Proceedings of the XVIII ECSMGE 2024
GEOTECHNICAL ENGINEERING CHALLENGES
TO MEET CURRENT AND EMERGING NEEDS OF SOCIETY

ISBN 978-1-032-54816-6
DOI 10.1201/9781003431749-387

ECSMGE 24
XVIII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

Improvement of local soils by adding marble powder

Amélioration des sols locaux par ajout de poudre de marbre

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ABSTRACT: Soil compaction is a critical consideration in earthworks in arid areas because of a lack of water sources, low precipitation, and high evaporation rates. Water transportation is expensive and has a negative impact on the project's cost. The soil compaction with its natural moisture content is the alternative solution to achieve the earthworks projects in these areas. The present paper studies the feasibility of soil compaction at low water content using dune sand located in the Oued-Souf region of Algeria. A series of laboratory tests were conducted, including grain size distribution, standard and modified Proctor compaction tests, and California bearing ratio (CBR) tests. The used soil compacted at its natural moisture content, which is about 2%, with a progressive energy level in the first phases. The results show that increasing the energy level does not enhance the density or the California Bearing Ratio values. In the second phase of this paper, the grain size was corrected by the progressive addition of marble powder to the dune sand. The results of California bearing ratio (CBR) tests and density are significantly improved.

RÉSUMÉ: Le compactage des sols est un facteur critique dans les travaux de terrassement dans les zones arides en raison du manque de sources d'eau, des faibles précipitations et des taux d'évaporation élevés. Le transport d'eau est coûteux et a un impact négatif sur le coût du projet. Le compactage du sol avec sa teneur en eau naturelle est la solution alternative pour réaliser les projets de terrassement dans ces zones. Le présent article étudie la faisabilité du compactage des sols à faible teneur en eau d'un sable de dune localisé à la région d'Oued-Souf en Algérie. Une série d'essais en laboratoire ont été effectués, comportant l'analyse granulométrique, les essais de compactage Proctor normal et modifié et les essais de portance (CBR). Le sol utilisé est compacté à sa teneur en eau naturel, qui est d'environ 2%, avec un niveau d'énergie progressif dans la première phase. Les résultats montrent que la densité et portance du sol sont faible et l'augmentation de l'énergie de compactage est sans effet. Dans la deuxième phase, une correction de la granulométrie est effectuée par ajout progressive de poudre de marbre au sable de dune. Les résultats de la portance et de la compacité sont considérablement améliorés.

Keywords: Compaction energy; low water content; dune sand; marble powder.

1 INTRODUCTION

The development of Saharan regions requires the design of communication roadways, especially roads, to connect urban areas. The scarcity of materials and the arid climate have promoted engineers and researchers to look at various possible solutions to this challenge. One of these solutions is to reuse local materials, including dune sand, as a subgrade material in the engineering of Saharan pavements. The construction of pavements in deserted areas is challenged by the unavailability of water necessary for the compaction of materials. The scarcity of water makes compaction in these regions costly and difficult.

According to estimations, constructing 1 km of road in these areas could require up to 2,800 m3 of water, which could represent up to 20% of all construction costs. (Newill and O'Connell 2020). The Sahara covers about a third of the surface of Africa. Moreover, the dune sand covers about 30% of the Algerian Sahara, which represents around 80% of the surface of Algeria (Daheur, Goual et al. 2019). The use of dune sand for the construction of Saharan roads has great interest. Dry compaction is one of the most economical solutions for pavement structures For example, the experimental road embankment of a black silty clay of Sudan compacted at low moisture content has performed satisfactorily for one and a half years (Ellis 1980), and the road projects in Kenya constructed at low moisture content have performed equally well for two years (O'Connell 1987).Recently, many researchers have developed a lot of techniques and solutions to improve these materials at a reasonable cost, such as the effect of adding finer particles to the dune sand. The CBR value increased

with the increase in wastemarble powdercontent (Yorulmaz, Sivrikayaet al., 2021). 25% of marble dust has been considered to improve the CBR value of sandy soil. (Jain, Jha et al. 2020). The optimum moisture content (OMC) decreases as the percentage of marble powder increases; however, the values of the maximum dry density (MDD) increase as the percentage of marble powder increases to 6% (Rouaiguia, El Aal et al. 2020). The maximum dry density (MDD) increases with increasing ceramic waste and marble dust added to the soil. Moreover, the CBR values increase with the addition of ceramic waste and marble dust (Deboucha, Aissa Mamoune et al. 2020).

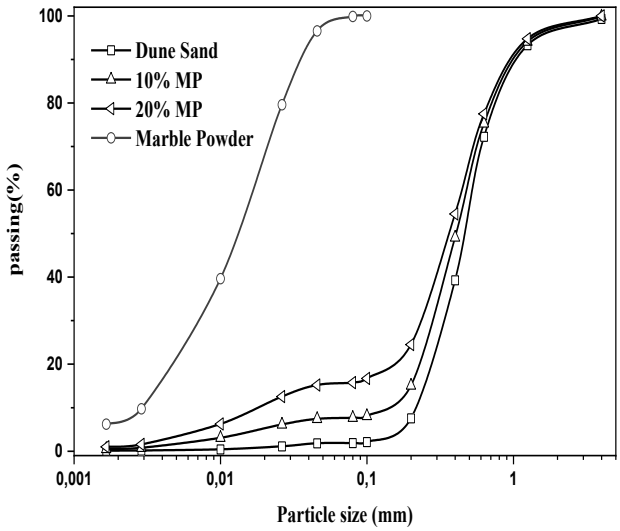

Figure 1. Particle size distribution of dune sand and Marble powder and mixture of dune sand with different adding of marble powder.

Table 1. Studied material formulations.

Designation	Dune sand (%)	Marble Powder (%)
DS100	100	0
DS90+MP10	90	10
DS80+MP20	80	20

2 MATERIALS AND METHODS

2.1 Dune sand of oued-souf

The dune sand (DS) is extracted from Oued-Souf city, located 640 km in the south-east of Algieria and characterized by a hot desert climate. This dune sand has a very high amount of sand (94%) and a low content of fine particles (2.5% silt and 0.5% clay). This dune sand is classified as fine sand (A-3) according to the American Association of State Highway and Transportation Organizations classification system (AASHTO) and poorly graded sand (SP) according to the Unified Soil Classification System (USCS).

2.2 Marble powder

The marble powder was obtained from the cutting and polishing of marble stones, and it was extracted from the FIL-FILA Quarry, which is about 25 km east of Skikda city, north-east of Algeria. The particle size distribution of the materials is presented in Figure 1.

2.3 Methods

The materials investigation is conducted by experimental tests, such as the sieve analyses and laser diffraction analysis (ASTM E3340-22), specific gravity (Gs), test by Gas Pycnometer (ASTM D5550-14)), sand equivalent test (ASTM D2419) and Methylene Blue Index (MVB)(ASTM C837) The particle size distribution of the materials is presented in Figure 1. Table 2 presents the principal properties of the materials. Standard and modified Proctor compaction testsis conducted according to the ASTM standard (ASTM D1557) in the aim to obtain the MDD and OMC. The same mould is used with a volume of 944 cm3 on each material. The California Bearing Ratio (CBR) tests are done in the CBR mould according to ASTM standard (ASTM D1893) to measuring the bearing capacity of the used soil at OMC.The dune sand is mixing with different proportions of marble powder which varying from 0, to 20% by weight. As seen in Table 1.

Table 2. Basic properties of dune sand.

Properties	Oued-Souf sand
Specific gravity	2.63
Gravel (%)	3
Sand (%)	94
Silt (%)	2.5
Clay (%)	0.5
Uniformity coefficient (Cu)	2.5
Coefficient of gradation (Cc)	0.9
MBV	0.07
Liquid Limit LL (%)	NP
IP	NP
ES	77

3 RESULTS AND DISCUSSION

3.1 Compaction caracteristique at the optimum

The result of compaction caracteristics as shown in figure 2, the Dune sand of Oued-souf under modified compaction effort, has a MDD value of 17.2 kN/m³, while under the normal compaction effort, is 16.9 kN/m³. For the modified compaction effort, the OMC is 7.6%, while for the normal compaction effort, it's 9%. The high sand content (94%) and lack of fines (3%) makes Oued-Souf soil less susceptible to compaction energy. This behaviour can be explained by the non reduce of voids between sand's particles because of its uniformed size, while compacting, as indicated by Cu and Cc coefficient, The CBR value under modified compaction test is 13%,wich is low value for the sub-grade construction.similar work has been seen in (Virgil Ping, Yang et al. 2002).

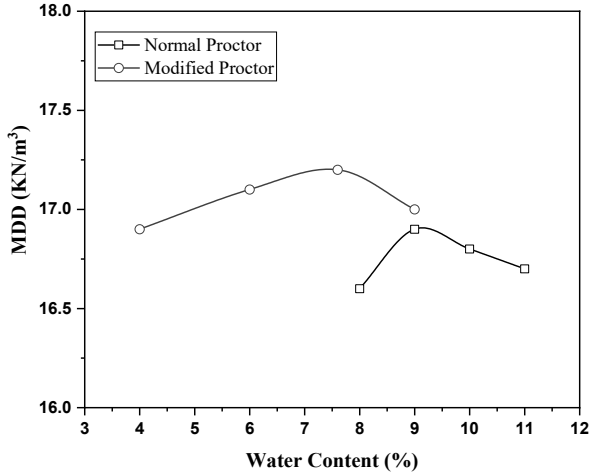

Figure 2. Normal and modified Proctor test curves.

3.2 Dune sand improvement by adding marble powder at low water content

3.2.1 Effect on grain size distributions

As shown in the figure 1, the progressive incorporation of marble powder (MP) modified the curve's shape; an upward movement was noticed of the grain size distribution curve for the treated soil. this shift is consequently due to the content of marble powder's role in displacing and reducing sand particles that leads to an increase of fine particles content in the mixture. the oued-souf material with no addition of marble powder has a poorly graded particle size distribution (cu = 2.25 and cc=1.05). the addition of 20% of marble powder changes the particle size distribution to to well graded, cu and cc rise respectively to 22.78 and 7.8, indicating that the particle size distribution has become less steep with a wide range of particle sizes.

3.2.2 Effect on compaction characteristics

The dune sand of Oued Souf under modified compaction effort at low water content (W=2%) reaching a maximum value of MDD, 20 KN/m^3 with the addition of 20% of marble powder (80DS + 20 MP) with an increase of 16%,as shown in Figure 3, this increase in MDD is related to the effect of finer particles that's helps the reduction fo voids in this dune sand, the peak of MDD at 20% of marble powder that's mean the powder occupied all the voids and reach the maximux density, similar behavior has been seen in (Omar, Zentar et al. 2022).

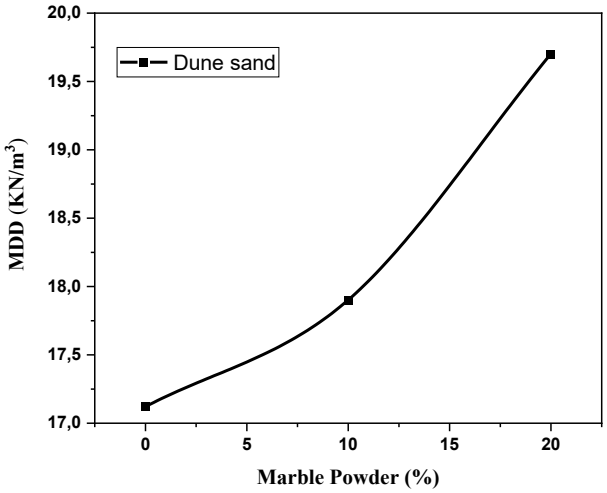

Figure 3. Effect of Marble Powder on the MDD of Dune sand.

3.2.3 Effect on the California Bearing Ratio (CBR) tests

The CBR values results for dune sand, with various content of marble powder is given by Figure.4. The CBR values increase from 10% to 37% Which is almost 4 times increase at the addition of 20% of marble powder, indicating that the material has reached its maximum compactness at this water content (W=2%).

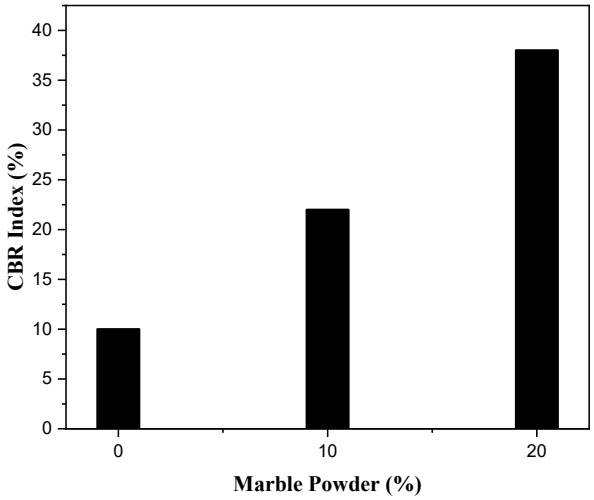

Figure 4. Effect of Marble Powder on on the CBR value of Dune sand.

4 CONCLUSION

The present experimental work on soil compaction at low water content involves mixing marble powder. The main results obtained are as follows. Increasing compaction energy has almost no effect on sand with uniform grain size as dune sand. The improvement of the density and bearing capacity of uniform grain size sand can be well achieved with the addition of insensitive water finer particles and mixing together. This solution helps to reduce the void ratio and increase the MDD. The compaction parameters as MDD and the CBR values have shown a considerable improvement with the addition of 20% of marble powder at low water content.

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