

Hydrodynamic modeling of partial dikes

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Due to lack of space, the city of Monaco has extended over the sea, first by land reclaiming. The bordering waterdepths are now so deep that the city has been considering building housings set on jacket types of structures. These constructions would have to be protected from sea waves, by so-called "partial dikes". An example of such partial dikes is the BYBOP caisson that was installed recently at the mouth of Port Hercule (figure 1). Its shape was optimized through systematic model tests (Colmard 1997). Quite noticeable are the slanted parts that protrude both on the up-wave and down-wave sides. The appendix on the lee-side was found to have quite a strong effect on the reduction of the transmission coefficient.

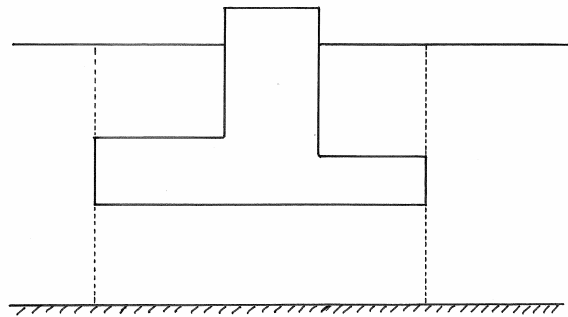
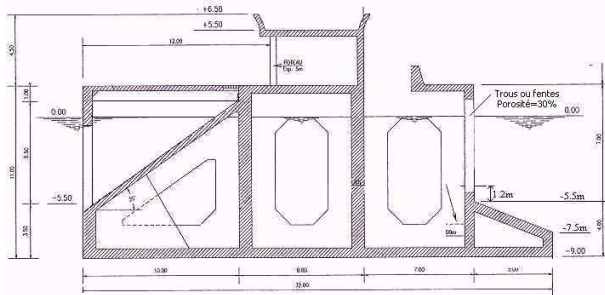


Figure 1: The BYBOP caisson (left) and the rectangular caisson indented with two "buckets" (right).

In this paper we investigate the effect of such appendices by simplifying the geometry as shown in the right-hand side of figure 1: a rectangular caisson, with two rectangular indentations at free surface level (the "buckets"). The fluid domain therefore divides into 5 rectangular sub-domains, up-wave, down-wave, below the dike and the two buckets. Eigen-functions expansions are used to solve the linearized diffraction problem. Note that these geometries do not satisfy John's criterion ensuring uniqueness of the solution.

In the numerical results that follow we keep constant the waterdepth (70 m) and the draft (9 m).

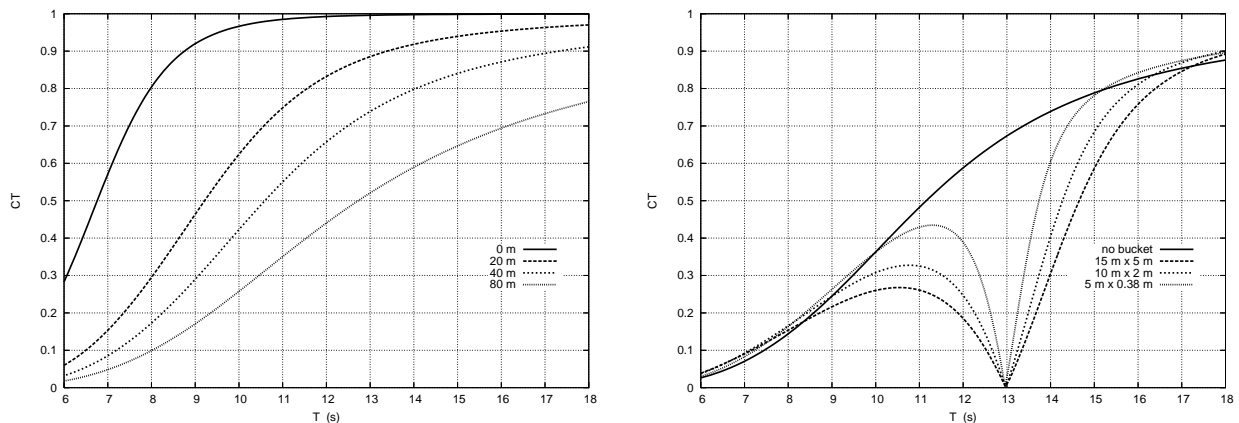


Figure 2: Transmission coefficient. Rectangular caisson (left) and caisson indented with one bucket (right).

Figure 2 (left) shows the calculated transmission coefficient in the case of a rectangular caisson with no buckets. The width is taken successively equal to 0, 20, 40 and 80 m. The hydrodynamic performance is rather poor:

at the largest width the transmission coefficient is still higher than 0.25 for wave periods beyond 10 seconds. Increasing the width does not help much. Increasing the draft is a bit more efficient hydrodynamically but not economically.

We take the total width equal to 50 m and we indent the up-wave side with a bucket. Calculations are run for three dimensions of the bucket:

- length 15 m, water-height 5 m
- length 10 m, water-height 2 m
- length 5 m, water-height 0.38 m.

Obtained transmission coefficients (C_T) are shown in the right-hand part of figure 2, together with the rectangular caisson case for the same 50 m width. With a bucket C_T becomes nil at a wave period close to 13 seconds. The larger the bucket, the wider the trough in the curve but the same complete cancelation is obtained at 13 seconds, no matter the size of the bucket.

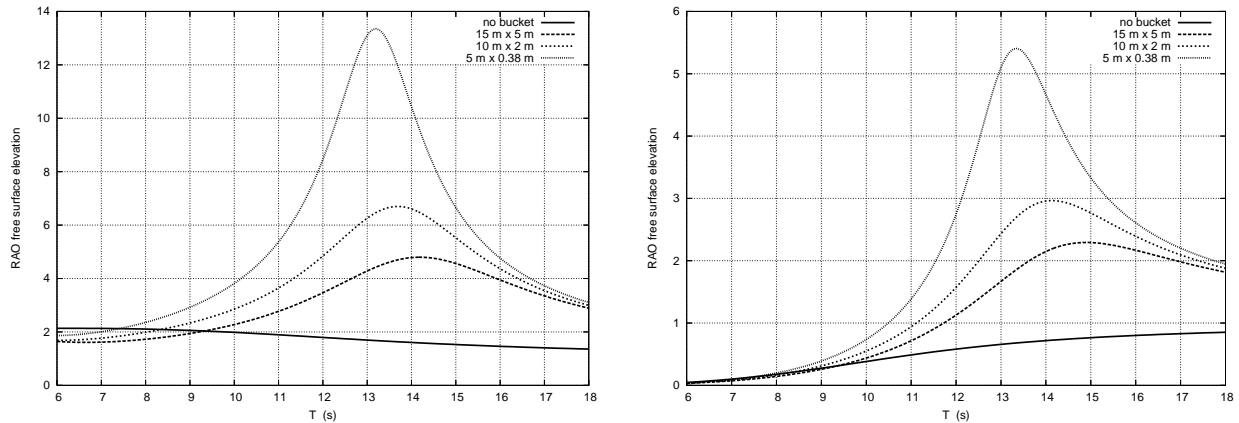


Figure 3: Free surface RAOs at the bucket wall. Bucket on the up-wave side (left) and on the lee side (right).

Figure 3 (left) shows the RAO of the free surface elevation at the up-wave wall. Strong resonance is observed, with peak values highly dependent on the size of the bucket. Obviously the range of validity of linear theory cannot be expected to be very large when the RAO peaks at a value of nearly 14! From a practical point of view the bucket cannot be too small.

Figure 3 (right) shows the free surface RAOs with the bucket moved to the lee side. It has been known for a long time that the transmission coefficient is the same whatever the orientation of the body (see Kashiwagi 2007 where other references can be found). The induced resonance in the buckets is much lower than in the previous case. From the bucket sloshing stand-point, it appears preferable to move it to the lee side.

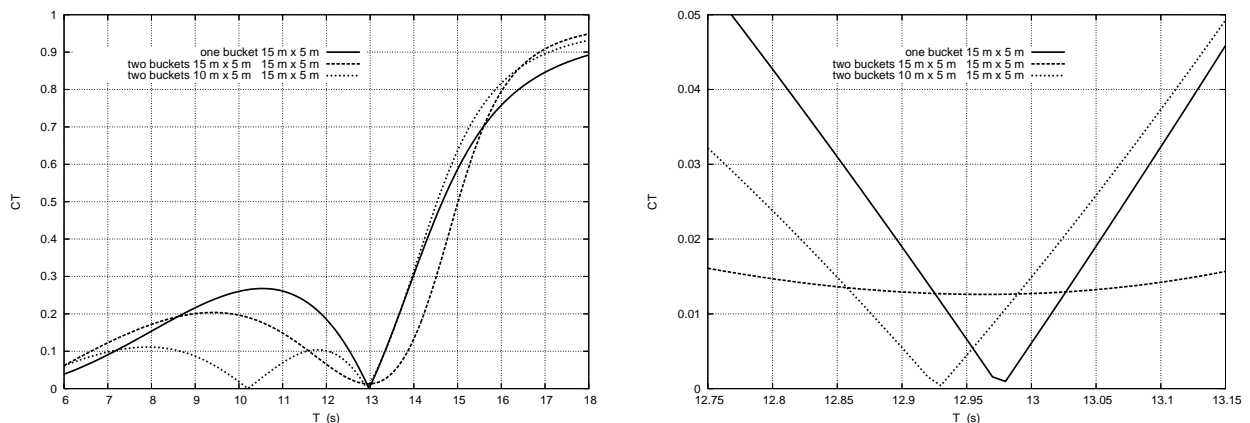


Figure 4: Transmission coefficients vs. wave period.

In figure 4 we show the transmission coefficients for the following cases:

- one bucket 15 m x 5 m
- two identical buckets at either side 15 m x 5 m
- two different buckets 10 m x 5 m and 15 m x 5 m.

With the two identical buckets the trough at 13 seconds period becomes wider than with only one bucket but the minimum value is no longer zero. With two different buckets the transmission coefficient becomes nil at two wave periods, around 10.2 and 12.9 seconds in our case. Figure 5 proves that the transmission coefficients are zero identically.

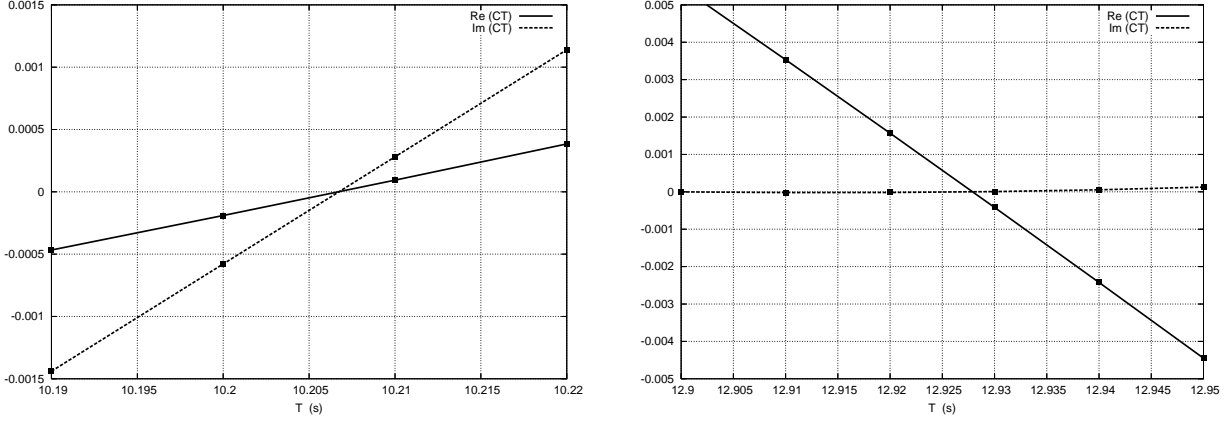


Figure 5: Two buckets 10 m x 5 m & 15 m x 5 m. Transmission coefficient around 10.2 and 12.9 seconds.

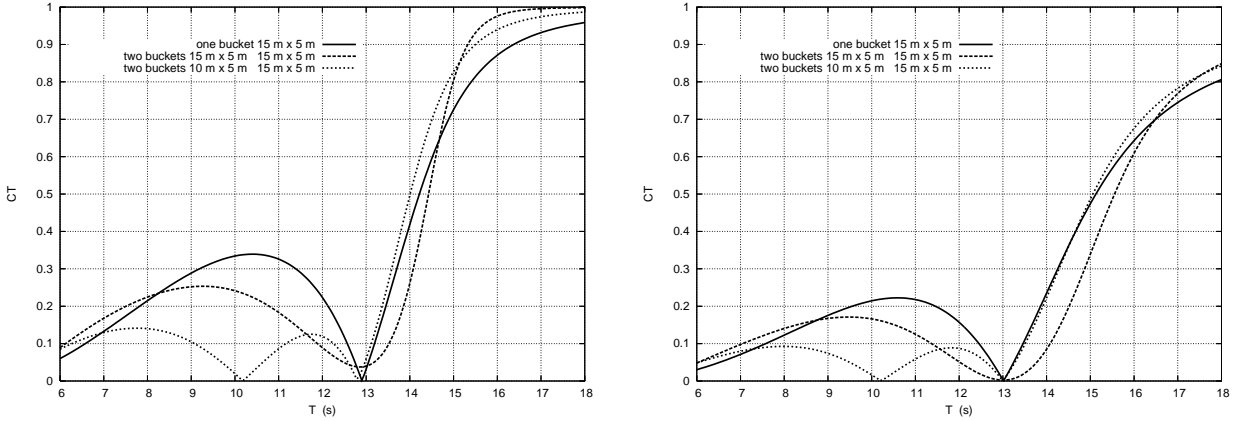


Figure 6: Total width 30 m (left) or 70 m (right).

Figure 6 shows the transmission coefficients obtained, in the same bucket cases, when the total width is reduced to 30 m or increased to 70 m. With the dual bucket case 10 m x 5 m plus 15 m plus 5 m, the transmission coefficient is little sensitive to the total width, at least for wave periods smaller than 14 seconds.

Finally we introduce Jarlan walls, modeled as porous plates of no thickness where a quadratic discharge law is applied (see e.g. Molin 2001):

$$\varphi_2 - \varphi_6 = -i \frac{4}{3\pi} \frac{1 - \tau_1}{\mu_1 \tau_1^2} \frac{Ag}{\omega^2} \|\varphi_{2,x}\| \varphi_{2,x} \quad (1)$$

the velocity potential being written

$$\Phi(x, z, t) = \frac{Ag}{\omega} \Re \{ \varphi(x, z) e^{-i\omega t} \}$$

In equation (1), subscripts 2 and 6 refer to the two sub-domains at either side of the up-wave Jarlan wall, τ_1 is its open-area ratio and μ_1 a discharge equation assumed to be equal to one here. The non-linearity is overcome

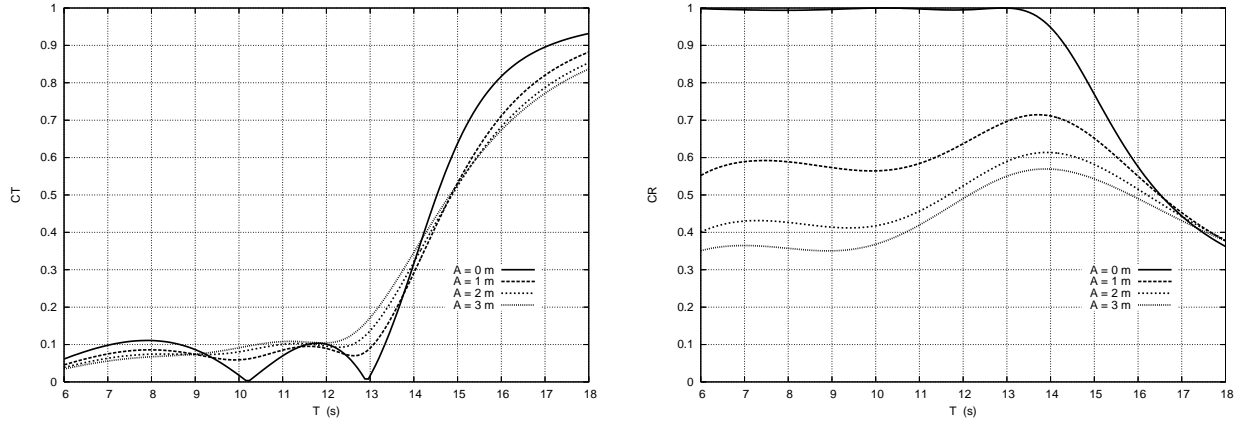


Figure 7: Buckets 10 m x 5 m & 15 m x 5 m. Total width 50 m. With Jarlan walls. Transmission (left) and reflection (right) coefficients.

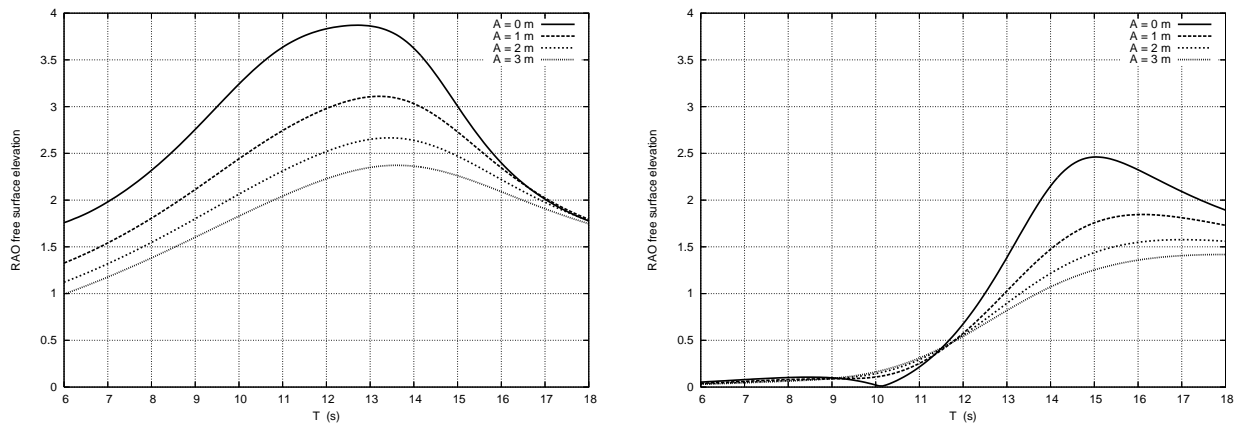


Figure 8: Buckets 10 m x 5 m & 15 m x 5 m. Total width 50 m. With Jarlan walls. RAOs of the free surface elevation at the up-wave (left) and down-wave (right) walls.

by recurring to the iterative scheme

$$\varphi_2^{(j)} - \varphi_6^{(j)} = -i \frac{4}{3\pi} \frac{1 - \tau_1}{\mu_1 \tau_1^2} \frac{Ag}{\omega^2} \|\varphi_{2x}\|^{(j-3/2)} \varphi_{2x}^{(j)} \quad (2)$$

where $(j - 3/2)$ means the averaged value between iteration $(j - 2)$ and iteration $(j - 1)$.

Figures 7 and 8 show the obtained hydrodynamic performance, with the Jarlan walls at 5 m from the solid walls, in the 10 m x 5 m plus 15 m x 5 m dual bucket case. The open-area of the up-wave Jarlan wall is taken equal to 30 % and the down-wave one is 20 %. As a result of the non-linearity of equation (1) the transmission and reflection coefficients become amplitude dependent. It can be seen that the transmission coefficient is little dependent on the incoming wave amplitude and that the reflection coefficient can be highly reduced. This result is beneficial to mitigate wave motion on the weather side of the dike. Likewise the Jarlan wall on the lee side improves harbor tranquility. Figure 8 shows that the sloshing motion in the buckets is somewhat reduced.

References

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