SMALL-SCALE EXPERIMENTAL EVIDENCE ON JOINT-BOUNDED BLOCK TRANSPORT BY RAPID FLOWS

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INTRODUCTION

Coastal boulders on shore platforms represent an unusual sediment accumulation because their transport is restricted to high-energy wave events such as storms (Etienne and Paris, 2010), or tsunamis (Paris et al., 2009). They typically appear in six different morphological arrangements: isolated mega-blocks on coastal platforms (Scheffers, 2005); boulder beaches (Etienne and Paris, 2010); cliff-top boulders (Williams and Hall, 2004); boulders fields and boulder clusters (Goto et al., 2010); boulder ridges and ramparts (Nott, 1997). The pre-transport environment of these boulders can be submergence, sub-aerial, cliff-edge, cliff-top, or joint-bounded (Nott, 2003).

The use of coastal boulders for recognizing past high-energy events has been extensively researched over the last decade, and their interpretation remains controversial (Switzer and Burston, 2010). The presence of large boulders (Fig. 1) inland from rocky coasts could be a useful signature for understanding the local size of their wave events (Nandasena et al., 2011) and inundation distance on the ground (Pignatelli et al., 2009). Studies of modern boulder deposits and their characteristics (Nandasena et al., 2013), at least qualitatively, relate the characteristics of high-energy flows to their deposits (Jaffe and Gelfenbaum, 2007). Therefore, modern field investigations and experimental studies on boulder transport can provide benchmarks for numerical models, which subsequently help evaluate different emplacement mechanisms for boulders of unknown wave origin and reconstruct the local magnitude of the waves.

Fig. 1 Boulder deposits by high-energy waves (tsunamis or storms); (a) boulders transported by the 2011 Great East Japan tsunami (modern boulder deposits – photo taken by the PI), (b) an isolated boulder in Tonga, (c) isolated boulder in Japan. Boulders (b) and (c) are supposed to be transported by historic tsunamis/storms (Nandasena et al., 2013; Scheffers and Erdmann, 2022).

INCIPIENT MOTION OF JOINT-BOUNDED BLOCK

The minimum flow velocity to initiate the transport of a joint-bounded rectangular block (Nandasena et al., 2011) is given by

$$u^2 \geq \frac{\{(\rho_s - \rho_w)/\rho_w\}ag}{C_l} \qquad \text{Eq. (1)}$$

where u is the minimum flow velocity, ρ_s the density of the boulder, ρ_w the density of water, a is the length of the boulder in the major axis, g is the gravitational acceleration, and C_l is the coefficient of lift. However, in field conditions, the pre-transport arrangement of a joint-bounded block and the shape of the block (Fig. 2) can be different from the theoretical consideration. Therefore, the validity of results from Eq. (1) is questionable for some cases. Despite these limitations, Eq. (1) has been applied in past studies to reconstruct the local size of high-energy events from their joint-bounded blocks.

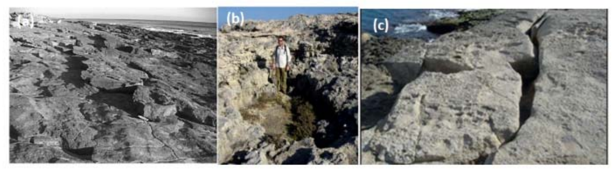

Fig. 2 Joint-bounded blocks. (a) blocks were transported and sockets are present – a large number of joint-bounded blocks are created by rock fracturing (Nott, 2003), (b) a large socket after displacing the block (Mottershead et al., 2014), (c) Large-scale joint-bounded blocks, they are ready to transport by high energy wave impact (Mottershead et al., 2020).

Therefore, in this study, we conduct experimental studies on joint-bounded blocks with different shapes and pre-transport arrangements to investigate their transport potential for different flows. The measured flow velocity is compared to the theoretical flow velocity for the incipient motion whereby Eq. (1) is validated and the deviation of the theoretical results from the actual results is discussed.

EXPERIMENTAL STUDY

The experimental work is conducted in the Fluid Lab of the Department of Civil and Environmental Engineering, UAEU.

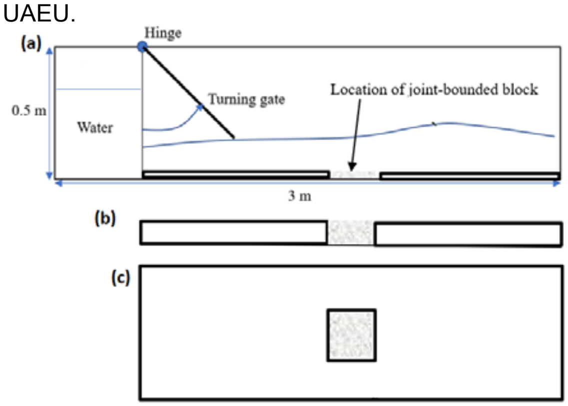

Fig. 3 Experiment setup (a) sectional view of Dam-break flume, (b) sectional view of joint-bounded block in the flume, (c) plan view of joint-bounded block in the flume.

In this study, we develop a dam-break flow model to generate tsunami-like flow over the joint-bounded block. The inundation flow is generated by quickly releasing a water body stored at one end of the tank. The tank has a length of 3 m, a width of 0.4 m, and a height of 0.5 m (Fig. 3). The incipient transport of the block is mostly happened by the highest flow. Therefore, in the experiment, we simulate the highest onshore inundation of the wave train over the block.

EXPERIMENT CASES

The incipient motion of a joint-bounded block is controlled by the connection (gap?) between the block and socket. The same hydrodynamic force is not enough to transport the block if they are in different arrangements. Therefore, the effect of the gap and orientation on the transport potential of a joint-bounded block is investigated. A test matrix is developed based on the possibilities for the block in the field (Fig. 4).

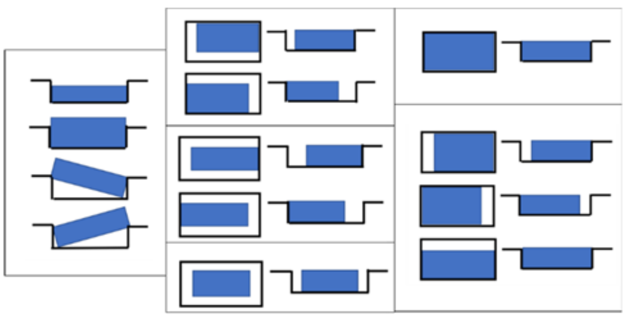

Fig. 4 Orientations of joint-bounded block in its socket; (a) block exactly fitting the socket, (b) one-degree freedom - three sides of the block touching the socket, (c) two-degree freedom - two sides of the block touching the socket (d) three-degree freedom - one side of the block touching the socket, (3) full freedom - no sides touching the socket, (f) block exactly fitting socket; four cases (top to bottom) submerged block in the socket, emerged block in the socket, anti-clockwise angled, and clock-wise angled.

The incipient motion of the joint-bounded block at each pre-transport arrangement (Fig. 4) is tested with the flow magnitude. The flow velocity and flow depth over the block are increased by increasing the water level in the tank (Fig. 3). An iterative process is used to estimate the threshold flow condition for the transport. Electromagnetic current meters are used to measure the flow velocity. Videos are taken from the top and side and they are used to explain the nature of the incipient motion. The flow depths are traced from video footage. The minimum flow velocity from Eq. (1) is compared to the measured flow velocity for the incipient motion of the block so that the credibility of Eq. (1) is confirmed.

RESULTS

Experimental studies were started in September 2023. The completion is anticipated in January 2024. Preliminary results confirmed that the incipient motion of joint-bounded blocks is greatly controlled by the gap size and elevated height of the block from the rock outer crops.

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