RESEARCH REGARDING THE CUTTABILITY OF SANDSTONE HARD INCLUSIONS IN THE CONDITIONS OF ROMANIAN LIGNITE OPEN PIT MINES

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Abstract: One of the frequent problems that need to be addressed when mining coal deposits is the presence in the working face of cohesive materials having high mechanical strength in relation to the average rock to be excavated. These are generally called "hard formations" or "hard inclusions" and are in the form of either continuous layers or boulders.

This problem is of particular importance in Europe where lignite deposits are exploited in large opencast mines utilizing Bucket Wheel Excavators (BWEs) as the main means of excavation. Often it is difficult or impossible to excavate these hard inclusions with BWEs , because the excavators operating in these countries are not fully adapted to such conditions. In Romania, a typical situation is encountered in Husnicioara open pit. As a first approach in order to study the impact of these inclusions on the working regime of BWEs, the laboratory essays devoted to establish the main metrics of the cuttability of these rock formations.

Key words: hard rock formation, cuttability, sandstone excavation, BWE

1. FOREWORD

The diversity of the mechanical properties of the excavated material, the volume and the cutting contour of the bucket, the shape and the condition of bucket teeth, and the bucket cutting speed, are only few of the numerous parameters determining the energy required for the excavation of a material.

To date there is no reliable method to calculate the cutting resistance of a material, i.e. the force required to excavate it.

Laboratory tests can only be used as an initial indicative guideline for a specific material since there is a scale effect and the results significantly vary depending on the size and geometry of the test sample.

In the definition of mining resistance of excavated rocks, known as cutting

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resistance, or cuttability, which is an integrated a parameter at the boundary of intrinsic rock mechanical parameters are now a subject of debates among specialists. In our approach, for the project's purpose's, the issue is to select- find the best metric to be used applicable for – "normal " resistance , "excessive" resistance both in case of continuous layers (insertion) in excavated block and "accidental " excessive resistance occurred when unexpected intercalations or boulders appears in the excavated face.

2. LABORATORY TESTS FOR CUTTABILITY ASSESSMENT

In the literature and BWE design and construction practice several kind of metrics are used:

A) Specific cutting resistance K_e which is related to

1) Length of cutting edge K_L , in kN/m
2) Cross section of chip K_F , in kN/m^2
3) Depth of cut (height of chip) K_h , in kN/m.

and

B) Specific cutting energy W_S , which is expressed in energy/volume, and in SI units in MPa. It is confirmed that a good linear correlation exists between W_S and UCS.

A1 is used mainly in German literature; it has as historical origin in first use of Bucket Wheel machines in reclaiming/loading of bulk material purposes. In our opinion, this metric is suitable for actual BWEs only for soft rocks, and generally appropriate for loaders/reclaimers, with buckets without teeth (with edges only) and very good for tools with large width, such as dredges and bulldozers.

A2 is preferred by the majority of specialists, but it is really an alternative of the specific cutting energy, hidden behind other unities of measure. So it is at least redundant, if not useless taking into account that it is relatively invariant on technological factors.

For BWEs the average values of K_L and K_F are utilized for calculating the cutting force acting on an entire bucket whereas K_h allows calculating the cutting force on individual tooth, by considering the geometry of chip as resulting from the geometry and the kinematics of the bucket wheel, boom and bucket.

In the past years we have determined these parameters in our department, for hundreds of samples of lignite and overburden rocks, collected to cover the entire coal field of Oltenia. Our opinion after analyzing the great amount of results obtained is that the pair K_h and W_S are the most appropriate for accurate estimation of cutting forces starting from individual tooth towards bucket and wheel (bottom to top or element to ensemble approach) because the number of teeth in contact with the rock and the number of buckets involved in excavation is variable during an unitary cut and a block cut.

This approach is more relevant to analyze and highlight the variability of load on wheel, which exists even in rock with "normal" resistance and increases dramatically in the case of encountering formations with "excessive" resistance.

There were more theories based on analytical deductions to explain the main

cutting parameters on the basis of basic physical mechanical properties of the excavated rock. Despite these theoretical efforts, the best results were obtained based on data measured on test rigs and very rarely in situ. Each manufacturer, for each particular field, developed methodologies for measuring and transferring the results towards tool design and excavation regime recommendations. The measurements performed in order to assess the forces acting on teeth of the bucket wheel excavator during the excavation process in real working conditions is difficult and expensive.

The laboratory tests performed on the testing rig eliminates these disadvantages, even if they cannot reproduce all the conditions from the working place. Using full scale teeth for the laboratory tests is not possible, because that requires samples of large size impossible to be collected and manipulated.

On the other hand, in order to satisfy the statistically reasonable number of samples the amount of material used as samples would be very high and impossible to be collected. By these reasons, both worldwide and in Romania, the laboratory tests are performed using assay teeth at reduced scale, rationally selected, such as the results could be translated into reality. In this respect, it is necessary to find out a few laws of dependence between the parameters of the cutting regime (specific energy consumption, specific cutting resistance) and the size of detached chips or particles.

Three main categories of rock were identified regarding their behavior on cutting, in Husnicioara open pit mine, i.e., lignite, clay - which is the „softest" overburden rock and sandstone - which occurs as boulders, thus being the most difficult to be excavated, in terms of hardness and abrasiveness.

The figures 1 and 2 depict the comparative results obtained for these categories of rocks in terms of average cutting forces - F_{xm}, and specific energy - W_S obtained by laboratory assays.

It can be noticed that the cutting force F_{xm} is 30 times larger in case of sandstone than in case of clay, and 15 times larger when compared with the lignite. The energy consumption W_S for sandstone cutting is 50 times larger compared with the clay and 25 times compared with the lignite.

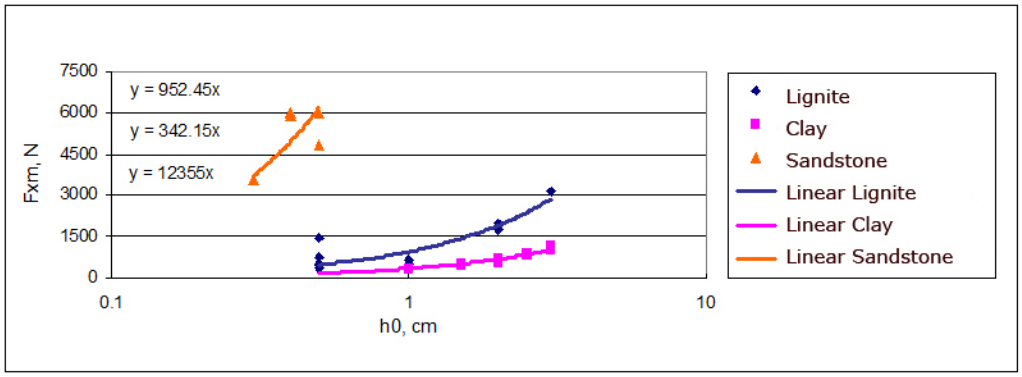

Fig. 1. Comparison upon F_{xm} as function of h_0 (x log scale)

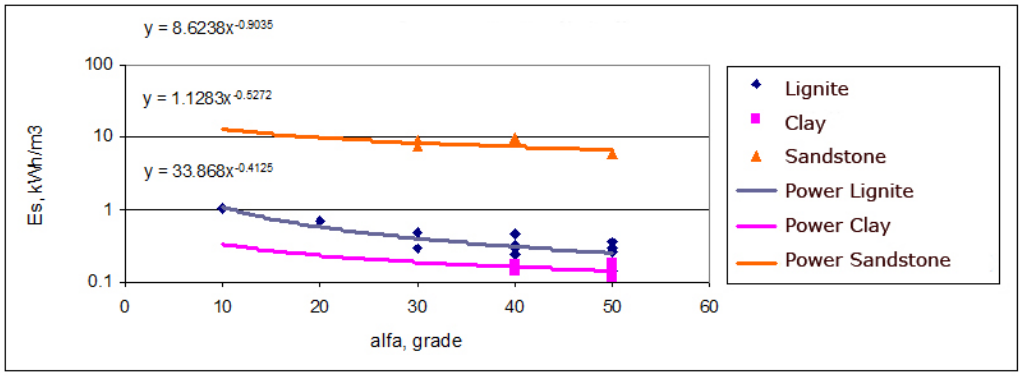

Fig. 2. Comparison upon W_S as function of α (y log scale)

3. CONCLUSION

The tests performed on samples of sandstone, collected from Husnicioara coal field shown that this rock cannot be sheared rationally using the bucket wheel excavators , because of the high specific resistance , cutting and penetration forces and on the other hand because of the high energy consumption. In order to highlight the behavior of the sandstone, its cuttability parameters were compared with those of lignite and the clay from the same coalfield..

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