Algerian Journal of Research and Technology

ISSN : 2543-3954

A.J.R.T Volume 4 (N° 2) (2020) 23 - 28

Experimental Evidence on the Compaction of Binary Granular Assemblies: Influence of Equivalent Intergranular Void Ratio

Y. Mahmoudi [1*], A. C. Taiba [1], K. Doumi [1], L. Hazout [2], M. Belkhatir [1, 3], W. Baille [3]

[1] Laboratory of Material Sciences & Environment, Civil engineering Department, University of Chlef Algeria.
[2] Civil engineering Department, University of Blida- Algeria.
[3] Laboratory of Foundation Engineering, Soil and Rock Mechanics, Department of Civil and Environmental Engineering, Bochum Ruhr University-Germany.

**Corresponding author: E-mail:* mahmoudiyoucef16@yahoo.fr

Abstract. The assessment of compaction technique of soils is of vital importance in numerous geotechnical engineering constructions such as highways, airports, earth dams and other structures. Evaluation of affected parameters on this technique remains a major challenge in geotechnical engineering. For this context, this laboratory study presents the influence of the low plastic fines fraction on the compaction of sand-silt mixtures. The samples were reconstituted with fines content ranging from 0% to 30%. The soil samples were tested by compaction apparatus. A series of compaction tests were performed on different reconstituted sand-silt mixture samples to study the compaction characteristics of the two sand named as Chlef clean sand “CCS” and Chlef fine sand “CFS” mixed with low plastic Chlef silt “I_p=5%”) using the concept of the equivalent intergranular void ratio (e*). The test results show that the values of the maximum dry density increase with the increase of fines content for both tested materials (Chlef clean sand-silt mixtures and Chlef fine sand-silt mixtures) under consideration. Moreover, the obtained data indicate that the equivalent intergranular void ratio appears as a suitable parameter for prediction the compaction of different graded sand-silt mixtures for the tested low plastic Chlef fines ranging from (F_c=0% to F_c=30%) under study.

Keywords. Sand-silt mixture, Fines content, Equivalent void ratio, Compaction

INTRODUCTION

The compaction is a classical ground improvement technique in earthwork structures. Its assessment is of vital importance in numerous geotechnical engineering constructions such as highways, airports, earth dams and other structures. Many parameters such as soil type, level of compaction, compactive effort, and particle shape and saturation degree may affect the compaction of soils (Cho et al., 2006. Doumi et al., 2017. Cherif Taiba et al., 2018). Many other behaviors of soils, such as shear strength (Cherif Taiba et al., 2013; ;, Mahmoudi et al., 2013; 2014; Wang et al., 2013; Mahmoudi et al., 2016a,b; 2017; 2018), gradation (Cherif Taiba, 2016; 2017a,b) permeability (Wang et al., 2012) may also be affected by soil density and/or water content. Indeed, the void ratio in terms of global void ratio, intergranular void ratio and equivalent void ratio may affect the compaction of soils. Therefore, The predecessor of the equivalent intergranular void ratio (e^*) is the intergranular void ratio, (e_g). Mitchell (1976) to determine the inactive clay content on soil structure eg first introduced the concept of the intergranular void ratio. Thevanayagam (1998) proposed a simplified formulation of the intergranular void ratio:

$$eg = \frac{\mathrm{e+F}c}{1-\mathrm{F}c} \quad (1)$$

However, Zlatovic and Ishihara (1995) reported that fines particles started to come in between sand particles contacts from 5% fines content and sand particles contacts vanished completely at 30% fines content. Many others reported the same observation, i.e. some fines particles are active in between sand particles contacts at higher fines content (Kuerbis et al., 1988), (Pitman et al. 1994) and they should be consider in ‘equivalent’ void ratio formulation. Then in, Thevanayagam et al. (2002) presented a more general form of ‘equivalent’ void ratio, called equivalent granular void ratio, e^* by introducing a parameter b which represents the fraction of fines that actively take part in the force structure of sand particles. Thus the e^* can be presented as following:

$$e^* = \frac{\mathrm{e+(1-b)F}c/100}{1-(1-b)\mathrm{F}c/100} \quad (2)$$

Where e^* is equivalent granular void ratio and b is the fraction of fines particle that are active in between sand particles contact. The b ranges from 0 to 1. At low fines content b = 0. Its value was taken back often analyzed in much of the literature (Ni et al., 2004; Thevanayagam et al., 2002; Yang et al., 2006). However, a number of literatures reported correlation between the properties of soil classification and analysis the value of b (Ni et al., 2004). The functional relationship, b = f (Fc, χ), can be presented by the following equation (Rahman et al., 2007):

$$\mathrm{b} = \left[1 - \exp\left(-0{,}3\,\frac{\left(\frac{\mathrm{Fc}}{\mathrm{Fthre}}\right)}{k}\right)\right] * (\mathrm{r}\,\frac{\mathrm{Fc}}{\mathrm{Fthre}})^{\mathrm{r}} \quad (3)$$

Where: r: the ratio of the particle size, D/d and $\mathrm{k} = 1 - \mathrm{r}0{,}25$, Fthre: is the content of fine particles threshold. It should be noted that the concept of applies only Fc < Fthre. We determine Fthre by the following equation:

$$\mathrm{Fthre} = 40(\frac{1}{1+e^{\alpha-\beta x}} + \frac{1}{\mathrm{X}}) \quad (4)$$

$$\alpha = 0{,}50 \text{ and } \beta = 0{,}13$$

The main objective of this work is to present an experimental study on the influence of equivalent integranular void ratio on the compaction of two materials named: Chlef clean sand and (CCS) and Chlef fine sand (CFS) mixed with low plastic fines content ranging from F_c=0% to F_c=30 %.

EXPERIMENTAL PROGRAM

Index properties of tested materials

The tests were conducted on the mixtures of two different materials Chlef clean (CCS) sand and Chlef fine sand (CFS). These materials were mixed with low plastic fines ranging from 0% to 30%. The index properties of these materials are presented in table 1. The grain size distribution curves of the tested silty sand are shown in figure 1. The variation of e_{max} (maximum void ratio corresponding to the loosest state of the soil sample) and e_{min} (minimum void ratio corresponding to the densest state of the soil sample), were determined according to ASTM D 4253”Standard test method for maximum index density and unit weight of soils using a vibratory table and ASTM D 4254 “Standard test method for maximum index density and unit weight of soils using a vibratory table standards respectively (ASTM D 4253-00,2002; ASTM D 4254-00,2002).

Table 1. Index properties of sand and silt.

Index properties of materials	**Materials**		
	CCS	CFS	Silt
Specific gravity, Gs	2.652	2.664	2.667
Maximum Diameter, D_{max} (mm)	2.000	0.250	0.08
Effective Diameter, D_{10} (mm)	0.266	0.094	-
Mean grain size, D_{50} (mm)	0.596	0.155	0.023
Maximum gross void ratio, e_{max}(.)	0.795	1,016	1.563
Minimum gross void ratio, e_{min}(.)	0.632	0,774	0.991
Liquid limit, W_L(%)	-	-	31.72
Plastic limit, W_p (%)	-	-	26.71
Plasticity Index, I_p (%)	-	-	5
Unified Soil Classification System	SP	SP	ML
Grain Shape	Rounded	Rounded	Rounded

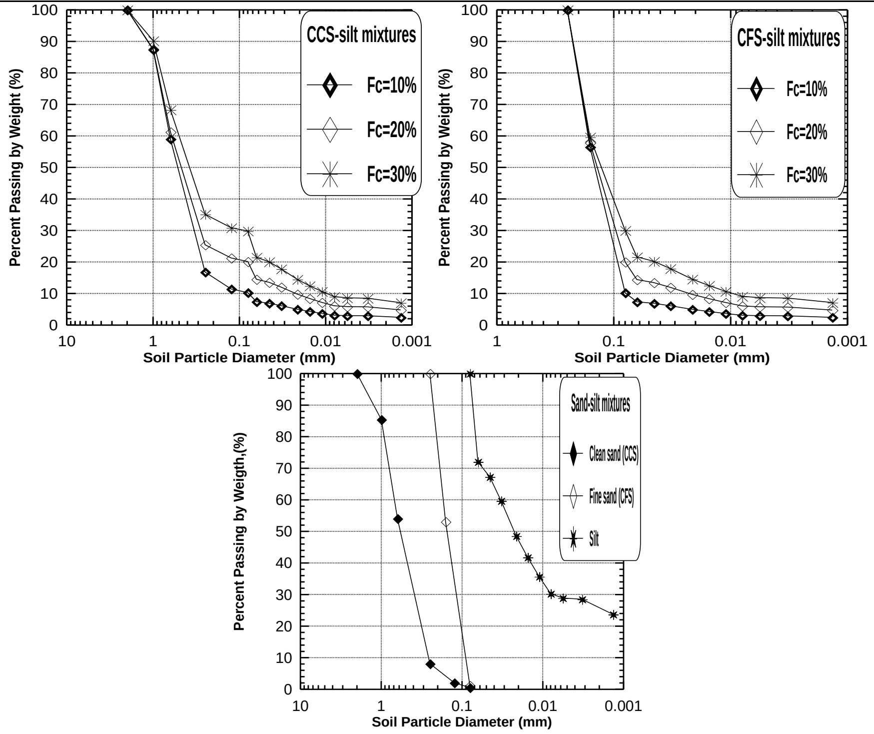


Fig.1. Grain size distribution curves of tested materials.

Sample preparation

In the compaction test, the sample was air dried prior to mixing with the required amount of water (2%, 4%, 6%, 8%, 10%) using a masonry trowel. The mixture was transferred to a plastic bag, and left overnight at constant temperature and humidity to ensure a uniform distribution of moisture.

Testing apparatus

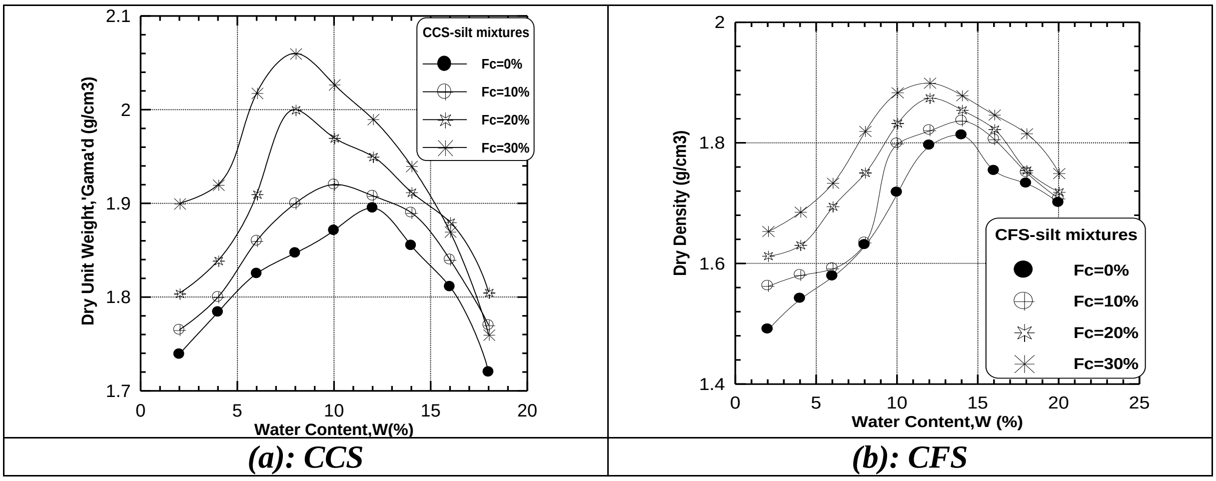
The compaction characteristics of the soil sample were established using a Standard Proctor apparatus was conducted with the rammer, it is of cylindrical shape with 50.8 mm diameter and 114.3 mm height, having a weight of 2.5 kg and the mold has 101,6mm diameter and 117mm height.

Compaction loading

In compaction test, it was performed in three layers with 587Kj/m^3 energy compaction and it was conducted under 25 blows per layer with 30.5mm drop height.

COMPACTION RESULT

Figure 2 illustrates that dry unit weight versus water content for two materials: CCS and CFS mixed with low plastic fines ranging from 0% to 30%. The obtained result indicates that the dry unit weight increases with the increase of water content and fines content. It peaks for water content ranging from 7.5% to 12.5% for (CCS) and from 11.5% to 13.5% for (CFS), then it decreases from optimal water content. These results were agreed to study of (Heitor, 2013).



(a): CCS ***(b): CFS***

Fig.2. Dry density versus water content of sand-silt mixtures.

INFLUENCE OF THE EQUIVALENT INTERGRANULAR VOID RATIO ON COMPACTION OF SAND -SILT MIXTURES

Figure 3 shows equivalent intergranular void ratio (e*) versus fines content for two materials: CCS and CFS mixed with low plastic fines ranging from 0%to 30%. It clear from a figure that the equivalent intergranular void ratio increase with the increase of the maximum dry density and fines content from (Fc=0% to Fc=30%) for (CCS and CFS). The following expression is suggested to evaluate the equivalent intergranular void ratio that is a function of the fines content (F_c): (γ_{dmax}) = A*(e*) + B (5)

Table 2 illustrates the coefficients A, B and the corresponding coefficient of determination (R^2) for the selected material under consideration:

Table 2. Coefficients A, B and R^2 for equation (1).

Materials	**A**	**B**	**R^2**
CCS	1.56	1.80	0.80
CFS	1.62	0.4	0.92

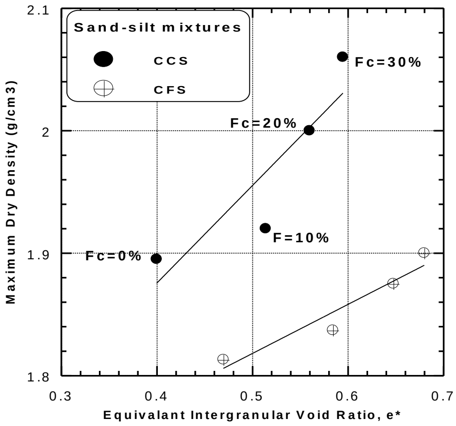


Fig.3. Maximum dry density versus equivalent intergranular void ratio of silty sand.

CONCLUSION

This study includes a series of compaction tests to evaluate the influence of low plastic fines content on the compaction response of different classes derived from Chlef sand in terms of equivalent intergranular void ratio approach mixed with low plastic fines ranging from 0% and 30%.The main conclusions of this study are summarized below:

1. The values of the maximum dry density increase with the increase of fines content for both tested materials under consideration (Chlef clean sand-silt mixtures and Chlef fine sand-silt mixtures).

2. The study reveals an approach to equivalent intergranular void ratio (e*) gives a better correlation with the maximum dry density of sand-silt mixture samples.

REFERENCES

ASTM D 4253-00, (2002). Annual Book of ASTM Standards. American Society for Testing and Materials, West Conshohocken, PA, pp. 1–14.

ASTM D 4254-00, (2002). Annual Book of ASTM Standards. American Society for Testing and Materials, West Conshohocken, PA, pp. 1–9.

Cherif Taiba A., Mahmoudi Y., Belkhatir M., Kadri A., Tom Schanz T., 2013. 6ème symposium international sur la construction en zones sismiques, Chlef, Algérie.

Cherif Taiba A., Mahmoudi Y., Belkhatir M., Kadri A., Tom Schanz T., 2014. Colloque international : Caratérisation des matériaux et structures. Tizi Ouzou, Algérie.

Cherif Taiba A., Mahmoudi Y., Belkhatir M., Kadri A., Schanz T., 2016. Geotech Geol Eng. DOI 10.1007/s10706-015-9951-z.

Cherif Taiba A., Mahmoudi Y., Belkhatir M., Kadri A., Tom Schanz T., 2017a. International Journal of Geotechnical Engineering. DOI: 10.1080 /19386362.2017.1302643.

Cherif Taiba A., Mahmoudi Y., Hazout L., Belkhatir M., Schanz T., 2017b. International Symposium on Construction Management and Civil Engineering (ISCMCE-2017) Skikda-Algeria.

Cherif Taiba A., Mahmoudi Y., Belkhatir M., Schanz T., 2018. Geotechnical Testing Journal. DOI.10.1520/GTJ20170118.

Cho G.C., Dodds J., Santamarina J.C., 2006. J. Geotech. Geoenviron. Eng. ASCE. 132 (5), 591–602.

Doumi K., Cherif Taiba A,. Mahmoudi Y,. Belkhatir M., Schanz T., International Symposium on Construction Management and Civil Engineering (ISCMCE-2017) Skikda-Algeria.

Heitor A., Rujikiatkamjorn C., Indraratna B., 2013. Proceedings of the 18t^{h}International Conference on Soil Mechanics and Geotechnical Engineering, Paris.

Kuerbis R., Negussey D., Vaid Y. P., 1988. Geotechnical Special Publication 21, ASCE, New

York. 330-345.

Mahmoudi Y., Cherif Taiba A., Belkhatir M., Kadri A., Schanz T., 2013. 6ème symposium international sur la construction en zones sismiques (SICZS2013) Chlef, Algérie.

Mahmoudi Y., Cherif Taiba A., Belkhatir M., Arab A., Schanz T., 2014. Colloque international "Caratérisation des matériaux et structures" Tizi Ouzou, Algérie.

Mahmoudi, Y., Cherif Taiba, A., Belkhatir, M., Schanz, T., 2016a. Geotechnical Testing J. DOI: 10.1520/GTJ20140183.

Mahmoudi Y., Cherif Taiba A., Belkhatir M., Arab A., Schanz T., 2016b. International Journal of Geotechnical Engineering. DOI: 10.1080/19386362.2016.1252140.

Mahmoudi Y., Cherif Taiba A., Hazout L., Belkhatir M., Schanz T., 2017. International Symposium on Construction Management and Civil Engineering (ISCMCE-2017) Skikda-Algeria.

Mahmoudi Y., Cherif Taiba A., Hazout L., Wiebke B. Belkhatir M., 2018. Studia Geotechnica et Mechanica. 40, 1-7

Mitchell J. K., 1976. Fundamental of soil behaviour, John Wiley & Sons, Inc.

Ni Q., Tan T.S., Dasari G. R., Hight D. W., 2004. Géotechnique. 54(9), 561-569.

Pitman T. D., Robertson P. K., Sego D. C., 1994. Canadian Geotechnical Journal. 31(5), 728-739.

Rahman M. M., Lo S. R., 2007. 10th Australia New Zealand Conference on Geomechanics: Common Ground, Brisbane, Australia, 674-679.

Thevanayagam S., 1998. J Geotech Geoenviron Eng Div ASCE. 124(6), 479–491

Thevanayagam S., Martin G.R., 2002. Soil Dynamics and Earthquake Engineering. 22 (9-12), 1035-1042.

Troncoso J. H., Verdugo R., 1985. Proc.11th International Conference on Soil Mechanics and Foundation Engineering, 1311-1314.

Wang J.J., Zhang H.P., Zhang L., Liang Y., 2012. Eng. Geol. 147–148, 52–56.

Yang S.L., Sandven R., Grande L., 2006. Can Geotech J. 43(11),1213–1219.

Zlatovic S., Ishihara K., 1995. Proceedings of IS-TOKY0'95/ The First International Conference on Earthquake Geotechnical Engineering/Tokyo/ 14-16. Tokyo, Japan, 239-244.