# A finite element model for predicting sound radiation from marine impact pile driving

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## ABSTRACT

Marine pile installation using impact hammer is a common practice during many nearshore and offshore construction activities. The associated noise emissions have the significant potential to adversely impact on the surrounding marine environment. Predicting sound radiation from marine impact pile driving activities based on numerical simulations has been proved to benefit not only the assessment of resulted marine environmental impact, but also the investigation of effective mitigation measures to minimise the impact. In this paper, we present a finite element (FE) model for the prediction of noise emissions from marine impact pile driving based on the software COMSOL, where the characteristics of the sound field in the near field are investigated. Based on this FE model, the radiated sound signals at a set of receivers placed at different distances and depths within the water column from a driven pile have been calculated, and the sound signals in the time domain have been analysed to characterise the attenuation over distance. This FE model has been validated based on comparisons with previous benchmark case studies.

## 1 INTRODUCTION

Prediction of noise emission from pile driving noise is of great significance in assessming noise impact on marine environment. Different numerical simulations have been devlepoped to characterized the resulted noise levels from marine piling operations, including analytical solutions (Peng et al., 2021), finite element (FE) method (Reinhall and Dahl, 2011a, 2011b), and wavenumber integration (Lippert and Lippert, 2012). To validate and compare these models, COMPILE studies presented the benchmark cases including a generic case (Lippert et al., 2016) and a real-life benchmark scenario (Lippert et al., 2017).

An FE model has been developed in this study, based on the software COMSOL, to predict sound radiation from marine impact pile driving. This paper aims to introduce the basic setup of the model and presents the results derived from the FE model.

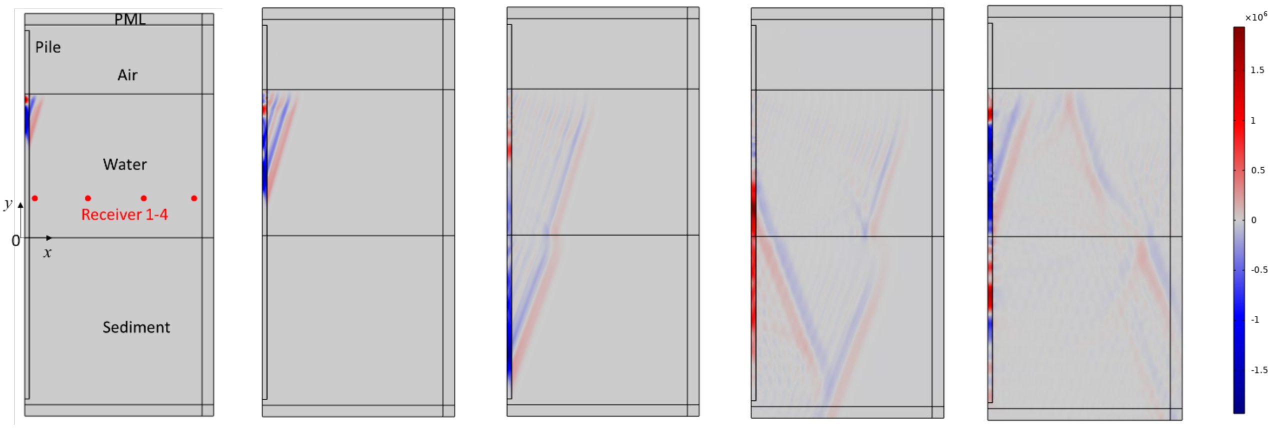
## 2 METHODOLOGIES

Following the methods provided in (Reinhall and Dahl, 2011a, 2011b), the model was established using the finite element method based on COMSOL. The marine pile is modelled as a hollow cylinder and the strike of hammer is treated as a time-dependent bondary load on the edge of the pile profile. The hammer function is deplayed in Equation (1), which is a peicewise function of time $t$ with the maximum amplitude being $F_m$ = 20 MN, and a rise and decay time of $t_r$ = 0.2 ms and $t_d$ = 1.6 ms, respectively. This forcing function is consistent with the function provided in COMPILE studies. Seabed sediment is modelled as elastic media which sustain compressional wave.

$$F(t) = \begin{cases} F_m \frac{t}{t_r}, & \text{for } t \le t_r \\ F_m e^{\left(\frac{t-t_r}{t_d}\right)}, & \text{for } t > t_d \end{cases} \tag{1}$$

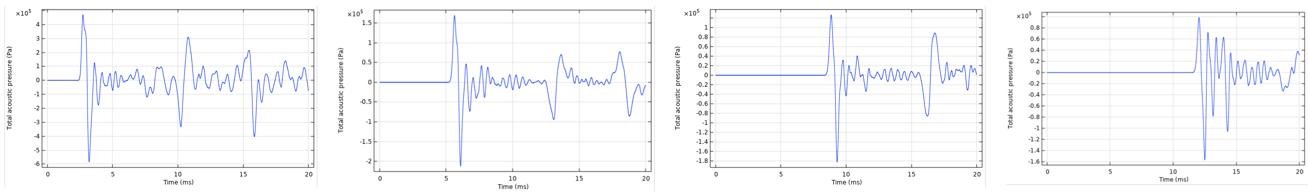
The radius of pile is 38.1 cm and thickness is 2.54 cm. The length of pile is 32 m, with 5.5 m exposed in the air, 12.5 m in water and 14 m inserted in the sediment. The material of pile is steel with density of 7850 kg/m$^3$, Young's modulus of 200e9 Pa and Poisson's ratio of 0.3. Water has the density of 1025 kg/m$^3$ and speed of sound 1500 m/s. Sediment has the density of 2000 kg/m$^3$ and speed of sound 1800 m/s, with Young's modulus of 4e6 Pa and Poisson's ratio of 1.5e6. The material loss factors of the pile and the sediment are considered to account for the energy attenuation during the wave propagation by adopting complex elastic moduli for the sediment (with a loss factor of 0.1).

Figure 1 shows the profile plot of acoustic pressure after 2, 3, 6, 10 and 16 ms of hammer strike, where the Mach wave radiation can be observed clearly. Figure 2 shows the waveforms received at different receivers 0.5 m, 5m,10 m and 15 m away from the pile. A clear difference of arrival time for wavefront can be observed on comparison the waveforms obatained at these four receivers. In addition, it can be seen that at receiver 1, the maximum amplitude of waveforms is above 4e5 Pa while the maxium amplitude at receiver 4 is below 1e5 Pa.




(a) (b) (c) (d) (e)

Figure 1: Profile plot of acoustic pressure after 2, 3, 6, 10 and 16 ms of hammer strike



(a) (b) (c) (d)

Figure 2: Waveforms at different receivers (receivers are located 5m above the water-sediment surface, 0.5 m, 5 m,10 m and 15 m away from the pile wall

## 3 RESULTS

The following observations have been found besed on the simulation work:

- These results show a good agreement with previous benchmark case studies. The propagation of Mach wave down the pile can be observed in the profile plot of acoustic pressure after impact.
- A delay of arrival time for wavefront can be found with the increasing of distance between pile wall and receivers. In addition, around 12 dB attenuation of acoustic pressure have been observed with the distance of 15 metres.

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