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Conference Paper

Study of the Effect of Waste Glass Fibers Incorporation on the Collapsible Soil Stability Behavior

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Abstract

Soil collapse remains a major issue affecting structural foundations, particularly in arid and semi-arid zones where humidification is a key factor contributing to the collapse. Much research has been devoted to identifying treatment methods which enhance the stability and load bearing capacity of this type of soil. This paper investigates the potential advantages of the addition of milled glass fibers (F_g). Soil samples were prepared at different compaction energies and various water contents, then treated with different percentages of milled glass fiber, before being submitted to the simple consolidation odometer test. The results obtained in this study showed that soil samples treated with an optimal dosage of 6% of milled glass fibers compacted at 60 blows and humidified at 6% of moisture content. This represents an improvement in the stability of the soil, reducing the collapse potential (C_p) from 11.95% to 1.62%. This treatment method produces soil which can be classified as a moderate risk foundation soil according to the Jennings and Knight evaluation metrics (1975).

Keywords: collapsible soils, arid zones, fiberglass, odometer test.

1. Introduction

One of the most important geotechnical problems in the world, especially in arid and semi-arid regions, is that of collapsible soils, as they can be a real danger for the foundations stability and consequently for the constructions built on it if they are not substituted or treated. Studies claim that the loess covers about 17 % of the United States, about 17 % of Europe, 15 % of Russia and Siberia, and large areas of China [1]. A study by Nouaouria et al., showed that the properties of loess in southern Algeria are similar to those existing in other regions such as the soil of Iowa (USA) and Libya, this kind of soil can be classified as a silty loess [2].

The collapsible soils, due to their specific particle size, their low dry density and their reduced water content, are unsaturated metastable soils with a loose and open structure. Such soils can support heavy loads in the dry state, however, their humidification, even without additional loading, causes the disintegration of the connections giving a denser structure followed by an important settlement.

The treatment of collapsible soils in arid and semi-arid regions is a major issue in both economic and security aspects. Indeed, several researchers have focused on the study of the treatment of this type of soil with the aim of exploiting it without any danger.

A method using lime was proposed by Abbeche et al. [3]. Another one using cement was studied with the double odometer [4], This study showed that for a minimum compaction, a cement content of 4 % and a water content of 6 %, the soil is not collapsible. But Mohamed and El Gamal have concluded that the treatment of collapsible soil by sulfur cement, increases its compressive strength by about three times than the ones stabilized by Portland cement [5].

Fattah et al. affirm by their study that the treatment of undisturbed collapsible gypsum samples with acrylate liquid, with different properties and with various gypsum contents, can reduce the collapse potential by more than 50-60% [6–8].

In this paper, a new soil treatment is proposed, which will be carried out with different percentages of a milled glass-fiber. The soil will be subject to different compaction levels and different water contents in order to find the needed rate to reduce the soil subsidence, and thus to improve security level for the structures built on this type of soil.

2. Experimental Study

Tests were conducted on soil samples reconstituted in the laboratory with the composition of 80 % of sand (D <2 mm), and 20 % of kaolin as fine particles (grains size < 80 μm). The stream sand is from Oued Maitar at Boussaâda (Algeria) and the clay is a kaolin of Elmilia region located in Mila (eastern Algeria). The treatment is carried out with a milled glass-fiber (Fg) often used for its mechanical, thermal and chemical resistance (E-glass, product specification 1320 K, fiber length: 180μm). The geotechnical characteristics of the laboratory reconstituted soil are summarized in Table 1 and its particle size distribution curve is shown in Figure 1.

Table 1: Geotechnical characteristics of reconstituted soil

Liquid limit, $W_{L\%}$	18.53
Plastic limit $W_{p\%}$	13.13
Specific density, G_S	2.63
Coefficient of uniformity, C_u	9.44
Coefficient of curvature, C_c	2.64
Maximum dry density γ_{opt} (g/cm^3)	1.91
Optimal water content $W_{opt\%}$	10

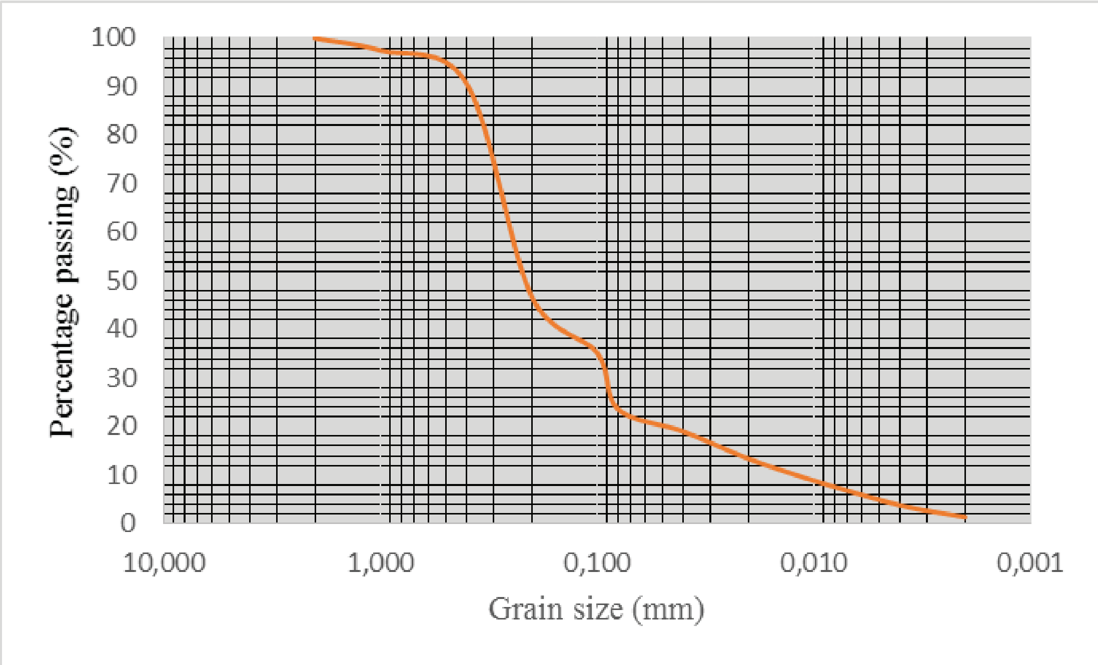

Figure 1: Grain size distribution curve of the reconstituted soil

3. Experimental Program

The study consists in consolidation in the oedometer [9], of samples according to the procedure of Jennings and Knight [10]. The samples were prepared at different moisture contents and compaction energy. Then, the same test will be carried on samples of soil treated with different percentages of milled glass-fiber. Content in glass-fiber is varied in order to determine the rate beyond of which the collapse C_p becomes without any danger for the structure ”no damages” according to the classification of Jennings and Knight [10], Table 2. The reserved parameters are:

- Initial water contents: 2, 4 and 6 %;
- Energy of compaction 20, 40 and 60 blows;

- Contents in glass-fiber: 0, 3, 4, 5 and 6 %.

TABLE 2: Collapse Potential Values (Jennings and Knight 1975)

C_p (%)	**Severity odisorders**
0 - 1 %	Without risk
1 - 5 %	Moderate trouble
5 - 10 %	Trouble
10 - 20 %	Severe trouble S
> 20 %	Very severe trouble

4. Test Procedure

The first stage of sample preparation is to mix the two components (sand and kaolin) to obtain a well homogenized soil. The soil is then compacted at a given water content in a standard oedometric mold in one layer due to the small height of the ring (20 mm). The equipment used for the compaction procedure, which was made at the laboratory, is composed of a disk having a diameter slightly smaller than that of the ring, which is fixed to a stem of guidance and a disk shaped weight. The weight of 121 g, sliding along the stem and falling from 15 cm height, comes to strike the disk, compacting thereby the material in the oedometer ring. The total compaction energy E_c at stake for a soil specimen, being the work of the mass M (kg) at a height h(m), is expressed by the equation:

$$E_c = M\ g\ h\ n \text{ (joules)} \quad (1)$$

Where n is the number of strokes of the mass M, and g the acceleration gravity.

The oedometer tests are made according to Jennings and Knight's procedure which consists in the application of loads: 25, 50, 100 until 200 kPa, then the sample is flooded with water and a new settlement value is recorded, afterwards the loading is increased up to 400 kPa. During the test, the settlements are recorded after 15 s, 30 s, 1 min, 2 min, 5 min, 10 min and 24 h [10], the collapse potential (C_P) is defined as:

$$C_p(\%) = \left[\frac{\Delta e}{1 + e_0}\right] \times 100 \quad (2)$$

$\Delta e = e_1 - e_2$,

e_1: void ratio before flooding

e_2: void ratio after flooding

e_0: initial void ratio.

5. Results and Discussion

5.1. Test results without treatment

To verify the collapse of the laboratory reconstituted soil, oedometer consolidation tests were executed at different moisture content and compaction energy. The results showed that the coefficient of collapse C_p varies according to compaction from 11.95 to 7.3 for an initial water content of 2 %, from 8.74 to 6.59 for an initial water content of 4 % and from 7.47 to 5.26 for an initial water content of 6 %. These values show a clear tendency of the untreated soil to collapse, they correspond to the variation of the state of the soil from severe to a moderate disorders according to the classification of Jennings and Knight [10] given in Table 2.

In these tests, which were carried to verify the collapsibility of the laboratory reconstituted soil, we noted that the ratio of the instant collapse is about 80% and the remaining one occurs slowly. The sudden collapse is due probably to the elimination of the capillary tension by the addition of water, the other part (slow collapse) is caused by the impermeability of the clay bridges making links between the soil grains. This confirms the mechanisms of collapse postulated by Morgenstern and de Matos[11], Ganeshan [12], Knight [13] and Booth [14].

The influence of the variation of initial water content, for different compaction energy, is clearly visible in Figure 2.The same observation can be noted for the compaction energy. Indeed, we notice that the value of C_p decreased with increasing energy of compaction (Figure 3). This result confirms the work of Barden *et al.*[15], Lefebvre and Belfadhel [16] and Lawton et al.[17].

Consequently, we can notice that the laboratory prepared soils have an analogous behavior to those met in situ.

5.2. Test results after treatment

The results illustrated by Figures. 4, 5 and 6, represent the variation of the collapse potential (C_p) against the treatment of the soil with different percentage of glass-fiber at different moister content.

We notice for the addition of 3% of glass-fiber a little decrease of the collapse, C_p decreases of 14.7% for 2% of water content and a compaction energy of 20 blows, until reaching 48.12% for the same previous water contents and a compaction energy of 60 blows. For the addition of 6% of glass-fiber, C_p decreases of 55.2% for 2 % of water

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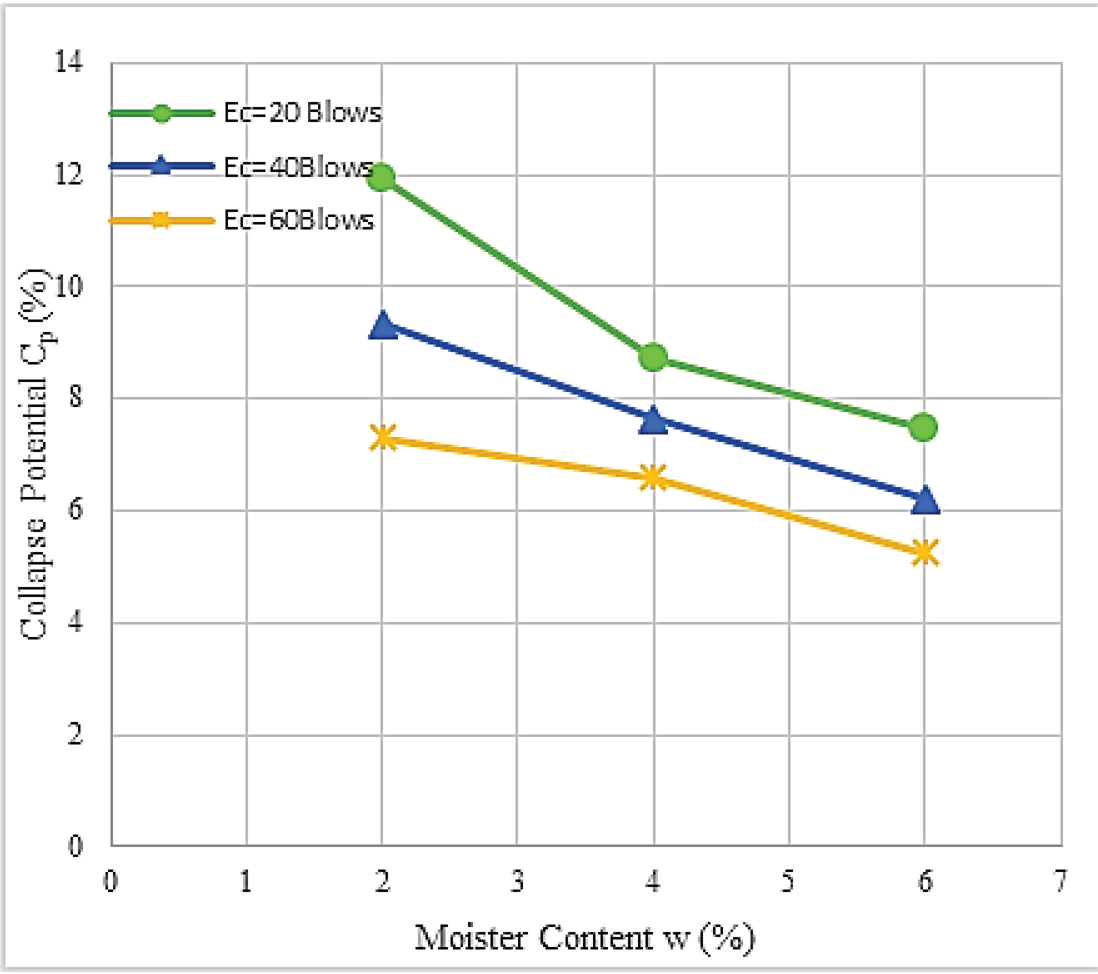

Figure 2: Variation of the collapse potential against moister content

content and a compaction energy of 20 blows, until 70.88% for the same previous water contents and a compaction energy of 60 blows (Figure 4). That is to say, that soil state passes from severe to moderate disorders according to the classification of Jennings and Knight [10], given in Table3.

When the water content is 4% (Figure 5), the results of treatment by 3% and 4% of glass-fiber (energy of compaction of 20 blows) seem to be close. The results go then from a decrease of 7.67% of Cp, for 3% of glass-fiber (Fg) and 20 blows, until reaching 8.12% for 4% of Fg and 20 blows as compaction energy.

The same remark can be done for the treatment with 5% and 6% of glass fiber for 40 blows of compaction energy.

For 6 % of water content (Figure 6), the collapse becomes insignificant until it vanishes from treatment with 5% of glass fiber especially for 60blows of compaction energy. The C_p value is 1.62% for 6% of glass fiber and 60 blows.

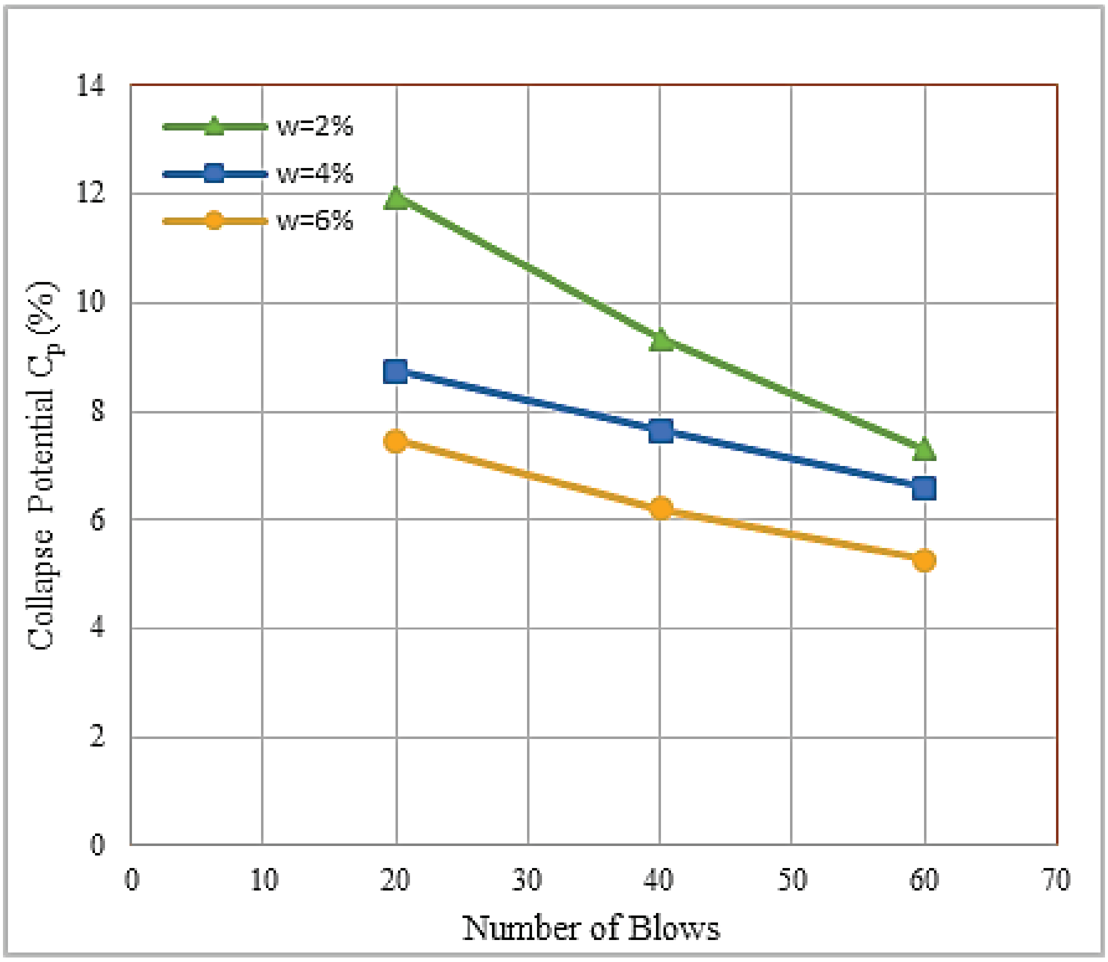

Figure 3: Variation of the collapse potential against number of blows

According to the obtained results, we can notice clearly the influence of the treatment of the soil by glass-fiber and its efficiency in reducing, or eliminating the danger of collapse of the soil and therefore structures built on it.

6. Conclusion

In this work, soil samples were prepared at the laboratory, and then they were treated with different percentages of glass-fiber in order to improve their mechanical characteristics and to eliminate the collapse problem. The results of physical and mechanical tests show that the laboratory reconstituted soil, with a water content lower than the optimum of Proctor and a moderate compaction energy, manifests the same physical and mechanical characteristics of a natural collapsible soil. The mechanical tests show clearly the variation of the collapse according to the augmentation of water content percentage and compaction energy. The oedometer results confirm the efficiency of the treatment with the glass fiber, and show that we can get a soil with moderate disorders

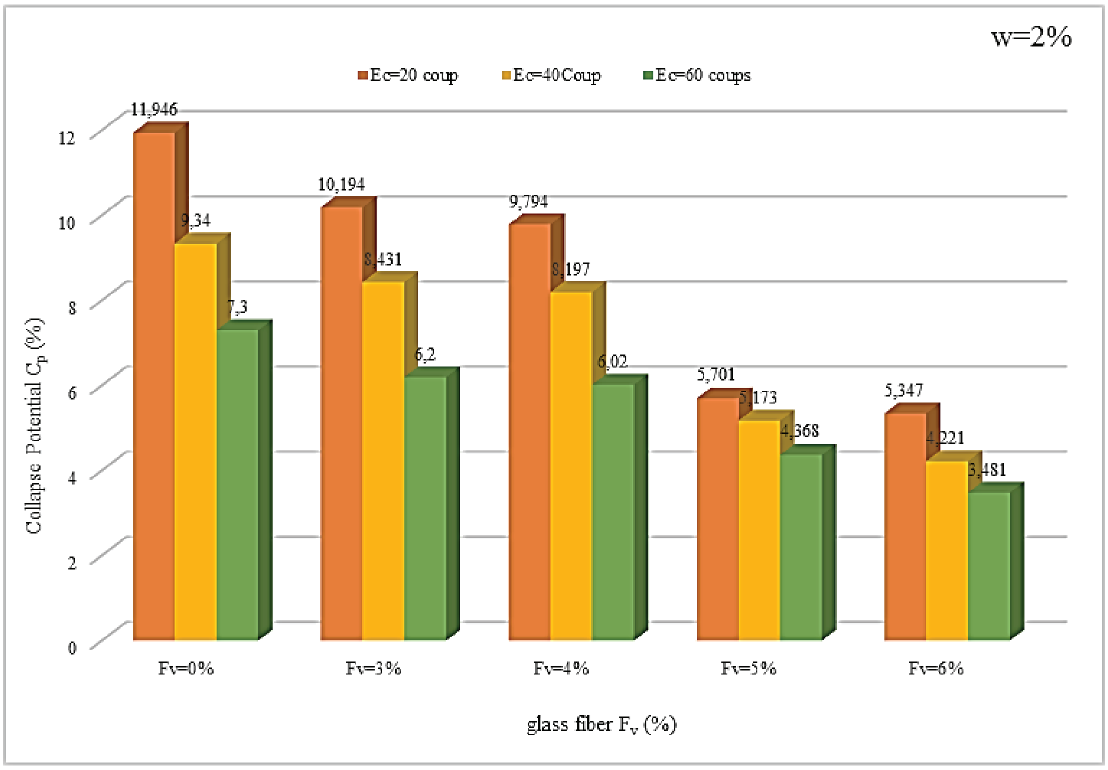

Figure 4: The Collapse Potential of soils compacted at various number of blow against glass fiber contents, w=2%

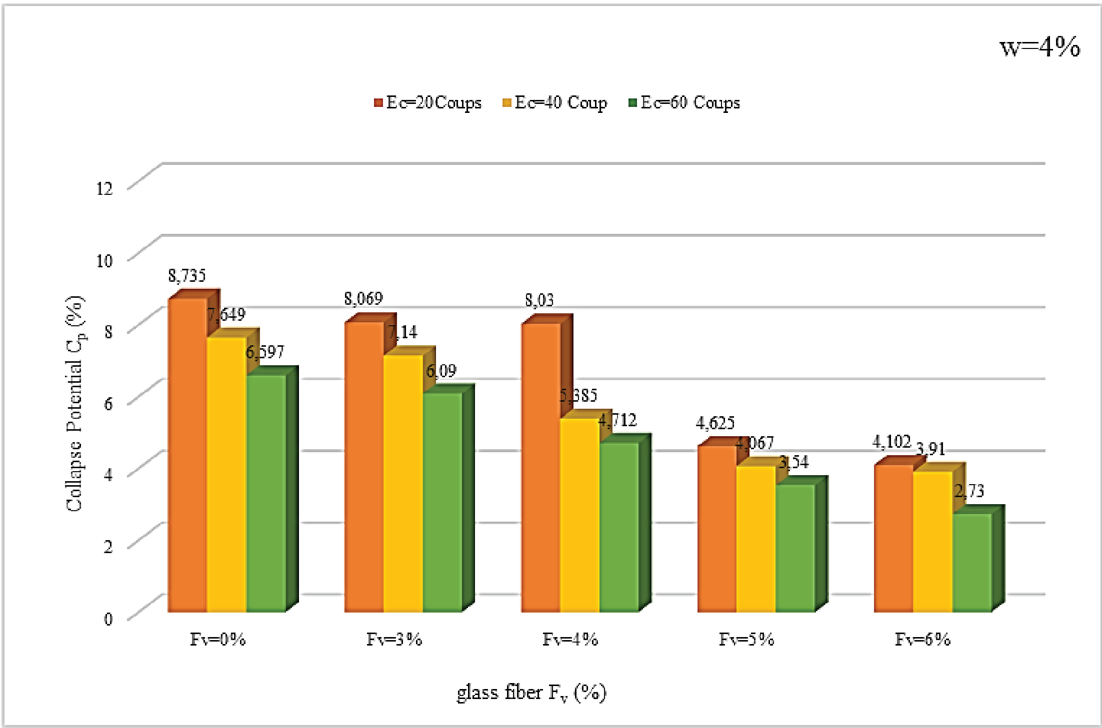

Figure 5: The Collapse Potential of soils compacted at various number of blow against glass fiber contents (w=4%)

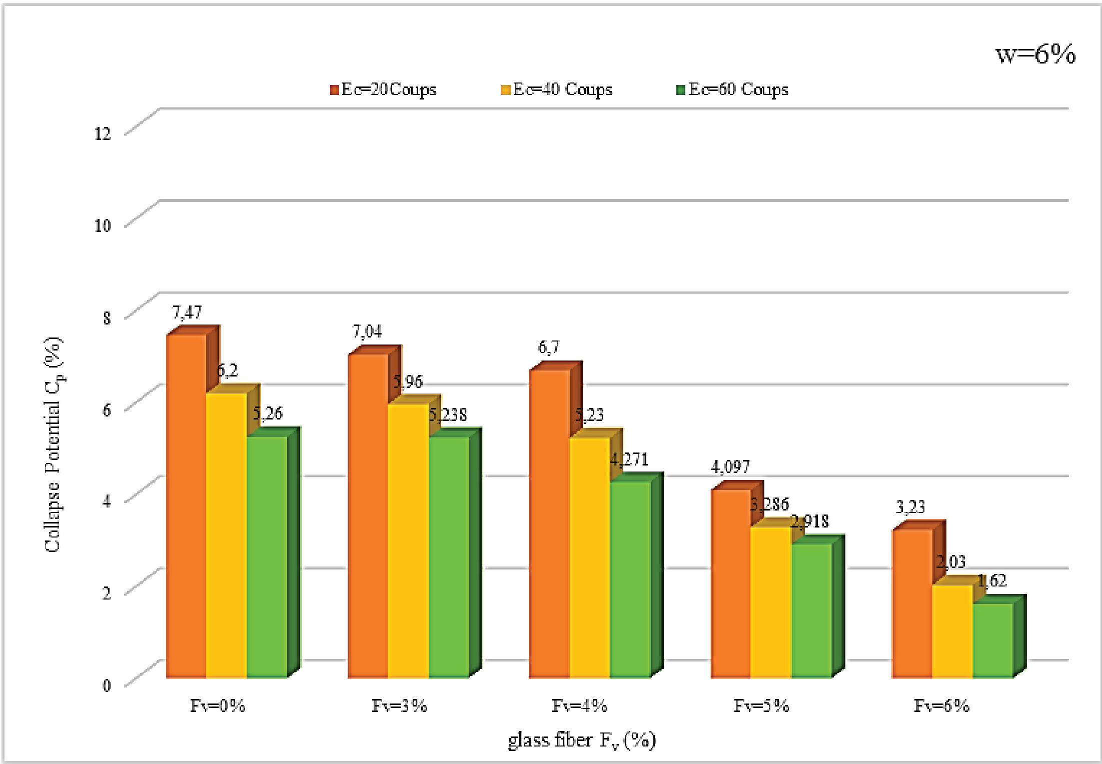

Figure 6: The Collapse Potential of soils compacted at various number of blow against glass fiber contents, w=6%

since adding 5% of glass fiber at different cases of water content and compaction energy.

Finally, it can be concluded that for the evolution of the reduction of collapse with the addition of milled glass fiber, soil without disorder can be obtained for a treatment upper to 6% of fiber content.

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