Numerical model for rocking of a mono-pile in a porous seabed

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Outline

1. Introduction
2. Theoretical formulations
3. Numerical results
4. Conclusions & future work

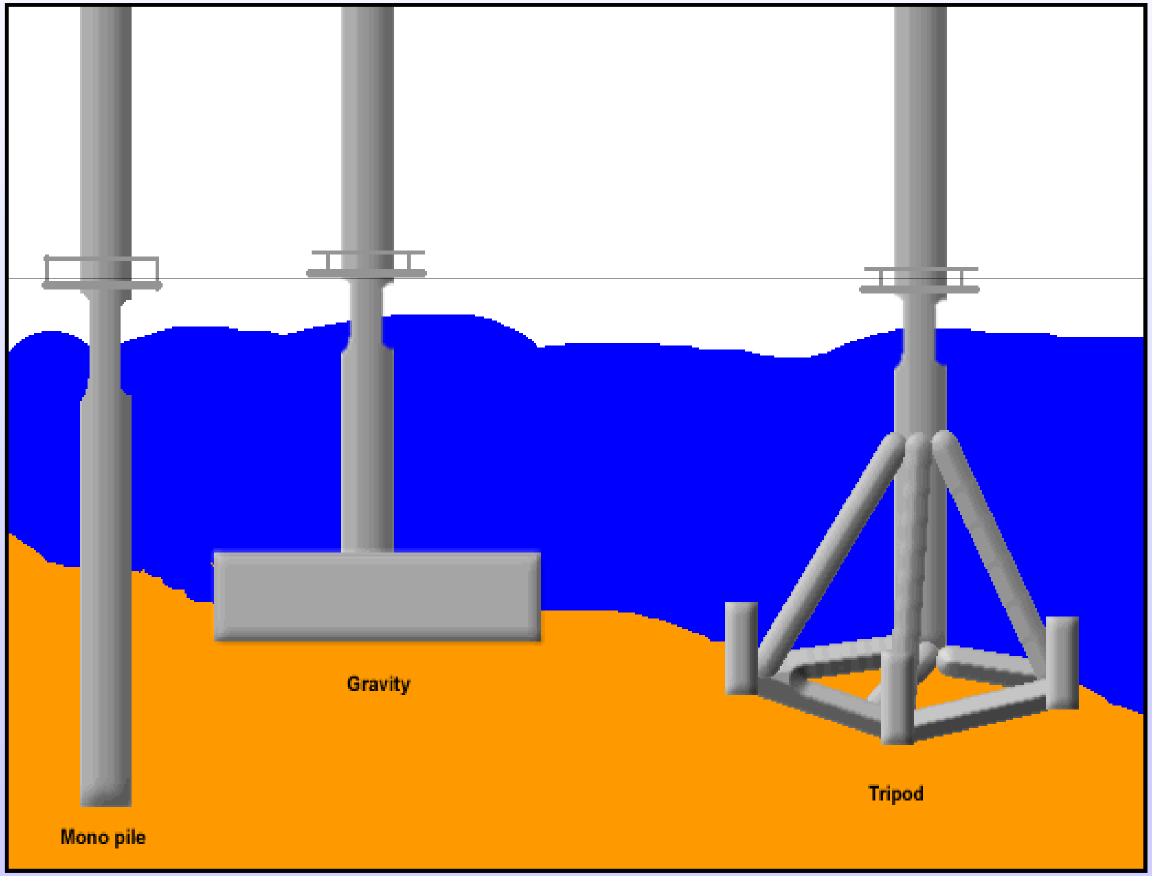
1. Introduction

Offshore windfarm system

http://www.offshorewindfarms.co.uk

1. Introduction

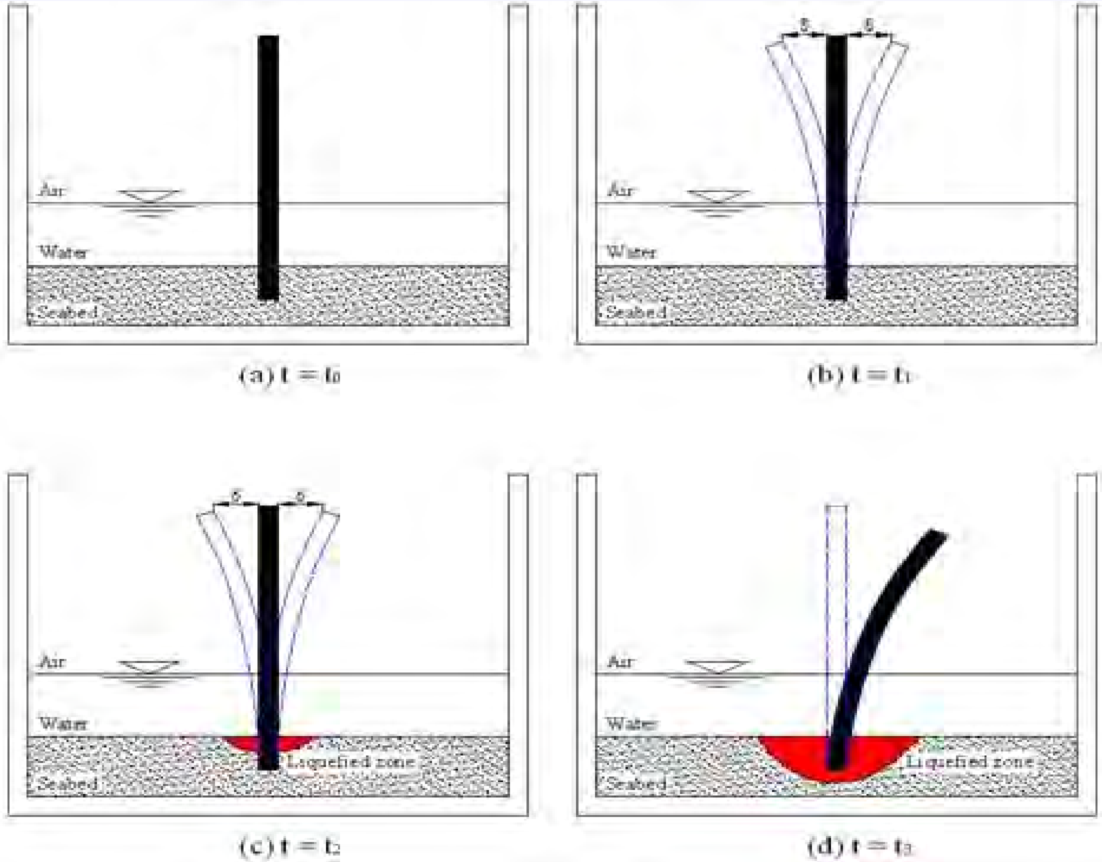
Foundation of offshore windfarm system



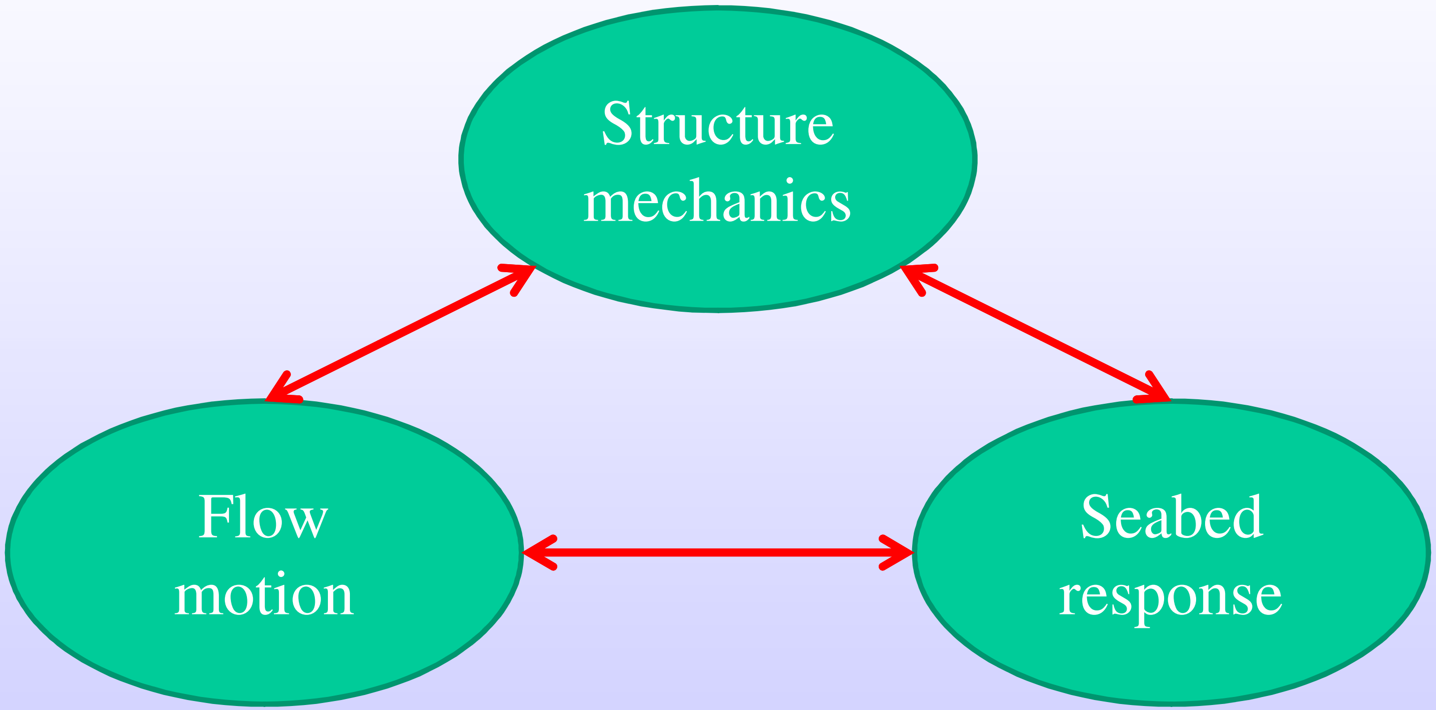
http://www.offshorewindfarms.co.uk

1. Introduction

Rocking of mono-pile structure



2. Theoretical formulations



2. Theoretical formulations

(1) Structure mode

- The structural mechanics theory is based on a weak formulation of the equilibrium equations expressed in the global stress components.

$$-\nabla \bullet \sigma = \vec{F}_m$$

in which $\vec{F}_m$ denotes the periodic volume forces from external wind.

2. Theoretical formulations

(2) Flow mode

- Reynolds-Averaged Navier-Stokes (RANS) equations
- Sponge layer at two sides for damping flow energy

2. Theoretical formulations

(3) Seabed mode

- Biot's poro-elastic theory

$$\nabla^2 p - \frac{\gamma_w n_s \beta_s}{K}\frac{\partial p}{\partial t} = \frac{\gamma_w}{K}\frac{\partial \varepsilon_s}{\partial t}$$

p: rocking-induced pore pressure

$$G\nabla^2 u_s + \frac{G}{1-2\mu_s}\frac{\partial \varepsilon_s}{\partial x} = \frac{\partial p}{\partial x}$$

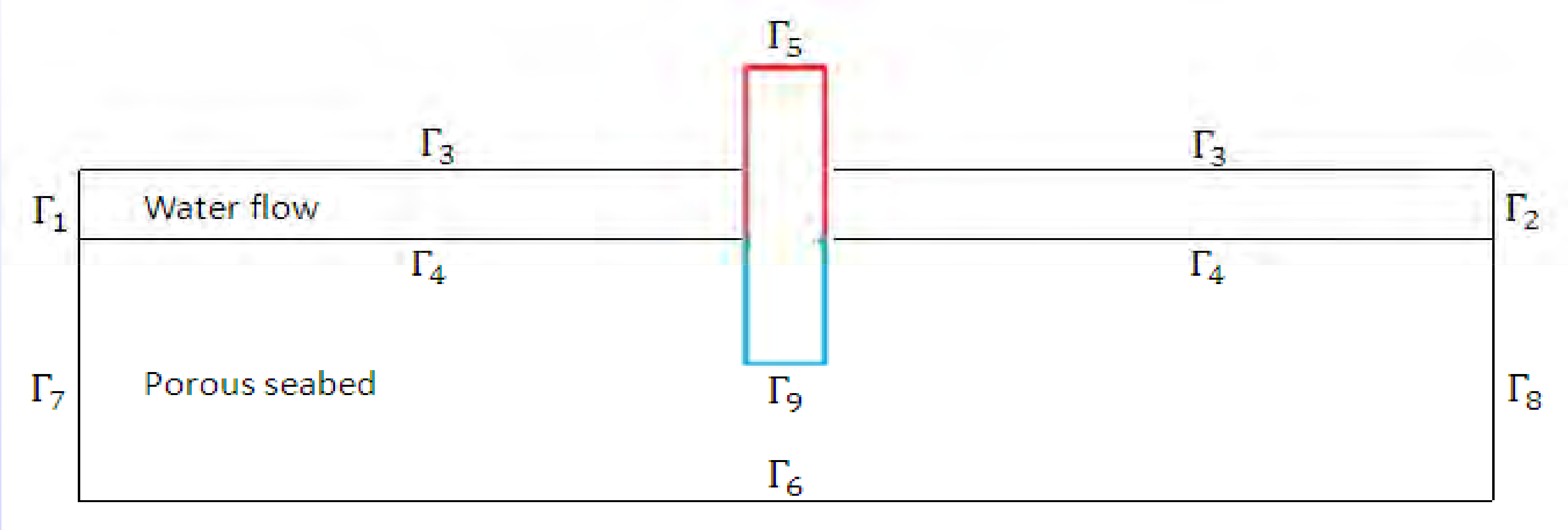
u_s: soil displacement in x-direction

$$G\nabla^2 w_s + \frac{G}{1-2\mu_s}\frac{\partial \varepsilon_s}{\partial z} = \frac{\partial p}{\partial z}$$

w_s: soil displacement in z-direction

2. Theoretical formulations

Boundary conditions (conducted in COMSOL)

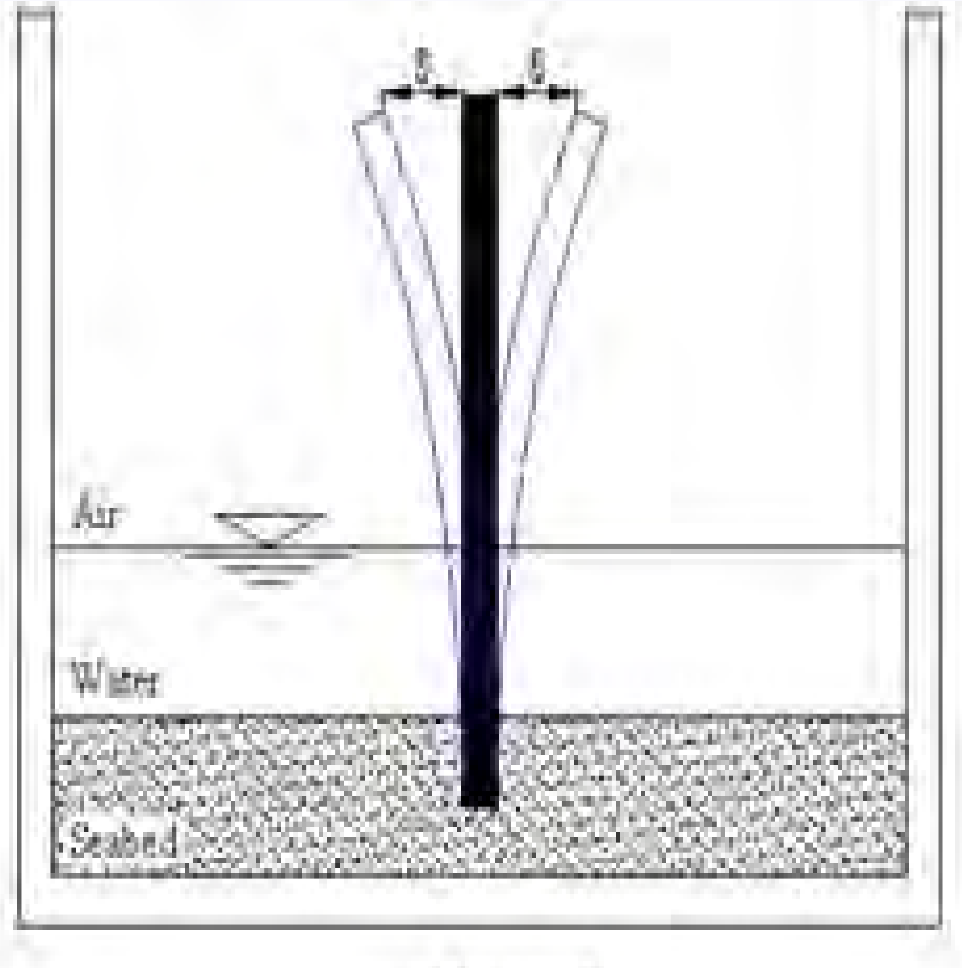


Γ1-2: sponge layer; Γ3: zero air pressure; Γ4: no-slip, flow pressure and shear stress to seabed mode; Γ5: no-slip, periodic wind force to structure; Γ6: impermeable sea bottom; Γ7-8: fixed wall; Γ9: no-slip, structure deformation to seabed.

3. Numerical results

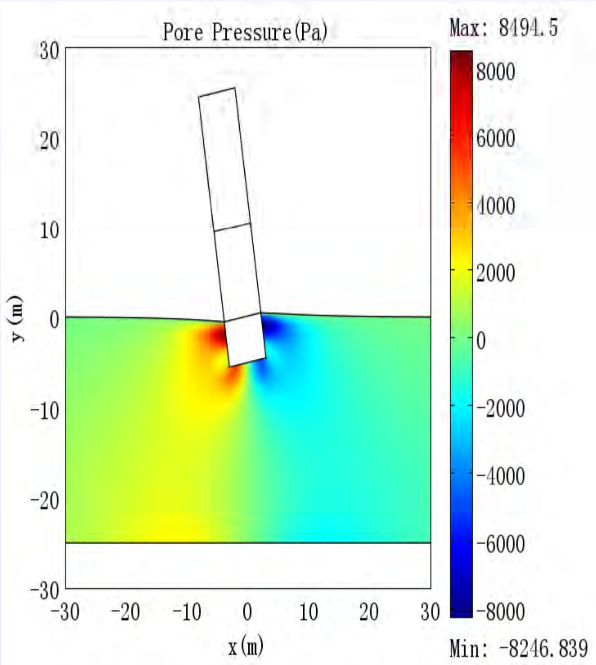
Table 1: Structure and soil characteristics	
Mono-pile diameter	**6 m**
Height above sea floor	**25 m**
Seabed thickness	**25 m**
Soil porosity	**0.3**
Shear modulus	**10^7 N/m^2**

Table 2: Parametric studies	
Soil permeability	**9.0E-3 ~ 1.5E-2 m/sec**
Multi-layer soil	**One-layer & two-layer**
Degree of saturation	**85% ~ 100%**
Embedded depth	**5.0 ~ 8.0 m**
Rocking period	**4.0 ~ 8.0 sec**
Rocking amplitude	**0.05 ~ 0.1 m**

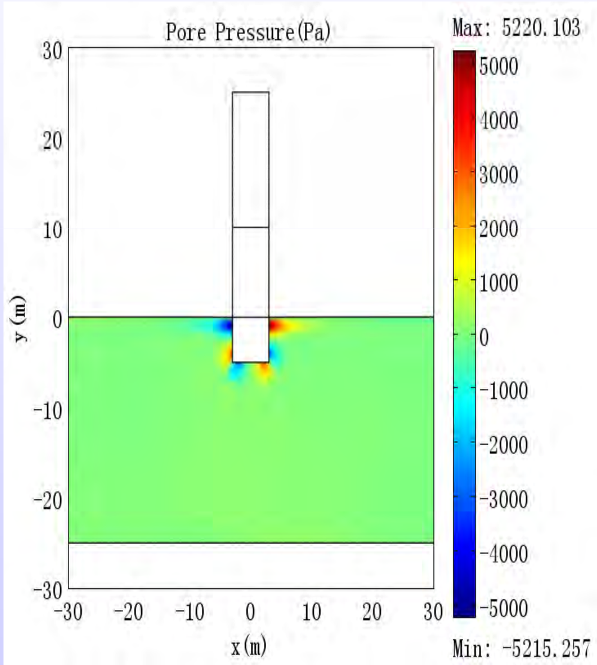


3. Numerical results

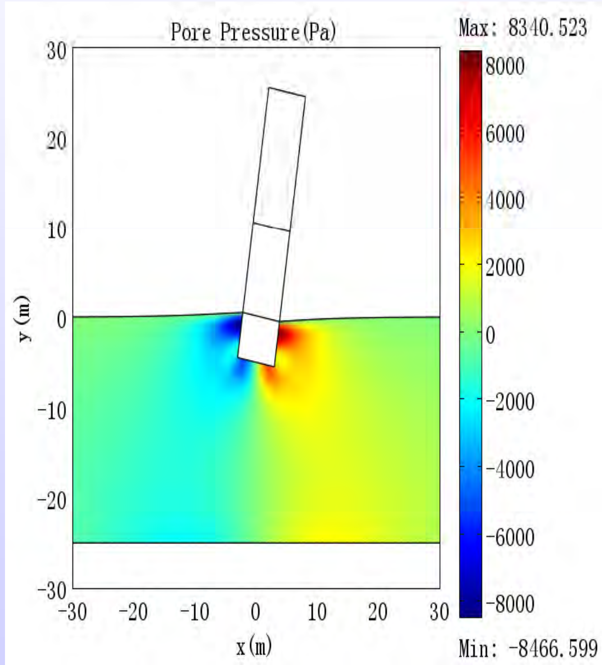
Distribution of rocking-induced pore pressure



t=T/4



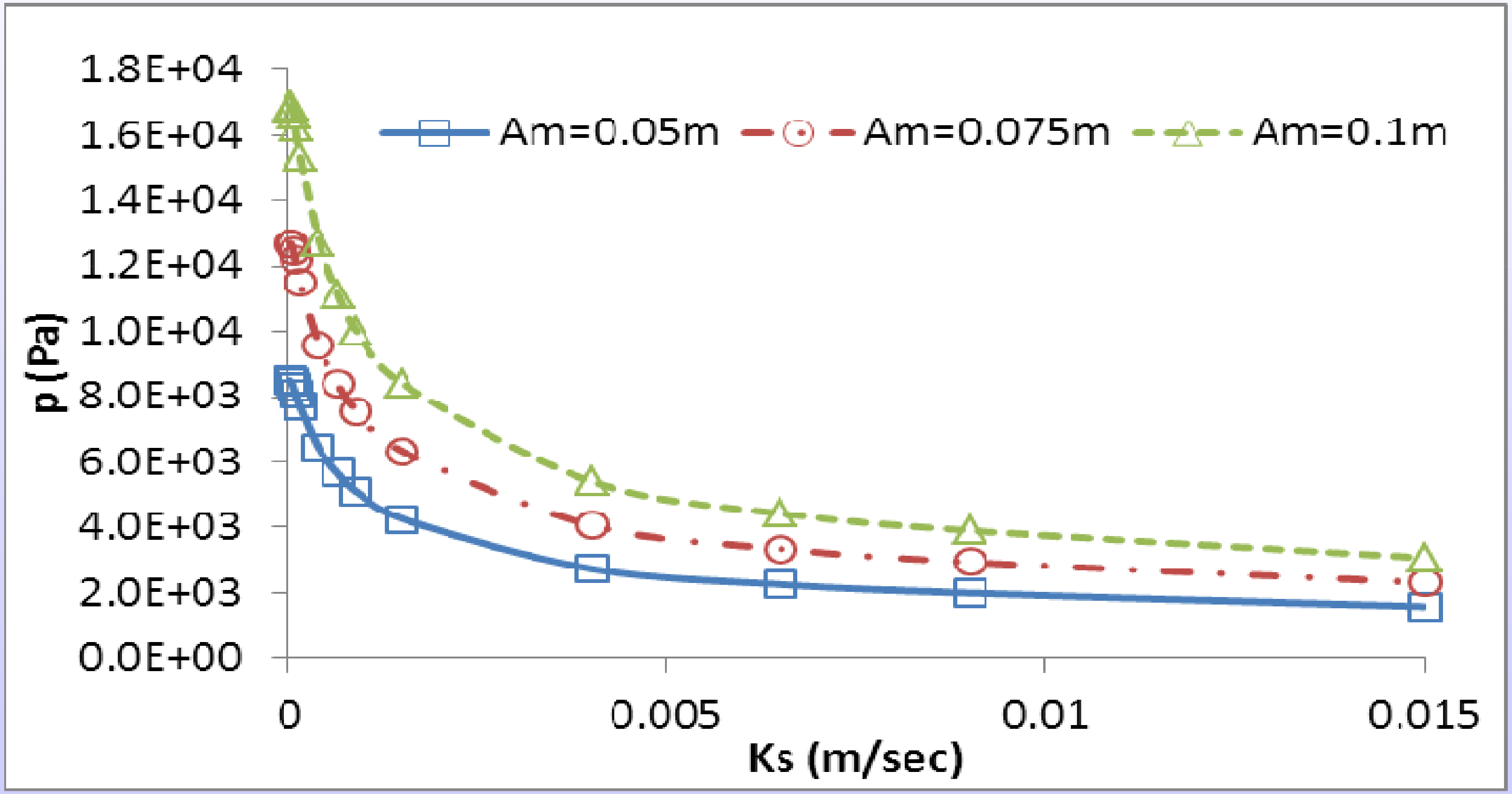
t=T/2



t=3T/4

3. Numerical results

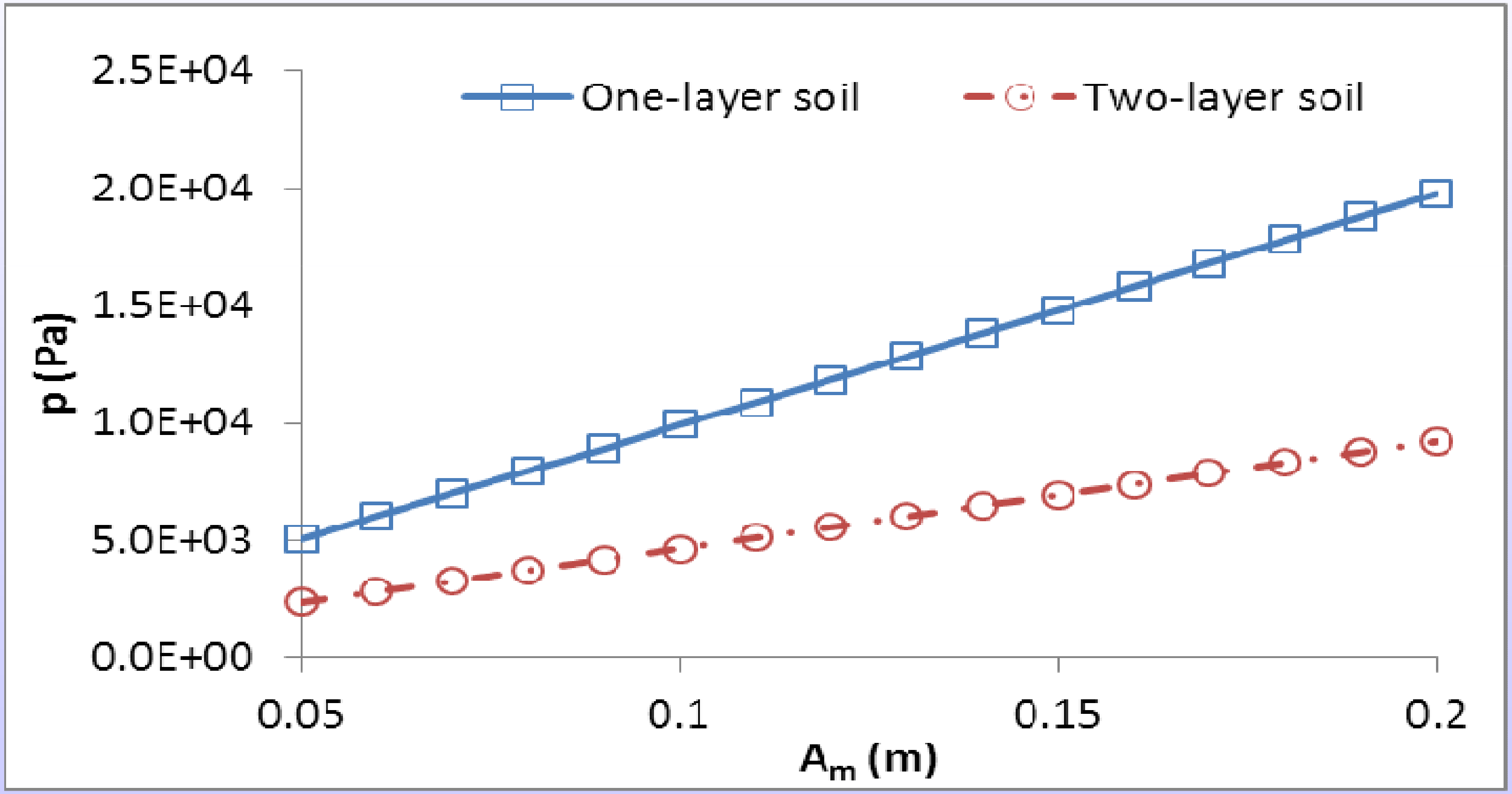
Effect of soil permeability on maximal pore pressure



S=0.95

3. Numerical results

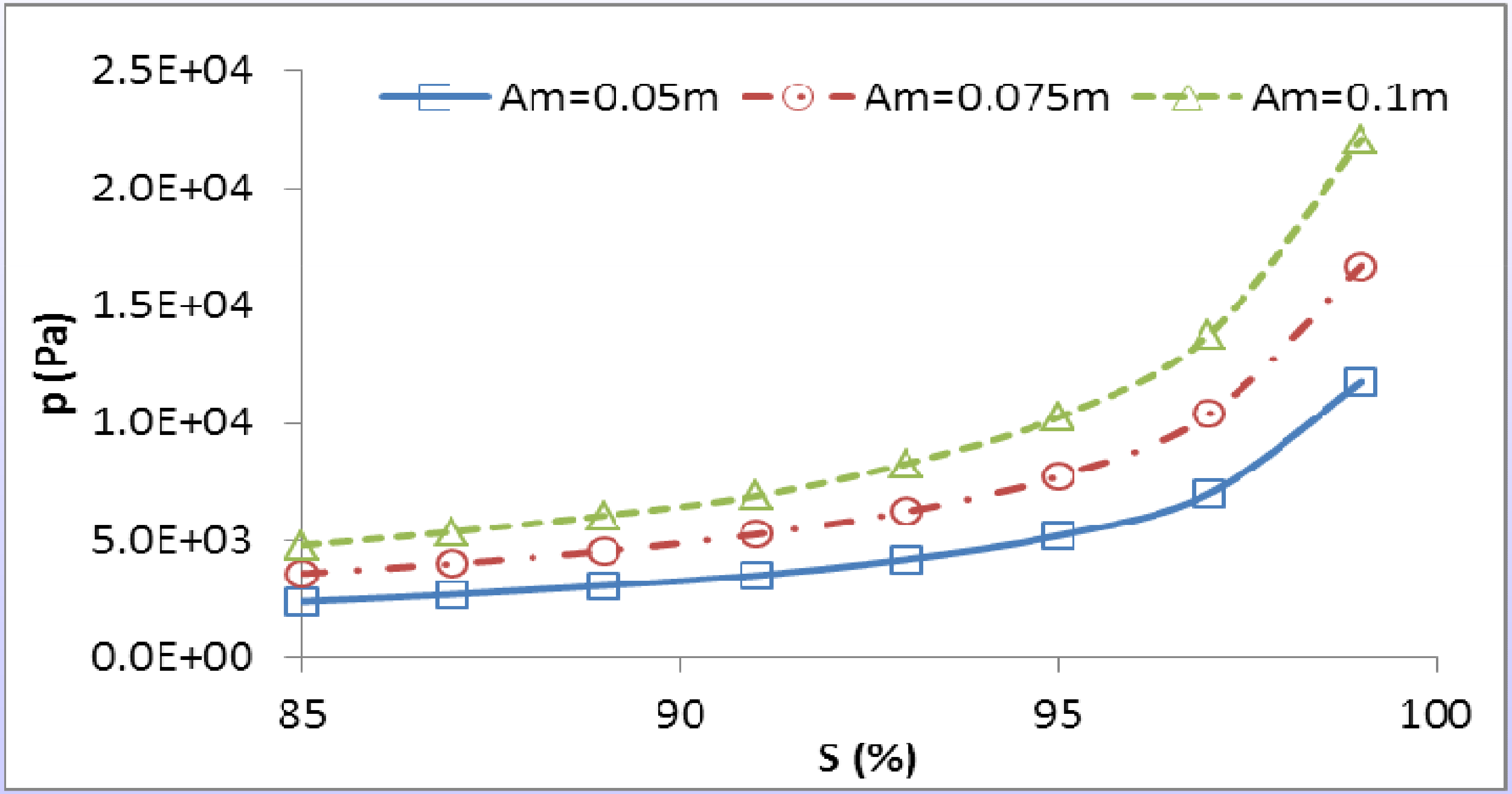
Effect of multi-layer soil on maximal pore pressure



Upper 2m soil with Ks=9.0E-3m/sec and the rest with Ks=8.4E-4m/sec

3. Numerical results

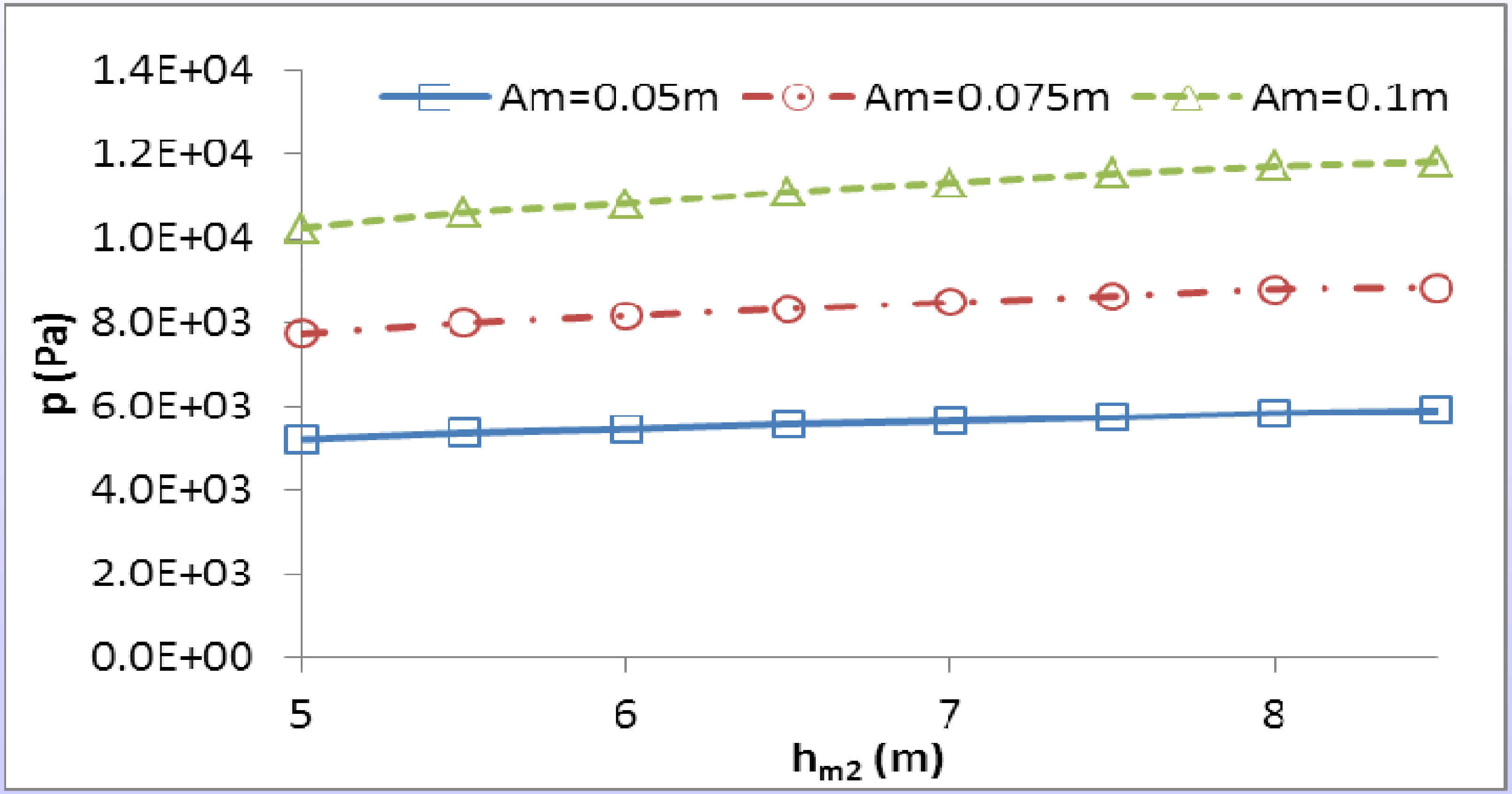
Effect of saturation degree on maximal pore pressure



Ks=8.4E-4m/sec

3. Numerical results

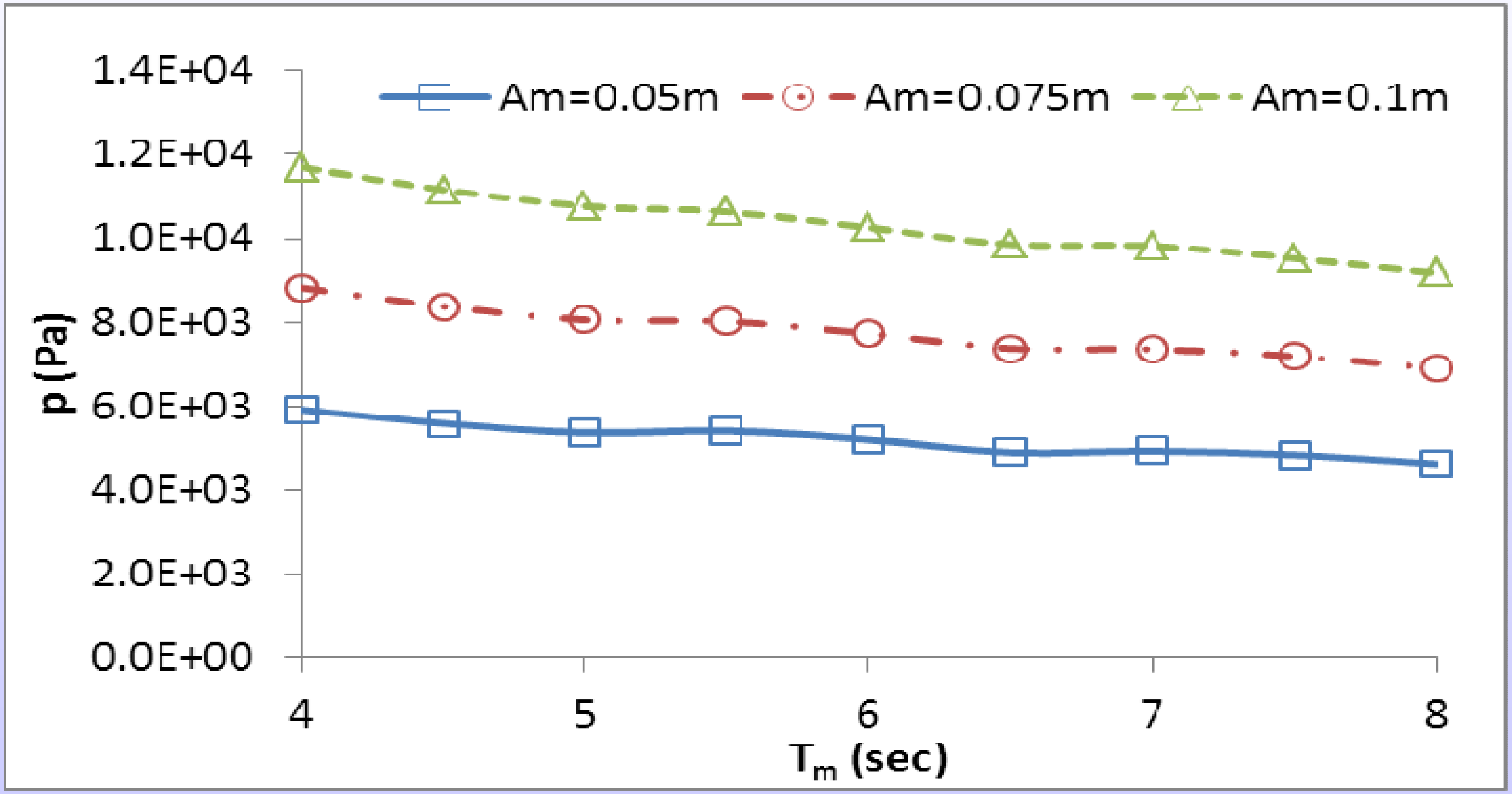
Effect of embedded depth on maximal pore pressure



S=0.95 and Ks=8.4E-4m/sec

3. Numerical results

Effect of rocking period on maximal pore pressure



S=0.95 and Ks=8.4E-4m/sec

4. Conclusions & future work

- The COMSOL Multiphysics has a good potential in modeling the rocking-induced seabed response.
- The seabed properties, structure dimensions and rocking parameters may significantly affect the rocking-induced maximal pore pressure.
- Further development and detailed validation of this integrated model are needed.

Many thanks for your attention!