INFLUENCE OF THE ADDITION OF WASTE GLASS ON THE REDUCTION OF CLAY SWELLING

INFLUENCE DE L'AJOUT DE DÉCHETS DE VERRE SUR LA RÉDUCTION DU GONFLEMENT DES ARGILES

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Abstract - Earthworks, such as excavation and construction activities, often generate significant amounts of clay. However, not all types of clay are suitable for use in backfill applications due to their specific properties and technical requirements. Thus, they are stabilized to improve their properties and make them suitable for use in various geotechnical applications. The present work aims to study the influence of the addition of waste glass on the evolution of the mechanical characteristics of clays stabilized with crushed glass. The work consists of carrying out oedometric and direct shear tests on natural clay taken as a reference material and mixtures composed of natural material and crushed glass at different percentages (10%, 20% and 30%). It has been observed that the compression and swelling indices of the clay decrease by increasing glass percentage. The behavior of mixtures composed of clay and crushed glass at long-term has been examined through direct shear tests in Consolidated-Drained (CD) conditions. It has been found that the addition of glass to clay changes the intrinsic characteristics of the clay itself. It can be concluded that the addition of crushed glass to clay improves its consistency and behavior, making it suitable for road fill and similar applications.

Keywords: Swelling clay, Stabilization, Glass Waste, Compressibility, Direct shear test.

Résumé - Les déchets de verre peuvent être récupérés et utilisés dans diverses applications géotechniques telles que les travaux routiers. D'autre part, les travaux de terrassement génèrent souvent des quantités importantes d'argile. Cependant, tous les types d'argile ne sont pas adaptés aux applications de remblaiement en raison de leurs propriétés spécifiques et de leurs exigences techniques. Lorsque l'argile ne répond pas aux spécifications requises pour une application particulière, elle peut être stabilisée pour améliorer ses propriétés et la rendre adaptée à diverses applications géotechniques, y compris les remblais. Le présent travail vise à étudier l'influence de l'ajout de déchets de verre sur l'évolution des caractéristiques mécaniques des argiles stabilisées au verre broyé (particules inférieures à 630µm). Le travail consiste à réaliser des essais œdométriques et de cisaillement direct sur de l'argile naturelle prise comme matériau de référence et des mélanges composés de matière naturelle et de verre broyé à différents pourcentages (10%, 20% et 30%). En augmentant la quantité de verre ajoutée à l'argile, il a été observé que les indices de compression et de gonflement de l'argile diminuent. Le comportement à long terme des mélanges composés d'argile et de verre broyé a été examiné au moyen d'essais de cisaillement direct en conditions Consolidé-Drainé (CD). Il a été constaté que l'ajout de verre à l'argile modifie les caractéristiques intrinsèques de l'argile elle-même. Sur la base de ces résultats, on peut conclure que l'ajout de déchets de verre à l'argile améliore sa consistance et son comportement, ce qui le rend approprié pour des remblais routiers et des applications similaires.

Mots - clés : Argile gonflante, stabilisation, déchets de verre, compressibilité, essai de cisaillement direct.

1-Introduction

Expansive soils are materials that have the tendency to increase in volume when they become moist. These soils pose a natural hazard to engineering structures, particularly lightweight structures and highway pavements [1], [2]. There are several ways to mitigate the harm caused by expansive soils, including material replacement, specific foundation types, and soil stabilization methods. Soil stabilization can be achieved through mechanical, chemical, or a combination of both methods [3]. Chemical stabilization can indeed be used to increase the durability, strength, and stress/strain behavior of soils. By mixing the soil with specific chemicals, the properties of the soil can be modified to achieve desired engineering characteristics [4], [6]. Extensive research has been conducted on various chemical additives for the chemical stabilization of expansive soils. Some of the commonly investigated chemical additives include cement, lime, and asphalt, among others [2], [6]. The use of chemical additives in soil stabilization can significantly enhance the ability of subgrade soils to support pavement structures and withstand traffic loads with minimal deformations [7], However, researchers are motivated to explore more environmentally friendly and cost-effective building materials and techniques due to the concerns over high energy consumption, greenhouse gas emissions, carbon emissions, and increased demand for construction materials [8]. In civil engineering projects such as railroads, roadways, and embankments, large quantities of soil are often required [9], However, in some cases, the distance between the project site and the sources of suitable earth materials can pose logistical challenges and increase transportation costs. Additionally, expansive soils, particularly high-plasticity clays, are unsuitable for use in these applications due to their potential for volume changes and detrimental effects on the stability of the structures. Therefore, treatment of expansive soils becomes necessary to make them suitable for use [10].

Researchers have been exploring the use of solid waste as an alternative building material to traditional treatment techniques in order to mitigate negative environmental and economic impacts [11]. Non-chemical stabilizers and chemical stabilizers are two approaches that can improve the properties of expansive clay soils. Recycled glass has the potential to be an effective non-chemical stabilizer due to its particle size and shape, which are similar to sand [12], [13]. The angular and granular nature of glass particles can contribute to improved interlocking and shear strength within the soil matrix. Promoting the use of recycled materials like glass in geotechnical engineering not only addresses waste management challenges but also aligns with sustainable practices by reducing the demand for virgin materials and minimizing environmental impacts associated with traditional stabilization techniques [14]. Broken glass, which primarily consists of silica sand, has been suggested as a potential material to enhance the capabilities of clay as a roadbed material. This can lead to enhanced load-bearing capacity and reduced deformations, making it a viable option for road construction. This study is aimed to investigate the influence of adding glass waste to a swelling clay on its mechanical properties and its intrinsic characteristics. The experimental work consists of carrying out oedometric and direct shear tests on natural clay (reference material) and mixtures composed of natural material and crushed glass at different percentages (10%, 20% and 30%).

2-Materials and methods

2.1- Materials

In this study, two materials were used, namely plastic clay and crushed glass. The clay is brought back from Medressa (Tiaret province). Its main characteristics are summarized in table1.

According to the Roadworks Guide (NF P 11-300), the clay used is classified in class A and subclass A3, which means that the material is a very plastic clay. The material classification is also confirmed by the Casagrande's abacus [15], [16].

The Glass is collected from glassmakers' waste then crushed using the Los Angles device. After sieving, only the 0/0.63 mm fraction is retained.

Table 1 : Main characteristics of the used clay.

Tableau 1 : Principales caractéristiques de l'argile utilisée.

Symbol	Quantity	Value
Dmax(mm)	Max grain Diameter	4
VB	Methylene blue value	3,33
WL(%)	Liquidity Limit	63,7
Ip	Plasticity Index	37,6
CaCO3 (%)	Carbonate content	4
γ_s (g/cm3)	Specific density	1,46

2.2- Methods

In order to investigate the influence of the addition of waste glass on the evolution of the mechanical characteristics of clays stabilized with crushed glass, oedometric and direct shear tests were performed according to the standard tests XP P 94-090-1 and NF 94-071-1, respectively. The different mixtures are prepared by adding glass waste to the clay at different percentages (10%, 20% and 30%) reported to the mass of the clay.

3-Results and discussion

According to the Proctor test results (table 2), it can be noted that the addition of crushed glass to the mixture can lead to a significant increase in the dry density of the soil. This is due to that the glass has a higher density (1,55 g/cm3) compared to the studied clay (1,46 g/cm3). In addition, glass particles provide better interlocking and fill the voids between the clay particles more effectively during the compaction process. This leads to a higher degree of compaction and results in an increased dry density of the mixture. Regarding the evolution of water content, it can be noted that this parameter decreases by adding glass, because the latter doesn't absorb water. But, when more glass is added, the mixture needs an extra amount of water for mix workability [17].

Table 2 : Optimum Proctor characteristics of the different mixtures.

Tableau 2 : Caractéristiques de l'Optimum Proctor des différents mélanges.

Mixture	WOPN(%)	γ_d max(g/cm3)
Clay	22,48	1,64
Clay +10% Glass Waste	21	1,65
Clay +20% Glass Waste	18,69	1,70
Clay +30% Glass Waste	19,31	1,75

Figure 1 illustrates the oedometric curves for the different mixtures. It can be observed that the compressibility curves are classified by percentage of glass added to clay (0%, 10%, 20%, 30%). It can be noticed that that the initial void index is all the lower as the percentage of the glass is greater. This is in agreement with the results of Proctor test in which it was found that the maximum dry density increases with increasing the percentage of added glass.

Regarding the swelling and compression indexes, it can be noted that these two parameters decrease by increasing the addition of crushed glass (Figure 2). The decrease in swelling observed when glass particles are mixed with clay can be attributed to the formation of a new structure that mitigates the swelling behavior of the clay. When glass particles are introduced into the clay matrix, they interact with the clay particles and form a composite material. Moreover, the addition of crushed glass to clay can result in decreased compressibility by reducing the void ratio and enhancing particle interlocking and packing.

In order to simulate the long-term behavior of the materials, direct shear tests were carried out in CD (Consolidated-Drained) conditions. It can be seen in figure 3 that the effective cohesion in drained condition increases by increasing the crushed glass percentage. When the percentage of crushed glass is increased, more glass particles are introduced into the soil mixture. These glass particles can contribute to the overall cohesive forces within the soil, resulting in higher effective cohesion. Concerning the effective angle of friction, it was noticed that this parameter decreases a little bit

for the dosage of 10%. However, at a dosage of 30%, a notable increase in the effective angle of friction is observed. This indicates that a significant amount of crushed glass contributes to the development of a new pseudo-granular structure within the soil mixture.

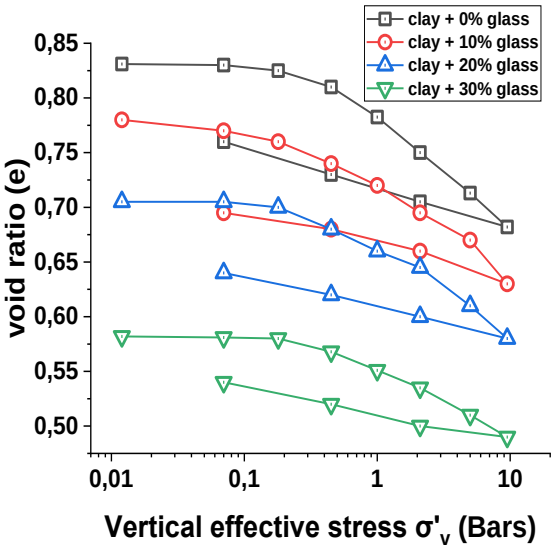

FIGURE 1 : Compressibility curves of the different mixtures.

FIGURE 1 : Courbes de compressibilité des differents mélanges

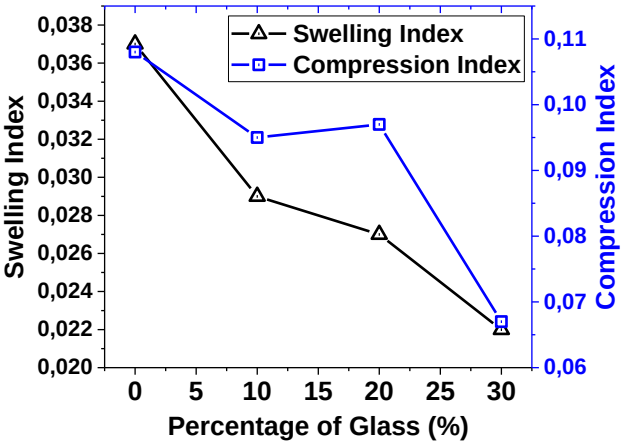

Figure 2 : Swelling and compression indexes vs glass percentage

Figure 2 : Indices de gonflement et de compression en fonction du pourcentage de verre

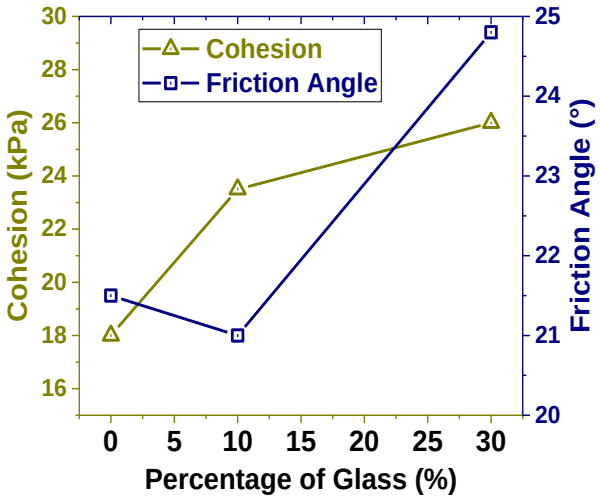

Figure 3 : Variation of cohesion and friction angle Vs glass percentage.

Figure 3 : Variation de la cohésion et de l'angle de frottement en fonction du pourcentage de verre**.**

4- Conclusion

In this work, the influence of the addition of waste glass on the evolution of the mechanical characteristics of clays stabilized with crushed glass (particles smaller than 630µm) was investigated. The stabilized material is plastic clay. The additive is a glass grains (< 630µm) obtained from grinding of glass waste using the Los Angeles apparatus. The tests carried out in this study are mainly oedometric and direct shear tests. Based on the outcomes and the analyses of the results, the following conclusions can be drawn:

-Regarding the Proctor tests, it was found that the addition of crushed glass significantly increases the dry density of the mixture. This is proportional to the dosage of the glass waste, which reflects the good compactibility of the clay-crushed glass mixtures.

-The mechanism of compressibility was studied through the oedometric test, from which it was found that the compression and swelling indexes decrease by increasing the amount of added glass.

-Concerning the intrinsic characteristics of the stabilized clay, it was found that both the effective cohesion and the angle of friction increase by increasing the dosage of the added glass, which leads to an improvement of the resistance of the soil.

Finally, it can be concluded that the addition of glass waste to plastic clay improves its mechanical characteristics, which allows it to be used in backfill or other geotechnical applications.

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