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# MECHANICAL RESISTANCE OF IRON ORE DUST SUPPRESSANT FILMS

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**Abstract.** *Dust suppressants are highly used in the mining industry, they aim to reduce dust emission during the transport and handling of ores. Choosing suppressants that present better performance is a task of economic and environmental importance, which selection can be aided through the knowledge of the mechanical resistance dust suppressant films formed through the application on the ore. In this work are presented results of resistance to the penetration of the layer of polymeric film formed from the application of the iron ore suppressant. Two suppressants are analyzed with different mass of suppressant applied on the ore and concentration. The results were obtained from tests carried out in one small cylindrical container in which the ore is deposited and the suppressant is applied. The sample is subjected to a penetration strength. The results are displayed in stress-displacement curve; thus, it is considered to analyze the material behavior tested as it is subjected to mechanical stresses. It was noted a region in which there is a reduction or stabilization of the tension and then the tension continues to increase as the penetration increases. This study implies an additional and novel parameter analysis for suppressant development and selection for industrial applications.*

**Keywords:** *dust suppressants, mechanical resistance, suppressant film, iron ore, dust emission.*

## 1. INTRODUCTION

The technological advances achieved in the last decades have brought numerous advantages, many of these advantages have also been accompanied by new challenges. The mining industry, for example, has made possible a huge advance in the construction of equipment that have making life easier for humanity. However, mining activity is associated with an increase in air pollution due mainly to particulate matter emission during transport, storage and handling.

The United States Environmental Protection Agency (EPA, 2021) presented studies that links particle levels to increased hospital admissions and emergency room visits. For instance, Long-term exposures to particle pollution, such as those experienced by people living for many years in areas with high particle levels, have been associated with problems such as reduced lung function and the development of chronic bronchitis and even premature death.

Water is the most common method to control the emission of pollution due to fugitive dust. Santos Junior (2017, 2018) carried out tests in a wind tunnel to assess the effect of moisture on dust emission, in general, the results show a significant reduction in dust emission as the humidity increases. However, the water evaporation rate is a major disadvantage, which can compromise the sustainability of its use. In this view, dust suppressors are needed, in particular, those environmentally friendly. Biocompatible liquid polymers, acting as dust suppressants, have been used as additives in water to prolong moisture conditions in the dust sources (Lee *et al.*, 2019). Borba (2017) tested some polymers as suppressant, including a chemical recycling process of Polyethylene Terephthalate (PET), developed through research carried out by Vale Company in partnership with Federal University of Espírito Santo (UFES).

Differently of the suppressant used in spray systems (Ma *et al.*, 2018; Yan *et al.*, 2020). Dust suppressants based on glycerin from the biodiesel chain have employed with success, but with some environmental problems (Yan and Hoekman, 2012). Bao *et al.* (2020) have developed a dust suppression gel, which presented good results for coal dust pollution minimization, revealing an efficiency more than 9 times that of spraying water. Chia mucilage was studied by Gama *et al.* (2021) to minimizing the iron dust generation in wagon model in wind tunnel experiments, providing good

resulted in preliminary tests. In this study, the main objective is to evaluate those suppressants which have a solidifying characteristic as they agglomerate over the soil and produce a solid film (Liu *et al.*, 2018), which is commonly applied in stockpiles and in train wagons. This kind of suppressant increases the particle cohesive effect, minimizing the wind erosion rate, keeping moisture in the bulk material, thus preventing the generation of dust.

Most of experimental studies on the evolution of solidifying dust suppressant are performed in wind tunnel. However, the mechanical resistance of these suppressant is a very important parameter. Jin *et al.* (2019) comments that the mechanical strength of suppressant is a key factor for assessing the dust suppression effect. These authors used a Universal Testing Machine for measuring the mechanical strength of a soybean protein isolate as suppressant for coal samples. The maximum compressive strength of the hardened layer was 0.46 MPa for 4% and 0.48 MPa for 5% suppressant, with the deformation being 2.65 mm and 2.30 mm, respectively. Mingyue *et al.* (2020), also working on coal samples, have measured the compressive strength of a cured film of dust suppressant reached up to 25.7 kPa.

This work presents an experimental study on the mechanical compressive strength of an iron ore sample with 8% moisture. Results are shown in terms of applied stress versus probe displacement through the sample. The results show a clear increase in strength when a suppressant is used on the ore surface. Two suppressants were evaluated reaching a maximum strength of 25 kPa.

## 2. METHODOLOGY

The experiments were performed using an iron ore sample with 8% of moisture content. The material was drying in laboratory oven with temperature at 105 °C for 24 hours and, after the drying process, water is added to the iron ore to obtain the required moisture. An Industrial Mixer Automatic was used to preparation of the sample. 260.87 grams of water and 3,000 grams of iron ore were mixed for 5 minutes in the mixer, this machine was used to reduce the human interference in the process. After that, the sample is put in one cylindrical container with a diameter of 120 mm, and then, the suppressant is applied on its surface. The suppressant is mixed with water at concentrations of 2% and 4%. Two quantities of suppressant mass were used, 36.0 g and 43.0 g, corresponding to 3.18 kg/m<sup>2</sup> and 3.80 kg/m<sup>2</sup>, respectively. After suppressant application, the sample is exposed to light radiation for a cure of 30 min.

The experiments were performed carried out in triplicate, using an equipment for mechanical resistance of iron ore dust suppressant films, which scheme is shown on Figure 1. In this test, a probe is vertically displaced against the ore surface, and the stress and displacement values are recorded for plotting the stress-displacement curve. The maximum displacement that the probe will penetrate into the sample is predetermined in about 3 mm and the velocity of penetration is 1 mm/min.

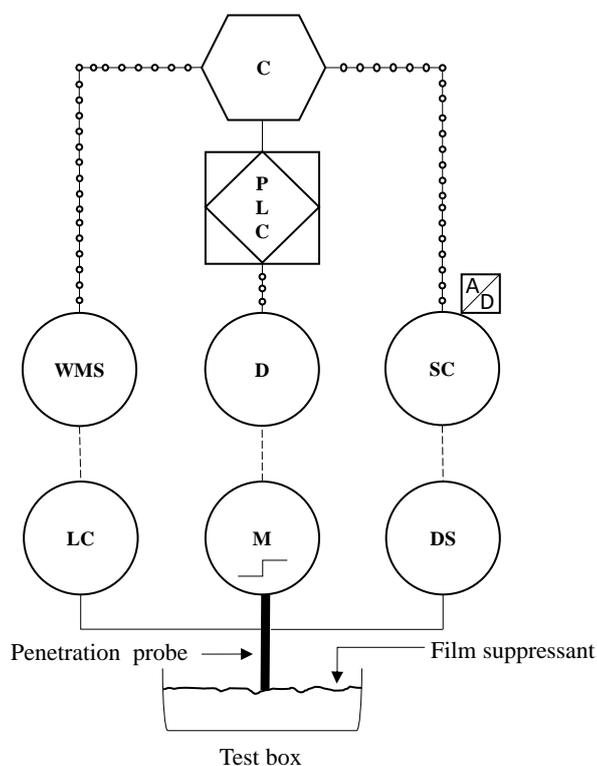


Figure 1. Compressive strength testing.

The diagram on Figure 1 shows each component of the equipment, which is controlled by a computer (C), connected to a programmable logic controller (PLC), a weighing measurement system (WMS) and a signal conditioner (SC). The PLC controls the motor (M) and its drive (D) for the displacement of the penetration probe. The WMS reads the signal from the load cell (LC), and the SC reads the displacement sensor (DS). Both signals are sent to the computer processing.

### 3. RESULTS

#### 3.1 No suppressant

The compressive strength tests without any suppressant applied are shown on the Figure 2. The maximum stress observation was in about 7 kPa. Three experiments were performed with a large variation between the curves. The behavior is due to the way as the material is filled in the cylinder. Even with this variation it is possible to observe a similar behavior among the samples, indicating that soil compaction affects on the results.

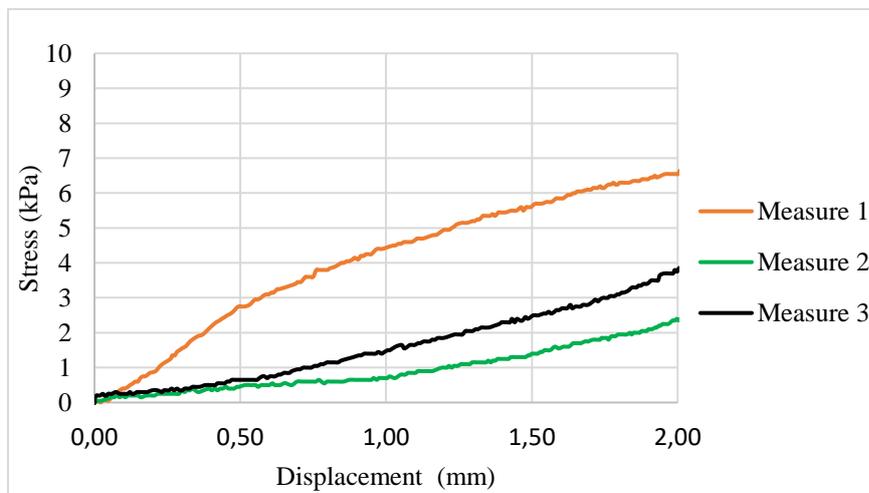


Figure 2. Stress-displacement curve (no suppressant).

#### 3.2 Suppressant A

Figures 3-4 presents the stress-displacement curve with application of the suppressant A with application rate of 3.18 kg/m<sup>2</sup> and 3.80 kg/m<sup>2</sup>, respectively, with the same concentration of 2%. Figures 5-6 presents the same result with a concentration of 4%. It is noticed a great increase in the stress in comparison with the test with no suppressant. However, With the increase of the application rate there were no significant changes during the test. The difference between the inclination of curve in 1 mm displacement in each result, represent a possible rupture region.

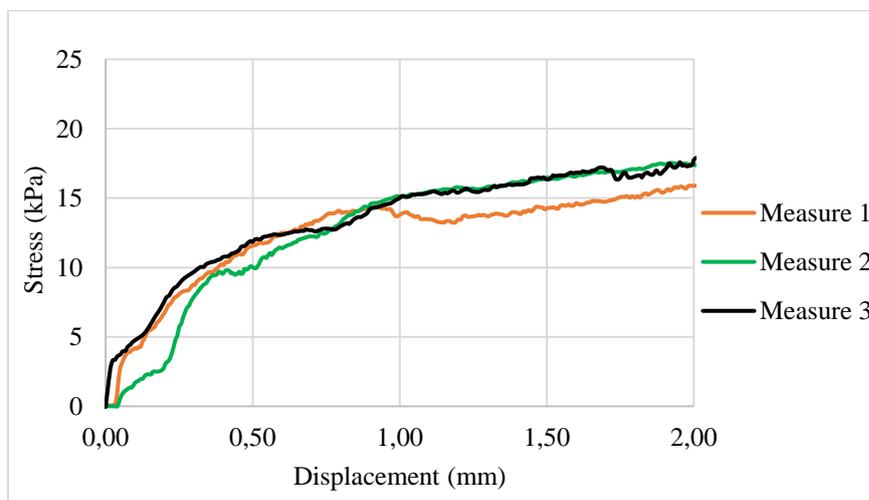


Figure 3. Suppressant A. Concentration 2% and application rate of 3.18 kg/m<sup>2</sup>.

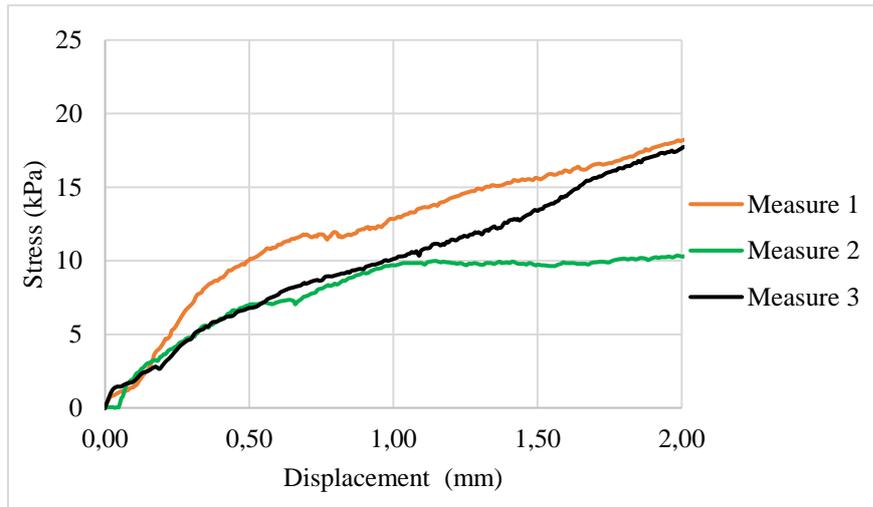


Figure 4. Suppressant A. Concentration 2% and application rate of 3.80 kg/m<sup>2</sup>.

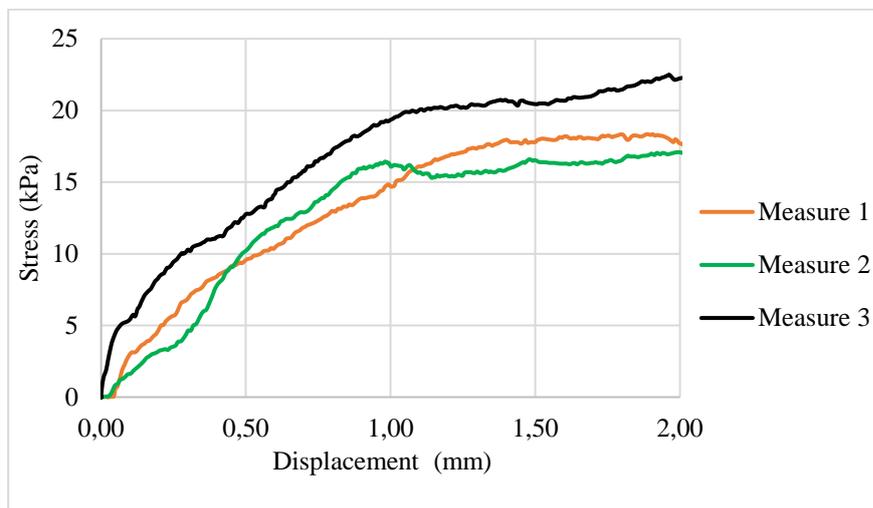


Figure 5. Suppressant A. Concentration 4% and application rate of 3.18 kg/m<sup>2</sup>.

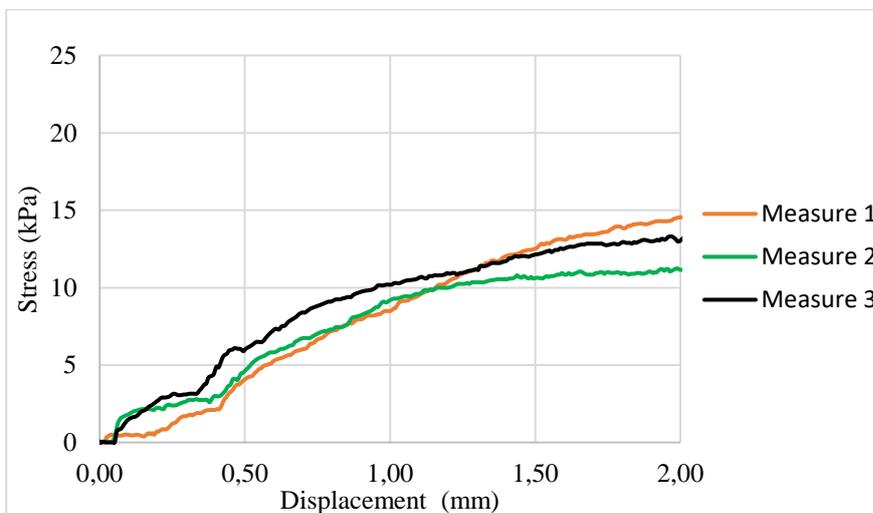


Figure 6. Suppressant A. Concentration 4% and application rate of 3.80 kg/m<sup>2</sup>.

For concentration of 4% and application rate of  $3.18 \text{ kg/m}^2$ , Figure 5, the measure 2 (green line) showed a smooth drop compared to the others with the same displacement variable between 1 and 2 millimeters, showing a possible region of the rupture of the suppressant film.

### 3.3 Suppressant B

Using a second suppressant, although keeping the others variables the same, Figure 7-10 shows the tests performed for suppressant B. The results show a similarity from the behavior of the suppressant A. In addition, the sharpest drops occur close to 1 mm of displacement, with the strength value being around 20 kPa.

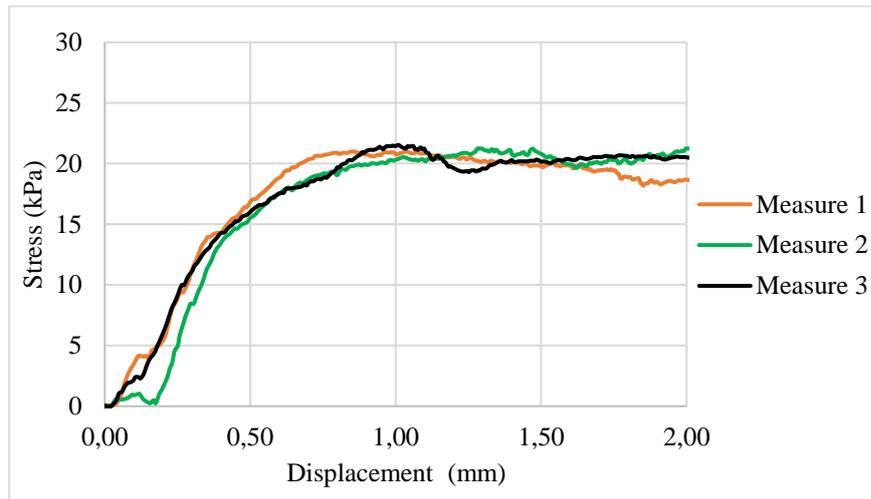


Figure 7. Suppressant B. Concentration 2% and application rate of  $3.18 \text{ kg/m}^2$ .

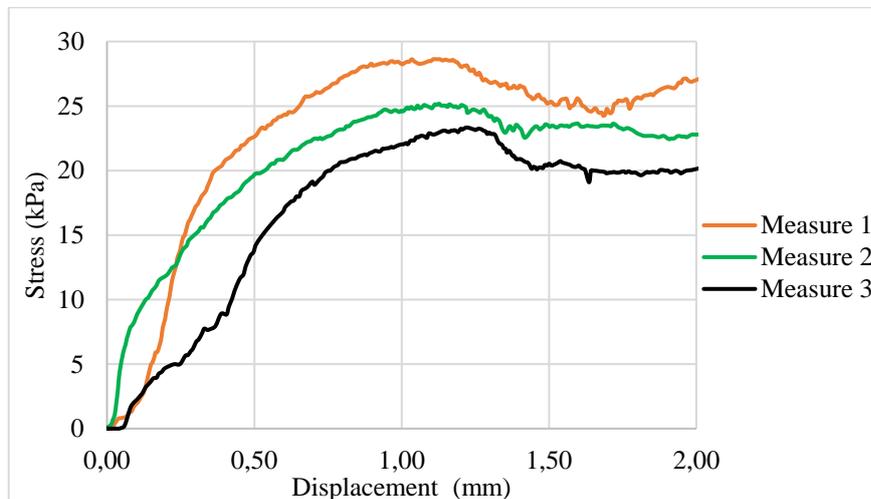


Figure 8. Suppressant B. Concentration 2% and application rate of  $3.80 \text{ kg/m}^2$ .

### 3.4 Summary of the results

Figure 11 presented an evaluation of the effect of suppressant concentration. The curve was obtained for the same application rate of  $3.80 \text{ kg/m}^2$ . Each curve was obtained by average from the three tests performed. It is observed that the concentration, at least on these values, has not a sensible effect. The analysis of the application rate on a suppressant concentration constant of 4% is presented on Figure 12. For suppressant B the resistance increases with de application rate, however for the suppressant A the behavior is the inverse. Finally, Figure 13 presents the synthesis of the results with the comparison of the behavior without suppressant. The effect of the suppressant is very important increasing close to 9 times the compressible strength resistance, similar to result obtained by Bao *et al.* (2020). Also, the value of the maximum resistance at the rupture zone in about 25 kPa, which is very close to the result obtained by Mingyue *et al.* (2020).

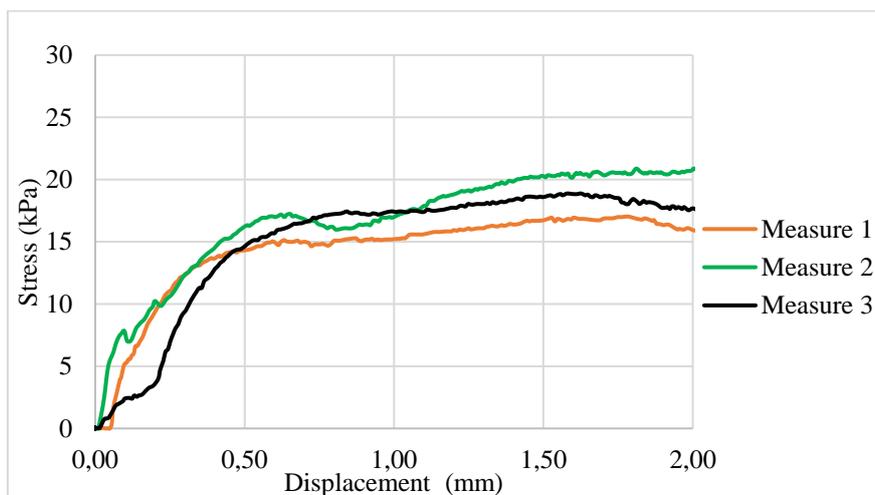


Figure 9. Suppressant B. Concentration 4% and application rate of 3.18 kg/m<sup>2</sup>.

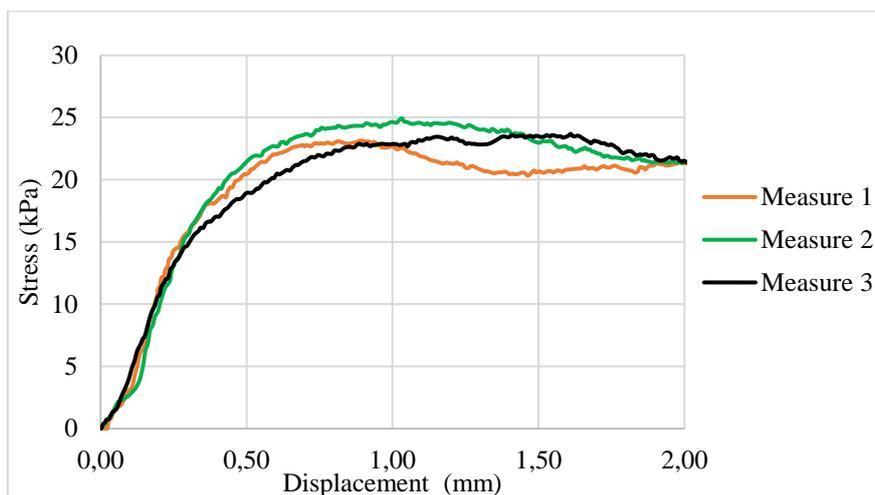


Figure 10. Suppressant B. Concentration 4% and application rate of 3.80 kg/m<sup>2</sup>.

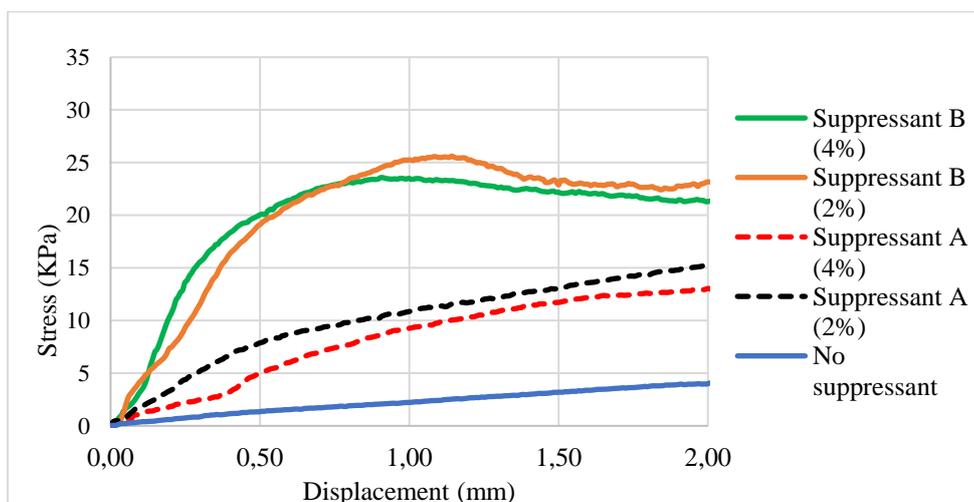


Figure 11. Analysis of the effect of concentration at application rate of 3.80 kg/m<sup>2</sup>.

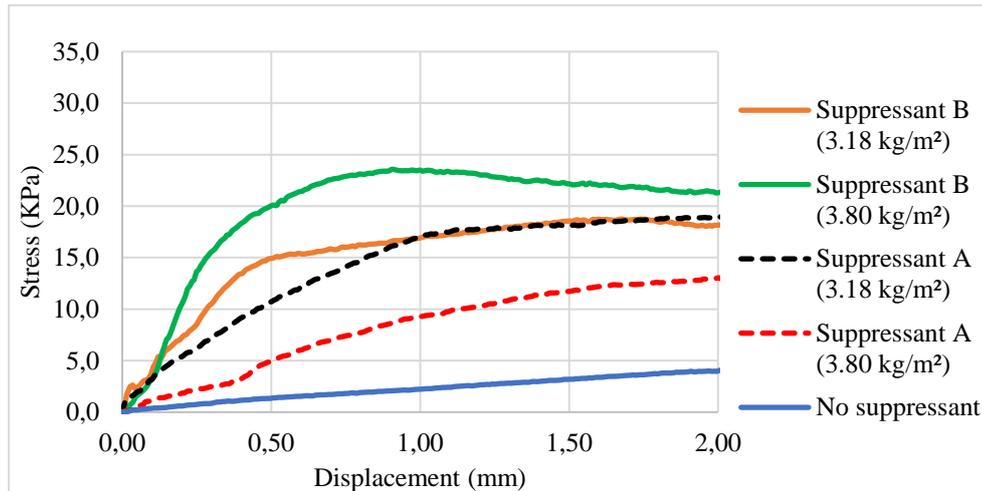


Figure 12. Analysis of the application rate. Concentration 4%.

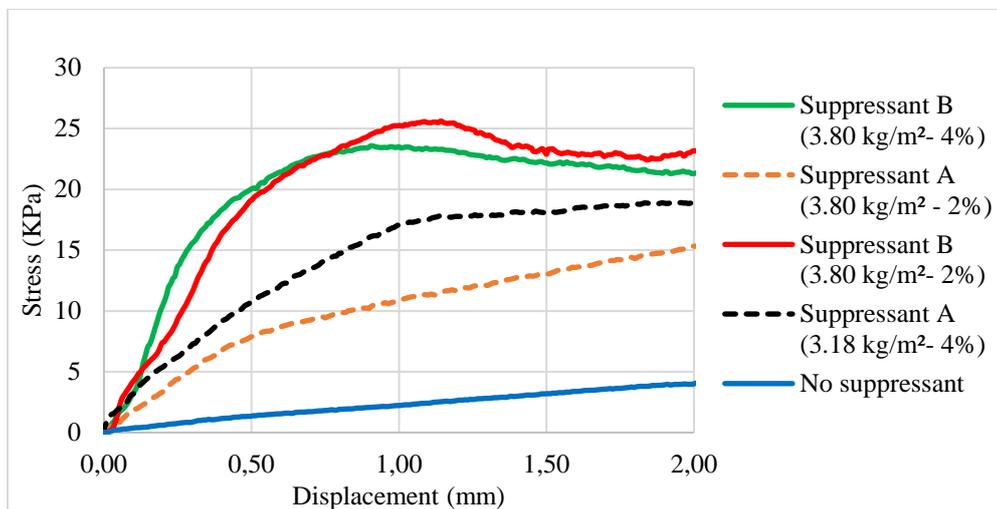


Figure 13. Analysis of the best results.

#### 4. CONCLUSIONS

An experimental study was performed on the mechanical resistance of two solidifying dust suppressant applied on iron ore samples with moisture content of 8%, in which it was evaluated the effect of the concentration of the suppressant in a water solution and the application rate for two commercial suppressants.

The experiments presented some variation, which more important for the sample without suppressant, that is considered an effect of the sample formation, probably due to the soil compaction. This aspect will be investigated in future tests with a pre-compression on the samples.

The results clearly show that the use of suppressant on the surface of iron ore causes an improvement in the mechanical strength resistance. For the best suppressant, the resistance is increased by about 9 times compared to the iron ore sample without suppressant. This result is in agreement with a result available in the literature, carried out on coal samples

The maximum compressive strength obtained in the tests was around 25 kPa, which corresponds to a similar result available in the literature, performed on coal samples.

The experimental study proved to be able to evaluate the mechanical resistance of solidifying dust suppressants. However, some adjustments in data processing and sample formation are needed to improve the experimental methodology.

#### 5. ACKNOWLEDGEMENTS

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