SCOUR AMPLIFICATION CAUSED BY STRUCTURE PROXIMITY IN EXTREME FLOWS

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RESEARCH NEEDS

Forensic engineering field surveys of recent tsunamis (Saatcioglu et al. 2005, Chock et al. 2013) highlighted the importance of scour-related damage to structures located in coastal communities. To date, only a limited number of studies have investigated the interaction of extreme hydrodynamic flows and groups of structures, and none have studied the scour around multiple structures interacting with each other. One field example discussed by Yeh et al. (2013) documented flow concentration in between two tsunami-resistant buildings, leading to a deep scour hole between them and infrastructure failures onshore of the gap between the two buildings. This field example shows that multiple buildings, often crammed, lead to complex flow-structure interactions, leading to flow and scour either amplification or reduction depending on the relative position of the buildings. Nouri et al. (2010) and Thomas et al. (2015) investigated the flow velocity amplification caused by structures proximity, which concentrated the flow onto a downstream monitored structure. Their results informed the ASCE7 Ch.6 “Tsunami Loads and Effect” standard on flow velocity amplification caused by nearby structures. However, ***in this standard, there is currently no link between flow velocity amplification factors and their effects on scour around structures.***

OBJECTIVES AND NOVELTY

A comprehensive experimental program was performed to:

- Examine structures’ sheltering effects on tsunami-induced scour: one structure placed directly upstream of the monitored structure.
- Examine structures’ lateral effects on tsunami-induced scour: two structures placed on the same transversal line to the flow direction.
- Examine structures’ upstream constriction effects on tsunami-induced scour: two structures constricting the flow between them onto a downstream positioned structure.
- Inform current design standards on the benefits of optimizing structures’ relative position in tsunami-prone areas.

EXPERIMENTAL SETUP

The experiments were performed in the newly constructed Dam-break Flume at the University of Ottawa, Canada. The bore was developed using a dam-break wave, whereby an impounded volume of water was rapidly released by a fast-moving swing gate. One-, two- and three-square structure with same width (b) setups were installed on a sand bed to measure the scour forming around them. The structures were positioned far enough from the swing gate that a fully turbulent bore developed.

In total, 26 structure positions were investigated in the experimental program to test the effects of structure’s spatial configuration on tsunami-induced scour. In addition, three impoundment depths were used to verify scour amplification dependency on the bore hydraulic properties.

Figure 1 – Bore impact on three-structures setup

RESULTS AND DISCUSSION

Sheltering: A structure positioned directly upstream of the monitored structure (distance (L_D) = 2b to 4b) reduced the scour by up to 80% at the monitored structure.

Lateral spacing: A structure placed on the same transversal line as the monitored structure (spacing (S) = 0b to 4b) increased the scour when the space between the structures was equal to or less their width. When the spacing was greater, scour at the structures decreased by up to 20% compared to single column tests. This reduction is explained by the interaction of the horseshoe vortices in the gap between the structures, which reduced their strength.

Upstream constriction: The presence of two laterally spaced structures (upstream structure spacing (W_c) = 0b to 4b) positioned upstream of the monitored structure (distance = 2b to 4b) resulted in an increase in scour at the downstream structure of up to 33% due to flow acceleration and plunging between the upstream structures. Upstream structures with a spacing of 1b resulted in a decrease of up to 20% at the monitored structure.

CONCLUSIONS

The study presents novel results related to the effect of structure’s relative position on tsunami-induced scour. The results showed that structures positioned directly upstream or laterally spaced to the monitored structure can reduce the scour depth at the former. Pairs of structures positioned upstream, that allow flow to pass between them, amplify the scour forming at a structure positioned downstream of the gap between them. Findings are expected to inform the ASCE7 Chapter 6 provisions on flow amplification.

REFERENCES

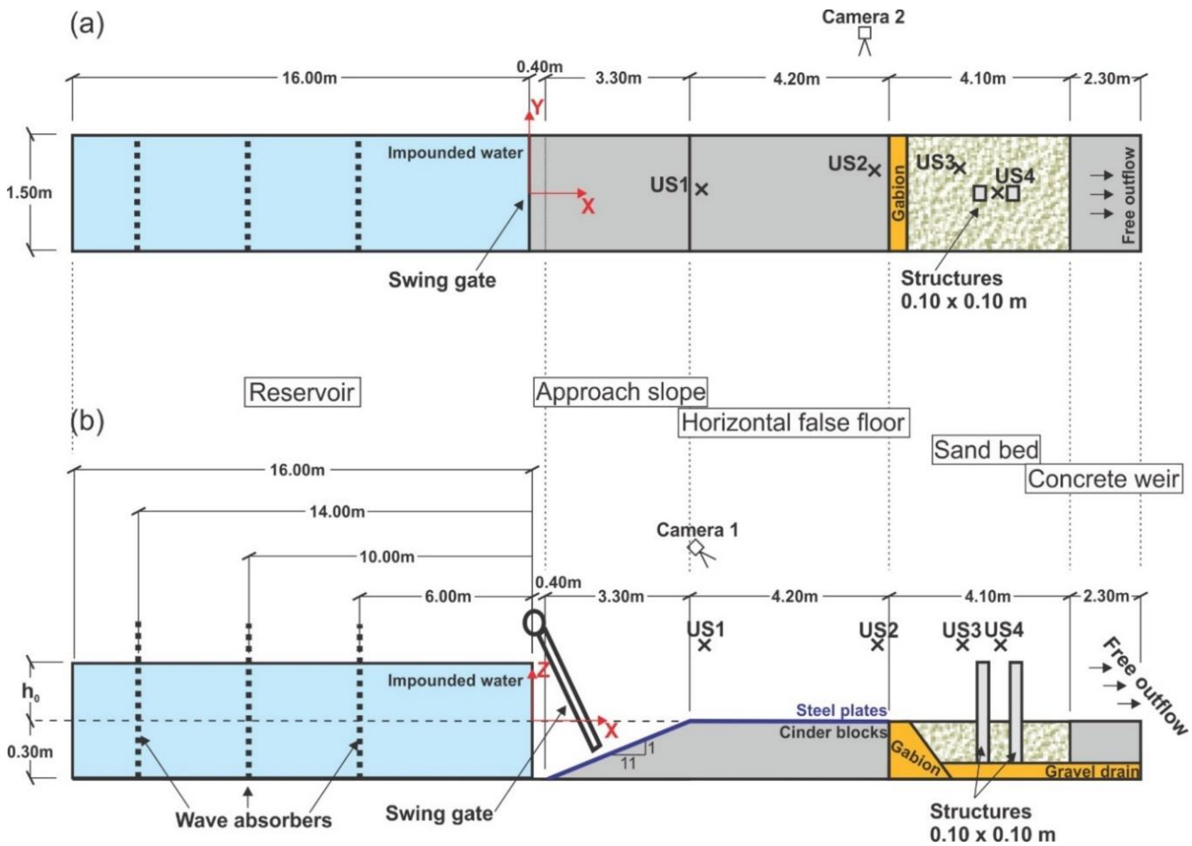
Chock, Roberson, Kriebel, Francis, Nistor (2013): Tohoku Japan tsunami of March 11, 2011, American Society of Civil Engineers.

Nouri, Nistor, Palermo, Cornett, (2010): Experimental investigation of tsunami impact on free standing structures. Coastal Engineering Journal, vol. 52, pp. 43-70.

Saatcioglu, Ghobarah, Nistor, (2005): Effects of the December 26, 2004 Sumatra earthquake and tsunami on physical infrastructure. Journal of Earthquake Technology vol. 42, pp. 79-94.

Thomas, Killian, Bridges, (2015): Influence of Macroroughness on Tsunami Loading of Coastal Structures. Journal of Waterway, Port, Coastal and Ocean Engineering vol. 141, pp. 1-14.

Yeh, Sato, Tajima, (2013): The 11 March 2011 East Japan Earthquake and Tsunami: Tsunami Effects on Coastal Infrastructure and Buildings, Pure and Applied Geophysics, vol. 170, pp. 1019-1031.


(a)
Camera 2
16.00m
0.40m
3.30m
4.20m
4.10m
2.30m
1.50m
Y
X
Impounded water
US1
US2
Gabion
US3
US4
Free outflow
Swing gate
Structures
0.10 x 0.10 m
Reservoir
Approach slope
Horizontal false floor
Sand bed
Concrete weir
(b)
16.00m
14.00m
10.00m
6.00m
Camera 1
0.40m
3.30m
4.20m
4.10m
2.30m
US1
US2
US3
US4
Free outflow
Impounded water
Z
X
Steel plates
Cinder blocks
Gabion
Gravel drain
1
11
h_0
0.30m
Wave absorbers
Swing gate
Structures
0.10 x 0.10 m