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Preliminary study of wear induced by granular soil on metallic parts of EPB tunnelling machines

1. Introduction

The wear phenomena of the metallic parts of soil EPB TBM is playing both an important role at the design stage of a tunnel and for the global evaluation of the projects.

Concerning EPB excavation technology, one main issue is the wear of parts of the machine (mainly tools, cutterhead and screw conveyor) (Peila et al., 2012; Peila, 2014), which increases the number of stoppages and therefore the time and cost of the tunnel project.

The study of this topic, in granular soils is very complex, as it regards not only the properties of the excavation tools and machine parts (shape and material) but also both the characteristics of the ground to be excavated (hardness, mineralogy, shape and size of the particles and moisture content) and the content and characteristics of conditioning agents.

Nilsen et al. (2006a, 2006b and 2007) and Jakobsen and Dahl (2010) proposed some modifications to the standard NTNU test used for rock masses, in order to make them suitable for the study of granular soils while Thuro et al. (2007) adapted to soil LCPC abrasivity test. Nevertheless in these tests the water content was not taken into account as discussed by Gharahabagh et al. (2011), Barbero et al. (2012), Jakobsen et al. (2012) and Rostami et al. (2012). Furthermore, these authors did not take the effect of conditioning, that is an essential part of EPB process, into due account.

Gharahabagh and Rostami (2010), Rostami et al. (2012), Barbero et al. (2012) and Hedayatzadeh et al. (2015) have developed new test procedures with the purpose of simulating the interactions between soil particle sand excavation tools when conditioning is used.

The aim of the present research is to show the influence of water content on the wear phenomenon using the test procedure proposed by Barbero et al. (2012) and to study the positive effect of a new anti wear agent.

2. Testing procedure

Fig. 1 shows the cross section of the used apparatus while the test procedure is the following (Barbero et al., 2012):
- sample preparation: 20-25 kg of granular soil is mixed with water, foam and/or other chemical additives depending on the set of conditioning to be tested;
- weighing of the disc before the test;
- assembly of disc on drive shaft;
- filling of the first layer of ground: the tank is filled from the bottom to the height of disc, in order to ensure the right contact between the particles of the ground and the lower surface of the disc;
- filling the test chamber and application of a confinement pressure of 2 kPa;
– development of the test with the rotation of the disc for 10 minutes;
– measurement of the disk weight loss after the test.

Fig. 1. Scheme of the proposed test (Barbero et al., 2012).
Schema della prova proposta (Barbero et al., 2012).

2.1. Used soil

Tests were carried out using like wear material a quartz coarse sand which has a natural water content of 2% (by weight) with the grain size distribution showed in fig. 2 and $d_{10} = 0.9 \text{ mm}$, $d_{60} = 6.5 \text{ mm}$ and $U = 7.22 \text{ mm}$. The mineralogy analysis of the sand obtained through microscopic analysis shows that quartz is the main component: 98%, while the remaining 2% consists of feldspars and iron impurities.

Fig. 2. Grain size distribution of the used quartz sand.
Distribuzione granulometrica della sabbia quarzosa utilizzata per le prove.

2.2. Used wear element

Tests were carried out using two discs made of aluminum and steel with diameter of 120 mm and a thickness of 50 mm. Vickers hardness (HV) was measured for both discs, obtaining an average values of 189 and 116 for the steel and the aluminum respectively.

Fig. 3. Loss weight diagram for quartz sand conditioned with different percentage of water obtained by using aluminum and steel discs.
Diagramma dell’usura per la sabbia quarzosa usata nella sperimentazione al variare del contenuto d’acqua sia per il disco in alluminio che per il disco in acciaio.

3. Performed tests

As a first step of the research, the wear phenomena was studied by using both steel and aluminum discs, with different percentage of water in the soil.

The used range of water was set between 2% and 15% (between the natural water content and the saturation limit). The results of the tests are summarized in figs. 3 and 4.

Fig. 4. Torque diagram for quartz sand conditioned with different percentage of water obtained by using aluminum and steel discs.
Diagramma della coppia per la sabbia quarzosa usata nella sperimentazione al variare del contenuto d’acqua sia per il disco in alluminio che per il disco in acciaio.
In the second step, at the percentage of water corresponding to the highest value of weight loss, it was studied the effect of a new anti-wear agent in reducing the wear effect.

The diagram of fig. 5 describes the reduction of weight lost due using the anti-wear agent. This agent has the property to cover the soil particles by a thin layer of polymer that allow to decrease the friction between ground and steel tools (fig. 6).

**Fig. 5.** Weight loss vs different percentage of used anti wear agent. The amount of this additive was calculated at a constant total water content of 10%. Test campaign performed by using aluminum disc.

Andamento della perdita di peso al variare del contenuto dell’agente anti usura nell’acqua aggiunta al terreno. Le prove sono state eseguite per un contenuto totale di acqua del 10%. Le prove sono state realizzate con disco in alluminio.

**Fig. 6.** Effect of a drop of water and anti wear agent (2% by the weight of water) on quartz grain.

Effetto di una goccia di acqua contenente il 2% in peso di agente antiusura su un grano di sabbia quarzosa.

### 4. Conclusions

The understanding of the wear phenomena in EPB soil tunnelling is a complex task. Using an experimental device, it was observed the great importance of the moisture content in the soil on the observed wear of the tools. Furthermore some tests performed by adding an experimental anti wear agent to the added water, show an important reduction on the wear when using this product.

### References


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