THE IMPACT OF THE AMOUNT OF LIME ON THE DYNAMIC CHARACTERISTICS OF CLAYEY SOILS

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Abstract
In order to guarantee the stability and safety of infrastructure erected on or within clayey soils, engineering design, construction, and risk assessment all depend on an understanding of the dynamic behavior of these soils. To assess the impact of lime 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 lime on the dynamic properties of clayey soils; particularly the shear modulus and damping ratio. Prior research has mostly examined how lime affects the physical, mechanical, biological, and index characteristics of soil; little attention has been paid to how lime affects the dynamic features of clayey soils. In the present study, various percentages (0 to 10%) of lime 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, as the amount of lime content rises, the damping ratio and shear modulus progressively increase. Conversely, when the confining pressure rises, the shear modulus rises as well, but the damping ratio falls as a result. Based on the findings, it can be deduced that using an ideal lime concentration raised the damping ratio and shear modulus, increasing resilience against seismic damage.

Keywords: Lime, Shear modulus, damping ratio, resonant column

1. INTRODUCTION

Dynamic loading is the term for loads that change over time in terms of size, direction, or location. 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. Dynamic soil parameters are commonly defined as soil parameters that indicate the mechanical reaction of the soil under dynamic loading. 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 site characteristics and, consequently, the ground reaction under dynamic loads may alter as a result of ground modification intended to improve soft ground conditions.

Numerous investigations have been carried out in the past on soft soil modification [1-14]. Their studies show that the modification increases the dynamic properties. Clayey soils are generally, considered to be soft soil having high compressibility and low shear strength [15, 16]. 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 [11].Therefore, the lime impact on the dynamic characteristics of clayey soils is the main focus of this study. The shear modulus and damping ratio alone determine the dynamic characteristics of clayey soil. Resonant column testing is used in the laboratory-based comprehensive testing and analysis. For engineering design, construction, and risk assessment to guarantee the stability and safety of infrastructure erected on or within clayey soils, an understanding of the dynamic behavior of these soils is crucial. Before incorporating lime into engineering or building projects, appropriate testing and assessment should be carried out to determine the impact of lime on the dynamic properties of clayey soils.

2. MATERIALS AND METHODS

The clayey soil was used in this study as shown in Figure 1. Clayey soil sample, having a specific gravity (Gs) of 2.68. The lime sample and the soil gradation curve has shown in **Error! Reference source not found.** and Figure 3 r espectively. The optimum moisture content was 16% based on the modified proctor test.The chemical analysis of lime are given in Table 1.

Figure 1. Clayey soil sample

Figure 2. Lime sample

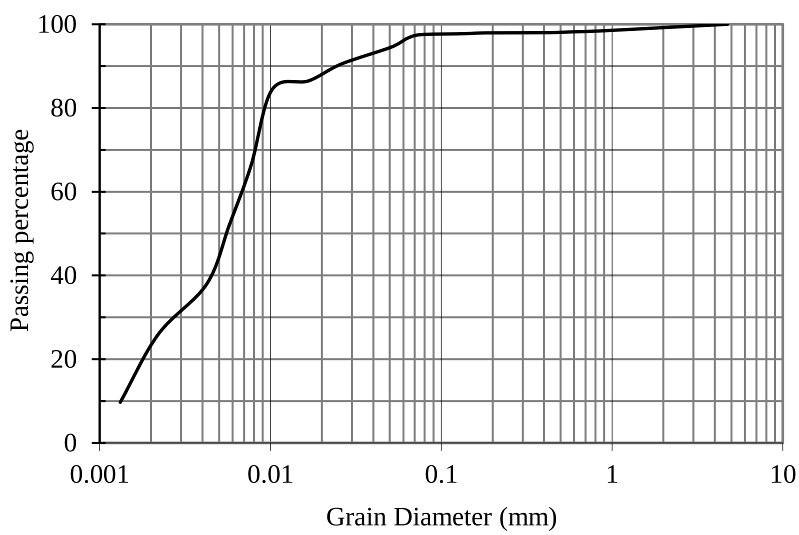

Figure 3.Particle size distribution curve

Table 1. Lime content chemical analysis [17].

Constituent	Quantity
Insoluble in hydrochloric acid	0.03%
$CaCO_3$	3%
Substitutes do not precipitate by NH_4.ox(an SO_4)	2.5
Chloride	50 mg/kg
Sulfate	500 mg/kg
Fe	500 mg/kg
Cu	5 mg/kg
Zn	5 mg/kg
Pb	2 mg/kg

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 4 and Figure 5. The key points about its use are to measure the extreme shear modulus (G_{max}) of soils under very small shear strains (typically less than 0.001%). G_{max} 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. G_{max} 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 G_{max} 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 G_{max} values obtained from resonant column tests. It's a more sophisticated laboratory test than other shear modulus measurement techniques like cyclic triaxial testing.

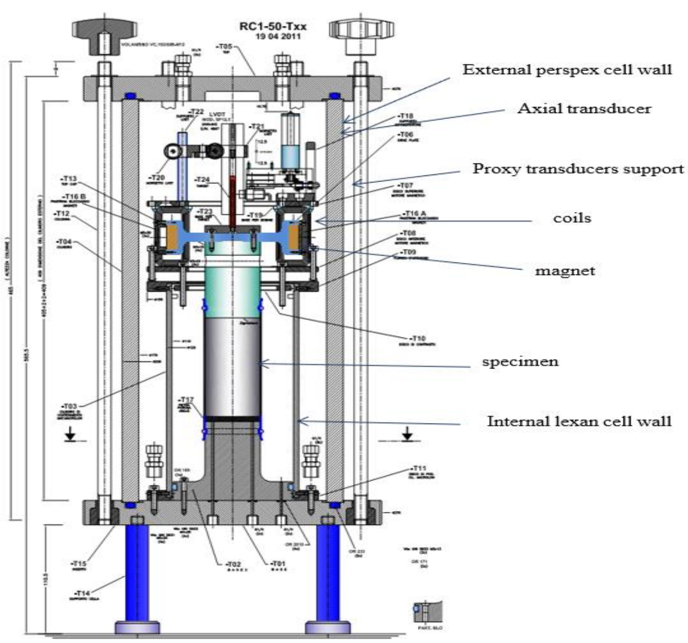

Figure 4. The Resonant column Chamber

Figure 5. Combine cyclic torsional shear equipment with resonant column

4. SAMPLE PREPARATION

For reliable and consistent G_{max} results from resonant column testing, sample preparation is essential. In order to create reconstituted soil specimens, lumpy dirt from Karachi, Pakistan's east, was crushed. Before adding water, a known weight of the material was blended with the necessary percentage of lime after passing through Sieve No. 40 (0.425 mm). 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 6. Pure clayey soil sample and Figure 7. Samples with different lime content % mixed with the clayey soil.

	
Figure 6. Pure clayey soil sample	Figure 7. Samples with different lime content % mixed

5. TESTING PROCEDURE

Resonant column testing was conducted at four different confining pressures (90 kPa, 135 kPa, 180 kPa, and 225 kPa) utilizing a frequency range of 40 to 70 Hz in order to investigate the impact of lime on the dynamic response of clayey soils. 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.	Lime 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 EFFECT OF LIME CONTENT ON THE SHEAR MODULUS (G_{MAX})

The lime content effect on the shear modulus of a clayey soil is given in Table 3 .it is given that increase in the lime content the shear modulus increases. From Figure 8, it can be seen that at 90 kPa and 135 kPa confining pressures there is no significant increase in the shear modulus, at higher confining pressure 180 kPa and 225 kPa considerable increase in shear modulus encountered at increasing lime contents. So, it shows that at increasing confining pressure the shear modulus increases. The increase in shear modulus of natural cohesive soils at small strain by the increase of lime contents is also shown by [18].

Table 3. Effect of lime and confining on the shear modulus G

Lime contents (%)	**Confining pressure (kPa)**			
	90	**135**	**180**	**225**
	Shear modulus G			
0	17.59	18.56	19	19.22
2	19.36	26.37	25.28	27.8
4	19.68	27.1	34	40
6	21.39	28.8	44.68	47.95
8	23.04	32.58	51.55	54
10	24.07	34.29	62.87	64

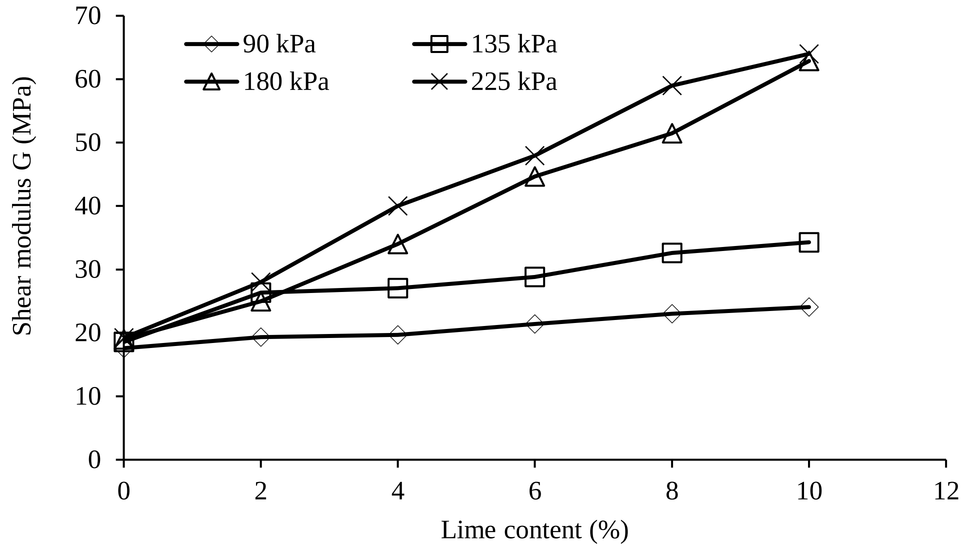

Figure 8. Effect of lime and confining pressure on the shear modulus G

6.2 EFFECT OF LIME CONTENT ON THE DAMPING RATIO (D) OF CLAYEY SOILS

The lime content effect on damping ratio is given in Table 4 and graphically shown inFigure 9, it can be clearly seen that at zero per cent inclusion for 90 kPa and 135 kPa the damping ratio is more as compared to confining pressures of 180 kPa and 225 kPa at different inclusion percentage. Both trends show the increase in the damping ratio. The strain was kept 2 x 10-3 for 90 kPa and 135 kPa and for 180 kPa and 225 kPa was kept 1.5 x 10-3, results show that damping ratio increases with strain, as [19] conducted a study on clayey soils and concluded that damping ratio increase with shear strain. Damping ratio increases with lime inclusion as mentioned in the literature by [18] that lime inclusion decreases the plasticity of soft soils, [19] mentioned in their study results that the damping ratio is inversely proportional to the plasticity of the soils at small strains, so as the plasticity decreases the damping ratio increases.

Table 4. Lime content effect on the damping ratio at various confining pressure.

Lime contents (%)	**Confining pressure (kPa)**			
	90	**135**	**180**	**225**
	Damping ratio %			
0	1.26	1.22	0.53	0.5
2	1.62	1.33	0.6	0.6
4	1.93	1.45	0.6	0.5
6	2.46	1.78	0.98	0.71
8	2.62	2.52	1.09	0.82
10	2.63	2.65	1.87	0.98

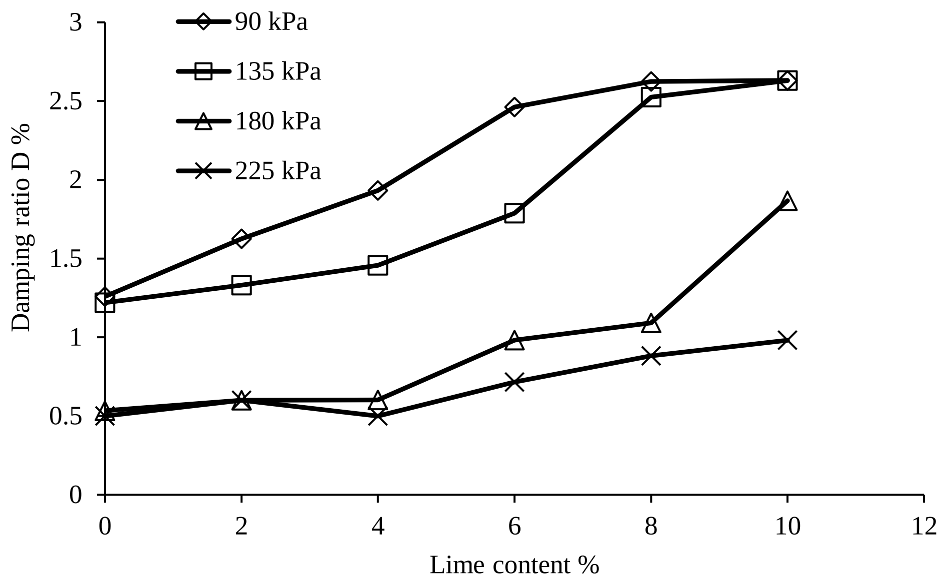

Figure 9. Effect of lime and confining pressure on the damping ratio D %

7. CONCLUSIONS

It may be concluded from the experimental results:

1. As the amount of lime increases, the damping ratio and shear modulus both rise.
2. In the same way that an increase in shear modulus makes soft soils more rigid and improves soil responsiveness to earthquakes, an improvement in damping ratio dissipates seismic waves and lessens amplification.
3. Further, the effect of confining pressure is examined on the shear modulus and damping ratio in respect of lime. It is concluded that shear modulus increases with the increase in the confining and damping ratio decreases with the increase in confining pressure.
4. The use of soil stabilizing agents have positive impact on the seismic response of the soil in general.

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