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4D Monitoring of Subsurface Conditions in Concrete Infrastructure Prior to Failure Using Ground Penetrating Radar

Authors : Lee Tasker, Ali Karrech, Jeffrey Shragge, Matthew Josh

Abstract : Monitoring for the deterioration of concrete infrastructure is an important assessment tool for an engineer and difficulties can be experienced with monitoring for deterioration within an infrastructure. If a failure crack, or fluid seepage through such a crack, is observed from the surface often the source location of the deterioration is not known. Geophysical methods are used to assist engineers with assessing the subsurface conditions of materials. Techniques such as Ground Penetrating Radar (GPR) provide information on the location of buried infrastructure such as pipes and conduits, positions of reinforcements within concrete blocks, and regions of voids/cavities behind tunnel lining. This experiment underlines the application of GPR as an infrastructure-monitoring tool to highlight and monitor regions of possible deterioration within a concrete test wall due to an increase in the generation of fractures; in particular, during a time period of applied load to a concrete wall up to and including structural failure. A three-point load was applied to a concrete test wall of dimensions 1700 x 600 x 300 mm^3 in increments of 10 kN, until the wall structurally failed at 107.6 kN. At each increment of applied load, the load was kept constant and the wall was scanned using GPR along profile lines across the wall surface. The measured radar amplitude responses of the GPR profiles, at each applied load interval, were reconstructed into depth-slice grids and presented at fixed depth-slice intervals. The corresponding depth-slices were subtracted from each data set to compare the radar amplitude response between datasets and monitor for changes in the radar amplitude response. At lower values of applied load (i.e., 0-60 kN), few changes were observed in the difference of radar amplitude responses between data sets. At higher values of applied load (i.e., 100 kN), closer to structural failure, larger differences in radar amplitude response between data sets were highlighted in the GPR data; up to 300% increase in radar amplitude response at some locations between the 0 kN and 100 kN radar datasets. Distinct regions were observed in the 100 kN difference dataset (i.e., 100 kN-0 kN) close to the location of the final failure crack. The key regions observed were a conical feature located between approximately 3.0-12.0 cm depth from surface and a vertical linear feature located approximately 12.1-21.0 cm depth from surface. These key regions have been interpreted as locations exhibiting an increased change in pore-space due to increased mechanical loading, or locations displaying an increase in volume of micro-cracks, or locations showing the development of a larger macro-crack. The experiment showed that GPR is a useful geophysical monitoring tool to assist engineers with highlighting and monitoring regions of large changes of radar amplitude response that may be associated with locations of significant internal structural change (e.g. crack development). GPR is a non-destructive technique that is fast to deploy in a production setting. GPR can assist with reducing risk and costs in future infrastructure maintenance programs by highlighting and monitoring locations within the structure exhibiting large changes in radar amplitude over calendar-time.

Keywords : 4D GPR, engineering geophysics, ground penetrating radar, infrastructure monitoring
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