Proc. of the 5th IAHR Europe Congress — New Challenges in Hydraulic Research and Engineering
Editor(s) Aronne Armanini and Elena Nucci
doi:10.3850/978-981-11-2731-1_301-cd

Wave impact on oriented impervious buildings

C. Ylla Arbós, D. Wüthrich & A.J. Schleiss
Laboratory of Hydraulic Constructions (LCH), Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

M. Pfister
Haute Ecole d'Ingénierie et d'Architecture de Fribourg (HEIA-FR, HES-SO), Fribourg, Switzerland

ABSTRACT

Recent studies showed that a specific design can reduce the impact of water waves on structures, thus limiting the damages. Herein the impact of waves on buildings is addressed, pointing out the influence of orientation on the hydrodynamic process.

1 INTRODUCTION

Dam-break waves, impulse waves and tsunamis are considered extremely rare phenomena. However, some recent catastrophic events with high casualties and significant damages to the built environment pointed out the importance of a specific design to increase the hydrodynamic performance of buildings. This leads to safer vertical shelters where people can find refuge during such events.

Previous studies showed that building orientation along the coastline plays an important role on the resulting hydrodynamic process ([1], [2]). The impact of a dry bed surge on a frontal impervious building was previously presented by [3]. This paper focuses on the effect of orientation, pointing out some key flow features observed during the hydrodynamic impact of water waves on buildings with various angles.

2 EXPERIMENTAL SET-UP

Hydrodynamic waves were produced releasing a known volume of water from an upper reservoir into a lower basin linked directly to the channel. Different volumes resulted into waves with various characteristics in terms of velocities and height. These were shown to be similar to a dam-break waves [4]. Surges propagated on an initially dry bed, while bores were generated on a still water depth ($0.01 < h_0 < 0.03$ m). The propagation of the wave took place in a smooth horizontal channel with a length of 15.5 m and a width of 1.4 m. The buildings were reproduced using an aluminium structure (0.3×0.3×0.6 m), sufficiently rigid such that its dynamic response could be neglected. This represented a residential house of 9×9×18 m if a Froude scaling ratio of 1:30 is assumed. The oriented configurations were rotated by an angle $\theta = 22.5°$ and 45° degrees, commonly observed on coastal areas.

Both the propagation of the wave and the impact on the building were captures using 7 US (Ultrasonic distance Sensor) with an acquisition frequency of 12.5 Hz. All buildings were installed on a Force-Plate (AMTI MC6-1000), allowing to measure forces and moments in all three main directions with an acquisition frequency of 1 kHz. The key features of the impact were captured using high speed cameras and GoPro videos.

3 VISUAL OBSERVATIONS

Dry bed surges were characterised by a constant increase in water depth. Wet bed bores showed a turbulent aerated roller, similar to a translating hydraulic jump. Surges were associated with higher flow velocities, whereas bores had higher water depths [4].

Both surges and bores impacting on a frontal structure resulted into high splashes and some air entrainment on the upstream side of the building, generating a stationary roller. After the impact, a '*quasi-steady*' flow regime was observed around the building, until the water depth decreased after the passage of the wave [3]. A picture of the impact is presented in Figure 1.

The rotation of the building modified the dynamic of the impact, leading to a change in flow behaviour. For both tested angles, the wave initially hit the vertical edge of the building and a separation of the flow toward the sides was observed (Figure 1). This was symmetrical for $\theta = 45°$, whereas the for $\theta = 22.5°$, higher splashes were observed on one side of the building. For both scenarios a recirculating roller was formed on the upstream side of the building, similar to that observed for the frontal configuration (Figure 1). However, the presence of an orientation angle resulted into better hydrodynamic performances and a longer transition phase was observed between the impact and the quasi-steady flow regime. In this phase, because of the enhanced hydrodynamic profile of the rotated building, narrower streamlines were observed in the channel.

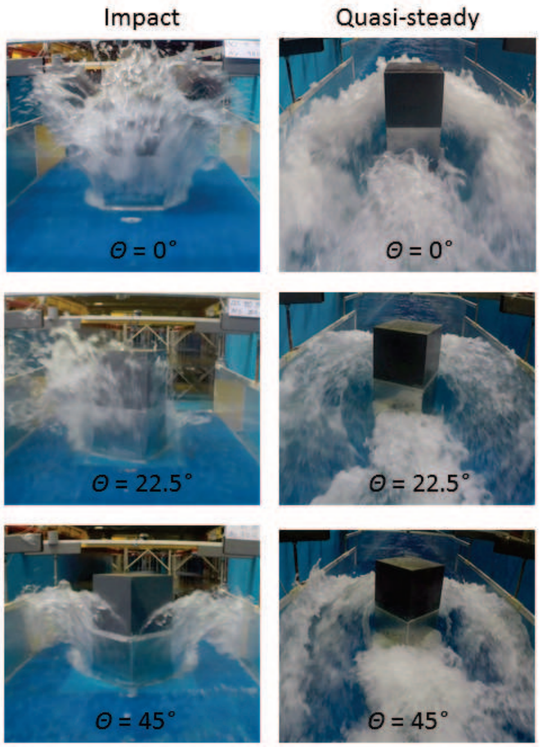

Figure 1: Impact of a dry bed surge (d_0 = 0.63m) on buildings with orientation angles θ = 0°, 22.5° and 45°.

4 FORCES

For all configurations the force measurements showed an increasing phase, followed by a constant load during the quasi-steady flow regime around the building. The forces decreased after the passage of the wave. This behaviour is consistent with previous studies ([1], [2], [5]).

The difference in flow behaviour during the impact resulted into a modified loading process. An example of the horizontal forces F_x generated by a dry bed surge (d_0 = 0.63 m) on the buildings with θ = 0° and 45° is shown in Figure 2. The time development of the loading process is presented in Figure 2, there T = 0 corresponds to the arrival of the surge at the building location (x = 14 m). The rotation of the building resulted into a larger cross-section and therefore an higher blockage ratio. For this reason, all forces were normalised using the building cross-section perpendicular to the flow (B_{proj}). One can notice that during the initial time of the impact ($T/x \cdot (gd_0)^{0.5}$ <1), lower horizontal forces per unit width (F_x/B_{proj}) were measured for both configurations at θ = 45° and 22.5°. The presence of the building edge resulted into a deviation of the flow towards the lateral direction, thus reducing the total horizontal forces exerted on the building. This difference became negligible during the quasi-steady phase, in which similar forces are observed for both configurations.

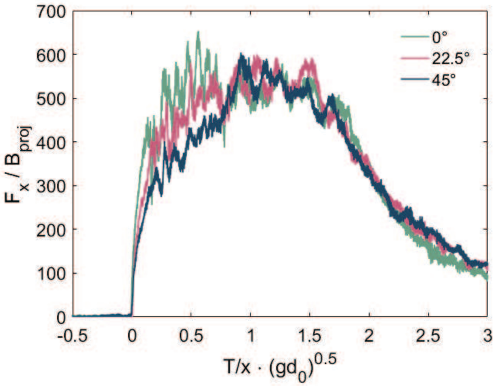

Figure 2: Horizontal forces per unit width for the frontal (θ = 0°) and oriented (θ = 22.5° and θ = 45°) buildings.

5 CONCLUSIONS

This study focused on the effect of building orientation during wave impact. Visual observations showed a different dynamics of the impact, with a flow separation on the upstream side. This translated into different load conditions, with lower forces per unit width for the configuration oriented with an angle.

6 ACKNOWLEDGEMENT

This research was funded by the Swiss National Science Foundation (SNSF), grant 200021_149112.

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