Monitoring Masonry Walls Subjected to Earthquake Loading with a Time-of-Flight Range Camera

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SUMMARY

Structural loading tests are usually observed with sensors capable of measuring only single point locations and in one dimension. Such sensors have to be placed close to or in contact with the moving object and are therefore at risk of damage in destructive experiments. The time-of-flight (ToF) range camera technology allows collection of areal 3D measurements at video frame rate from a safe distance. This enables the monitoring of a complete structure with a single sensor. The requirement of only one relatively low-cost and compact active sensor is an additional advantage compared to passive imaging approaches that require at least two sensors or terrestrial laser scanners that cannot image dynamic scenes. This paper presents a ToF range camera approach to measure the structural deformations of masonry wall sections subjected to earthquake loading on a single-axis shake table. The walls were 2.2 m high by 2.2 m wide and constructed with concrete masonry units of size 390 x 190 x 190 mm. The loading tests were performed with the walls placed parallel to the shaking direction for in-plane movement and orthogonal to the shaking direction for out-of-plane movement (three tests each). The dynamic experiments as well as static observations were conducted with a SwissRanger SR4000 range camera and signalized targets attached to the walls. Based on these measurements, the potential and limitations of such sensors are evaluated in terms of accuracy and temporal resolution for dynamic structural loading tests. Repeated static tests to quantify the accuracy show a high dependence on the radial distance in the image plane. Central targets in single frames could be measured with an RMS of 0.4 mm in position and 5 mm in range, whereas at the periphery of the image format, the accuracy decreased to an RMS of 7 mm (position) and 18 mm (range). To detect the smallest deformations possible, the measurements were averaged spatially per row of five targets and temporally with a moving average over five camera frames. This increased the accuracy in range to 1.6 mm - 2.6 mm and in position to a sub-millimetre level. Comparison of the in-plane movement measured from the SR4000 with a laser displacement sensor quantified the tracking accuracy per frame at each target location with an RMS between 1.7 mm

and 7 mm, which was again dependent on the radial distance. The differences between the SR4000 and the input signal to the shake table were even smaller, with accuracies up to 0.6 mm RMS.