Spatial Variation of Wave Propagation from a Cylindrical Foundation Embedded in an Elastic Stratum

by

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1.Introduction

It is very important for the analysis of soil-embedded structure interaction to grasp how waves propagate from a the foundation embedded in an elastic stratum. Wave propagation on the surface of a model ground was visualized by Konagai and Maehara[(1)] and the validity of the assumption of plane-stress condition in the Quasi-Three-Dimensional Model, developed by Tamura et al.[(2),(3)], was confirmed. Visualization of spatial wave propagation of model ground provides us with useful information needed for the evaluation of the dynamic soil-embedded structure interaction. In this study, soft poly-acrylamide gel and moire grid with rubber-like flexibility were used for the visualization of wave propagation.

2.Visualization of wave propagation

2.1 Experimental setups

An artificial soil medium, made of transparent poly-acrylamide gel was prepared in an acrylic box (57x57x13.5cm). An acrylic cylinder with radius of 50 mm was embedded in it as shown in Fig.1. This cylinder has a small cone of brass on its bottom so that it can rock on the bottom of the acrylic box. A force transducer with an aluminum plate was fixed on the side of the cylinder 6cm above the artificial ground surface. A solenoid coil (0.18mH) was attached close to the aluminum plate, then the discharge of a capacitor (DC 3000v,50μF) through the solenoid coil served as an impulsive energy source (Fig.2).

Moire technique was applied to the visualization of wave propagation. Black stripes of 0.5mm thickness were printed at an interval of 1.0mm on a sheet of paraffin paper. The ingredients of the ink include synthetic rubber, phenol resin and pigment. Since it is difficult to stick the stripes directly onto the surface of the artificial ground, the stripes were stuck on the medicinal wafer (*oblaat*), first. Then the wafer was applied to the surface and to the surface of a vertical cross section of the model ground. The placement of wafer sheet stuck with stripes needs some preparatory procedures to be put within the model ground. To begin with, a partition was mounted in the center of the empty acrylic box. Then the liquid, material of the poly-acrylamid gel, was poured into one of the separated area and after it cured, the partition was removed. The wafer sheet was put on the vertical cross section of the model and finally, the same liquid was poured into the other part of the box. Since the material of stripes is rubber and the medicinal wafer sheet

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becomes very soft absorbing water, the stripes follow the motion of the gel very well. The moire fringe shows the contour of displacement in the orthogonal direction of the stripes. A reflex camera, a xenon lamp and retarder to delay the lighting of the xenon lamp were used to take pictures of moire fringes. Stripes before excitation and after excitation were photographed and superimposed on one frame of film so that moire fringes appear.

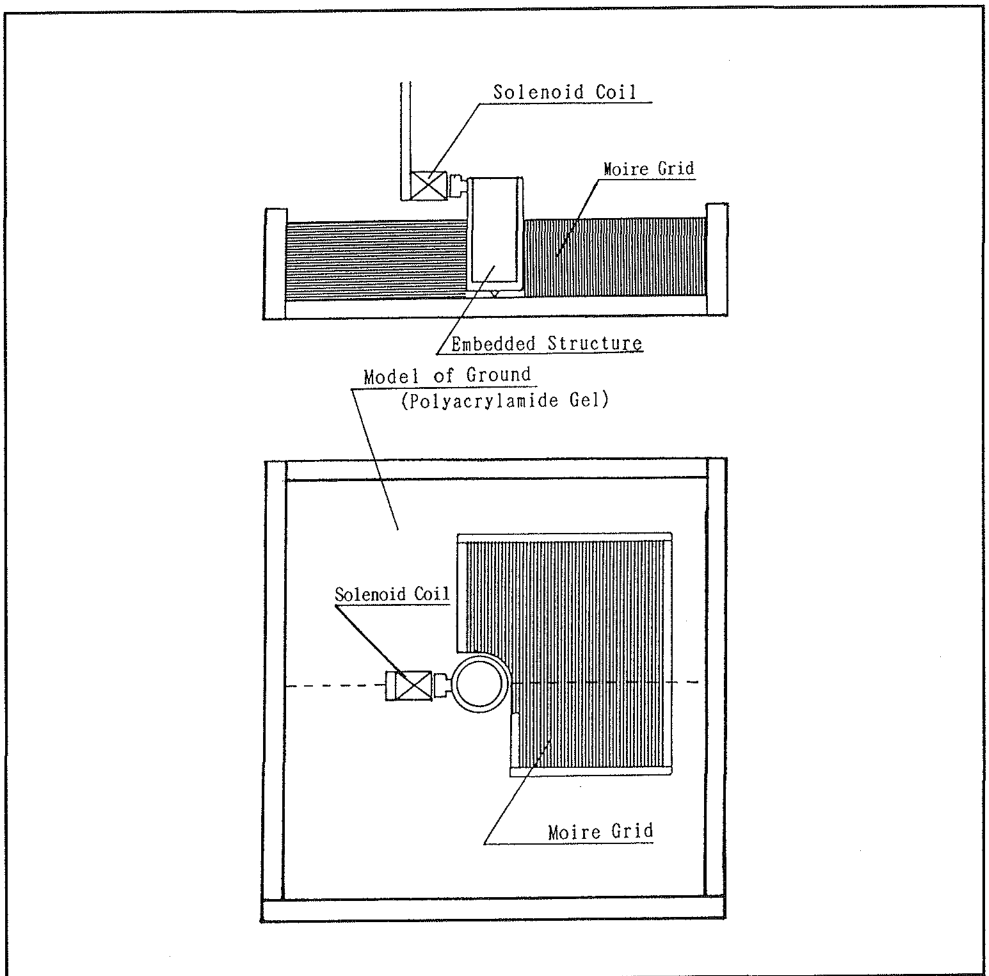


Fig.1 Soil-embedded structure model

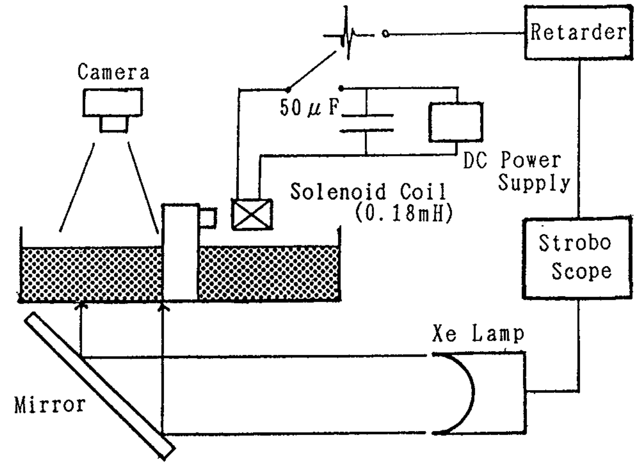


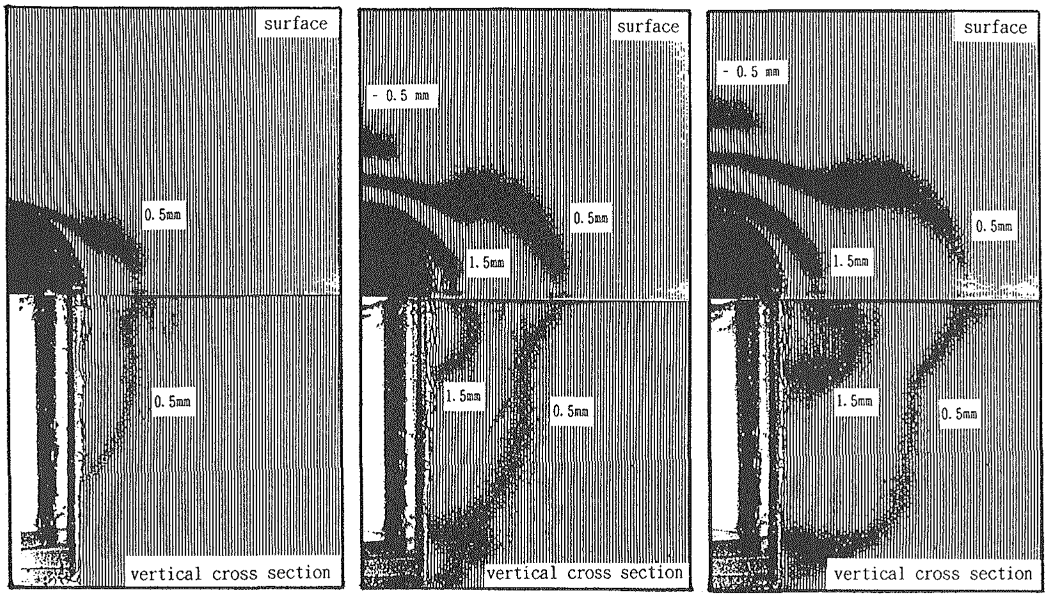
Fig.2 Experimental setups

2.2 Experimental results

Observed moire patterns on the surface and within the model are shown at the top and the bottom in Photo 1, respectively. Since an impulse was applied in the normal direction to the stripes, the moire fringe shows the contour of displacement in the direction of the impulse. For example, displacement of 1.5mm and 0.5mm moire fringes appear clearly. A shear wave front propagates in orthogonal direction to the excitation, and another different clear wave is observed in the longitudinal direction. The latter propagates at double the speed of the shear wave fronts as shown by Konagai and Maehara(1). A wave, propagating in the opposite direction to the excitation, appears in the orthogonal direction to the excitation. The bottom of photo 1 indicates that curvature of moire fringes rapidly changes near the surface due to the stress-free condition at the boundary.

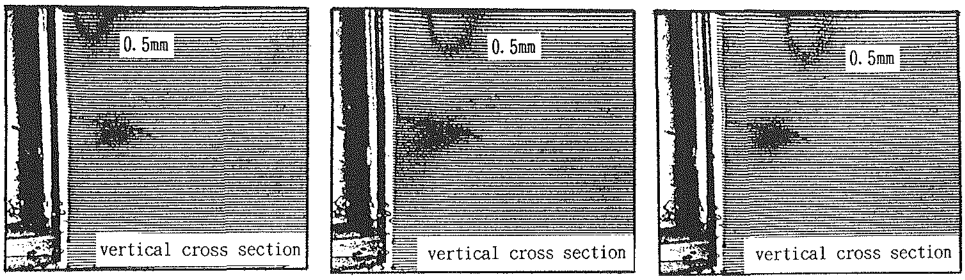
In Photo 2, moire fringes show 0.5mm displacement in the vertical direction since stripes were stuck parallel to the horizontal line. Maximum displacement of the model ground is about 2mm (at t=5ms) in horizontal direction. Though vertical displacement is less than the horizontal one, the former cannot be ignored near the caisson.

In photo 3, since stripes were placed parallel to the excitation direction, these moire fringes show the contours of displacement in orthogonal direction to the excitation.
The contour appears and propagates at angle about 45° from the excitation direction in the counterclockwise direction.



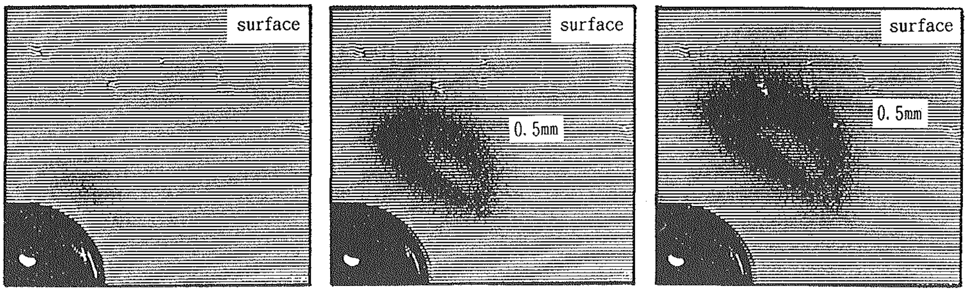
t = 2. 5 ms t = 5. 0 ms t = 7. 5 ms

Photo 1. Observed moire fringes
(horizontal displacement in the excitation direction)



t = 2. 5ms t = 5. 0ms t = 7. 5ms

Photo 2. Observed moire fringes
(vertical displacement in the excitation direction)



t = 2. 5ms   t = 5. 0ms   t = 7. 5ms

Photo 3. Observed moire fringes
(horizontal displacement in the orthogonal direction to the excitation)

3. Evaluation by Quasi-Three-Dimensional Model

A numerical simulation was made with Quasi-Three-Dimensional Model by using finite difference method. Fig.3 shows the concept of the model. Surface layer in which the rigid caisson is embedded is divided into many soil columns. Triangular mode shape of each soil column is adopted to the simulation because rocking of the rigid caisson affects strongly to the surrounding soil. Plane-stress condition is assumed to the Quasi-Three-Dimensional Model under stress-free condition on the surface. Observed displacement of the caisson was used as an input motion. Motion of caisson was computed until 7.5 ms in the area of 200 mm × 200 mm being set a quarter of the caisson at the corner of the area. Both longitudinal and transverse waves under the plane-stress condition do not reach the boundary until 7.5ms.

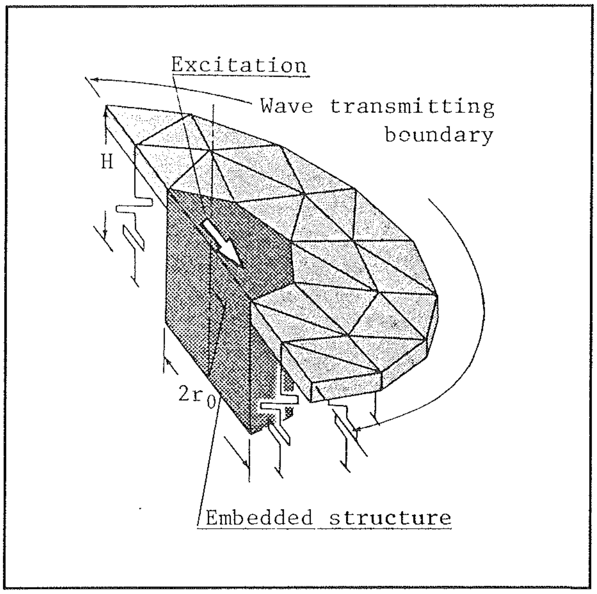


Fig.3 Model of surface medium

Fig.4 shows simulated moire fringes on the surface and within the model corresponding to the top and the bottom of photo 1, respectively. The fringe nearest to the caisson shows contour of displacement with ±0.1mm range (0.4mm ~ 0.6mm, 1.4mm ~ 1.6mm). On the surface, the 0.5mm simulated fringe agrees well with observed one but the 1.5mm fringe is overestimated. On the vertical cross section, simulated moire fringe agrees with observed one just after the impulse was applied. But the difference between these two becomes bigger as time goes on. This indicates that it is reasonable to assume triangular vibration mode of the ground near the caisson but far away from the caisson, higher vibration modes cannot be ignored.

Fig.5 shows contour line of displacement in orthogonal direction to the excitation corresponding to the photo 3. The pattern of ring-like fringe agrees well with the observed one.

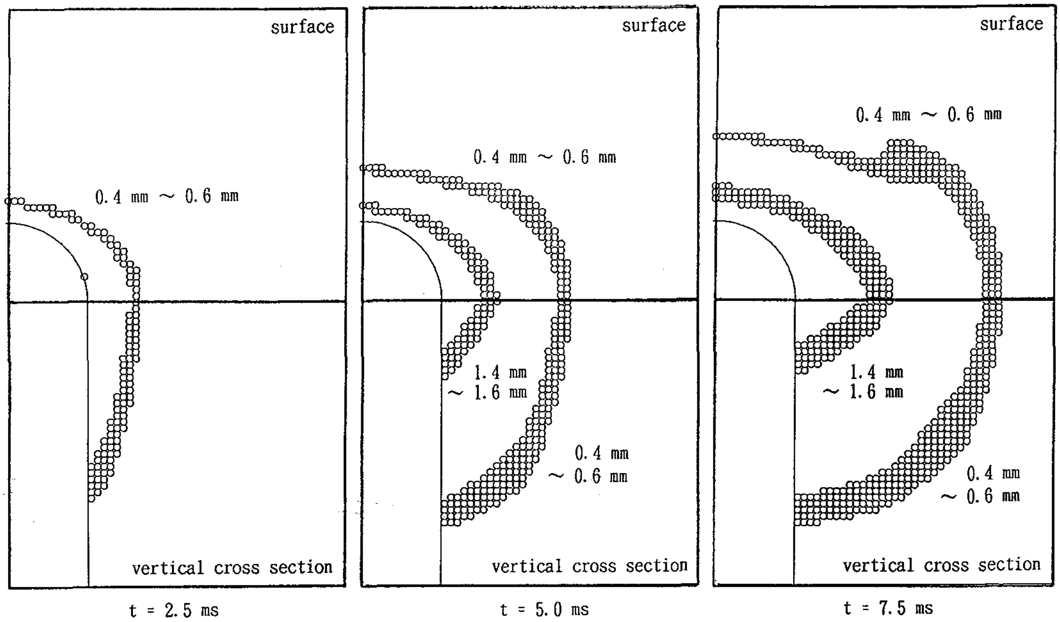


Fig.4 Simulated moire fringes
(plane-stress condition, corresponds to Photo 1)

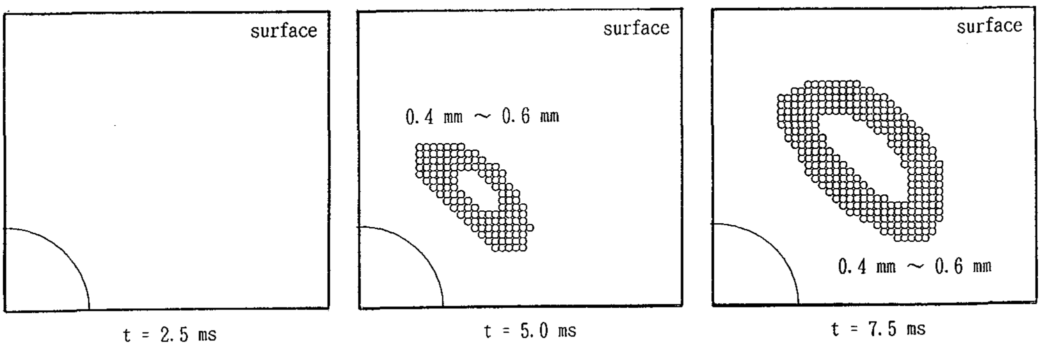


Fig.5 Simulated moire fringes
(plane-stress condition, corresponds to Photo 3)

4.Conclusions

Spatial wave propagation from a caisson was visualized by means of a model experiment using poly-acrylamide gel as a material of the ground. Knowledge obtained from the experiment is summarized as follows:
(1)It is reasonable to assume triangular vibration mode for the soil near the caisson but higher modes affect the vibration mode of the ground which is far away from the caisson.
(2)Vertical motion of the model ground (Poisson ratio ≈ 0.5) is 1/4 ~ 1/2 of the horizontal one near the caisson. Though vertical displacement is less than the horizontal one, the former cannot be ignored. The effect of stress-free condition on the surface can be considered by assuming plane-stress condition on the Quasi-Three-Dimensional Model.

Acknowledgement

Our special thanks are due to Professor Choshiro Tamura, Department of Industrial Technology, Nihon University, for helpful suggestions and comments.

References

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