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

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1. Introduction

The wear phenomenona of the metallic parts of soil EPB TBMs 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 Gharahbagh *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;

Studio preliminare dell'usura indotta da terreno granuale sulle parti metalliche di macchine di scavo a piena sezione. Il fenomeno dell'usura nelle macchine da scavo di gallerie a piena sezione non è di semplice descrizione in quanto vi sono molti i parametri che entrano in gioco durante il processo di usura che può estrinsecarsi sugli utensili di scavo, sulla testa di scavo, sullo scudo, nella camera di scavo e sulla coclea di estrazione. Nel presente lavoro viene descritta una prova sperimentale finalizzata a quantificare questo effetto e che cerca di riprodurre l'interazione tra utensili e materiale scavato, simulando le condizioni di scavo in termini sia di contenuto d'acqua sia di condizionamento del terreno. Inoltre vengono presentati i risultati preliminari dell'utilizzo di un nuovo agente antiusura per la riduzione dell'usura stessain termini di peso perso dell'elemento metallico usato per la prova.
***Parole chiave**: usura, prove di laboratorio, macchine EPB.*

The wear phenomena in EPB shield machines is not a simple issue as many parameters are playing an important role on it.The action of the wear due to the contact with the soil can occur on the excavation tools, on the cutterhead, in the excavating chamber and on the screw conveyor.
In this paper a test procedure is presented and discussed aimed to reproduce the interaction between the tools and the excavated material, simulating the excavation conditions in terms of soil conditioning and water content. In the work, the preliminary study of the influence of a new anti wear agent is assessed in terms of reduction of metal weight loss
***Keywords**: wear, laboratory tests, EPB tunnelling.*

– development of the test with the rotation of the disc for 10 minutes;
– measurement of the disk weight loss after the test.

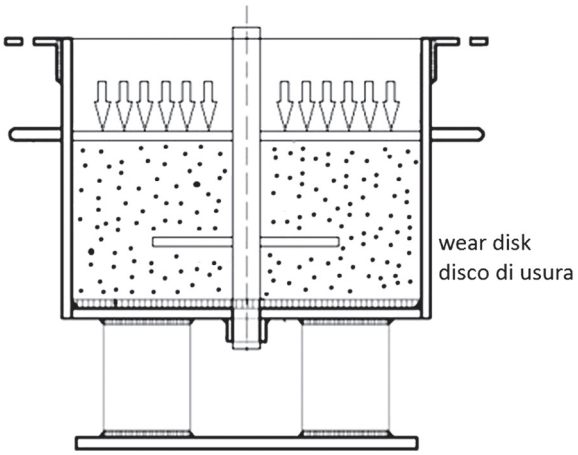

Fig. 1. Scheme of the proposed test (Barbero *et al.*, 2012).
Schema della prova proposta (Barbero et al., *2012).*

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 mm, d_{60} = 6,5 mm and U = 7,22 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.

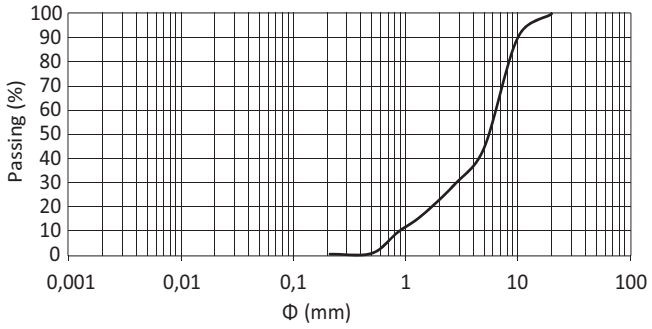

Fig. 2. Grain size distribution of the used quartz sand.
Distribuzione granulometrica della sabbia quarzosa utilizzata per le prove.

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.

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.

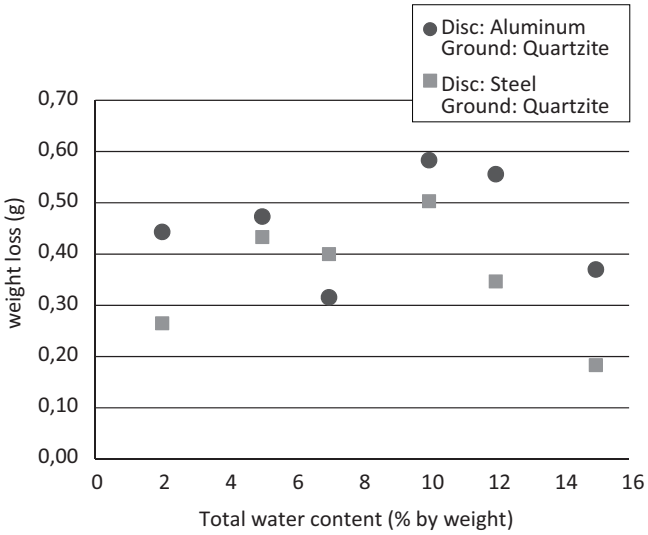

Fig. 3. Loss weight diagram for quartz sand conditioned with different percentage of water obtained by using aluminum and steel discs.
Diagramma dell'usura per la sabbia quarzosa usata nella sperimentazione al variare del contenuto d'acqua sia per il disco in alluminio che per il disco in acciaio.

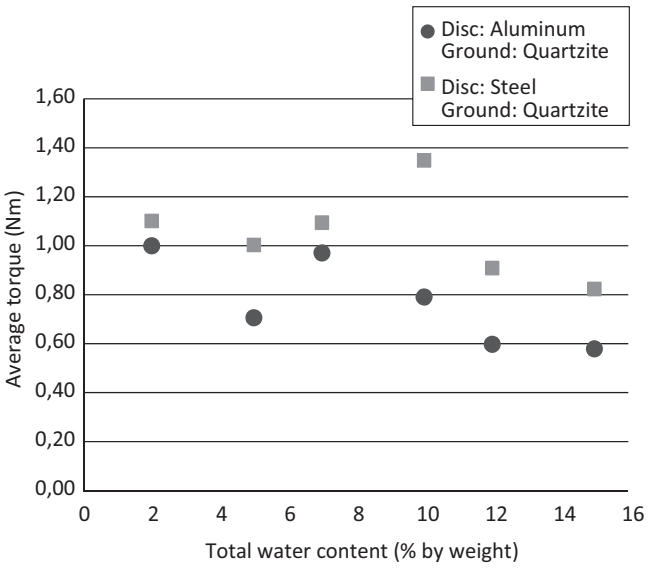

Fig. 4. Torque diagram for quartz sand conditioned with different percentage of water obtained by using aluminum and steel discs.
Diagramma della coppia per la sabbia quarzosa usata nella sperimentazione al variare del contenuto d'acqua sia per il disco in alluminio che per il disco in acciaio.

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) .

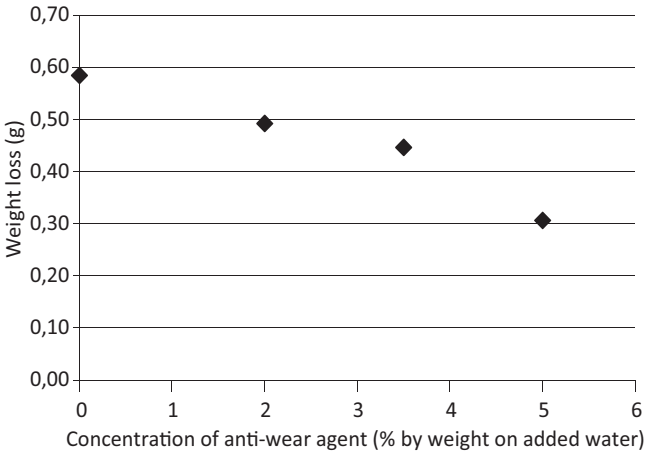

Fig. 5. Weight loss vs different percentage of used anti wear agent. The amount of this additive was calculated at a constant total water content of 10%. Test campaign performed by using aluminum disc.

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.

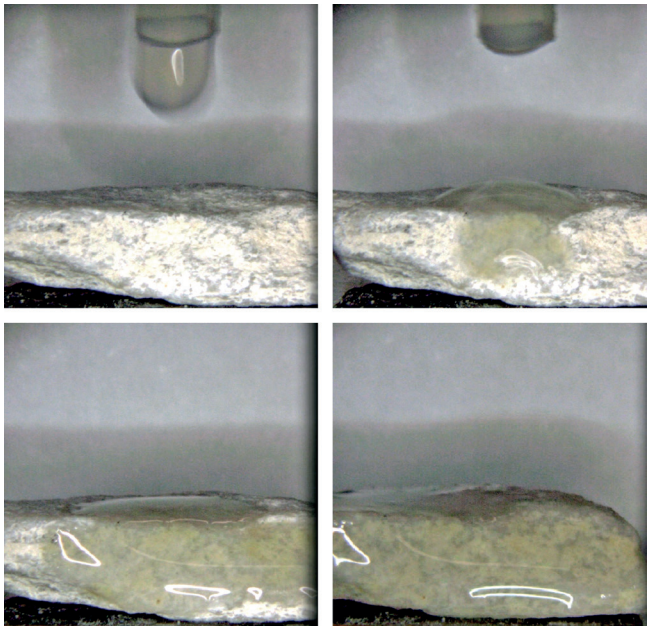

Fig. 6. Effect of a drop of water and anti wear agent (2% by the weight of water) on quartz grain.

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.

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