics. While numerous approaches, which include prefabricated vertical drains, geotextile reinforcing, lime and cement stabilization, have been efficiently used to deal with certain soils, they permanently remain the motivation for further modification of the methods, particularly in terms of economics and efficiency [13].Therefore, the wheat straw impact on the dynamic characteristics of clayey soils is the main focus of this study. The dynamic properties of clayey soil are based on the shear modulus and damping ratio only. The thorough testing and analysis are laboratory-based with the help of resonant column testing. Understanding the dynamic behaviour of clayey soils is essential for engineering design, construction, and risk assessment to ensure the stability and safety of infrastructure built on or within these soils. Proper testing and evaluation should be conducted to evaluate the wheat straw impact on the dynamic properties of clayey soils before implementing it in engineering or construction projects.

2. MATERIALS AND METHODS

Air drying the clayey, dark brown soil was used in this study as shown in Figure 1. Clayey soil sample, having a specific gravity (Gs) of 2.68.The Figure 2. Wheat straw sampleand Figure 3 shows the Wheat straw sample and soil gradation respectively. The optimum moisture content was 16% based on the standard proctor test.The index properties of Wheat straw are given in Table 1.

Figure 1. Clayey soil sample

Figure 2. Wheat straw sample

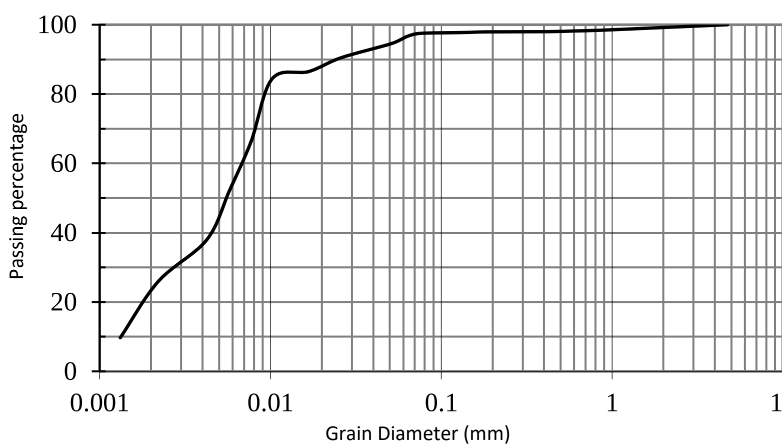

Figure 3. Particle size distribution curve

Table 1. Wheat Straw Index Properties [14].

Average length, L (mm)	Average diameter, D (mm)	Water Absorption (%)	Specific gravity (Gs)	Tensile strength (MPa)
18.4	3.1	300% (After 24 h)	0.34-0.38	10.133 (1470 psi)

3. EXPERIMENTAL SETUP

The Resonant Column test device is utilized to determine the damping ratio and small strain shear modulus. The experimental setup of the resonant column test is shown in Figure 2 and Figure 3. The key points about its use are to measure the extreme shear modulus (Gmax) of soils under very small shear strains (typically less than 0.001%). Gmax is an important parameter in soil dynamics analyses. It works by exciting a soil sample in a hollow cylindrical container at its natural frequency of vibration. This causes shear strains in the sample. Sensors measure the frequency and amplitude of vibration. Gmax can then be calculated based on the sample dimensions, mass, and the fundamental frequency of vibration. Samples are usually saturated and consolidated under normal stresses representative of field conditions. This allows Gmax to be measured at different effective confining pressures. Testing is done under very small shear strains to obtain the small-strain, nearly linear elastic behavior of soils prior to shear modulus degradation with increased strain levels. Results provide valuable input for site response analyses, liquefaction evaluations, seismic design of foundations and retaining walls, etc. Factors like soil type, density, stress history, cementation all influence Gmax values obtained from resonant column tests. It's a more sophisticated laboratory test than other shear modulus measurement techniques like cyclic triaxial testing.

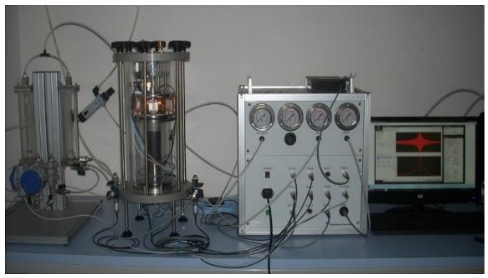

Figure 2. Combine cyclic torsional shear equipment with resonant column

Figure 3. Cell parts of the combined cyclic torsional shear equipment with resonant column

4. SAMPLE PREPARATION

Proper sample preparation is critical for ensuring accurate and repeatable Gmax results from resonant column testing. Reconstituted soil specimens were prepared by crushing the lumpy soil taken from the East of the Karachi-Pakistan. A known weight of the material was passed through Sieve No.40 (0.425 mm) and blended with the required percentage of the wheat straw prior to adding water. The amount of water mixed kept equivalent to the liquid limit of the soil (around 37% approx.:). The homogenously blended sample was compacted in a mould of 50 mm diameter and 100 mm length to a targeted density and allowed for soaking. Figure 4 shows samples with different wheat straw contents.

Figure 4. Different wheat straw content % mixed with clayey soil

5. TESTING PROCEDURE

To study the wheat straw effect on the dynamic response of clayey soils, Testing of resonant columns was done at four distinct confining pressures (90 kPa, 135 kPa, 180 kPa, and 225 kPa) using a frequency range of 40 to 70 Hz. The tests were conducted as per ASTM D4015-21. The detailed experimental design with control parameters is given in Table 2.

Table 2. Experimental Design and Control Parameters

	Sample preparation					Strain %	Variables	
S. No.	Wheat Straw Content (%)	Layers	No. of Blows	Curing (Days)	No. of Tests	Amplitude Range (%) $\times 10^{-3}$	Frequency Range (Hz)	Confining Pressure Range (kPa)
1	0	3	25	7	4	1-6	40 – 70	90-225*
2	2	3	25	7	4	1-6	40 – 70	90-225
3	4	3	25	7	4	1-6	40 – 70	90-225
4	6	3	25	7	4	1-6	40 – 70	90-225
5	8	3	25	7	4	1-6	40 – 70	90-225
6	10	3	25	7	4	1-6	40 – 70	90-225

*90, 135, 180, 225

6. RESULTS AND DISCUSSION

6.1 WHEAT STRAW'S IMPACT ON THE SHEAR MODULUS (G_{MAX})

The impact of adding wheat straw to clay soils at different confining pressures on their shear modulus is displayed in Figure 5. The results illustrate that the shear modulus of the soil gradually increases as the amount of wheat straw increases. The increase in the shear modulus could be because of the tensile strength induced by the fiber into the clayey soils. The soil particle rearrangement caused by fibre addition is may also be responsible for the dynamic property of soft soil. It is quite evident from the previous studies that the soils become fibre-saturated at their optimum content, which means fibre-filled all void of soil, enhancing site stiffness and reducing vibration amplitude to produce a stiffer composite. [3].

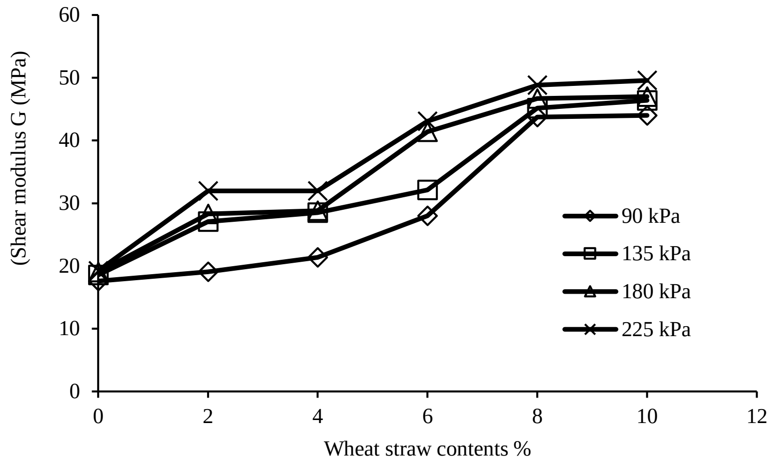

Figure 5. The % impact of wheat straw content on the shear modulus at various confining pressures

6.2 WHEAT STRAW'S IMPACT ON THE DAMPING RATIO (D)

The impact of varying confining pressures on wheat straw contents on the clayey soils' damping ratio is presented in Figure 6. It is clear from the figure that the damping ratio is gradually rising of the clayey soil this increase in clayey soil damping ratio as a result of the inclusion of wheat straw could be due to the fibrous behaviour of the wheat straw offering a cushion against oscillations induced due to the dynamic loading. As in literature mentioned by Amir-Faryar and Aggour 2012 that damping ratio increases with the increase in strain and fiber inclusion.

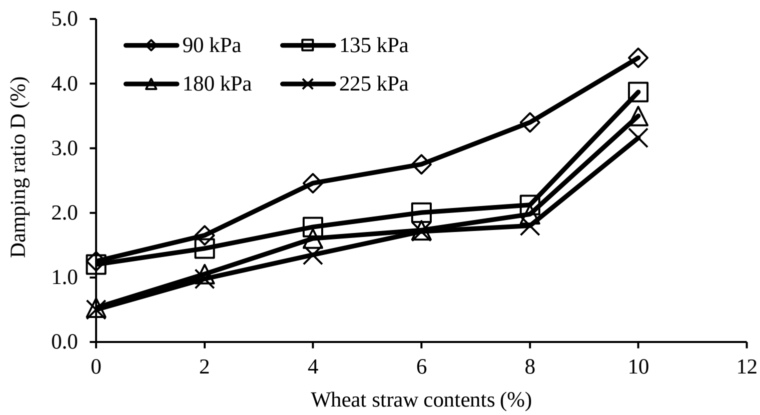

Figure 6. The % impact of wheat straw content on damping ratio at different confining pressures

7. CONCLUSIONS

Based on the findings of the experiment, it can be said that:

1. There is an increase in the shear modulus and damping ratio with the increase in the wheat straw content. The improvement in the damping ratio causes the dissipation of seismic waves and reduces the amplification, similarly, the increase in the shear modulus increases the stiffness of soft soils which also causes an increase in the soil response against earthquakes.
2. It is established that the damping ratio (D%) drops and the shear modulus (G) increases with an increase in confining pressure.

8. RECOMMENDATIONS

1. The use of soil reinforcing agents has a constructive effect on the seismic response of the soil in general. Typically, 10% wheat straw content is suitable.
2. For future studies, the effect of wheat straw is required to be investigated with high plastic soils at different strain percentages.

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