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EXPERIMENTAL DETERMINATION OF THE FRICTION COEFFICIENT FOR ESTIMATING SEA STORM INDUCED MEGABOULDERS MOVEMENTS

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ABSTRACT: The presence of numerous boulders on rocky coast is linked to phenomena of detachment and deposit due to the occurrence of sea storms. Currently, several hydrodynamic equations are known in the bibliography to estimate the wave height able to displace them, applying geometric parameters and hydrodynamic coefficients. A new methodological approach intends to consider the minimum energy required for the linear movement of a boulder along a weakly sloping rocky surface as a function of the friction coefficient.

KEYWORDS: Boulders, waves, friction coefficient

1. INTRODUCTION

Along the rocky coast of the Puglia region it’s evident the presence of geomorphological evidences represented by boulders deposits of various size whose origin has been connected to the occurrence of exceptional waves impact, due to *tsunami* and/or sea storms (cf. Mastronuzzi and Pignatelli 2012; Pignatelli et al., 2009) (Fig. 1). A new study has been carried out on the position and movement of these boulders using a new methodological approach, which consider the displacement of boulders by “many waves” impacting on rocky coast. This new approach requires the knowledge of the dynamic parameters of the rocky surface on which the detachment and displacement process occurs. This study, with respect to the equations known in the bibliography, focuses the attention on the energetic aspects of the storm rather than on the geometric parameter of a single wave.

2. MATERIAL AND METHODS

The preliminary part of a more geographically extended study, has been conducted along a stretch of gently sloping rocky coast in San Giovanni of Polignano a Mare, about 30 km SE of the city of Bari. In this location there are deposits of calcarenite blocks, from about 1 to 2,5 m^3 in size and 2 to 6 ton in weight, and located at different distances from the coast line, whose genesis has already been linked to the occurrence of exceptional

Fig. 1 - Boulders deposits in the studied area.

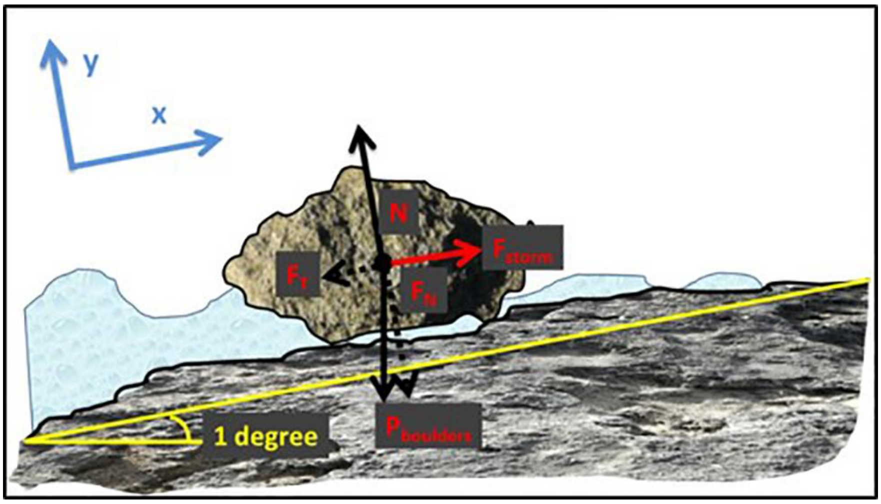

Fig. 2 - Sketch of the Force acting on a boulder.

waves, *tsunami* and/or storms, following previous studies (cf. Mastronuzzi and Sansò, 2004; 2000). The adopted methodological approach uses a "many waves" storm energy in place of the wave height, as a hydrodynamic parameter necessary to evaluate the way of moving these blocks. Preliminarily, an LST survey was carried out to acquire the geometric characteristics of the rock surface and the shapes of some blocks so as to obtain indications on the general roughness of the contact surfaces and a three-dimensional reconstruction of the same blocks from which their volume can be obtained. The starting point for evaluating the storm waves energy is the following relation (cf. Nandasena et al., 2011; Noormets et al., 2004; Nott, 2003; 1997) (Fig. 2):

$$F_R = F_{storm} - F_T$$

$$F_T = m_{boulder}\,g\,\sin\theta$$

$$F_{storm} = (\mu_s + \mu_d)P_{boulder} = (\mu_s + \mu_d)\rho_{boulder}Vg\,\cos\theta$$

This relationship implies the knowledge of these parameters: θ, slope of the rocky coastal surface; V and ρ, respectively, volume and density of the displaced rocky boulder; μ, the friction coefficient. θ and V were obtained directly from the LST survey and subsequent processing with specific solid modelling software. The parameter ρ is widely tabulated in the specific bibliography (cf. Andriani and Walsh, 2002). The estimate of the friction coefficient, on the other hand, was carried out using the following method: two boulders, A and B, with two different dimensions but a similar roughness of the contact surface, have been identified directly on rocky platform and chosen for the experimental proofs; then they have been subjected to some linear dragging along a rock surface by means of a mechanical apparatus; all the movement were recorded with a high resolution video camera positioned perpendicular to the direction of movement. The video analysis has allowed to obtain the displacement curve as a function of time (Fig. 3), which allowed to obtain the value of the average acceleration necessary to calculate the friction coefficient (Fig. 4).

3. RESULTS

The graphs elaborations obtained through the analysis of the different videos were used to derive the accelerations "a" impressed to the different boulders by a physical apparatus to start and keep a linear displacement; then, these values were put in the inverse relation of the dynamics in order to calculate the friction coeffi-

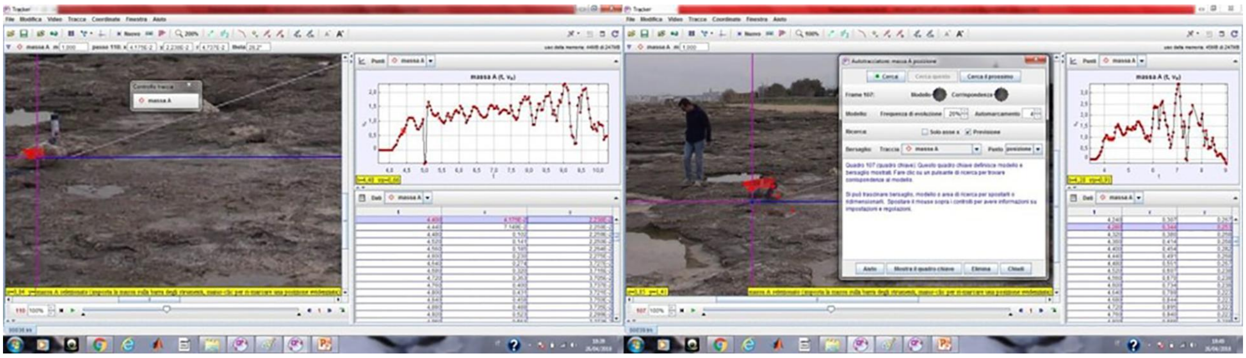

Fig. 3 - Two different examples of video analysis software.

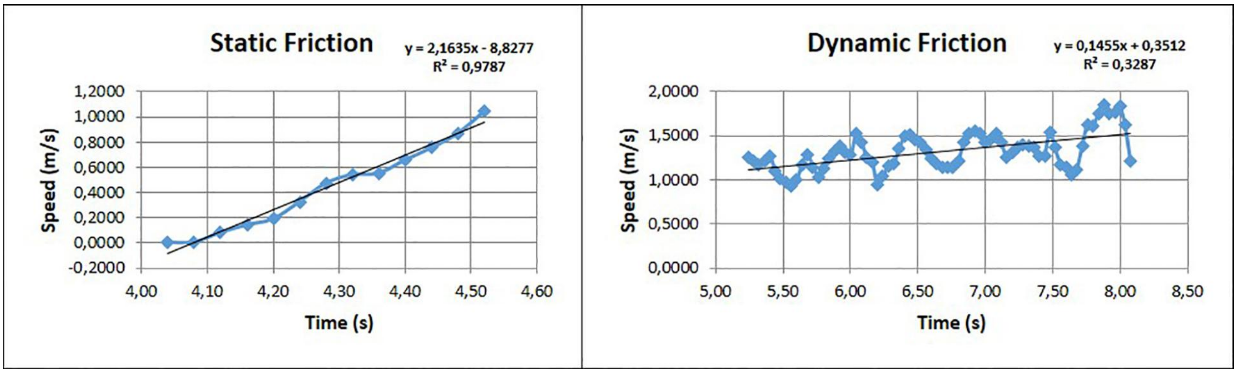

Fig. 4 - Two different examples of speed/time graphic.

cient, both static and dynamic, relative to the linear displacement of the considered boulders:

$$\mu_{s/d} = \frac{\left(\frac{a}{g} + sen\theta\right)}{cos\theta}$$

The results of the values obtained for the static and dynamic friction coefficient are shown in Tab.1.

4. DISCUSSION AND CONCLUSIONS

The analysis of the results obtained from the graphic elaborations highlights the difference between the values of the static friction coefficient relative to the two sample boulders, A and B, where the “A” coefficient is lower than the “B” one. Instead, the values of the dynamic friction coefficient relative to both boulders seem to be quite more similar.

These results are certainly a first approach towards the determination of an experimental physical parameter whose value, for this type of lithology, wasn’t found in the reference bibliography.

The determination of this coefficient is the first step to better estimate the energy to move a particular boulder on coastal surface and, then, to understand which sea storm can be responsible of this displacement.

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Boulders-Movement	Static Friction Coefficient μ_s	Dynamic Friction Coefficient μ_d
A-M1	0,291	0,081
A-M2	0,327	0,080
A-M3	0,284	0,079
Average A	**0,301**	**0,080**
B-M1	0,492	0,092
B-M2	0,573	0,096
B-M3	0,659	0,098
Average B	**0,575**	**0,095**

Tab. 1 - Friction coefficient values. “Mi”: number of movement.

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