APPLICABILITY OF PARTICLE METHOD FOR ANALYZING PERIPHERAL EFFECT DURING SEP VESSEL LEG PENETRATION

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1. INTRODUCTION

In December 2020, the Japanese government declared a goal to achieve a carbon-neutral, decarbonized society, by 2050 [1]. A "Green Growth Strategy" was formulated as a measure to achieve this goal and offshore wind power projects are currently being rapidly promoted. An important part of the offshore wind project works is the deployment of jack-up vessels. A jack-up vessel, as shown in *Fig. 1*, is a self-elevating vessel that can drive its legs into the seabed to raise its hull from the sea surface. *Fig. 2* shows the leg of the vessel, a truss structure with a large, flat, circular steel plate at the at the bottom known as the Spudcan. Spudcan distribute weight of the platform across a larger area of the seabed providing a stable platform for heavy lifting works to be carried out without being affected by the sea wave conditions. However, as common in most offshore foundation structures, Spudcan penetration can lead to large deformations. Thus, the study of leg penetration and its effect on the surrounding ground is very important.

Fig. 1 Self Elevating Platform (SEP) vessel

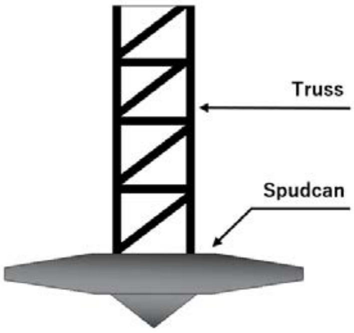

Fig. 2 Jack-up vessel spudcan

Finite Element Method (FEM) is a versatile method that is typically used to analyze deformations in geotechnical engineering. However, when it comes to simulating large deformations with material flow, FEM has its limitations. Offshore works such as leg penetration involves large deformations. Material Point Method (MPM), although more computationally expensive than FEM, helps make such analysis feasible. In this study a 2D model is used to study the applicability of MPM in simulating leg penetration in multilayered seabed and its effect on the surrounding area.

2. METHODOLOGY

Analyzing Spudcan penetration problems with conventional FEM methods is difficult because mesh twisting occurs when deformations become very large. In this study, a numerical approach using MPM is adopted. An axisymmetric formulation is used to study the applicability of MPM with a 2D model to simulate Spudcan penetration. An axisymmetric formulation enables the modelling of 3D phenomenon with the symmetric half of the planar model. The details of the adopted axis-symmetric formulation can be found in separate papers [2) 3)].

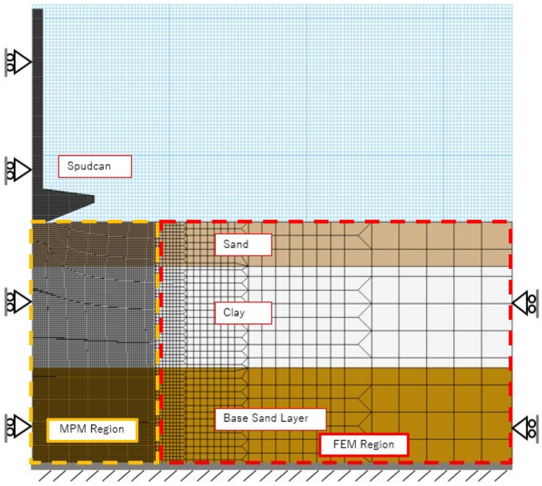

Fig. 3 Axisymmetric Analysis Model

Fig. 3 shows the analysis model. The seabed is divided into two computational regions. The area near the Spudcan is expected to experience large deformation and is modeled with particles using MPM. To decrease the computational effort for the simulation, areas further from the Spudcan that experience smaller deformation are modelled as elements. As for the boundary conditions the vertical sides of the model are fixed horizontally and the bottom boundary is fixed both horizontally and vertically. Three soil layers has been considered to verify the effect of varied soil strata on the penetration process. The soil parameters adopted for the model is shown in *Table 2*.

Key Words : *SEP Vessel, Material Point Method (MPM), Finite ElementMethod (FEM), punch through*
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Table 1 Representative values of Young's Modulus for Sand [4]

Soil Type	Es [kN/m²]	Φ [°]
Loose Sand	10,000 ~ 28,000	25 ~ 30
Medium Dense Sand	28,000 ~ 35,000	30 ~ 35
Dense Sand	35,000 ~ 70,000	35 ~ 40

Loose sand on top of clay has been considered since it is a feasible arrangement with potential risk for a punch through failure [4], a failure that occurs when the Spudcan penetrates from a strong to a weak soil layer. Parameters for loose soil was adopted from Dal et. al., as shown in in *Table 1* [5].

Table 2 Soil parameters for the model

	Φ [°]	c [kN/m²]	E [kN/m³]	γ' [kN/m³]	ν
Sand	30	5	10500	9	0.33
Clay	10	50	3500	7	0.45
Base Sand	40	5	2800	10	0.33

3. ANALYSIS AND RESULTS

The normalized penetration depth is represented by d/B, where d is the penetration depth and B is the Spudcan width.

・The flow mechanism due to deformation is consistent with the flow mechanisms visualizations from centrifuge test by Teh at al. [6], as well as mechanisms as proposed for shallow and deep foundations by Lee et al. [7]. Lee et al. observed that for shallower depths, the sand particles flow is restricted in the vertical direction but for deeper regions the flow turns side-wards with sand overflow occurring into the void region created by the penetration process. The slip surface of sand frustum can be seen to be close to vertical in *Fig. 5* for d/B = 0.896. This indicates a lower value of operational dilatancy angle which is consistent with the observations made by Lee et al.

・ The entire base of the Spudcan was already in contact with the soil at d = 0.263B. The leg penetration stops at a depth where the ultimate bearing capacity of the ground can suspend the preload from the SEP vessel. A layer of stiff soil is plugged between the Spudcan tip and the clay layer. This plugged stiff layer moves down and then sideways as the Spudcan penetrates deeper. The maximum displacement for this case was found to be d = 0.896B where the Spudcan has completely penetrated the clay layer.

・Figure 5 shows the boundary between MPM and FEM region at maximum deformation during the penetration process. The boundaries between MPM and FEM shows a smooth transition. Using FEM reduces the computation effort and while also help simulating lower deformations areas while MPM simulates the larger deformations.

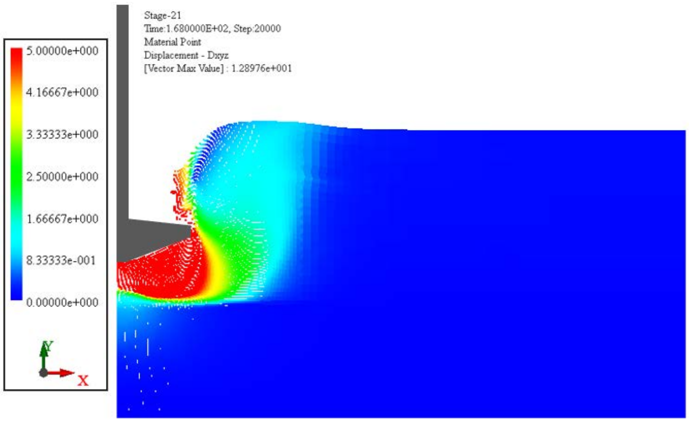

Fig. 4 Analysis result for displacement

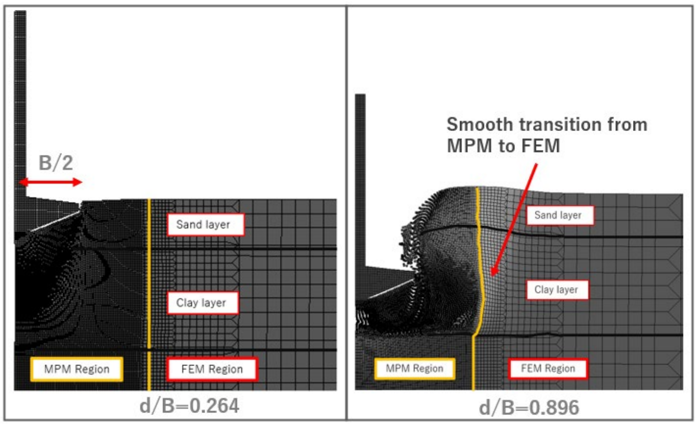

Fig. 5 Smooth deformation transistion from MPM to FEM

4. REFERENCES

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