Ⅲ- 9 STUDY ON VERTICAL BURIED SHELL WITH BOTTOM PLATE

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1. INTRODUCTION

As present design method on vertical buried shell with bottom plate such as sewage manhole, tunnel vertical shaft etc. does not consider the vertical stress acting on the shell and the rigid connection between the shell and the bottom plate, the method is not precise or rational. Through the previous analyses and experiments, it has become clear that the shell-plate theory analysis[1)], the centrifugal model test[2)], elastic FEM analysis and Elasto-plastic FEM analysis[3)] of one-load increment showed the same tendency. So, in this study, Elasto-Plastic FEM analysis with load increment is performed, and its results are compared and discussed with previous works.

2. ANALYSIS CONDITION

2.1 Analysis model

Elasto-plastic FEM Analysis is performed to a vertical buried shell with a bottom plate including ground that is 9m wide and 12m deep. The elasto-plastic FEM analysis for the prototype, of which the 1/60 model test was conducted by the centrifugal technique, is performed to be converted into the centrifugal model test. The slip-surface (shear spring constant $Ks=10^2$ N/mm, normal spring constant $Kn=10^5$ N/mm) is inserted between the vertical buried shell and the ground to examine the wall friction between them. **Fig. 1** shows the boundary condition, model dimensions and the load incremental condition.

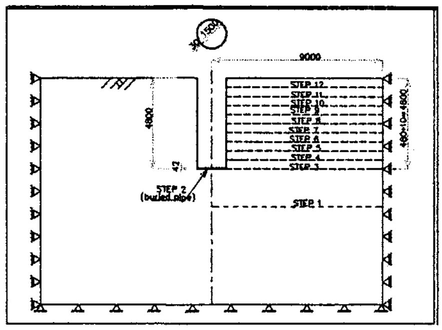

Fig. 1 analysis model

2.2 Material property

The shell is made of aluminum for the comparison with the result of the centrifugal model test. Buried shell made of concrete is replaced with shell made of aluminum which has same rigidity as concrete.

The ground is Toyoura standard sand which has 80% relative density. Duncan-Chang's constitutive law is used for FEM analysis. **Table 1** shows the material properties of a buried shell with a bottom plate and ground.

Table 1 material properties

	buried shell	ground
poisson ratio ν	0.33	0.272
breaking strength ratio Rf	-	0.86
cohesion C(N/mm^2)	-	0
angle of shear resistance ϕ	-	41°
Young's modulus E (N/mm^2)	700000	20
unit weight γ (N/mm^3)	6.9099×10^{-5}	1.5426×10^{-5}
atmospheric pressure Pa (N/mm^2)	-	0.10132
load exponent n	-	0.2
load factor K(ur)	-	341

3. RESULT OF ANALYSIS AND DISCUSSION

3.1 Deformation of ground

Fig. 2 shows the deformation of ground and the shell with the bottom plate. As demonstrated by **Fig. 2**, the vertical buried shell with the bottom plate sinks about 60mm. By the dead weight only, the shell with the bottom plate sinks about 2mm. The difference between the settlement of circumference of bottom plate and center of bottom plate is about 2mm, that shows the influence of wall friction acting on the shell and dead weight of the shell.

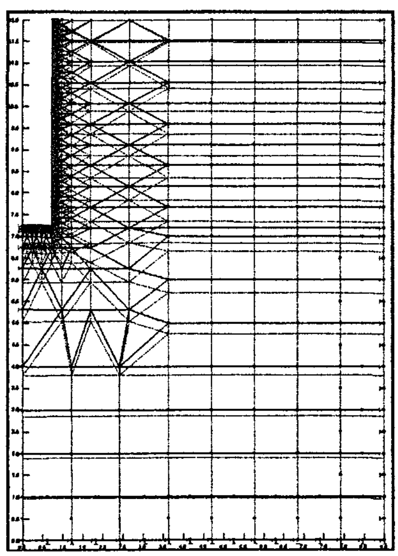

Fig. 2 deformation by FEM analysis

3.2 Stress, wall friction and earth pressure acting on shell

Fig. 3 shows the distribution of horizontal earth pressure acting on the shell. As shown by **Figs. 3-5**, all the curves have similar tendencies. The result of FEM analysis has the peak of horizontal earth pressure, where the principal stresses are reversed as shown by **Fig. 4**, although no peak is observed in the centrifugal model test and Jaky's earth pressure. All horizontal earth pressures acting on area close to the bottom plate are similar. As demonstrated by **Fig. 5**

extremely high stresses act on the area close to the bottom plate in comparison with other places. **Fig. 6** shows the distribution of the wall friction acting on the shell. In **Fig. 6,** there is an inflection point of wall friction in case of both 1-load incremental and load incremental elasto-plastic FEM analyses. The principal stresses reverse at the inflection point, too.

3.3 Stress and reaction force acting on bottom plate

Fig. 7 shows the distribution of the reaction force acting on the bottom plate and all reaction force curves except elastic FEM analysis have similar tendencies. At the area close to circumference of the bottom plate, the distribution of the reaction force acting on the bottom plate becomes complicated curve owing to influence of rigid connection between the shell and the bottom plate. Although the test value of the reaction force acting on the bottom plate shows good agreement with the calculated value at the center, the test value near the circumference is smaller than the calculated value.

4. CONCLUSION ANDFUTURE ASSIGNMENT

The conclusions in this study are as follows :

(1) Jaky's earth pressure can be used for the calculation of earth pressure.

(2) Extremely high stress acts on the area close to the circumference of the bottom plate.

(3) Stress acting on the shell reverses in the elasto-plastic FEM

(4) Owing to the influence of the rigid connection between the shell and the bottom plate, the distribution of the reaction force acting on the bottom plate becomes complicated curve at area close to the circumference of the bottom plate.

The further assignments are :

(5) The apparatuses for the centrifugal model test, especially, the measuring device for wall friction, should be developed.

(6) The estimation formulas of the external forces such as the horizontal earth pressure acting on the shell, the reaction force acting on the bottom plate etc. should be developed.

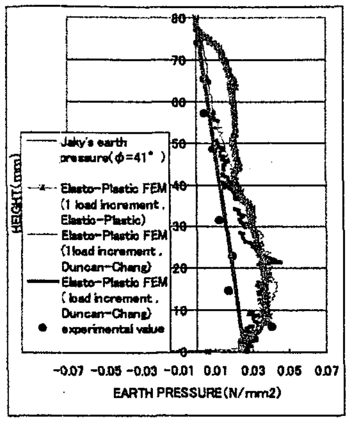

Fig. 3 distribution of horizontal earth pressure acting on shell

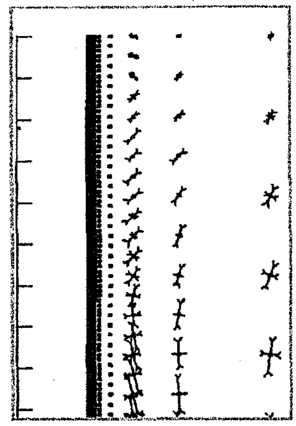

Fig. 4 distribution of principal stress

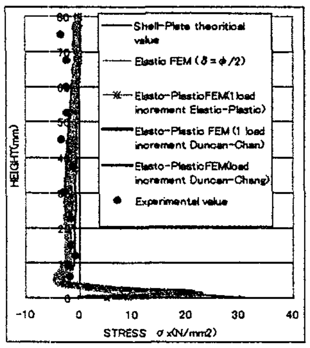

Fig. 5 distribution of horizontal stress acting on shell

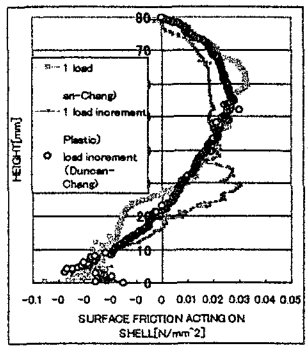

Fig. 6 distribution of wall friction

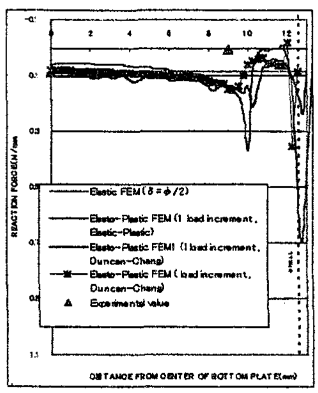

Fig. 7 distribution of reaction force acting on bottom plate

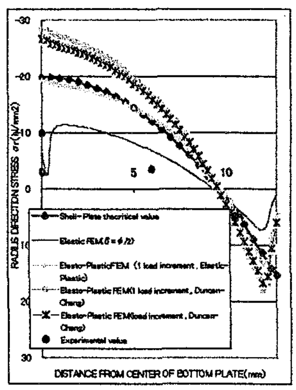

Fig. 8 distribution of radial stress in bottom plate

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