Shell Model FEM Analysis of Buried Pipelines under Seismic Loading

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ABSTRACT: This paper presents the development of a FEM program based on shell model for the analysis of buried pipelines subjected to sinusoidal seismic wave, differential settlement and dislocation of ground. Circumferential distribution of earth pressure and distortion of the cross section of the pipe, which can not be considered by the conventional method based on the beam model, were taken into consideration. Some comparison of the shell model and the beam model was made[1].

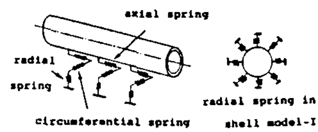

Fig.1 model of pipe-ground system

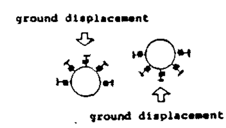

Fig.2 radial spring in shell model-II

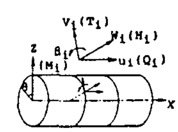
Fig.3 element in the sylindrical coordinates

MODEL AND ANALYSIS METHOD: Fig.1 shows the model(shell model-I) of pipe-ground system employed. An elastic continuous thin shell is supported by axial, circumferential and radial bilinear springs which are uniformly distributed on the shell surface. In order to considered the real distribution of earth pressure, another model (shell model-II) was developed for the analysis in which the radial spring was considered to be nonuniformly distributed along circumference[Fig.2]. Ground deformation is exerted to the thin shell from these springs. The matrix displacement method for the analysis of shell of revolution[2] was adopted for the numerical calculation.Fig.3 demonstrates an arbitrary element e_{ij} in the cylindrical coordinates. Assume the effect of inertia and damping to be negligible, the element governing equation can be written as[3]

$$\{f_{ijn}\}+\{p_n\}=([K_n]+[K_s])\{d_{ijn}\} \qquad (1)$$

where $[K_n]$ is the stiffness matrix of the pipe, $[K_s]$ the additional stiffness matrix due to the soil springs, $\{f_{ijn}\}$ the nodal force vector, $\{p_n\}$ the loading vector, $\{d_{ijn}\}$ the nodal displacement vector.

DISCUSSION OF RESULTS: In Fig.4 are illustrated the response values of a pipe induced by longitudinal wave with amplitude of 5cm, wave length of 100m and incident angle of 45. It is apparent that in the case of longitudinal wave loading where axial ground deformation is most significant, three models give approximately the same values of axial stress. In Fig.5 are demonstrated the results of a pipe subjected to differential settlement which is assumed to occur in the shape of a half wave length of a transverse wave travelling along the pipe axis with amplitude of 20cm and wave length of 20m. Shell model-I and the beam model obtain very close results, however, stresses obtained by shell model-II are much smaller. Obviously,in the case of transverse ground deformation loading, beam model and shell model-I evaluate too much stresses because they can not consider the real distribution of earth pressure. Fig.6 presents the results of a PVC pipe buried in stiff ground disturbed by a transverse wave travelling along the pipe axis with amplitude of 5cm and wave length of 65m. It is found that quite large circumferential stress occurred due to the distortion of the pipe cross section. Other calculations reveal that the effect of this distortion may become significant only when the pipe is very thin or the ground is stiff.

<u>CONCLUSIONS:</u> Program SMFABP developed in this paper is proper for the calculation of buried pipelines subjected to sinusoidal wave, differential settlement and dislocation. By using SMFABP, we found that the distribution of earth pressure has great influence on the stresses of buried pipes subjected to transverse ground deformation; differential settlement can generate much larger stresses than other kinds of loads; beam model is suitable only for the axial ground deformation loading.

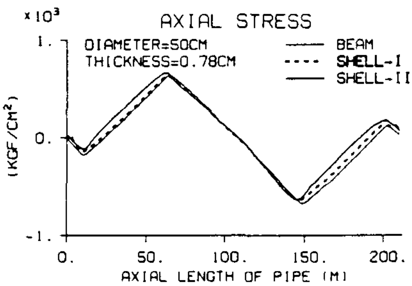

Fig.4 PIPE UNDER LONGIT. WAVE

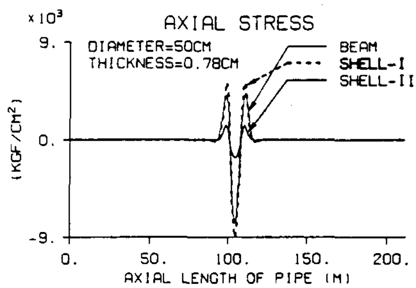

Fig.5 PIPE UNDER DIF. SETTLEMENT

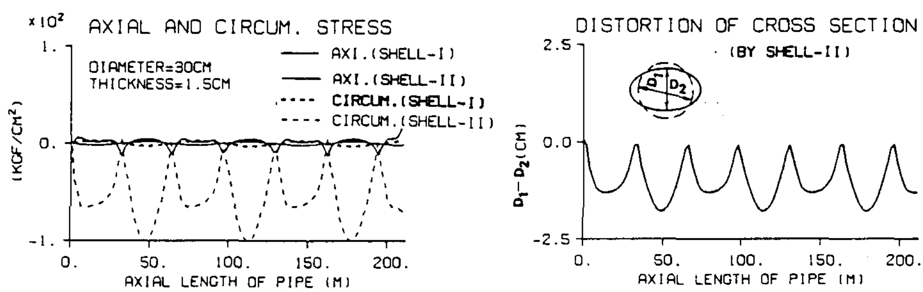

Fig.6 PVC PIPE UNDER TRANS. WAVE

<u>REFERENCES:</u>

1) S.Takada,K.Tanabe,"Three-dimension seismic response analysis of buried continuousandjointed pipelines",Transactions of the ASME, 80/ Vol.109,Feb.,1987.

2) S.Kawamata,"Shell structure analysis",structural engineering lecture based on computer II-6-A.

3) R.Yang,"Shell model-FEM analysis of buried pipelines under seismic loading", Master degree thesis, civ. eng. dep.,Kyoto Univ.,Feb 13,1988.