Remote structural health monitoring

Wednesday, 09.04.2025, 12:45 - 14:15, Room Tulla

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Crack monitoring of masonry walls with standard and enhanced Digital Image Correlation methods

Many contact and optical methods have been developed and tested over the past decades for structural crack monitoring. Contact instruments provide only localized information and require direct contact with the monitored surface. In contrast, optical methods remotely offer information at a larger scale. Among optical methods, Digital Image Correlation (DIC) has been widely used to monitor surfaces by tracking points in images collected using cameras with fixed positions between each collected frame. However, the fixed setup significantly limits the applications for long-term monitoring. To overcome DIC limitations, we investigated Crack Monitoring from Motion (CMfM) which can measure the propagation of cracks over time in images captured using cameras with non-fixed positions. Here, we present the results obtained during laboratory tests on masonry walls by comparing DEMEC mechanical strain gauge measurements, standard DIC and CMfM. Specifically, we measured the crack propagation in masonry walls under compression and bending loading at different stages using the DEMEC instrument and by collecting images with fixed and non-fixed cameras. We processed images collected with the fixed camera using Py2DIC standard DIC software and images from nonfixed cameras using CMfM. Comparing the crack propagation measured with the three techniques showed a high level of agreement, i.e. a few hundredths of millimetres in terms of median, Root Mean Square Error (RMSE) and Normalized Median Absolute Deviation (NMAD) of the differences, demonstrating the potential for monitoring cracks with permanent and non-permanent camera setup.

Keywords: Crack measurement, Masonry wall testing, Digital Image Correlation, Non-fixed camera setup

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A Feasibility Study to Monitor Crack Width Displacement using Images Taken with Pan-Tilt-Zoom Cameras

Ageing civil engineering structures such as bridges, tunnels and retaining walls are increasingly prone to failure. These structures must be monitored to ascertain their safety. Cracks and flakes are common visual indicators of weakening structures, which inspectors utilise for crack width monitoring over time. However, this traditional method, which uses crack gauge or scale, is time consuming and subjective to the inspector. Hence, over the last decade, myriads of research has been conducted using Digital Image Processing techniques to combat these issues and have proven to be effective as a form of non-contact monitoring. In this research, low-cost Pan-Tilt-Zoom (PTZ) cameras are explored as suitable instruments for image acquisition to monitor crack width of single cracks in bridges. There is little research on the use of PTZ cameras for civil engineering applications, and with their massive advancement over the years, PTZ cameras show potential for automatic image acquisition. Through laboratory tests, the influence of the distance, and zoom level of the lens are observed. By applying perspective projection, the displacement of the cracks can be measured. The results are evaluated by assessing the Root Mean Square Error and precision of the measurement system. The experimental results demonstrate the effectiveness of these cameras for crack width monitoring, validated by the case study in Okayama Japan.

Keywords: IP cameras, Crack width monitoring, Digital Image Processing, Bridge inspection

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Analysis and optimization of the reliable hole detection in sheet pile walls

At German ports and waterways, there are approximately 3,000 km of shoreline walls and about 2,500 km of traffic structures. As these structures have mostly reached an advanced age, it is essential to know whether they are still load-bearing. Therefore, these structures must be examined for their reliability. The common method to carry out this examination has been to deploy divers to inspect the walls underwater. This is very time consuming, especially given that underwater light conditions in German ports are often poor. To overcome these disadvantages, sheet pile walls can also be surveyed using a multi-sensor system with a Multi-Beam Echo Sounder (MBES). This system measures the walls under water using sound waves and provides a point cloud of the structure. In the subsequent investigation, holes represent a particular interesting type of damage. However, so far, no statement could be made about the reliability of detecting these using sonar. To evaluate in how far the system is capable to detect holes in sheet pile walls, test samples with different geometric shapes, surface materials, and holes varying in size and shape are constructed. Knowing the geometry as well as the location and size of the holes, the reliability of the hole detection is investigated, considering especially the noise and resolution capability of the MBES. Furthermore, different measurement settings, such as pulse length and pulse power are analyzed for the best settings to be used for the hole detection.

Keywords: Damage detection, Multi-beam echo sounders, Sheet pile walls, Quality analysis

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Impact of surface orientation of structures on their seasonal deformation: a case-study in the UK

Solar radiation varies in magnitude and duration throughout the year causing changes in solar absorption of structures, leading to seasonal movement; expansion during the hot season and contracting during the cold season. This seasonal movement can be dangerous for the health of structures if they exceed some limits. This paper aims to investigate the effect of the surface orientation of structures on the amplitude of deformation caused by the solar radiation through measurements using Terrestrial Laser Scanner (TLS). The monitored structure involves sheet piles, a capping beam, and a brick wall. The sheet piles consist of flanges and webs that have various surface orientation, and consequently this paper monitors the seasonal deformation of different parts of the sheet piles using one of the main cloud-comparison techniques; the Multiscale-Model-to-Model-Cloud-Comparison (M3C2) method. The structure was scanned five times starting from November 2020 with two scans each year: one in June and the other in November. The results show a clear difference between the different parts of the sheet piles; about ±25% of rise/decline in the seasonal lateral movement (±1 mm of change with respect to 4 mm of lateral movement in the capping beam) that is caused by the change in surface orientation. This suggests that the seasonal deformation of structures can be slightly controlled by the surface orientation. This is significant especially considering the climate change and its implications on the variation of solar absorption of structures.

Keywords: Climate change, seasonal movement, SHM, sheet piles, TLS, LiDAR, M3C2