Laser-based system for remote non-destructive inspection of concrete structures. Laboratory and field tests.

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Abstract:
A laser-based system for remote non-destructive inspection of concrete structures has been developed, assembled and tested in the laboratory and field conditions. The current design of the system is intended for the location of actually dangerous inner flaws in transportation tunnels. The technique is based on the initiation and detection of standing Lamb waves (or natural vibration) in concrete layer between surface and inner defect. A pulsed laser (Nd:YAG or CO2-laser) is used as a source of laser impact initiating vibration in concrete. A CW Nd:YAG laser radiation of 532 nm wavelength is used for probing/detection. Detection of initiated vibration is realized with the use of a laser photorefractive interferometer. The interferometer uses principles of two-wave mixing in photorefractive crystal (dynamic holography) and homodyne detection. A photorefractive crystal – Bismuth Silicon Oxide (BSO) – is used as a nonlinear medium for the recording of the dynamic hologram. The system performs automatic scanning the inspected object surface by the impact and probe laser beams. A specially designed algorithm analyses waveforms and spectra of initiated vibration in real-time mode and simultaneously produces a 2D map of the surface being scanned. The presence of detectable standing Lamb wave is used as a criterion of inner flaw detection: spectral power of standing Lamb wave is much higher in over-defect area where concrete layer is comparatively thin. Detection of various types of inner defects like voids, cracks and honeycombs has been demonstrated in laboratory conditions. Accuracy of defect location is about 1-3 cm. Detection depth is up to 5 cm. Actually, the laser-based system acts like a hammer, with the same accuracy and detection depth. However, remote character of inspection makes the laser-based technique much more attractive. The technique is supposed to be used for the inspection of bullet-train tunnels in Japan (shinkansen). A mobile prototype of the system has been assembled and demonstrated in the field conditions. Promising results of detection have been obtained in an actual bullet-train tunnel.

Keywords: