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(Review Article)

Synthesis of the influence of some parameters on dynamic shear resistance of coarse soil

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Abstract

On the basis of test results provided by literature, this article intends to examine the influence of parameters such as granulometry, relative density, sample size and the level of stress on dynamic shear resistance, dynamic shear modulus and absorption of coarse materials. The most significant results to learn are as follows: absorption might be very less influenced by granulometry and the size of tested materials. The dynamic shear modulus might increase as the percentage of strand, relative density or the level of stress increase. Although there is no significant difference in reaction to high distortions, resistance of tight granulometry to dynamic shear are higher than those with spread out granulometry for low and average distortions.

Keywords: Coarse materials; Dynamic shear resistance; Absorption; Shear modulus

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1. Introduction

Soil under static charge may display high resistance, but collapse under the action of a dynamic charge of lower intensity. In order to understand the effects of a dynamic charge on soil behaviour, cyclic triaxial tests were made. Resistances measuredby these cyclic tests are often called dynamic shear resistance. This resistance can be examined by the evolution of stress deviator $\sigma_{dp}$and of cyclic shear distortion γaccording to the number of cycles « N ». Given the dynamic aspect of stress, variations of the shear modulus $G$and of absorption λshould be known depending on cyclic distortions.

This article seems to present a synthesis on results of the effects of density, granulometry or sample size on dynamic shear resistance, absorption and dynamic shear modulus of course materials.

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2. Resistance to dynamic shear

The dynamic resistance of course materials was studied at experimental level by many authors, including Amer et al (1987), Seed et al (1971), Wong (1971) and lastly Lee and Fitton (1969). In the pages below, we shall present a synthesis of major results relating to the effects of such parameters as density and granulometry on resistance to dynamic shear.

Based on a series of tests on materials with uniform granulometry, from clay to gravel Lee and Fitton (1969) showed that resistance to cyclic shear under wet conditions, defined for a number of cycles equal to 30 and for cyclic distortions equal to 5% and 20% increases by an average 30 to 50% when relative density moves from 50% to 75%(cf. Figure 1

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and 2). This increase also appears in silts, as well as in sand or gravel. Similar results were obtained by Wong (1971) on a 20/40 gravel of Oroville where he noted an increase in resistance to dynamic shear of about 50%, measured after 30 cycles, for distortions between 2.5% and 7% when relative density moves from 40% to 60%.

2.1. Effect of relative density

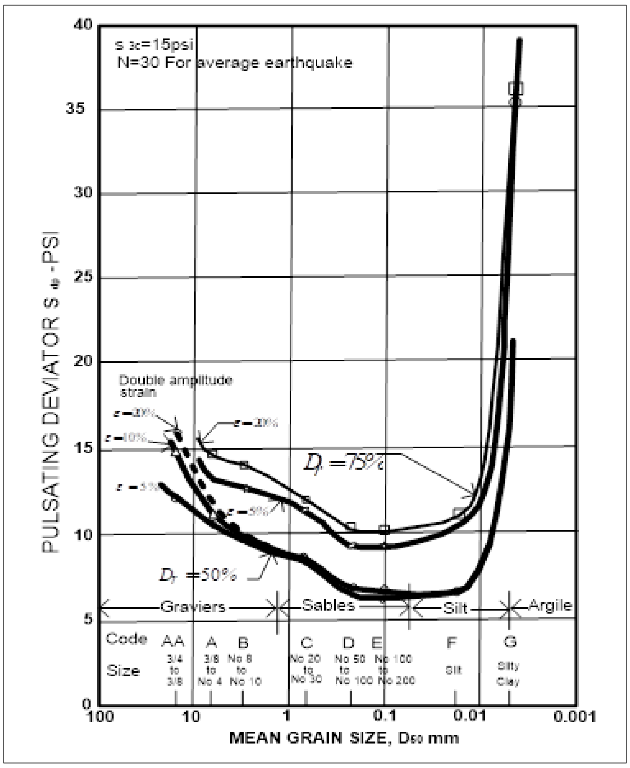

Figure 1 Resistance to dynamic shear for uniform granulometry soil according Lee and Fitton (1969)

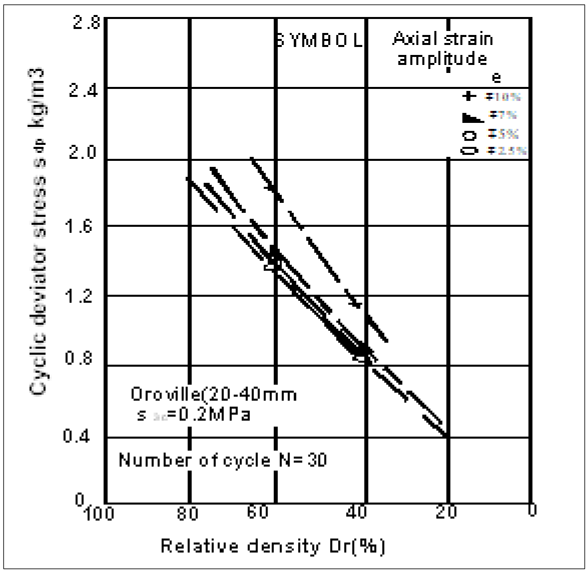

Figure 2 Effect of density on resistance to shear dynamics of coarse soil from Oroville Wong (1971)

But the author (Wong, 1971) however noted that materials with the same relative density may have different characteristics as concerns resistance to dynamic shear, due to their different vacuum index. In some cases, it is not the material having the lowest vacuum index (thus the most compact) that is the most resistant.

2.2. Influence of granulometry

All the results presented here are obtained from tests carried out under wet conditions, whereas on site, we know that partial dissipation of interstitial pressure during an earthquake considerably improves the behaviour of gravel as compared to sand.

By comparing the resistance to dynamic shear of well graded materials with that of materials with uniform granulometry (Figure 3), Wong (1971) noted that for small and medium distortion (2.5%), well graded materials are far less resistant (reduction factor of about 2) than materials with uniform granulometry with the same d_{50} and et the same relative density. According to the author, this difference could be attributed to a rapid increase of interstitial pressure in spread out granulometry materials, due to their low vacuum index. Conversely, for distortion rates above 10%, the difference in behaviour considerably reduces due to the increase in the stiffness of well graded soil, which offsets the adverse effect of interstitial pressure on resistance to dynamic shear.

Works carried out by Wong (1971), on uniform granulometry soil made of gravel or soil from Monterey or Oroville and having a relative density of 60% reveal that (Figure 3) resistance to dynamic shear corresponding to 2.5%(resp.10%) of axial distortion after 30 cycles increases by 30%(resp. 60%) when average diameter moves from 0.1mm to 30mm.

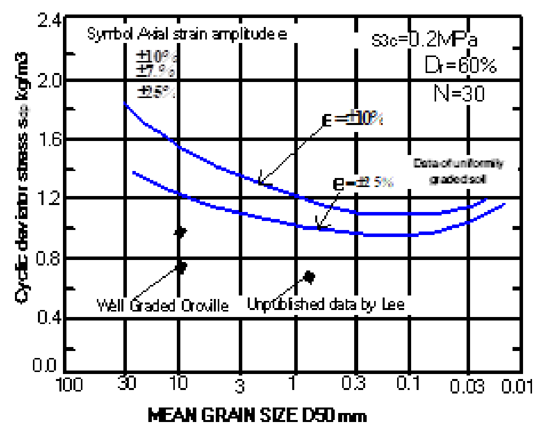

Figure 3 Resistance to dynamic shear of materials with uniform granulometry according to Wong (1971)

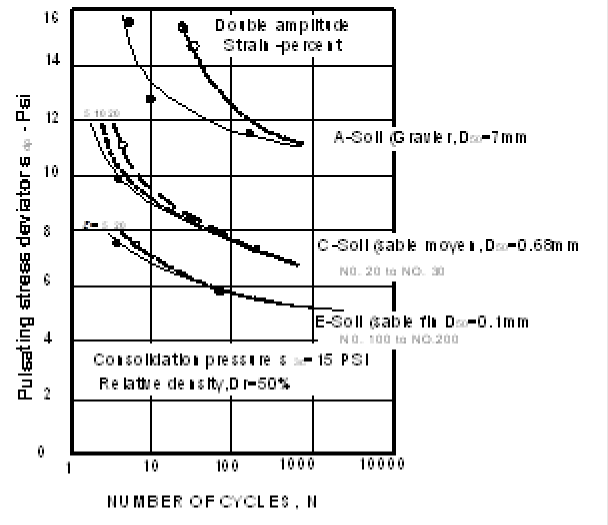

Figure 4 Resistance to dynamic shear depending on the number of cycles for different types of soil. Lee and Fitton (1969)

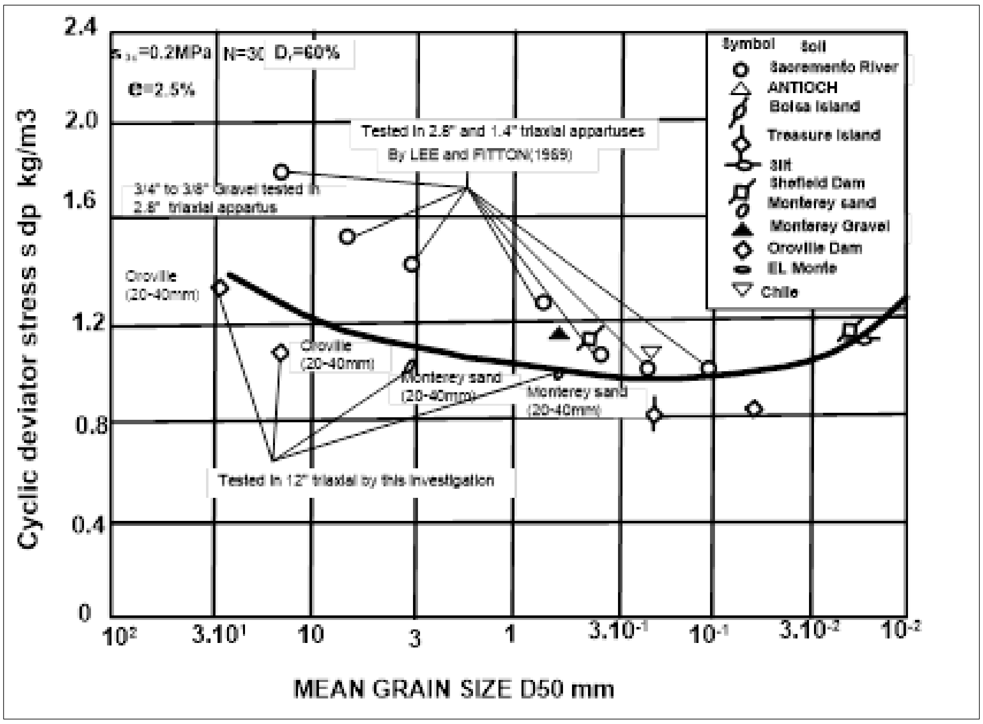

Figure 5 Effect of D50 on resistance to dynamic shear according to Wong (1971)

But Wong (1974) noted that if we consider the effect of the membrane, this difference reduces considerably and resistance to cyclic shear of gravels would be only slightly higher than that of sand. Figure 5 which illustrates his works are complemented by results obtained by some authors having carried out tests on uniform granulometry material samples with average diameter of d_{50} extends from 0.015mm to about 30mm. This conclusion is corroborated by works carried out by Lee and Fitton (1969) showing that for an initial relative density of 50%, resistance to dynamic shear (Figure 4) corresponding to 5% of distortions after 10 cycles increases by 50% when we move from d_{50}=0.1mm sand to d_{50}=7mm gravel.

But test results on intermediate zones show that for fine soil (silts, silty clay), shear resistance increases in a linear manner as d_{50} reduces, while for strand the influence of d_{50} reverses. Such a change which appears for d_{50s} situated between 0.1 –0.01mm could be due, according to Wong (1971) to the appearance of inter-particle binding forces and the persistence of a bond when interstitial stress is high.

3. Dynamic shear modulus

3.1. Effect of relative density or compactness

In the light of a series of triaxial cyclic wet tests carried out on materials from Pyramid, Oroville, Venato and Livermore, Wong (1971) showed (Figures 6, 7et 8) the influence of relative density on the dynamic shear modulus. In fact, he noted that the dynamic shear modulus value increases from 50% to 100% when relative density moves from 60% to 100%.

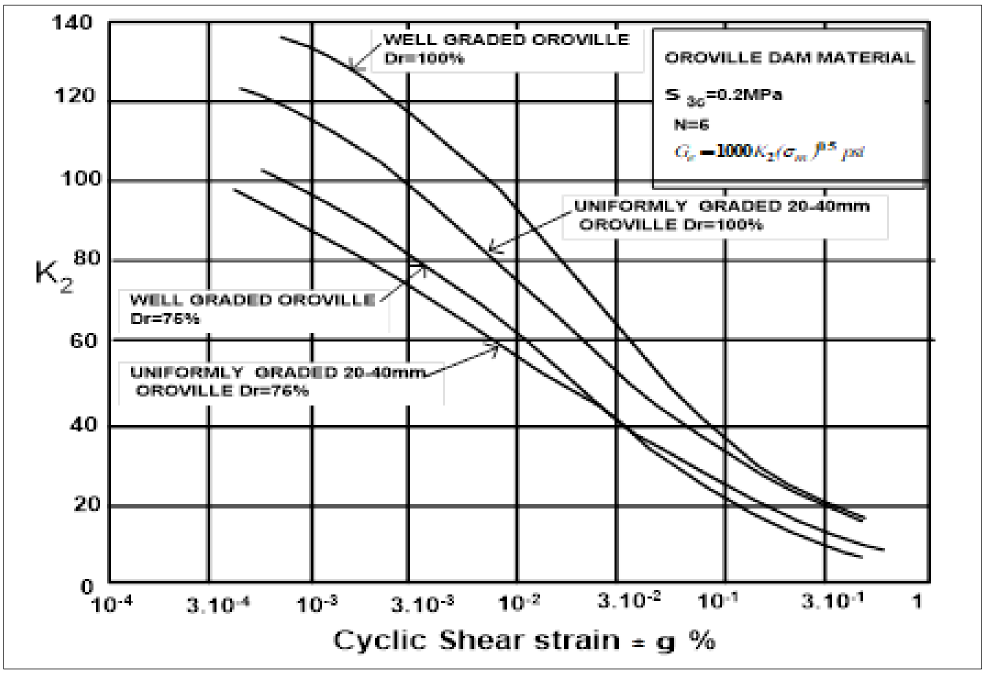

Figure 6 Effect of granulometry and relative density on the shear modulus according to Wong(1971)

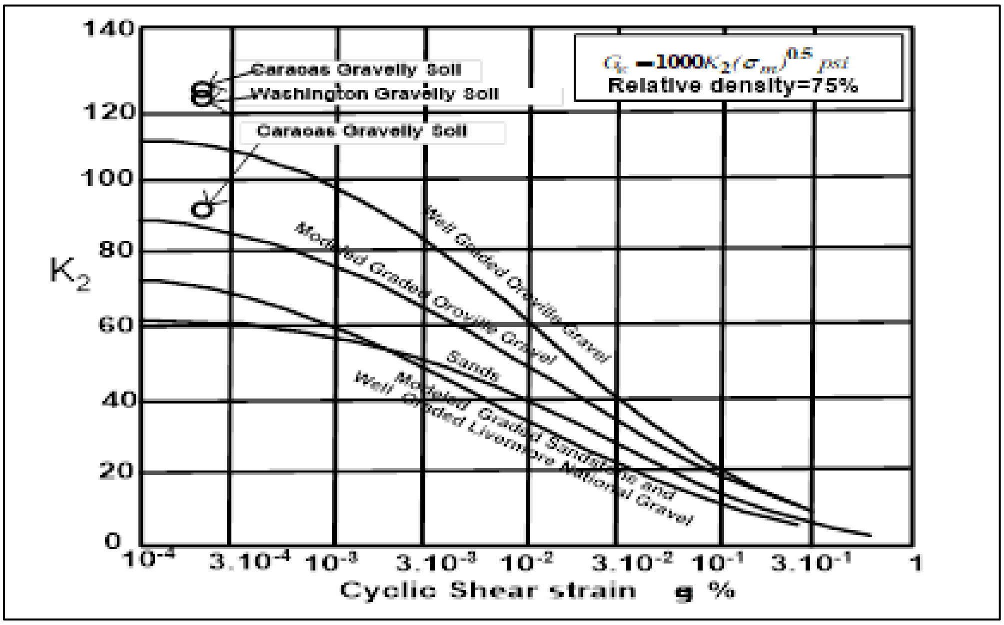

Figure 7 Effect of granulometry on the dynamic shear modulus according to Wong (1971)

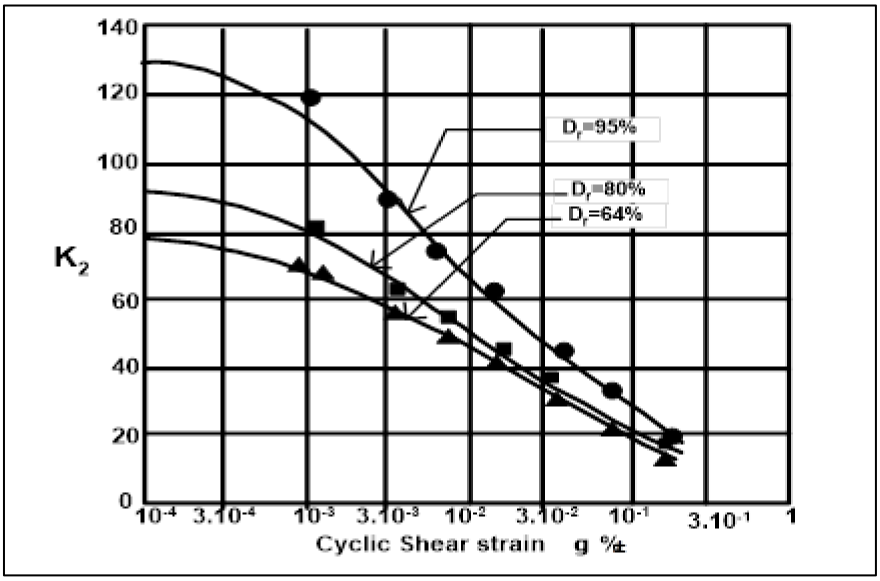

Figure 8 Effect of density on the dynamic shear modulus according to Wong (1971)

This increase is higher when relative density value isnear to 100%. This result is confirmed by tests carried out by GDS (1988) on Creys- Malvilles alluvium (Figures 9) and materials of La Cochette.

3.2. Influence of granulometry

A comparative study carried out by Wong (1971) 20/40 Oroville aggregates and sand seem to show that under identical test conditions, the dynamic shear modulus of aggregates could be 60% higher than that of sand. Similar results were obtained by GDS (1989) with materials from La Cochette as concerns 0/10mm and 0/50mm fractions. High values of dynamic shear moduluss for coarse materials seem to show that materials with big particles are stiffer than fine materials.

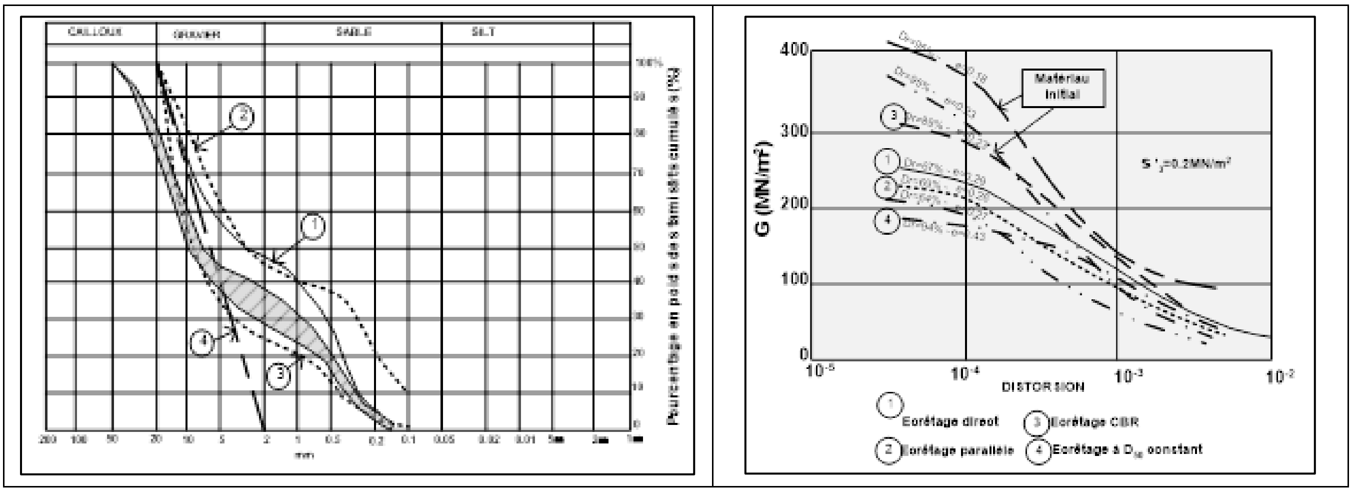

Figure 9 Effect of clipping method on the dynamic shear modulus of coarse materials GDS (1988)

In addition, results obtained from tests carried out on Oroville aggregates clipped at 50mm but whose entire granulometry was preserved have modules 20% higher than those measured on the 20/40mm fraction of the same material. This result seems to indicate that the values of dynamic shear modulus given by materials with spread out granulometric curve are higher than those obtained with uniform granulometry materials.

Clipping methods (Figure 9) may also influence the values of the dynamic shear modulus. In fact, from tests carried out on alluvial samples of Creys Malville, le GDS (1988), it appears that for distortion values lower than 10^{-4} the highest dynamic shear modulus is given by the direct clipping method, and the lowest by the d_{50} constant clipping method. On the contrary, for distortion values higher than 10^{-3}, differences between shear modulus values given by different clipping methods become insignificant. In addition, it is noted that the shear modulus given by the initial material remains higher than those obtained with samples produced through the various clipping methods, and irrespective of the distortion value.

3.3. Influence of the sample size

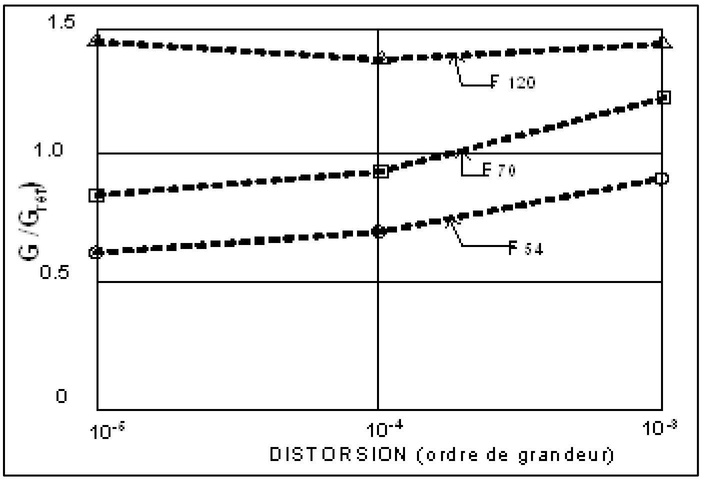

Figure 10 Effect of sample size on the dynamic shear modulus of GDS coarse materials (1988)

The influence of samples' size on the dynamic shear values was studied by Amer et al (1987), and then by GDS (1988). By carrying out cyclic triaxial tests on Creys-Malville alluvium samples (Figure 10) produced using the parallel clipping technique using cells of various diameter ($\phi 54$, $\phi 70$, $\phi 120$ and $\phi 300$) which were chosen such as scale factor ψ (which is the relation between the maximum aggregate dimension contained in the sample and its characteristic size) is constant and equal to 6; GDS (1988) noted that the dynamic shear modulus tended to increase as the cell size increases. However, if we consider (G_{ref}) as reference module, modules obtained using $\phi 300$ cell, we notice that its evolution depending on the cell size is not clearly established. In fact, by observing the evolution of relation $\frac{G}{G_{ref}}$ depending on distortion, we note that the latter is higher than 1 for samples tested in $\phi 120$ cells, irrespective of distortion.

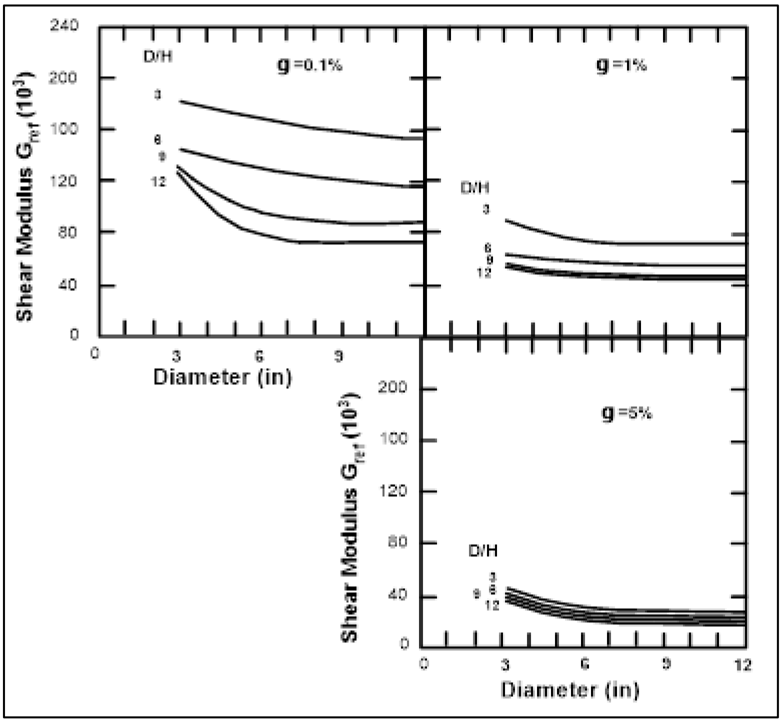

Figure 11 Effect of sample diameter and of the relation between this diameter and the sample height(D/H) on the dynamic shear modulus. Amer et al(1987)

On the contrary, for cells of $\phi 54$ and $\phi 70$, we noted that relation $\frac{G}{G_{ref}}$ increases as distortion increases, which suggests the existence o fa distortion value above which this relation becomes higher than 1. Amer et al (1987) who carried out cyclic shear (Figure 11) noted that the dynamic module reduces as the sample diameter increases and when the relation of the sample diameter to its height $\left(\frac{D}{H}\right)$ increases and becomes insensitive to this relation when the latter exceeds 6.

3.4. Influence of strain

In the synthesis of works concerning data on shear modulus values measured in laboratory and on site, Seed and Idriss (1971), noted that the module increaseswhen average strain increases, and also increases when distortion increases. They gave us envelope curves of the maximum shear volume according to distortion (or cyclic distortions) and on the basis of all data compiled, they proposed a correlation expressed by equation (1) :

$$G = 1000 k_1 \sigma_m^{0.50} \quad \text{..............(1)}$$

Whereby k_1 is a coefficient depending on materials, and σ_m average strain.

For coarse materials, we have: $80 \le k_1 \le 250$

4. Absorption

4.1. Influence of density

According to Wong (1971) dense materials (Figure 12) generally have an absorption rate higher than loose materials. The increase of the absorption value that can go up to 100% when relative density D_r moves from 60% to100%.

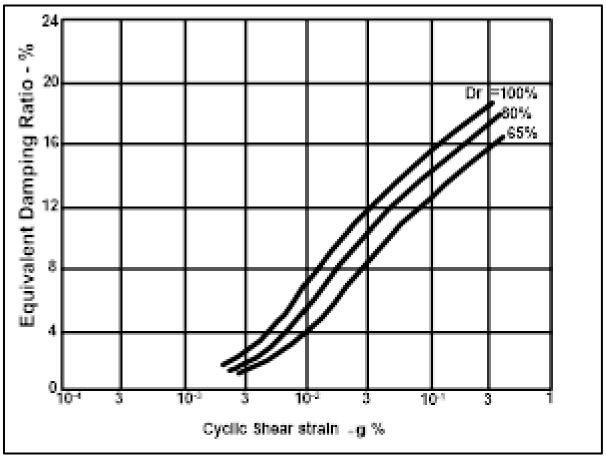

Figure 12 Effect of relative density on the absorption rate of gravelly soil; Wong (1971)

However, a few exceptions do exist ; as a matter of fact, tests carried out on materials mainly made of sandstone aggregates from Venato tend to show that absorption remains practically the same when D_r moves from 67% to 100% for distortions between 310^{-3} and 310^{-1} (figures 12). If we look at the absorption average values of many materials with equal relative density; it is noted that absorption is globally higher for materials with important relative density. The increase observed is between 20 to 25% when D_r moves from 65% to 80% (Figure 12). These results reached at by Wong (1971), are contrary to those provided by tests carried out on alluviums from Creys-Malville by GDS (1988) show that absorption might not be influenced by the material's compactness, either for gravelly soils or sandy gravels.

4.2. Effects of granulometry

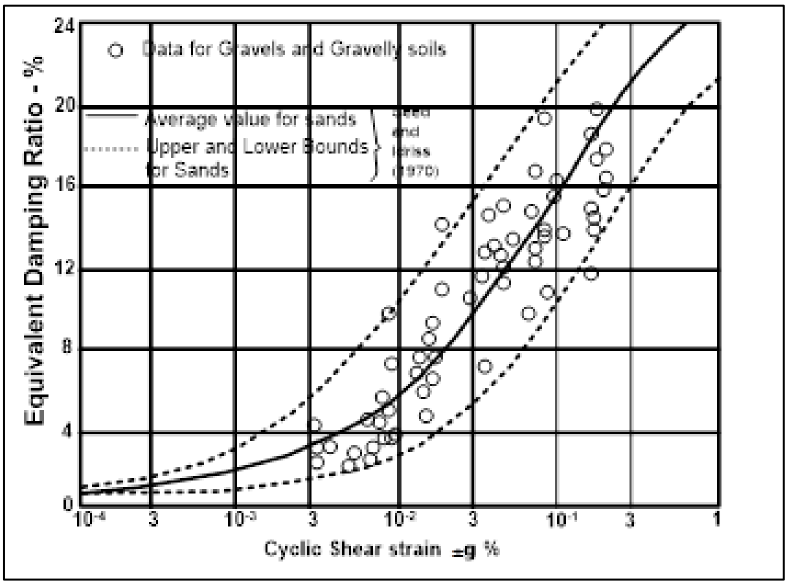

Figure 13 Comparing the absorption of sand with that of gravelly soil; Wong (1971)

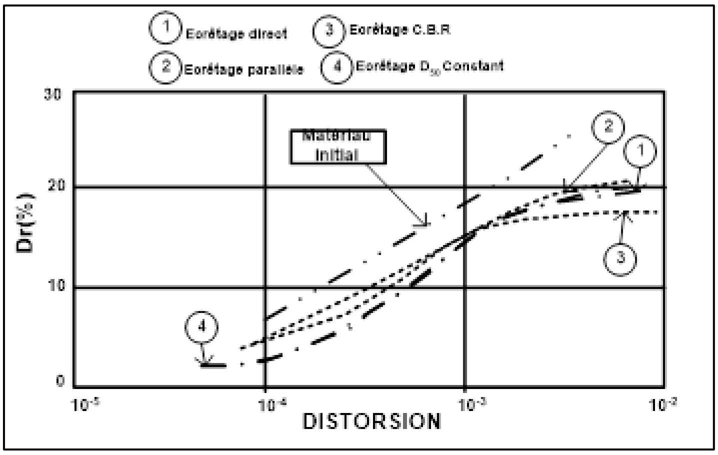

Figure 14 Effect of clipping on absorption; GDS (1987)

Tests carried out by Wong (1971) on clipped and unclipped gravel from Oroville showed that for equal relative density, internal absorption values are very close to each other. In addition, sand and gravelly materials' absorption are quite similar both in absolute value and in their variation according to distortion (Figure13). These results tend to show that granulometry has no significant influence on the absorption value of granular materials. CDS (1988) that studies the influence of the clipping method on alluviums from Creys-Malville (Figure 14) noted that absorption values obtained by various clipping methods are similar, but lower than those of the initial material. Conversely, these conclusions cannot be applied to fine materials (silts, clay) whose behaviour changes significantly under cyclic action.

4.3. Influence of sample size

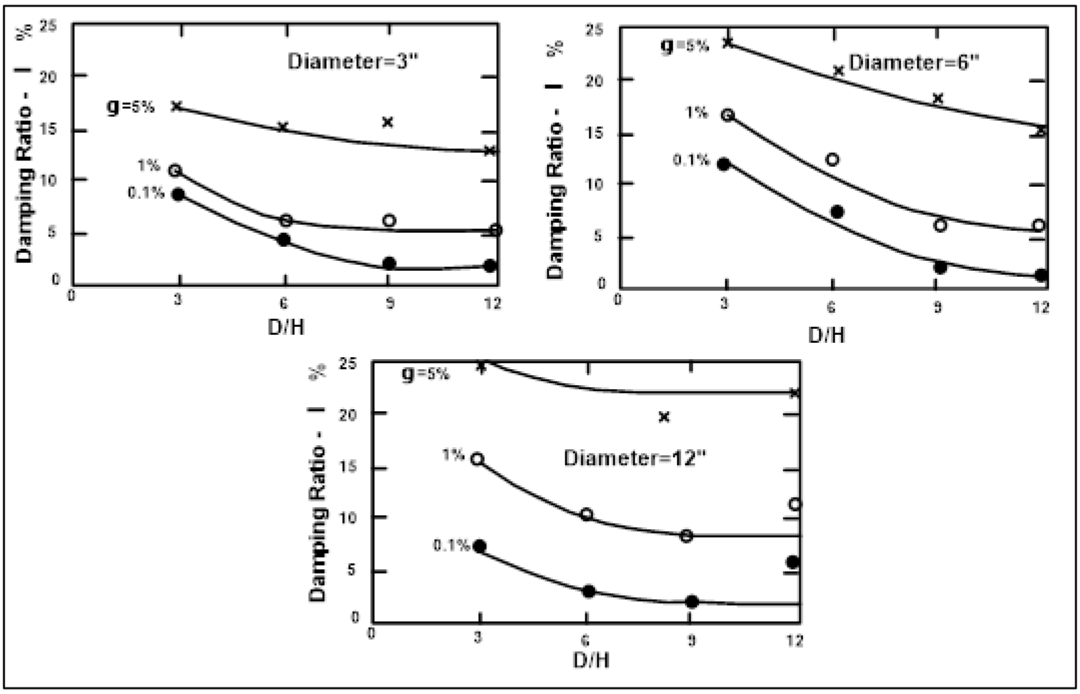

Figure 15 Effect of D/H relation on the absorption coefficient; Amer et al (1987)

The effect of sample size on absorption was studied by Amer et al (1987). On the basis of cyclic shear test results (Figure 15) carried out on granular materials, authors observed that the internal absorption of these materials reduces as the sample size increases or when the relation of the diameter of the sample to its height $\left(\frac{D}{H}\right)$ increases and becomes insensitive to this relation when the latter exceeds value 6.

In their synthesis carried out on data relating to internal absorption values measured in laboratory and on site, Seed et al (1971) showed us envelope curves on the variation of absorption according to distortion.

4.4. Influence of stress

On the basis of tests carried out on saturated and unsaturated sand, Siver and Seed (1971) noted that absorption reduces when confinement stress increases. This reduction is of 20% (resp. 33%) when stress moves from 50Psi to 400Psi for cyclic distortions of 10^{-2} (resp. 10^{-1}). The above conclusions are also confirmed by works carried out by Hardin et al (1971) Figure 16.

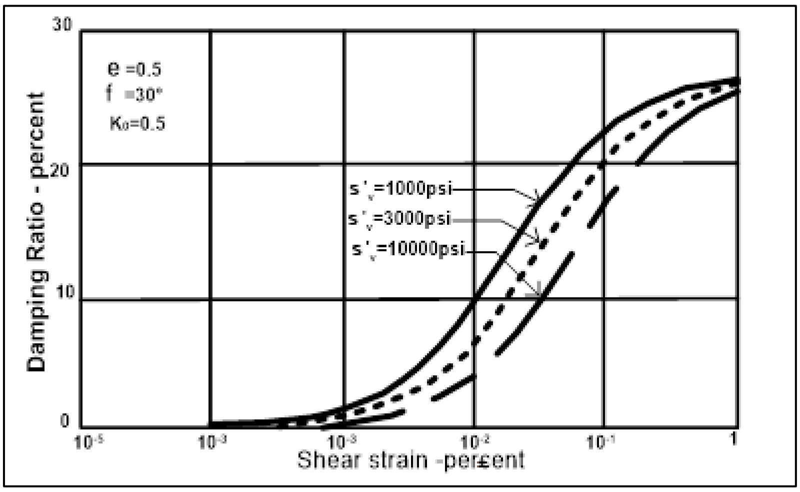

Figure 16 Effect of confinement stress on saturated sand absorption, based on the expressions of Hardin and Unevich (1971)

5. Conclusions

This synthetic study shows that absorption, resistance and dynamic shear modulus of coarse materials improve as relative density or uniformity coefficient increases. The influence of sample size on the dynamic shear modulus is not clearly established. Coarse materials with spread out granulometric curves may, under dynamic stress, produce interstitial pressure which may have a negative effect in seismic zones.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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