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Influence of building orientation on the hydrodynamic impact of waves on structures

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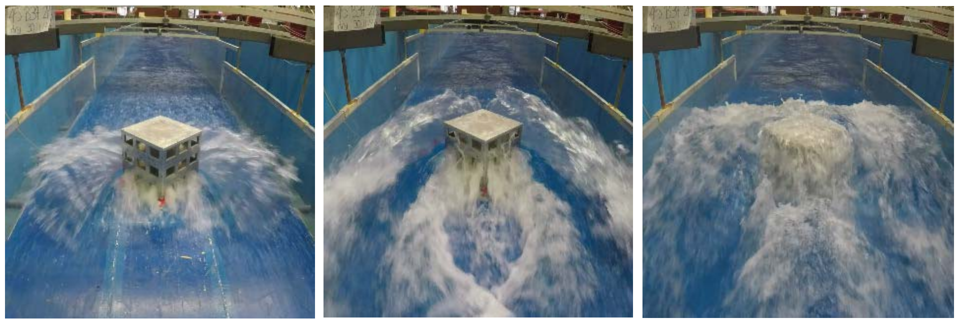
CONTEXT

Tsunamis, dam-break waves and impulse waves are rare but catastrophic events that cause thousands of victims and severe infrastructural damage. Understanding the **impact** that these waves have **on structures** is therefore necessary to properly dimension buildings in wave-hazard zones. Up to now, studies have separately investigated the influence of **building orientation** and **porosity**, yet these factors might appear simultaneously.

In this study waves of different characteristics (height, velocity, impulsiveness) are generated in a **laboratory** environment, and their impact on free-standing buildings with openings is analyzed for two different orientations.

VISUAL OBSERVATIONS

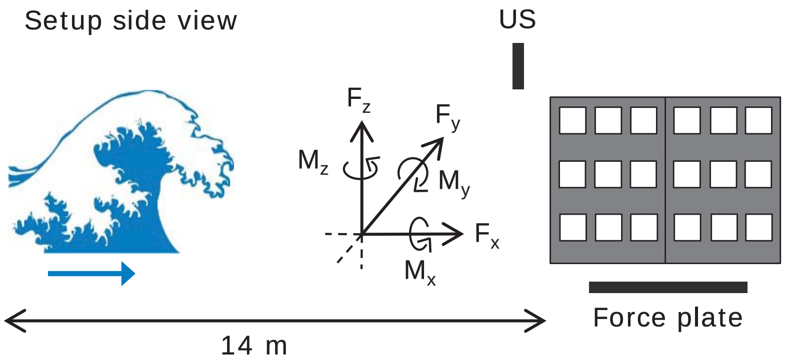
3 phases — Back view (45º)



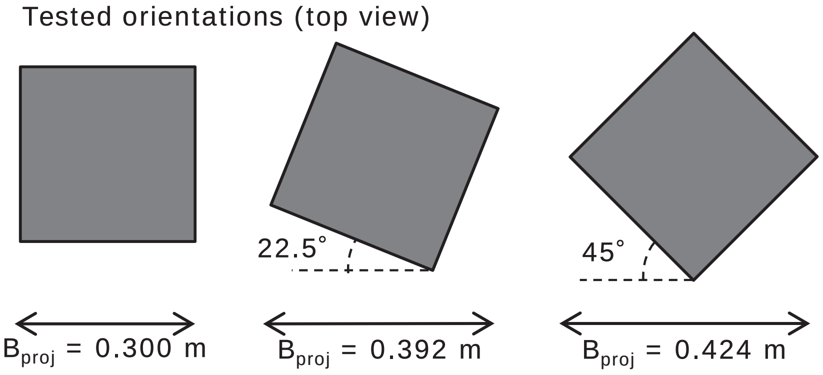
1. Impact — 2. Streamlining — 3. Quasi-steady state

EXPERIMENTAL SETUP

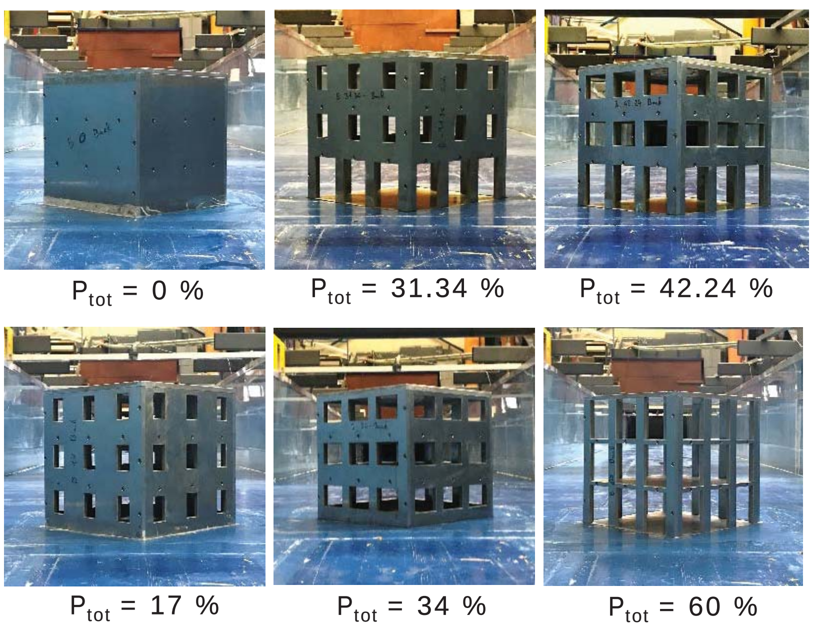
Setup side view



Tested orientations (top view)



Tested porosities (back view, 45º). P_{tot} = total porosity.

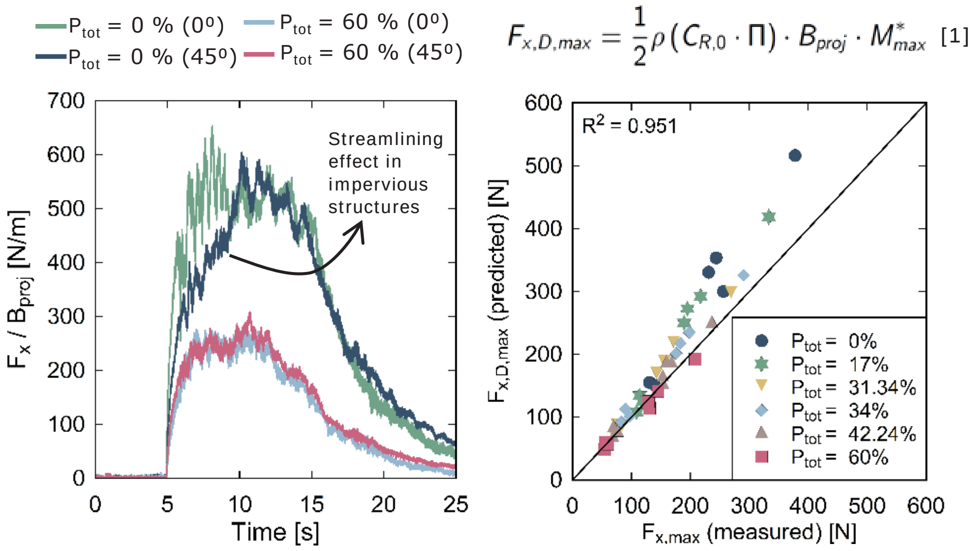


P_{tot} = 0 % — P_{tot} = 31.34 % — P_{tot} = 42.24 %

P_{tot} = 17 % — P_{tot} = 34 % — P_{tot} = 60 %

HORIZONTAL FORCES

$$F_{x,D,max} = \frac{1}{2}\rho\left(C_{R,0}\cdot\Pi\right)\cdot B_{proj}\cdot M^*_{max} \quad [1]$$



$F_{x,D,max}$ = maximum predicted horizontal force
ρ = water density (1000 kg/m³)
$C_{R,0}$ = resistance coefficient for impervious structures ($C_{R,0}$ = 2)
Π = Porosity coefficient (Π = 1 – P_{proj}, P_{proj} = projected porosity)
B_{proj} = projected building width
M^*_{max} = maximum value of momentum flux per unit width ($M^* = h(t)\cdot[\min(\chi U;\ V_m(t)^2)]$, h=water depth, χ=reduction coefficient, U=front celerity, V_m=depth-averaged flow velocity).

CONCLUSIONS

- When buildings are **oriented** with a corner facing the flow, wave fronts are split in two and ejected sideways upon impact against the structure. Such clear **streamlining** is not observed in non-oriented structures and results in a **progressive transition in F_x** between the initial impact and the force peak. This phenomenon is especially pronounced for low opening ratios. In **porous buildings**, the transition is so gradual that it becomes imperceptible in terms of F_x evolution, and thus their behavior is **similar to that of non-oriented structures**.
- **Eq. [1] successfully predicts** the maximum values of F_x. For those cases in which the transition phase is more pronounced, a **conservative** value is provided.
- The **influence of building orientation** on the total withstood forces per unit width is **negligible**.

[1] Wüthrich, D., Pfister, M., Nistor, I. & Schleiss, A. J. (2018) Experimental study on forces on free-standing buildings with openings. Coastal Engineering (under review).