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Discussion of "Proposition of correlations for the dynamic parameters of carbonate sands"*

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Discussion

The reader appreciates the authors' development of equations to predict the dynamic behavior of carbonate sands. The main reason that makes it difficult to accurately predict $G/G_{max} - \gamma$ is the existence of other independent variables.

The equation proposed by the authors has a structure similar to that of Ishibashi & Zhang (1993). It is essentially the product of a function only of γ and a power function of the confining stress. In the reader's opinion, the main difference between the two proposals is the fact that the authors' equation uses constant exponents, instead of functions of γ. This means the authors' equation, despite presenting good results, is not capable of providing $G/G_{max} \to 1$ for $\gamma \to 0$ (Ishibashi & Zhang; 1993; Ishihara, 1996).

It is actually possible to find approximate equations for the curves from Cataño & Pando (2010) and Javdanian & Jafarian (2018) tests, using a similar structure. Disregarding the influence of the relative density, the basic equation could be assumed as:

$$G/G_{max} = \left(\frac{1}{1+\gamma}\right)\sigma_0^{a(\gamma)} \tag{1}$$

where $a(\gamma)$ is a hyperbola. Through linear regression, $a(\gamma)$ is given by:

$$\begin{aligned}
&a(\gamma) = -\frac{\gamma}{0.0979 + 1.5575\gamma} \text{ for } \sigma_0 = 50\text{kPa} \\
&\text{(Cataño \& Pando, 2010)} \\
&a(\gamma) = -\frac{\gamma}{0.8677 + 2.8783\gamma} \text{ for } \sigma_0 = 300\text{kPa} \\
&\text{(Cataño \& Pando, 2010)} \\
&a(\gamma) = -\frac{\gamma}{0.2347 + 2.1738\gamma} \text{ for } \sigma_0 = 200\text{kPa} \\
&\text{(Javdanian \& Jafarian, 2018)} \\
&a(\gamma) = -\frac{\gamma}{0.3956 + 2.3519\gamma} \text{ for } \sigma_0 = 400\text{kPa} \\
&\text{(Javdanian \& Jafarian, 2018)} \\
&a(\gamma) = -\frac{\gamma}{0.6650 + 2.3786\gamma} \text{ for } \sigma_0 = 800\text{kPa} \\
&\text{(Javdanian \& Jafarian, 2018)}
\end{aligned} \tag{2}$$

Figure 1 compares the test results with the curves obtained by the proposed equations.

Despite the good agreement, it is very difficult to predict these equations. The Cataño & Pando (2010) test with a confining stress of 300 kPa resulted in G/G_{max} values higher than those from the Javdanian & Jafarian (2018) tests with confining stress of 800 kPa, for the same shear strains. Although it is not known exactly which characteristics most influenced these results, it can be observed the unit weight of the Cabo Rojo carbonate sand is much lower.

Let one assume there is a single ideal equation capable of predicting $G/G_{max} - \gamma$, defined as the following product:

$$G/G_{max} = f_0(\gamma)\prod_{i=1}^{n} f_i(A_i, \gamma) \tag{3}$$

Where A_i is each of the independent variables, n is the number of independent variables, and f_i is each function of only one independent variable.

Consider that two tests I and II are carried out on the same soil, changing only one of the independent variables A_j – for instance, the confining stress σ_0. Dividing Equation 3 for test I by the same equation for test II, all terms cancel out except the ones for the independent variable that changed. That is:

$$\frac{(G/G_{max})_I}{(G/G_{max})_{II}} = \frac{f_j(A_j, \gamma)_I}{f_j(A_j, \gamma)_{II}} \tag{4}$$

Now consider tests III and IV performed on the same soil. These tests also differ from each other only on the same variable A_j, with the same values from tests I and II. Carrying out the same previous process, a relation identical to Equation 4 is obtained:

$$\frac{(G/G_{max})_{III}}{(G/G_{max})_{IV}} = \frac{f_j(A_j, \gamma)_{III}}{f_j(A_j, \gamma)_{IV}} \tag{5}$$

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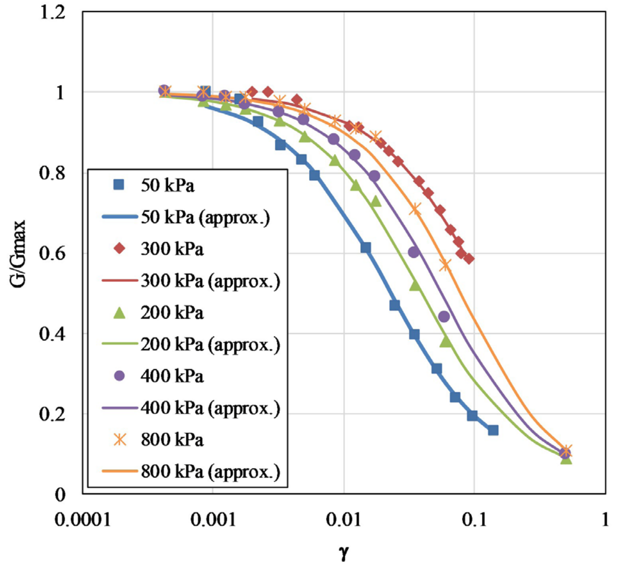

Figure 1. Comparison between Cataño & Pando (2010) (D_r = 21 %) tests, Javdanian & Jafarian (2018) tests, and approximate equations.

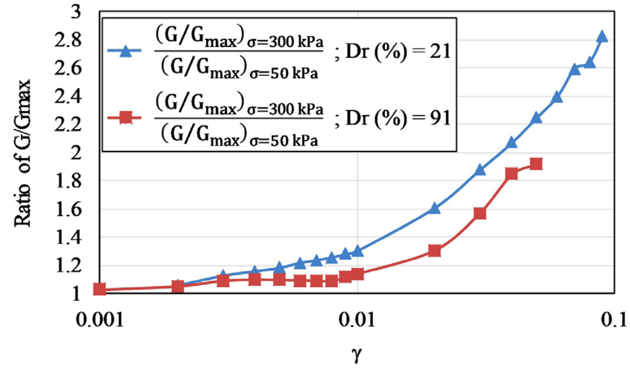

Figure 2. Ratio of G/G_{max} for each pair of Cataño & Pando (2010) tests.

Assume the only difference between the pairs of tests I-II and III-IV is another independent variable A_k – for instance, the relative density D_r. Thus, tests I and II have the same A_k, and tests III and IV also have the same A_k, but a different value.

Since $\left(A_j\right)_I = \left(A_j\right)_{III}$ and $\left(A_j\right)_{II} = \left(A_j\right)_{IV}$, one can write:

$$\frac{f_j\left(A_j,\gamma\right)_I}{f_j\left(A_j,\gamma\right)_{II}} = \frac{f_j\left(A_j,\gamma\right)_{III}}{f_j\left(A_j,\gamma\right)_{IV}} \rightarrow \frac{\left(G/G_{max}\right)_I}{\left(G/G_{max}\right)_{II}} = \frac{\left(G/G_{max}\right)_{III}}{\left(G/G_{max}\right)_{IV}} \tag{6}$$

The two pairs of tests by Cataño & Pando (2010) fit this analysis. According to Equation 6:

$$\frac{\left(G/G_{max}\right)_{\sigma=300\ ;Dr=91}}{\left(G/G_{max}\right)_{\sigma=50\ ;Dr=91}} = \frac{\left(G/G_{max}\right)_{\sigma=300\ ;Dr=21}}{\left(G/G_{max}\right)_{\sigma=50\ ;Dr=21}} \tag{7}$$

To verify the validity of Equation 7, the points of the curves $G/G_{max}-\gamma$ were interpolated so that the G/G_{max} values could be estimated for the same γ values for both pair of tests. Then, for each γ, the ratio between both G/G_{max} from each pair of tests were calculated. Figure 2 compares the results.

Despite showing the same growth trend, the two curves clearly do not coincide, which indicates that Equation 6 does not hold true. This does not necessarily mean that D_r is actually relevant for the Cataño & Pando (2010) tests. Instead it means that either another unforeseen independent variable has changed between the tests, or the ideal $G/G_{max}-\gamma$ equation – if it exists – cannot be represented by Equation 3.

List of symbols

D	damping ratio
D_r	relative density
G	shear modulus
G_{max}	maximum shear modulus
γ	shear strain
γ_r	reference shear strain when G/G_{max} = 0.5

References

Cataño, A.J., & Pando, M.A. (2010). Static and dynamic properties of a calcareous sand from Southwest Puerto Rico. In D.O. Fratta, A.J. Puppala & B. Muhunthan (Eds.), *GeoFlorida 2010: advances in analysis, modeling & design* (pp. 842-851). Reston: American Society of Civil Engineers. http://dx.doi.org/10.1061/41095(365)83.

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Author's reply

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The authors are grateful for the reader's contribution, enriching the discussion on the dynamic behavior of soils. The comment made proceeds in the search for a better correlation for the prediction of the soil dynamic parameter G/G_{max}, since the equation proposed in Barroso & Moura (2023) predicts less concordant G/G_{max} values for very small shear strains.

However, the equations presented by the reader, despite having more consistent results in relation to the original study for G/G_{max} when $\gamma \rightarrow 0$, were much subdivided in relation to the original research, so that the best convergence of results was already expected.

In addition, the good result of G/G_{max} predictions is restricted to the field of application of each equation, so that the application of a specific equation, for different soil or confining pressure, can provide G/G_{max} predictions that are less concordant than by the equations of the original study.

In Figure 1, the G/G_{max} obtained in the laboratory by Javdanian & Jafarian (2018), when σ_0 = 200 kPa, is compared with the G/G_{max} predictions by the equation proposed in Barroso & Moura (2023) and by one of the equations proposed by the reader. The equation developed by the reader for the soil by Cataño & Pando (2010) was applied, when σ_0 = 300 kPa, because this is the equation in which the confining stress is closest to the tests by Javdanian & Jafarian (2018) when σ_0 = 200 kPa.

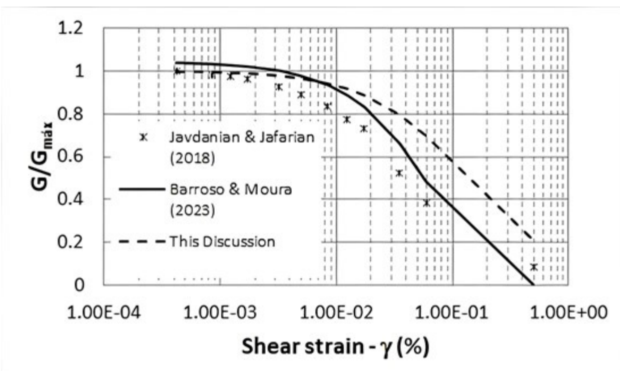

Figure 1. Comparison between the tests by Javdanian & Jafarian (2018), the equation from the original study, Barroso & Moura (2023), and one of the equations proposed in the discussion for σ_0 = 200 kPa.

From Figure 1, it can be seen that the equations proposed by the reader may result in less consistent predictions than those proposed by the original study for higher shear strains.

The authors of the original study agree with the reader about the difficulty of obtaining equations for predicting soil dynamic parameters. Thus, more studies and discussions are necessary to better understand this subject.

List of symbols

G	Shear modulus
G_{max}	Maximum shear modulus
γ	Shear strain
σ_0	Confining stress

References

Barroso, F.O.P., & Moura, A.S. (2023). Proposition of correlations for the dynamic parameters of carbonate sands. *Soils and Rocks*, 46(1), e2023001422. http://dx.doi.org/10.28927/SR.2023.001422.

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