Probabilistic Investigation of Debris Impact Velocities during Extreme Flooding Events

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BACKGROUND

Forensic engineering surveys of extreme flooding events, such as the 2011 Tohoku Tsunami and the 2012 Hurricane Katrina, demonstrated the importance of debris in estimating loading on structures. Debris are any solid objects entrained within the inundating flow. The resulting loads from these objects can be the result of debris damming, where debris accumulate at the front face of a structure, or of individual debris impact, where the debris exerts an impulse load as the it rapidly impacts the structure.

Research into debris loads has focused on the development of the loads associated with debris impact. Several studies have found that the debris impact force (F_i) is an iteration of the following formula:

$$F_i = u\sqrt{km_d} \quad [1]$$

where u is the impact velocity of the debris, k is the composite stiffness of the structure and debris, and m_d is the mass of the debris. As the stiffness and mass are properties of the type of debris, the primary considerations in assessing debris impact loading potential are the impact velocity and the likelihood of debris impacting the structure.

The study of waterborne debris has been challenging due to the probabilistic nature of the debris motion (Matsutomi, 2009). Naito et al. (2014) developed a conservative estimation of the maximum debris spreading from a limited dataset from the 2011 Tohoku Tsunami. Charvet et al. (2015) incorporated a binary debris impact consideration into fragility analysis based on the distance from a debris source.

Recently, in-depth experimental studies have been performed in an effort to understand the probabilistic nature of the debris motion (Goseberg et al., 2016; Nistor et al., 2016). In particular, addressing the debris lateral spreading potential as a result of a variety of factor, such as amount of debris, presence of obstacles, hydrodynamic forcing factor. However, further research is needed to combine the variables influencing debris motion into a comprehensive, probabilistic model.

OBJECTIVES AND NOVELTY

With the long-term objective of developing a comprehensive model to estimate debris impact potential in extreme flooding events, this novel study aims to:

- Examine the influence of the hydrodynamic forcing condition on debris entrainment and velocity development.
- Examine the influence of multiple debris on the acceleration characteristics of the debris.
- Develop a probabilistic approach for assessing the debris velocity characteristics.

EXPERIMENTAL SETUP

The experiments were performed in the dam-break flume at the University of Ottawa (Canada). The wave profile was developed using a dam-break wave, where an impounded volume of water was rapidly released by a swing gate. The debris, modelled as 1:40 scaled-down shipping containers, were placed 3.2 m downstream of the gate, allowing sufficient distance for the wave to fully develop.

Two debris configurations (each using 1 and 3 debris) and two hydrodynamic forcing conditions (waves generated by 0.20 m and 0.40 m water impoundment depths) were examined with a minimum of 15 repetitions for each test. The debris motion was tracked using an optical tracking algorithm previously developed by the authors (Stolle et al., 2016).

RESULTS AND DISCUSSION

The debris entrainment and acceleration characteristics showed significant differences as a result of both the debris configuration and the hydrodynamic forcing condition. The debris acceleration was dependent on the position of the debris within the wave. The debris within the wave front accelerated quicker to higher velocities than those falling behind in the wave body (Figure 1).

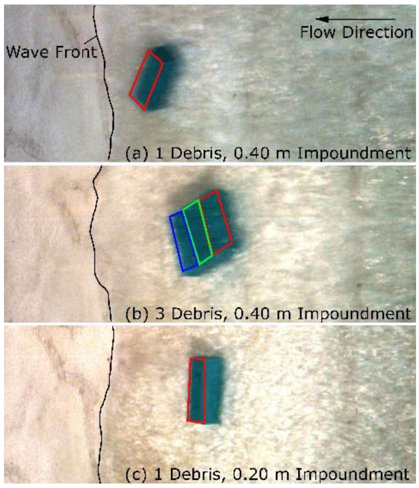

Figure 1 - Pictures frames outlining the debris falling behind the wave front.

The presence of multiple debris resulted in them agglomerating throughout the acceleration phase, essentially acting as a single mass. As a result, debris further accelerated slower, falling behind the wave tip and therefore reaching a lower maximum velocity. The lower impoundment depth caused slower, shallower flow conditions which also resulted in the debris falling behind the wave front and reaching a lower maximum velocity.

CONCLUSIONS

This study examined debris movement characteristics as debris were entrained within a dam-break wave. Based on the stated objectives, the following conclusions can be made:

- The position of the debris within the wave influenced the acceleration and maximum velocity of the debris. The debris moving within the wave front accelerated faster and reached a larger maximum velocity.
- The lesser hydrodynamic forcing condition (0.20 m impoundment depth) and using more debris resulted in the slower acceleration with debris falling behind the wave front.

REFERENCES

Due to space limitations, the references were not provided here.