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# Influence of limestone powder waste addition on the geotechnical behaviour of a soft soil: Preliminary results

## Influence de l'addition des déchets de poudre de calcaire sur le comportement géotechnique d'un sol doux : résultats préliminaires

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**ABSTRACT:** The natural stone industry is one of the most important industries in southeast Spain. Due to this industrial activity, about 500 000 tonnes of inert materials are generated every year from cutting and polishing natural stones. Although this industrial waste is a non-polluting material, put it in a landfill presents a strong environmental impact in the nearby areas of the dumpsite. Soil improvement can be one of the potential uses for this material, having two clear beneficial effects. On the one hand, using this industrial waste avoids putting it in a landfill. On the other hand, the use of this waste as an additive could improve some of the geotechnical characteristics of soft soils. In this preliminary study, the effect of limestone powder dust on the geotechnical behaviour of a soft soil is presented. A soft clay with medium-low plasticity and a natural moisture content of about 31% was studied. The additive employed was collected from a dump in a natural stone factory. The waste stone dust was used as a partial replacement of soil from 0 to 25% by weight. Deformability and strength properties of the mixed soil were studied by performing physical and mechanical tests. The obtained preliminary results show that limestone powder waste can be used as an additive to soil improvement for this clay with an increase in its strength and reduction on the swelling index.

**RÉSUMÉ:** L'industrie de la pierre naturelle c'est une des industries plus importantes du sud-est de l'Espagne. En raison de cette activité industrielle, environ 500 000 tonnes de matériaux inertes sont générées chaque année par le taillage et le polissage de pierres naturelles. Bien que ces déchets industriels soient un matériau non polluant, leur mise en décharge présente un fort impact environnemental dans les zones voisines du dépotoir. L'amélioration des sols peut être l'une des utilisations potentielles de ce matériau, avec deux effets bénéfiques évidents. D'une part, l'utilisation de ces déchets industriels évite la mise en décharge dans un dépotoir. D'autre part, l'utilisation de ces déchets en tant qu'additif pourrait améliorer certaines des caractéristiques géotechniques des sols doux. Dans cette étude préliminaire, se présente l'effet de la poussière de marbre sur le comportement géotechnique d'un sol doux. Une argile douce de plasticité moyenne à faible et humidité naturelle d'environ 31% a été étudiée. L'additif utilisé a été collecté dans un dépotoir dans une fabrique de pierre naturelle. La poussière de pierre a été utilisée comme remplacement partiel du sol de 0 à 25% en poids. Les propriétés de déformabilité et de résistance du sol mélangé ont été étudiées en effectuant des tests physiques et mécaniques. Les résultats préliminaires obtenus montrent que les déchets de poudre de calcaire peuvent être utilisés comme additifs d'amélioration du sol pour cette argile avec une augmentation de sa résistance et une réduction de son indice de gonflement.

**Keywords:** limestone powder; soil improvement; soft soil; geotechnical properties

# 1 INTRODUCTION

The natural stone industry is a key industry in southeast Spain, having a very positive socio-economic impact (Asociación Mármol de Alicante, 2012). Like any industrial activity, natural stone industry brings with it environmental issues. In its normal activity, cutting and polishing, about 500 000 tonnes of inert materials are produced and dumped in landfills every year. Although natural stone waste is a non-polluting material, putting it in a landfill has a strong environmental impact. To avoid this undesired effects, local governments and companies are searching for alternatives uses for this waste.

One potential use of this residual material is soil improvement. Some previous research using natural stone dust has had promissing results. Sabat et al. (2011) found that the swelling pressure of an expansive soil decreased when marble dust was added. At the same time, the unconfined compressive strength (UCS) of the soil increased with the marble dust addition. Similar results about the reduction of the expansive index were found in other researches (Ali, Khan, & Shah, 2014; Saygili, 2015). Saygili (2015) also reported the increase in the UCS and the internal friction angle of the soil when marble dust was added.

In the present work, the deformability and strength preliminary results of adding limestone powder to a soft soil are presented.

# 2 MATERIALS

## *2.1 Soil*

A soft clay with medium-low plasticity and a natural moisture content of 31% was studied. The basic natural soil properties are summarized in Table 1.

## *2.2 Additive*

The additive used in this work was limestone powder waste collected from a dump site in a natural stone factory. The calcium carbonate content of this additive was 93.0%.

*Table 1. Natural soil properties.*

| Property | Soil |
|---|---|
| 0.4 mm (% passing) | 100.0 |
| 0.08 mm (% passing) | 92.0 |
| Liquid Limit | 40.9 |
| Plasticity Index | 17.1 |
| % Carbonates | 16.9 |

# 3 METHODS

## *3.1 Sample preparation*

The soil was first oven dried at 40ºC and grounded with a rubber mallet without breaking the particles. Afterwards, 31% of water by total dry weight of the soil was added to simulate the natural moisture content of the real soil. Once a homogeneous mix is achieved, the dry limestone powder is added from 0 up to 25% by total dry weight of the soil. The samples for oedometer free swell tests were prepared by adding only 12% of water to make clearer the effect of the additive in the swelling index.

After being completely mixed, the samples were made in different moulds and stored for 7 days in a humidity and temperature controlled chamber (>95% RH and 20±2ºC).

As the research is in progress, at the time of writing this communication, preliminary results with different amount of samples and dosages are available. This information is different for each method, so, it will be stated in the following subsections.

## *3.2 pH determination*

The pH of the soil was determined in 1:2.5 soil/water extract. 10 g of the dried soil sample is added to 25 ml of distilled water and stirred for

10 minutes. After approximately 30 minutes, when the solution is clear, electrodes are immersed and pH value is determined (Juárez Sanz, Sánchez Sánchez, Jordá Guijarro, & Sánchez Andreu, 2004). Tests were conducted after mixing in duplicate for samples prepared by adding 0, 5, 10, 15, 20 and 25% of limestone powder by dry weight of the soil.

### 3.3 Swelling potential

Swelling axial strain is measured after watering sample discs under horizontal confined conditions. The tests are performed in the oedometer apparatus according to the Spanish standard UNE 103601 (AENOR, 1996) for samples prepared by adding 0, 10 and 20% of limestone powder by dry weight of the soil. The samples for the swelling tests were prepared by adding 12% of water to the dry natural soil. This water content was chosen according to Carter and Bentley (2016), corresponding to the lowest interval value of the optimum moisture content for compacting clays.One sample per dosage had been tested by the time of writing this paper.

### 3.4 Unconfined compressive strength

The UCS was determined as the maximum axial stress supported by cylindrical samples with 100 mm height and 50 mm diameter. Tests were performed according to the Spanish standard UNE 103400 (AENOR, 1993) for samples prepared by adding 0, 5, 15 and 25% of limestone powder by dry weight of the soil. One sample per dosage had been tested by the time of writing this paper.

### 3.5 Triaxial test

Triaxial tests according to the standard UNE 103402 (AENOR, 1998) were performed to determine the shear strength of the natural and the mixed soil. Three samples per test were tested with confining pressures of 100, 200 and 300 kPa. The specimen drainage conditions for all the tests were consolidated – undrained (CU). Two tests per dosage for the natural soil and the soil with 25% of the limestone powder were available at the time of writing this paper.

## 4 RESULTS

### 4.1 pH determination

The pH values measured for the samples of soil with a different amount of limestone powder are depicted in **Error! Reference source not found.**. As it can be seen in this figure, the additive does not have a clear influence in the pH of the soil.

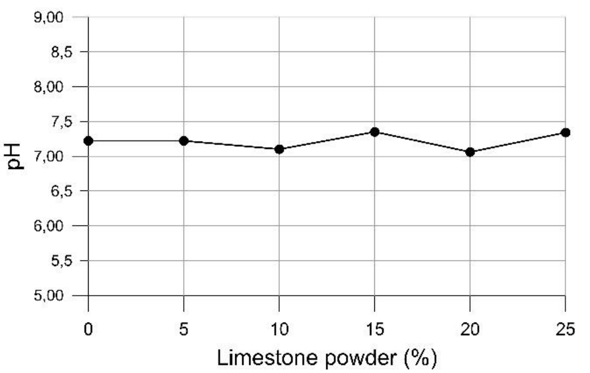


*Figure 1. pH values for soil with a different amount of limestone powder.*

### 4.2 Swelling potential

The results of the free swell ratio for samples prepared by adding 0, 10 and 20% of the additive by dry weight of the soil are depicted in Figure 2. The free swell ratio of the samples decreases with the amount of limestone powder.

### 4.3 Unconfined compressive strength

The UCS of the tested samples increased with the amount of limestone powder added, as it can be seen in Figure 3. The effect of the additive on the stress-strain behaviour can also be observed in this figure. The natural soil and the soil with 5% of limestone powder show a parabolic shape while the soil with a higher amount of additive can be modelled with a bilinear approximation.

The initial slope of the bilinear curve is similar for all the tests with limestone dust. Nevertheless, the second slope of the curve increases as the percentage of additive increases. The secant modulus at 50% strength, $E_{50}$, for 0, 5, 15 and 25% of limestone powder are 408, 475, 711 and 677 kPa, respectively.

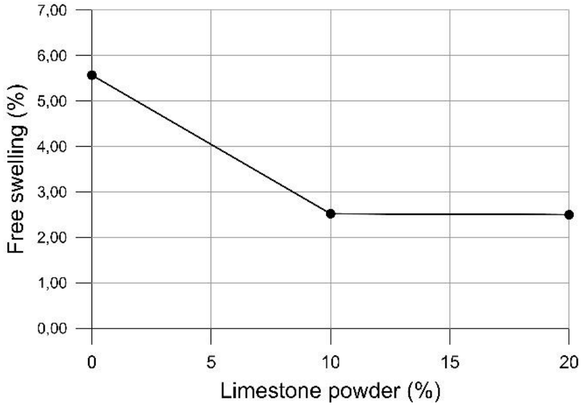


*Figure 2. Free swell ratio values for soil with a different amount of limestone powder.*

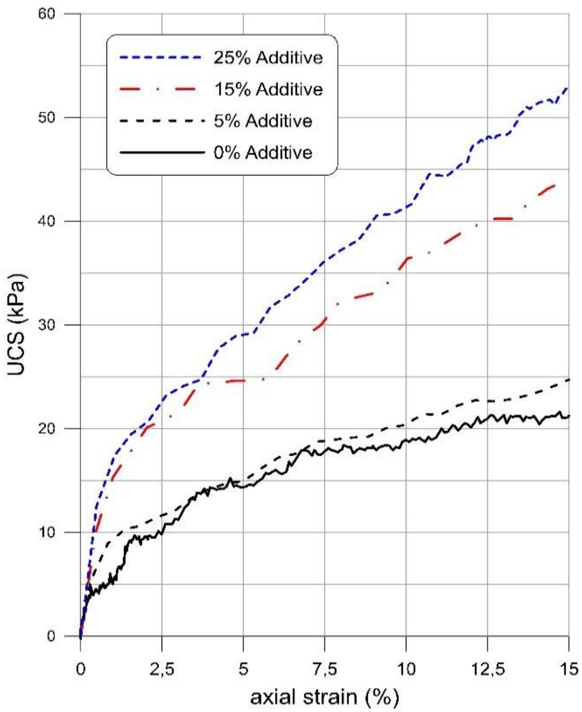


*Figure 3. Unconfined compressive strengths for soil with a different amount of limestone powder.*

### 4.4 Triaxial test

The values of cohesion and angle of internal friction determined with the CU triaxial tests are depicted in Figure 4. The angle of internal friction of the soil raised when 25% of limestone powder was added, whilst the cohesion remained approximately constant. Figure 5 shows the stress vs straing curves for two of the samples with 0 and 25% of additive.

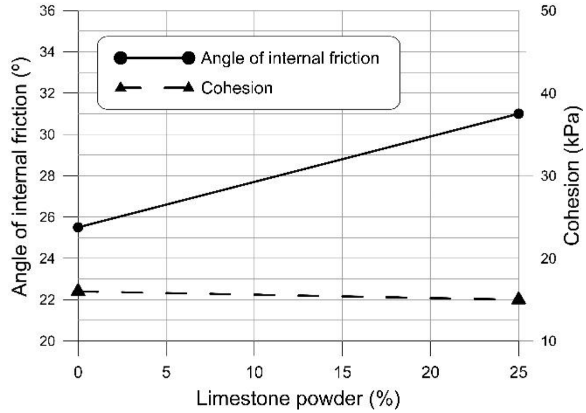


*Figure 4. Variation of cohesion and angle of internal friction against percentage of limestone powder.*

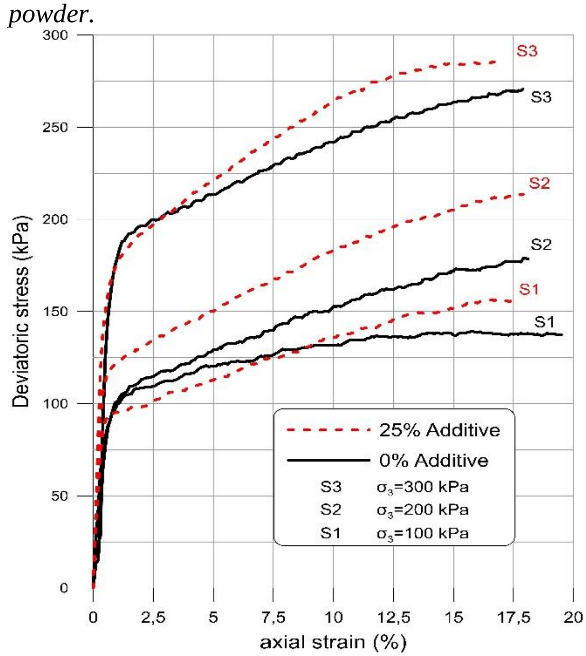


*Figure 5. Strain vs. Stress for the three specimens of the samples with 0 and 25% of additive.*

## 5 DISCUSSION

The results obtained up to now generally show a positive effect when adding limestone powder to the studied clayey soil.

As stated above, the addition of limestone powder does not have a clear impact on the pH values of the mixed soils. These outcomes are not well correlated with the results obtained by Sol-Sánchez et al. (2016) where an increase in the pH value was observed. This may be because the pH tests in the present research were done after mixing the soil and the additive, while the tests in the Sol-Sánchez et al. (2016) research were performed 7 days after mixing.

The free swelling presented by the natural soil is reduced by about one half when 10% of the additive is added. No further reduction of the free swelling has been detected when the addition is increased up to 20%. Previous research with marble dust (Sabat & P, 2011; Saygili, 2015) observed a reduction in the free swelling index when adding up to 30% of this additive.

The unconfined compressive strength of the soil significantly increases when the percentage of additive increases, up to the maximum addition studied in this research of 25%. The percentage increase in the UCS is 14, 95 and 141% when 5, 15 and 25% of limestone powder is added, respectively. Saygili (2015) found similar results using marble powder as an additive. Nevertheless, Sabat (2011) observed that UCS increased when adding marble dust up to 20%, decreasing when the percentage of addition was higher. The triaxial test results also show an increase in the drained shear strength of the soil when 25% of limestone powder is added. In this case, the angle of internal friction increased by 32%, whilst the cohesion remained approximately constant. The stress vs strain curves show a ductile behaviour in both tests, UCS and triaxial test.

The stiffness of the soil is related to $E_{50}$, so in general terms, the deformability of the soil decreases when the percentage of limestone dust increases. Nevertheless, $E_{50}$ for 25% additive is slightly lower than that for 15%.

## 6 CONCLUSIONS

The preliminary results reported in this work show that the addition of dry limestone powder waste to a clayey soil with a high moisture content improves the geotechnical behaviour of the soil. Increasing the shear strength and the stiffness of the soil and reducing its swelling index.

The use of this industrial waste as an additive in soil improvement would reduce the environmental impact of depositing this material on dumpsites.

## 7 ACKNOWLEDGEMENTS

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