Nonlinear bottom pressure distribution due to wave scattering by a submerged obstacle

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1. CONTEXT

Since the work of Longuet-Higgins (1950), it is well known that under a partially standing wave system, the second order pressure disturbances propagate to the bottom. In deep water conditions, they do not vanish and become independent from the water depth. As a consequence, the second order pressure term can be larger than the first order term. The purpose of this work is to compare the relative magnitude of first and second order pressure disturbances near a submerged obstacle.

To achieve this goal, we extend Longuet-Higgins' results to the nonlinear coupling of local (or evanescent) modes and propagating modes. Indeed, in the vicinity of submerged obstacles, local solutions of the Laplace equation are known, the so-called evanescent modes. We observe that for "deep" water conditions, the second order bottom pressure becomes much higher than the incident wave induced pressure. However, due the evanescent modes, 1st order bottom pressure remains higher in the vicinity of the location of the obstacle.

2. EXPERIMENTAL SETUP

The experiments were conducted in the **Ocean Engineering Basin (BGO) FIRST**, in La Seyne sur Mer, France. The setup corresponds to a **submerged plate**, as illustrated in figures 1 & 2. The instrumentation was constituted by 18 resistive wave probes, and 16 pressure sensors.

Figure 1: Picture of the plate submerged in a constant water depth of 3m, extending from 0.5m to 0.6m from the surface.

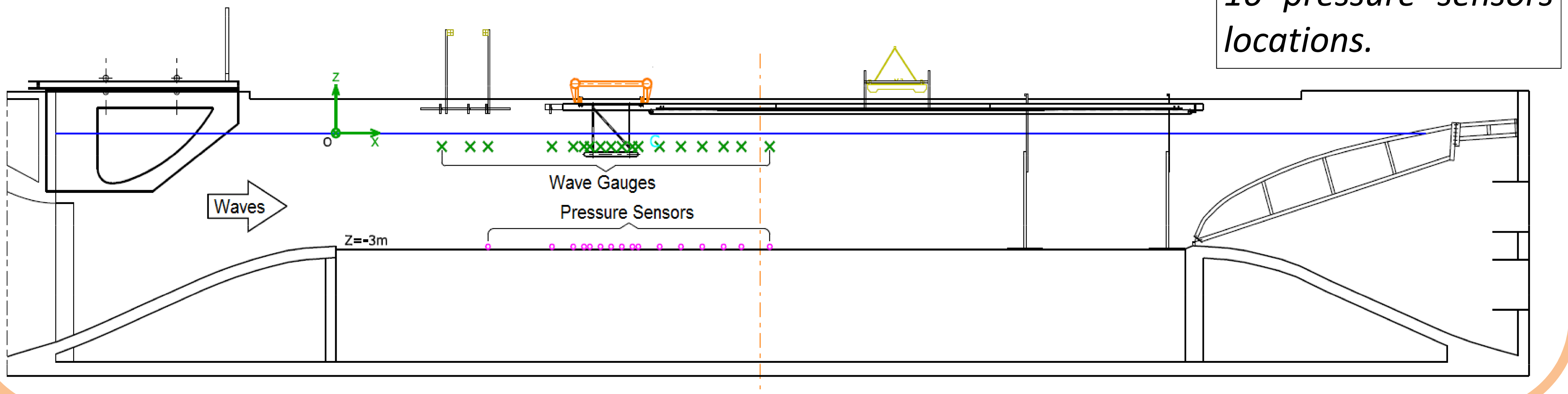


Figure 2: Side view of the experimental setup, presenting the 18 wave probes and 16 pressure sensors locations.

3. ANALYTICAL MODEL

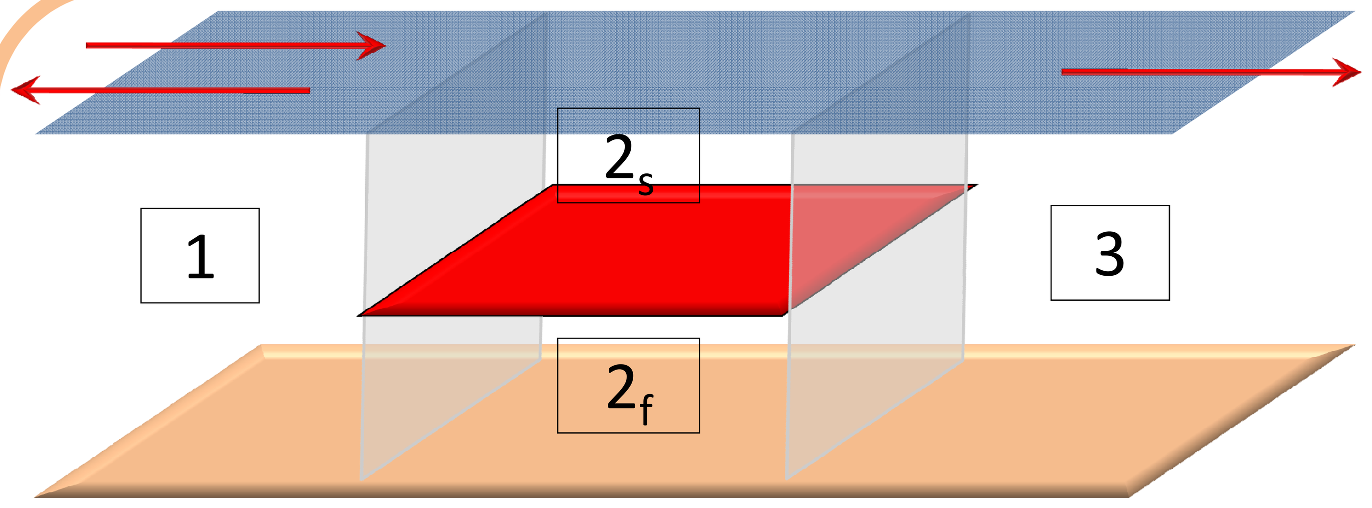


Figure 3: Sketch of the domain decomposition used in the analytical model (first & second orders).

The first order approach assumes that each domain (see figure 3) admits for solution two **propagating modes** and **2xN local modes**. A linear system is obtained by imposing the **continuity of pressure and flux** at each domain interface (Takano, 1960). The approach might be extended to the next order by considering the **forcing due to first order solutions**. These terms are:

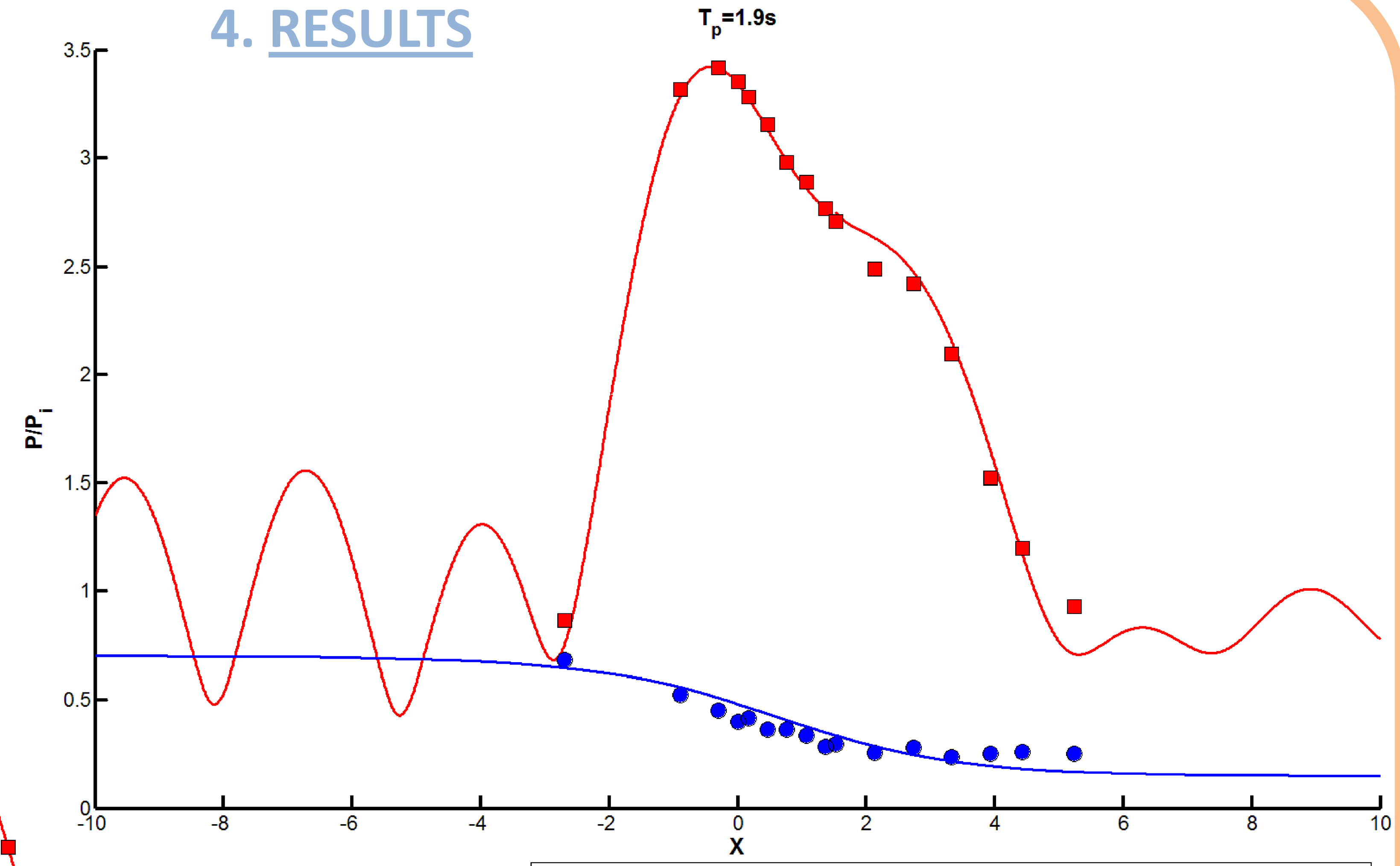
$$\phi_{\pm} = \frac{3i\varphi_{\pm}^2\omega^3\cosh(2k_{\pm}(h+z))}{4g^2\sinh^4(k_{\pm}h)}e^{2i(k_{\pm}x-\omega t)} \qquad \phi_{+-} = -\frac{i\varphi_{+}\varphi_{-}\omega^3(2\cosh(2k_{-}h)-1)}{2g^2\sinh^2(k_{-}h)}e^{-2i\omega t}$$

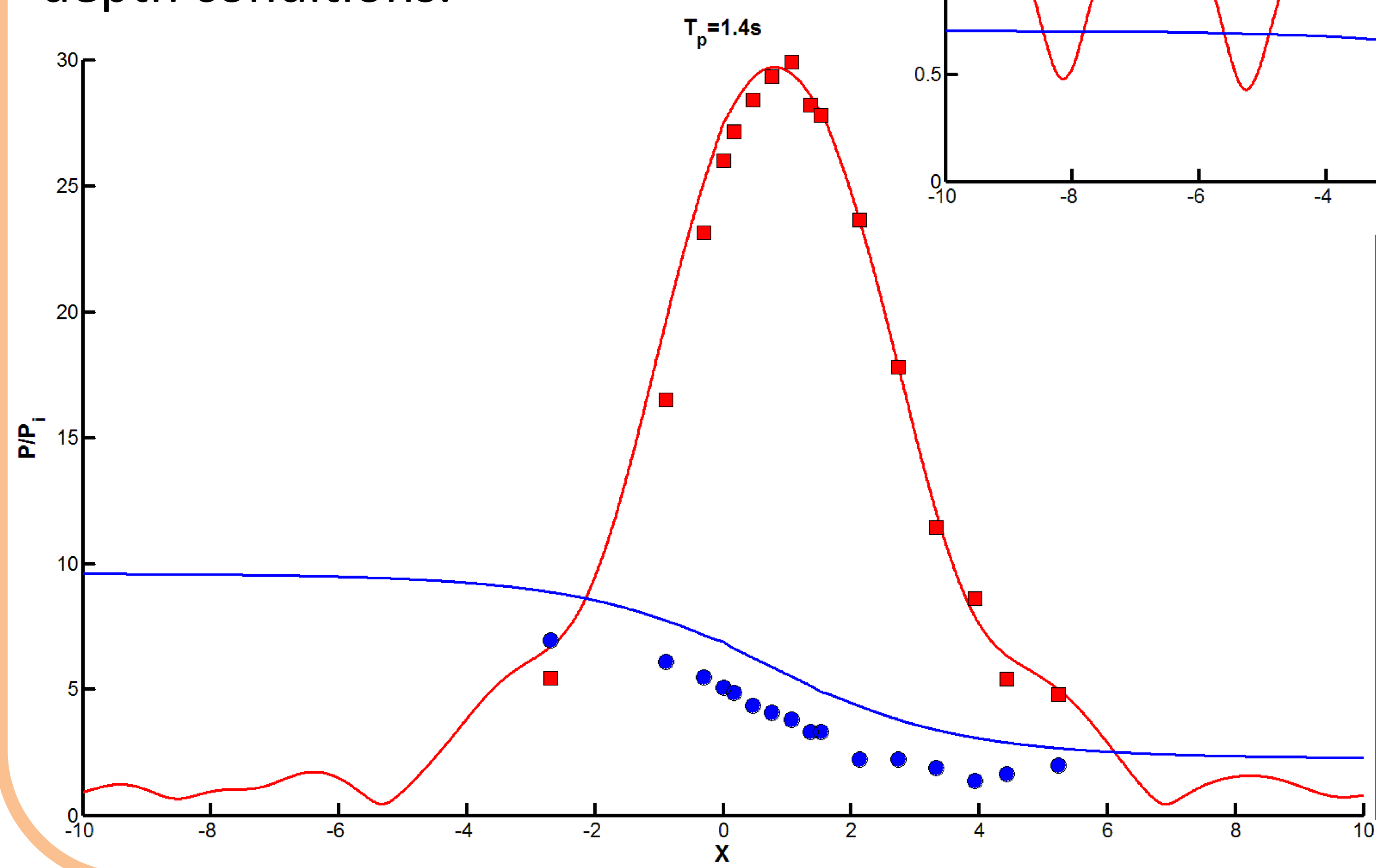
$$\phi_{e\pm} = -\frac{i\varphi_{\pm}\varphi_{e}\omega^3}{8g^2}\frac{[3\cosh(2k_{\pm}h)+3\cos(2k_{e}h)-2\cosh[2(k_{\pm}+ik_{n})h]-4]}{\sinh^2(k_{\pm}h)\sin^2(k_{n}h)}\frac{\cosh[(k_{\pm}-ik_{n})(z+h)]}{\cosh[(k_{\pm}-ik_{n})h]}e^{k_{n}x+ik_{\pm}x-2i\omega t}$$

these terms have to be considered in the new boundary conditions at each domain interface. A new linear system is obtained, and its solution provides the amplitudes of second order modes.

4. RESULTS

Results obtained analytically and experimentally are plotted together in figures 4 & 5. Figure 4 (T_p=1.9s) correspond to waves propagating in finite depth, while figure 5 (T_p=1.4s) correspond to waves propagating in infinite depth conditions.





Figures 4 & 5: Bottom pressure distribution normalized by the pressure induced by incident waves. Symbols correspond to the data obtained experimentally, while solid lines are the analytical results. Red curves correspond to the fundamental frequency, blue curves correspond to the first harmonic.