FEM-BASED INVERSION OF SURFACE WAVE METHOD AT EARTH-FILL DAM

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Introduction

As a kind of non-destructive seismic method, Surface-wave methods could be performed on surveying the stiffness of near-surface. Procedures of the methods are data acquisition, processing and inversion. The method we used in site investigation were Common Mid Point Cross Correlation Analysis (CMPCC)[1]. Geophone array of CMPCC is similar to Multichannel Analysis of Surface Waves Method (MASW) which requires Multichannel acquisition system consisting of 24 geophones and a seismograph. But for CMPCC, the difference is that seismic sources will be created between every two geophones by sledge hammer. Spectral analysis are used for inversion in conventional methods. Once we acquire data of wave, using CMP Cross-correlation Analysis can assist us in inversion processing and derive S-velocity structures. This research proposes a new simplified method for inversion by comparing first arrival between finite element modeling and in-situ investigation. By employing the FEM, any problems for various boundary conditions and heterogeneous media can be solved, easily. We created 2D finite element model with same scale as field observation and apply loads in short period to simulate the shot. Then compared the response of FEM models with data obtained from field observation to calculate errors. By adjusting parameter (Young's moduli) of FEM models, we can minimize errors and find optimal parameter as our solution of inversion.

Field Survey

In this research, we used data acquired at embankment of an earth-fill dam, which is located in Okayama. The diagram of survey lines is shown in Figure1. The investigation covered the whole levee by three lines and the wave data of first line were used in analyses. 24 geophones were set straight with 2m spacing on top of the levee, and 25 impacts were made between those receivers. Figure 2 shows array of geophones and shot gathers at first impact.

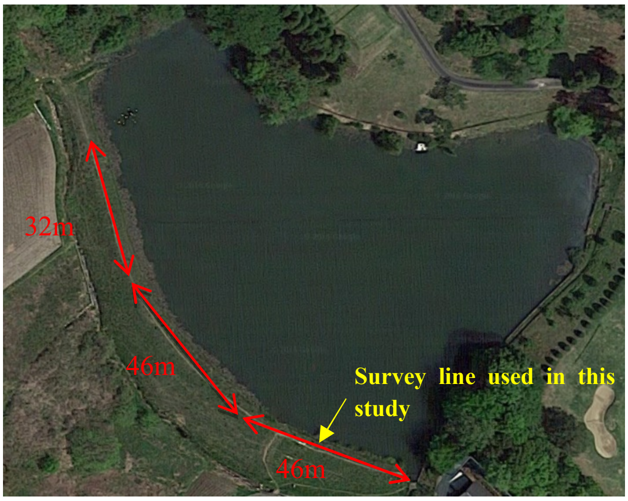

Figure 1 The survey lines on dam

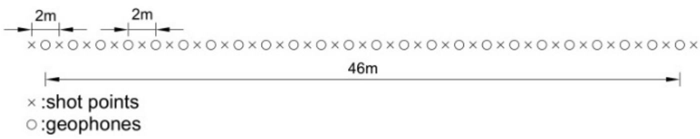

Figure 2(a) array of geophones and shot points

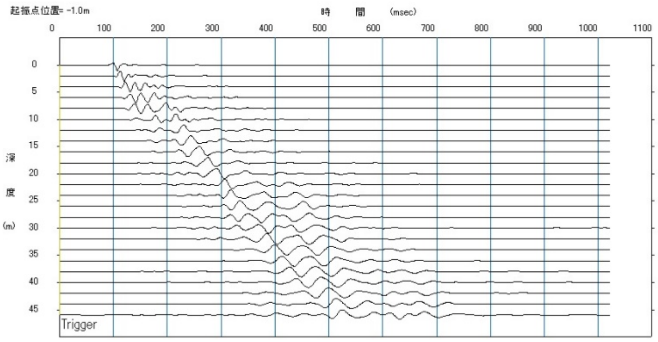

Figure 2(b) An example of observed shot records.

FEM Simulation

An FEM software named Quake3D[2] was performed on simulating wave propagation. The 2D model is 90 meters in length and 20 meters in height. Even though length of the line which have been surveyed is just 46m, we need a longer model to eliminate the influence of refraction at boundaries, because we have not implemented viscous boundary on this model. Figure 2 shows the model. In the main area, the size of elements in horizontal direction are set to 1m and 2.5m in vertical direction. To remove spurious oscillations resulting from oversize mesh dimensions[3]), elements, around every shot point (2m), were divided into 40 meshes on the horizontal direction.

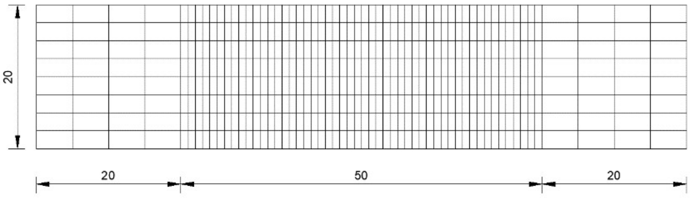

Figure 3 FEM simulation model

Figure 4 shows response of model at the first impact.

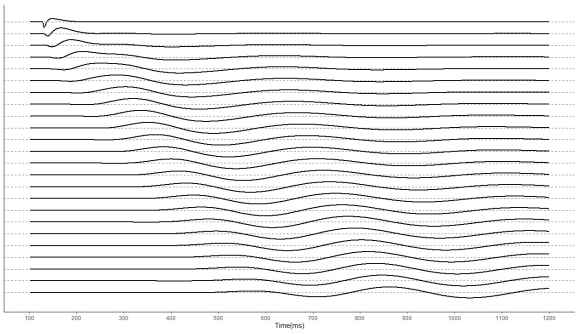

Figure 4 An example of FEM model response

In line with the field survey, the dynamic load should be applied on different nodes and the response should be solved at every time corresponding to the load change. In other words, we need to solve one model 25 times with different loads.

The errors between FEM simulation and field survey can be defined as difference between each first arrival. We used the method introduced by JGS Standards[4]) to distinguish first arrival from record of field survey manually. As for the FEM simulation, because there is no disturbance in records, it is ease to distinguish first arrival when the amplitude exceeds a certain value. Regarding the first arrival of geophone which is most close to the shot point as beginning can make it easy to create objective function Eq. (1).

$$F = \sum_{j=1}^{j=25} \sum_{i=1}^{i=24} \left[(t_{ij} - t_{1j}) - (T_{ij} - T_{1j}) \right]^2 \quad (1)$$

t_{ij}: first arrival recorded in field survey shot gathers

T_{ij}:first arrival in FEM simulation

Golden-section search are performed on finding the minimum of the objective function. After 6 searches, we can ascertain with this model, that the Young's moduli which lead a minimum error could be within (35835.95, 36393.21) kPa. The nearest value we calculated is 36180.30kPa and a comparison of first arrivals between simulation and field survey in this situation is shown in Figure 5. In this research, that value is the solution of inversion process.

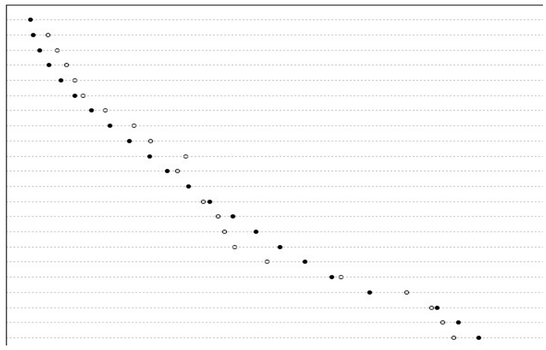

Figure 5 A comparison of first arrivals between simulation and field survey

Conclusion

This research has tried to study a new simplified method for inversion of surface wave methods by combining finite element modeling and optimization. Finite element modeling can be a tool for finding a first arrival of surface wave with certain parameters. Simple optimization technique performed well, while using a homogeneous medium for the finite element simulation. Although the complex models such as heterogeneous medium ask for complicated techniques to find optimal solution, the heterogeneous media should be solved as a next step.

References

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(2) The Japanese Geotechnical Society, Using Elastoplastic FEM, Maruzen,2003

(3) A. Zerwer, G. Cascante, D. Jean Hutchinson, Parameter Estimation in Finite Element Simulations of Rayleigh Waves, Journal of Geotechnical and Geoenvironmental Engineering , March 2002

(4) Japanese Geotechnical Society, Geotechnical and Geoenvironmental Investigation Methods Table of Contents, Maruzen Publishing, 2015