A STUDY OF SOIL NONLINEAR DYNAMIC PROPERTIES

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Abstract

This research examines the dynamic properties of soils, specifically the shear modulus decrease curves and damping curves for cohesive and non-cohesive soils. Available research materials, such as reports and articles, are gathered and examined in this study to determine the elements that influence soil dynamic features. The confining pressure and plastic index were discovered to be the most relevant elements for cohesiveness less and cohesive soils, respectively. The dynamic features of cohesion less and cohesive soils are examined, and shear modulus reduction curves and damping curves for cohesion less and cohesive soils are calculated, based on these parameters. The findings of this work may be used to disaster mitigation, such as calculating ground reaction to earthquakes using the shake computer programme and then assessing building safety during a seismic event.

Introduction

For correct ground response calculations, appropriate information on non-linear dynamic soil parameters, particularly dynamic shear modulus and damping ratio, is required in the creation of analytical methodologies for analysing the reaction of soil deposits under seismic ground motion. Shear modulus and damping ratio are often stated as a function of shear strain in the form of relationships. Data on dynamic shear module and damping ratio for cohesive and cohesion less soils under cyclic loading circumstances are summarised in this work. The findings of this work may be used to disaster mitigation, such as calculating ground reaction to earthquakes using the shake computer programme and then assessing building safety during a seismic event.

Soil dynamic characteristics

To measure soil dynamic properties, laboratory triaxial compression studies under cyclic loading conditions are often utilised. The shear modulus is commonly stated as the secant modulus defined by the extreme points on the hysteresis loop, whereas the damping factor is proportional to the area within the hysteresis loop, as illustrated in Fig. 1. The shear modulus G is then calculated at a strain level using the following equation:

$$G = \frac{\tau}{\gamma}$$

Where and are the amplitudes of shear stress and shear strain, respectively. When the strain is less, the secant modulus has a higher value. When is zero, the sparse shear modulus of soil achieves its maximum value Gmax under elastic conditions. The following equation may also be used to calculate Gmax from shear wave velocity:

$$G_{\max} = \rho v_s^2$$

Where Vs is the shear wave velocity in the soil layer and is the soil density. Shear modulus G is usually normalised by Gmax in the research of soil dynamic features to get shear modulus ratio G/Gmax. The shear modulus decrease charts are shown in Fig. 2. As illustrated in Fig. 2, when the strain level is lower, the shear modulus ratio is higher. As the strain level rises, the value of the shear modulus ratio drops. Similar correlations may be found for the damping ratio at a strain level, which are represented by the equation:

$$\xi = \frac{W_D}{4\pi W_s}$$

The wasted energy is WD, while the maximal strain energy is WS. Figure 2 also depicts the damping curve. The damping ratio rises as the shear strain level increases, as seen by the curve.

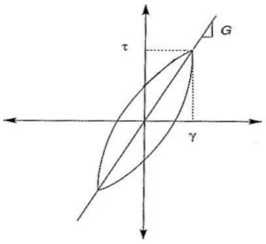


Fig. 1. Hyperbolic loop, non-linear soil model with extended Masing rule to define loading and unloading behaviour:

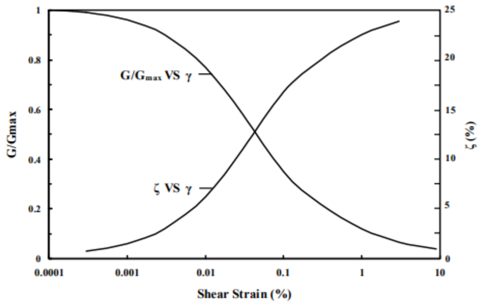


Fig. :- Shear modulus reduction and damping curves of soils.

Factors affect soil non-linear characteristics

Cohesion less Soil

Many researchers, including Seed and Idriss (1970), Hardin and Drnevich (1972), Iwasaki et al. (1978), Dobry and Vucetic (1987), Ishibashi and Zhang (1993), Hashash and Park (2001), and Stokoe et al. (2002), have presented a comprehensive survey of the factors affecting the shear modulus and damping ratio of cohesion less soils (2004). The key elements affecting shear modulus and damping ratio, according to their research, are effective confining pressure's, void ratio e, and shear strain; while less relevant ones include the number of loading cycles N and the over consolidation ratio OCR. Many researchers have recently investigated factors influencing shear modulus reduction curves and damping curves of cohesion less soil by effective confining pressure's, such as Hardin and Drnevich (1972) and Seed and Idriss (1970), who have shown that effective confining pressure has a significant impact on modulus values for sands. Furthermore, Iwasaki et al. (1978) demonstrated that when effective confining pressure rises, the effects of shear strain on shear modulus reduction diminishes. Ishibashi and Zhang (1993), Hashash and Park

(2001), and Stokoe et al. (2004), on the other hand, found that when effective confining pressure rises, the effects of shear strain on shear modulus reduction reduces. Dobry and Vucetic (1987) used damping curves to demonstrate that the damping ratio rises as the effective confining pressure rises.

Cohesive Soil

Many researchers have looked at the variables that influence cohesive soil's shear modulus and damping ratio. Plasticity index (PI), void ratio e, and frequency of cyclic loading are the principal parameters impacting shear modulus and damping ratio factors, according to the majority of these research. Many researchers have researched aspects affecting shear modulus reduction curves and damping curves of cohesive soil by plastic index in recent years, such as Kokushu et al. (1982), who proposed that damping ratio values may be connected to a soil's plasticity index. According to Stokoe et al. (2004) and Vucetic and Dobry (1991), damping ratio decreases as PI grows; nevertheless, damping ratio may decrease as PI increases at greater shear strain levels.

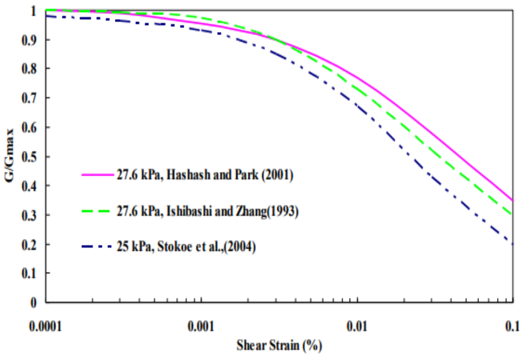
Dynamic characteristics of cohesion less soils

As previously stated, many investigators have also studied factors influencing shear modulus reduction curves and damping curves of cohesionless soil by confining pressure'm for the study of factors affecting shear modulus and damping ratio of cohesionless soil. He believes that the effective confining pressure'm is the primary factor affecting dynamic characteristics of cohesiveness soil. For practical reasons, existing information on the dynamic properties of sands under various effective confining pressures (Ishibashi and Zhang (1993); Hashash and Park (2001); and Stokoe et al. (2004)) is reviewed. Ishibashi and Zhang (1993) reported shear modulus reduction curves and damping curves at various effective confining pressures of 27.6kPa, 55.2kPa, 110kPa, 221kPa, and 442kPa, taking into account the effects of effective confining pressure.

Shear modulus reduction curves and damping curves were also published by Hashash and Park (2001) for various effective confining pressures of 27.6kPa, 55.2kPa, 110kPa, 221kPa, 442kPa, 833kPa, 1776kPa, and 10MPa. According to the findings, the influence of confining pressure on shear modulus decrease and damping ratio rise may be more significant at higher effective confining pressure. Stokoe et al. (2004) discovered that effective confining pressure did alter shear modulus reduction curves in experiments of shear modulus reduction curves and damping curves under effective confining pressures of 25kPa, 250kPa, and 2500kPa. In general, effective confining pressure rises as the depth of the soil layer rises. Samples are obtained from various depths with varied effective confining pressures during laboratory dynamic testing to assess both modulus and damping properties. Effective confining pressures are divided into four groups in this research to evaluate the influence of effective confining pressure fluctuations on dynamic characteristics'=2527.6kPa, 55.2kPa, 110kPa, and 221252kPa.'m = 2527.6 kPa effective confining pressure Under effective confining pressures= 2527.6 kPa, the shear modulus decrease curves are shown in Fig. 3(a). When shear stain values are higher than 310-3 percent, the variation in these three curves is very close to each other. When shear stain values are lower than 310-3 percent, the shear modulus presented by Hashash and Park (2001) has higher values than that of Ishibashi and Zhang (1993) and Stokoe et al. (2004). Figure 3 shows the damping curves for effective confining pressure's=2527.6kPa (b). As indicated in Fig. 3(b), Hashash and Park (2001) offer a damping ratio that is lower than that of Ishibashi and Zhang (1993) and Stokoe et al (2004). As the shear strain rises, the variations become more pronounced.

(2)'m = 55.2 kPa effective confining pressure The shear modulus decrease trends are shown in Fig. 4(a). At strain levels of 110-4 percent to 110-1 percent, two curves are demonstrated to be quite near to one other.

Under effective confining pressure's=55.2kPa, the damping curves are shown in Fig. 4(b). When shear strain values range from 110-4 percent to 310-3 percent, the difference between these two curves is relatively modest; however, when shear strain values exceed 310-3 percent, the damping ratio reported by Hashash and Park (2001) has smaller values than that of Ishibashi and Zhang (1993). As the shear strain value rises, the discrepancy becomes larger. Stokoe et al., on the other hand, did not describe the shear modulus and damping curves of cohesion less soils with effective confining pressure's=55.2kPa.



(a)

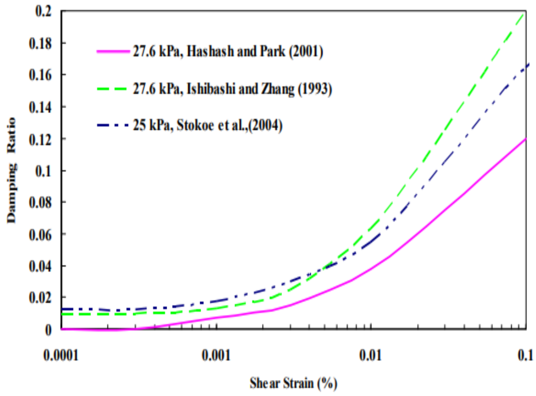
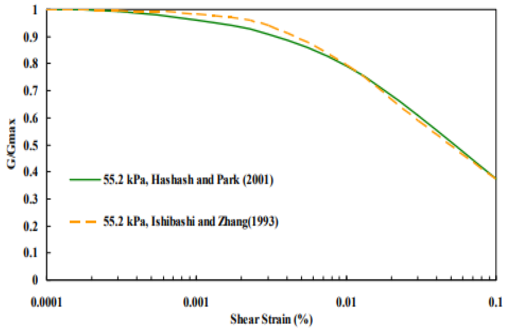


Fig: Influence of confining pressure for cohesion less soils with σ'm = 25~27.6 kPa, (a) shear modulus reduction curves, (b) damping curves.



(a)

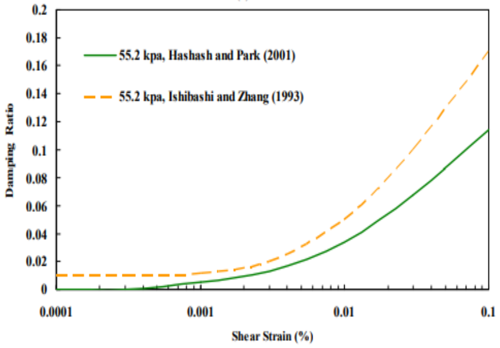


Fig.. Influence of confining pressure for cohesion less soils with σ'm = 55.2kPa, (a) shear modulus reduction curves, (b) damping curves.

Stokoe et al., on the other hand, did not publish the shear modulus decrease and damping curves for cohesionless soils with effective confining pressure'm=110kPa (2004). (4) 'm = 221250 kPa effective confining pressure The shear modulus decrease curves for'm=221250kPa are shown in Fig. 6(a). Curves are fairly near together for shear strains less than 110-3 percent, however Ishibashi and Zhang's (1993) result is greater than Hashash and Park's (2001) and Stokoe et al(2001) .'s results (2004). As shear strain rises, the curves found by Stokoe et al. (2004) decrease dramatically.

Both Ishibashi and Zhang (1993) and Stokoe et al. (2004) have the same damping ratio when the shear strain is less than 10%, however Ishibashi and Zhang (1993) have lower values than Stokoe et al. (2004) when the shear strain is larger than 10%. The outcome of Hashash and Park (2001) is usually lower than both of them. In conclusion, as long as the strain is less than 110-4 percent, discrepancies in shear modulus decrease curves are restricted. Stokoe et al. (2004) produced results with lower values than the rest.

As the shear strain value rises, the gap between them widens. The differences between graphs linking damping ratio to shear strain, on the other hand, are more substantial. Hashash and Park (2001) give damping ratios that are all lower than Ishibashi and Zhang (1993), with Stokoe et al. (2004) findings in the middle. The dynamic characteristics finding of Hashash and Park (2001) seems to better capture depth effects, based on the comparison of these studies.

Hashash and Park (2001) findings may better depict subsurface structure due to the confining pressure impact. (191986). The findings of Vucetic and Dobry (1991) for soils with PI=0 are likewise shown in Fig. 7. It is obvious from Fig. 7(a) that the shear modulus values reported by Hashash and Park (2001) are similar to those obtained by Seed and Idriss (1970) and Vucetic and Dobry (1991). Hashash and Park (2001) provide a damping ratio with lower values than Seed and Idriss (1970) and Vucetic and Dobray (2001).In dynamic assessments, it is recommended to apply shear modulus reduction curves and damping curves considering different proposed by Hashash and Park because effective confining pressure, apart from shear strain level, has a substantial impact on assessing the shear modulus and damping ratio (2001).

Dynamic characteristics of cohesive

SOILS Sun et al. (1988) found that the plasticity index appears to be the most dominant and consistent factor in the form of the normalised modulus reduction relationship for cohesive soils, based on an examination of the effects of many factors that influence the form of the normalised modulus reduction relationship.

The shear modulus decrease curves for cohesive soils of various plasticity are shown in Figure 8. Sun et al., on the other hand, did not include damping qualities of cohesive soils in relation to a soil's PI (1988). Seed and Idriss did not consider the influence of PI as a prominent element in their study on the dynamic features of cohesive soils (1970). Vucetic and Dobry

(1991) highlighted the impact of PI on the shapes of shear modulus decrease curves and damping curves after extensive laboratory testing on saturated cohesive soils with various PI. Shear modulus and damping ratio should be considered while studying the dynamic properties of cohesive soils.

As a consequence, the findings of Vucetic and Dobry (1991) are utilised in this investigation. Figure 9 depicts the findings of their research. PI levels are classified into six groups: 0, 15, 30, 50, 100, and 200. The normalised modulus clearly drops as PI rises. The damping ratio, on the other hand, rises as PI rises.

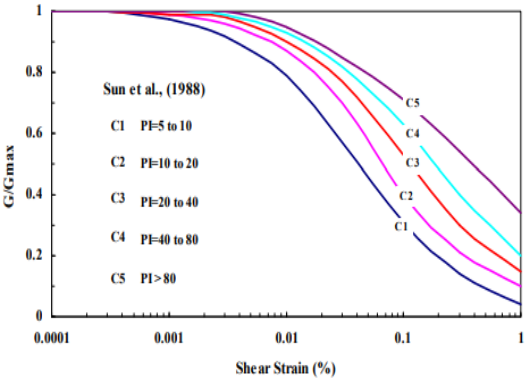


Fig. Shear modulus reduction curves for cohesive soils of different plasticity

Conclusions

The plasticity index and effective confining pressure are the major elements governing the shear modulus reduction curves and damping curves for cohesive and cohesion-less soils, respectively, based on the research mentioned in the previous pages. The use of shear modulus reduction curves, as well as the damping curves presented by Vucetic and Dobry (1991) and Hashash and Park (2001), can provide a convenient basis for determining dynamic properties for cohesive and cohesion-less soils, respectively, according to a number of available cyclic loading results.

This study's proposed correlations between the shear modulus and the damping ratio with the shear strain amplitude correspond well with the findings for plain soils. The findings of this research may be used to disaster mitigation, such as calculating ground reaction to earthquakes using the shake computer programme and then assessing building safety during a seismic event.

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