INTEGRATION OF ELASTIC WAVE VELOCITY INTO BIM OF DAM FACILITY

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Abstract
As for building information modeling (BIM), digital twin of point-clouds of spillway of a rock fill dam is demonstrated. Reproduction of existing structures with point-clouds from still or movie images are shown. Necessary information in addition to the point-clouds such as surface and internal condition of the structure are depicted. Information such as surface deterioration condition as well as internal condition composed of elastic wave velocities, which will be crucially important to realize life-cycle-oriented design, construction, and maintenance, is incorporated into the digital twin. Through the suggested model, overall damage of the spillway is discussed in combination with the pin-point excavations for the verification. Through the life cycle of the civil engineering structures roles of elastic wave approaches will be suggestively indicated.

1. Introduction

Digital twin/ tandem of civil structures is mandatory to start the digital transformation for civil infrastructures. Reproduction of existing civil structures on the computer display is the first step to manage them through the life. This is well implemented by using point-clouds generated from still images and videos. Bisides, surface condition shall be incorporated into the reproduced digital twin linking to real images. Currently reproduction of the existing structures with point-clouds and incorporating surface condition are thus enthusiastically studied elsewhere. As known, an urgent matter to tackle in existing infrastructure is to establish rational countermeasure against ones rated to be seriously ill and therefore the digital twin with surface condition will suffice the requirement to make a decision; however, to propose the reasonable maintenance program or establish a proactive maintenance program for the future, internal information of the structures will be essentially obtained. In this study, the internal condition will be visualized by elastic wave parameters as velocities through elastic wave tomography approaches.

A 40 year-old spillway of a rock fill dam is composed by orifice gate of concrete side walls is investigated for the damage by elastic wave tomography. Cracks along steel reinforcement and precipitation of efflorescence, seemed to be led by ASR (alkaline silica reaction), were observed. Substantial crack widths are 4 mm in bank side walls, 7 mm in lower current side wall, respectively. At present structural integrity due to ASR seems to be attributed only to these crack widths information without internal deterioration information. Tomographic reconstruction with elastic wave velocity is thus expected to replace those conventional idea only from surface condition. A 30 kHz resonant accelerometer is employed and arrayed in a space of 1.3-1.5 m. A spherical steel ball of 30 mm in diameter is used to excite the elastic waves. The excitations are made on the opposite side of sensor installation side. 10 times excitations in every designated point are made and stacked to eliminate noises, then recorded with a 200 kHz sampling rate.

2. Results

Tomogram is demonstrated as in Fig. 1. In Fig. 1, 2D sectional tomograms from section 1-5 are depicted. A good agreement of the location of serious surface cracks and areas showing small velocity as less than 3000 m/s is obvious indicated by a red circle in section 1 of Fig. 1. The surface crack condition of left bank side and 3D tomogram are shown in Fig. 2, where the binarized image based on the velocity of 3500 m/s is demonstrated in the middle of Fig. 2. Red areas show the velocity less than 3500m/s while the blue shows it larger than 3500 m/s. It is obvious that serious crack locations are well identified with red areas. It is noted that the area where surface cracks are observed on the left bank side (see the right photo of Fig. 2), there was no area of red, showing the velocity less than 3500 m/s, suggesting that the crack on this left bank surface will not be expanded into a deeper area of the wall. This estimation was subsequently verified by borehole cameras' observation after excavating holes up to 50 cm depth. The deepest cracks could be observed up to 13 cm depth. This result are well accorded to the estimation by the tomography.

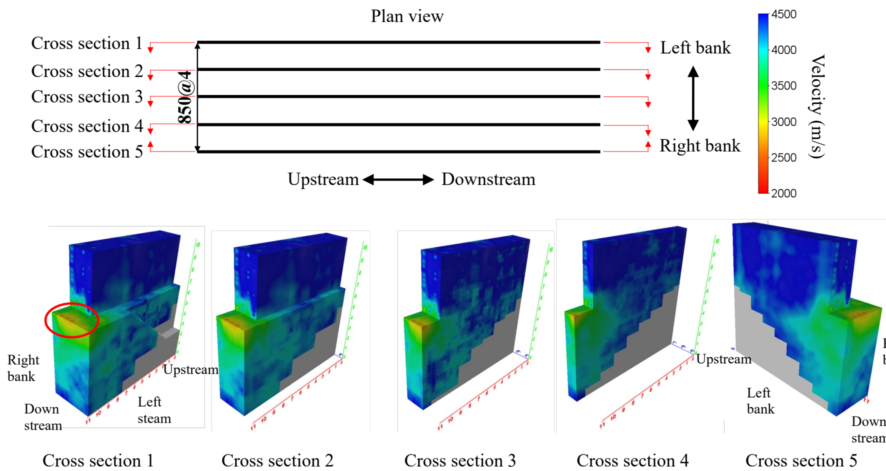

Fig.1 – Distributions of elastic wave velocity (Tomogram).

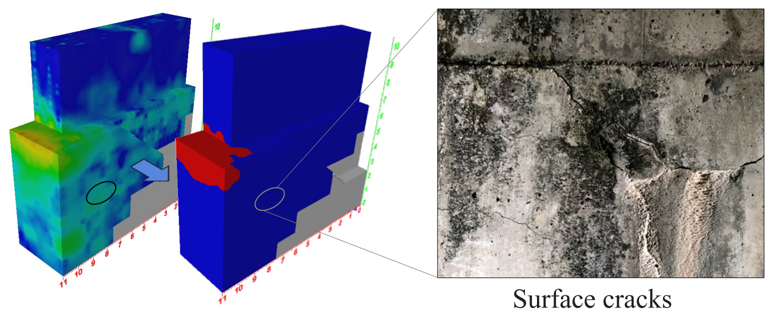

Fig. 2 - Comparison between tomogram and surface cracks of left bank side.

3. Conclusios - integration of tomogram into point clouds -

The spillway is reproduced by 3D point-clouds using still and video images, tomograms namely internal velocity distributions, 2D surface observations and design drawing. The integrated model and details of superposition of surface and internal information are demonstrated in Fig. 3. By using Fig. 3, the structure of interest can be visualized in 360 degrees in all directions. Damage specifications such as crack width, length as well as density can be visually quantified and overall internal damage can be confirmed by the tomograms. Classification of damages and interpretation of structural performance will be automatically implemented with using AI near future. When the shown inspections are periodically carried out and visualized with the proposed integration procedure, rational maintenance program through the life cycle of the structures will be reasonably proposed.

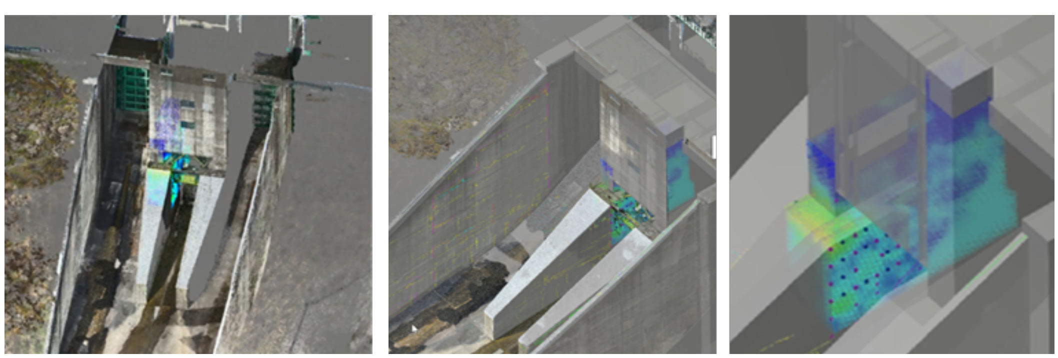

Fig. 3 - Resulted digital twin incorporated point-clouds, surface condition and internal elastic wave velocities.