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A New Remote Non-destructive Testing Method for Concrete Structures Using Water Jet Impact

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Abstract **-** A new concrete-structure testing method has been developed in which the traditional hammer has been replaced with a water jet. In this new method, objects are pounded by water droplets at regular intervals. Hidden voids in the concrete can be detected as they produce a distinctive sound which is picked up by a microphone. Our results found that it is possible to detect voids of 400mm at a depth of 30mm in concrete while moving.

Keywords**:** Non-destructive Testing, Concrete Structure, Water Jet Impact, Hammering Test

1. Introduction

Deterioration of old structures made of concrete such as bridges, tunnels as well as buildings is a worldwide problem [1]. Up until now, testing has involved hammering in order to detect voids. However, this method of testing is arduous and time consuming as well as costly. So, a new water jet impact acoustic method has been proposed and tested as a solutions to these problems. This new method was used for detection of a void in a concrete specimen in a stationary testing and a running test.

2. Water Jet Impact Acoustic Method

The Water Jet Impact Acoustic method consists of a jet of water impacting concrete in order to detect defects in concrete as shown in Fig. 1. The soundwaves that are created by the impact is detected by a microphone which can then be analysed to determine the existence of any hidden voids or delamination. When the stream of water is discharged from the nozzle, it is a solid stream but over specific distance it starts to separate. The interval distance of the droplets, s is theoretically 4.4 times that of the solid streams' diameter, d [2], [3].

$$s = 4.4\,d \tag{1}$$

So, the excitation frequency of the water jet impact, f can be obtained by dividing the water jet speed, V by 4.4 d. For instance, when V = 10 m/s and d = 5 mm,

$$f = \frac{V}{s} = \frac{10\ \text{m/s}}{4.4 \,*\, 0.005\ \text{m}} = 450\ \text{Hz.} \tag{2}$$

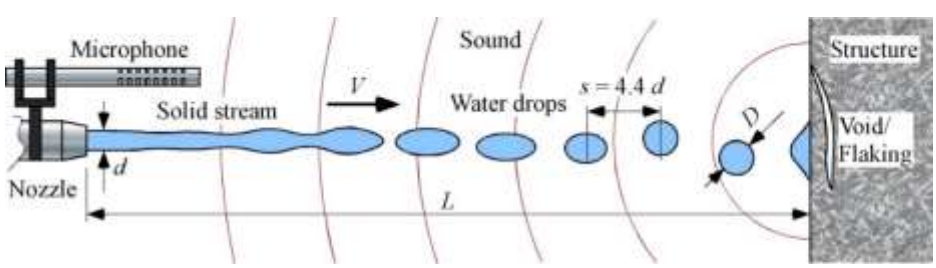

Fig. 1: Water Jet Impact Acoustic Method.

3. Experiment

A stationary testing of defect detection and a running test were performed on a concrete specimen. The stationary testing was under the detecting apparatus-fixed condition. The running test was under the detecting apparatus mounted on a traveling vehicle.

3.1. Concrete Specimen

Figure 2 shows a concrete specimen with a circular defect. The specimen is a square concrete plate with sides of 500 mm and a 90 mm thickness. The defect was a circular Styrofoam disk, simulating a void with a diameter of 400 mm.

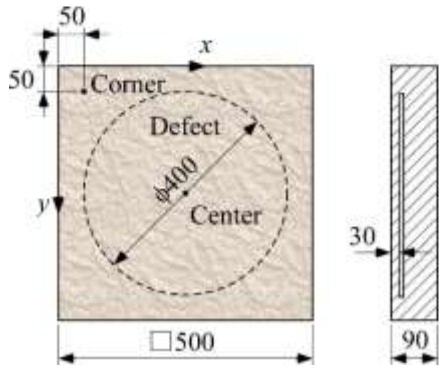

Fig. 2: Concrete specimen with a circular void.

3.2. Stationary Testing

Figure 3 shows a stationary testing of Water Jet Impact Acoustic Method. The velocity of the water jet was 10 m/s, the distance between the water gun and the specimen was 2 m and the nozzle diameter was 5 mm.

Figure 4 shows the power spectrums from the Water Jet Impact Acoustic Method on the specimen measured at the corner and the centre shown in Fig. 2. The corner is a sound part and the centre is a defect part.

As can be seen in Fig. 4, there is a dominant peak in the spectrum measured at the centre at 0.8 kHz indicating the existence of the defect. On the other hand, there are no significant peaks in the corresponding frequency range measured in the corner.

The results from Fig. 4 indicate that the impact sound of the water jet has the frequency of 2.0 kHz and more and there are no peaks in a range of 2.0 kHz or less.

Therefore, the existence of defects can be discriminated by using the intensity of the acoustic power with the frequency of 2.0 kHz or less.

Figure 5 shows the distribution of the acoustic power with frequencies up to 2.0 kHz at grid points of a 50 mm square lattices. As can be seen in Fig. 5, the counter lines at 0.2 in power indicate the circular shape of the defect.

Fig. 3: Stationary testing of Water Jet Impact Acoustic Method.

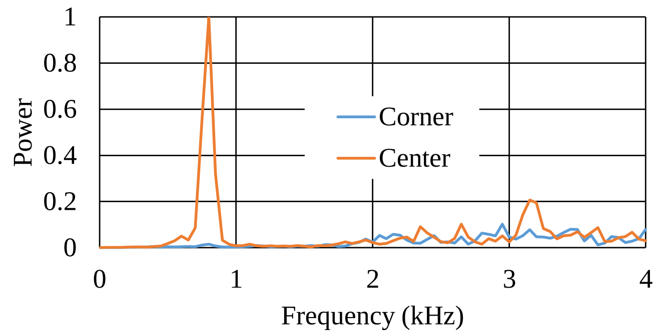

Fig. 4: Power spectrums of the impact sound of the water jet.

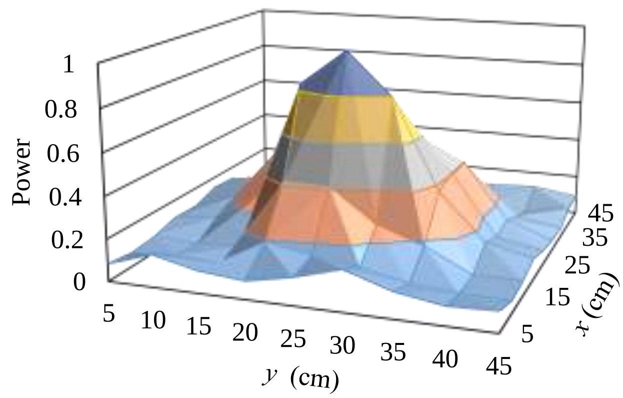

Fig. 5: Acoustic power distribution on the specimen in a stationary testing.

3.3. Running Test of Water Jet Impact Acoustic Method

A test of the Water Jet Impact Acoustic Method while in motion was performed on a concrete specimen as shown in Fig. 6.

The apparatus of the Water Jet Impact Acoustic Method was mounted on a vehicle. Figure 7 shows the apparatus mounted on the roof; including a water gun, a microphone, and a video camera. The water supply unit; a water tank, a pump, a battery and an inverter were mounted in the vehicle. The rate of flow of the water can be controlled by changing the frequency of the inverter.

The specimen was placed on a concrete wall as shown in Fig. 6. The test conditions were as follows; the speed of the vehicle was 1.0 m/s, the velocity of the water jet, V was 10 m/s, the distance between the water gun and the specimen surface was 2.0 m, and the diameter of the nozzle was 5 mm.

Figure 8 shows the distribution of the acoustic power when the intervals between the scanning lines were 100 mm. The number of scanning lines were five. At the x = 100 cm point, the water jet impacted directly over the vertical central axis of the circular defect.

Fig. 6: Running test of Water Jet Impact Acoustic Method.

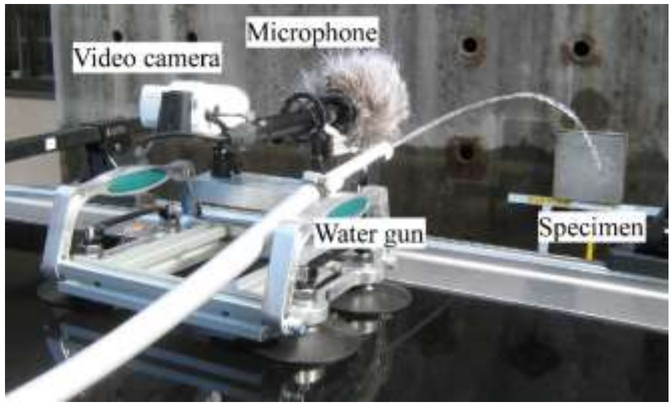

Fig. 7: Roof-on apparatus of the Water Jet Impact Acoustic Method.

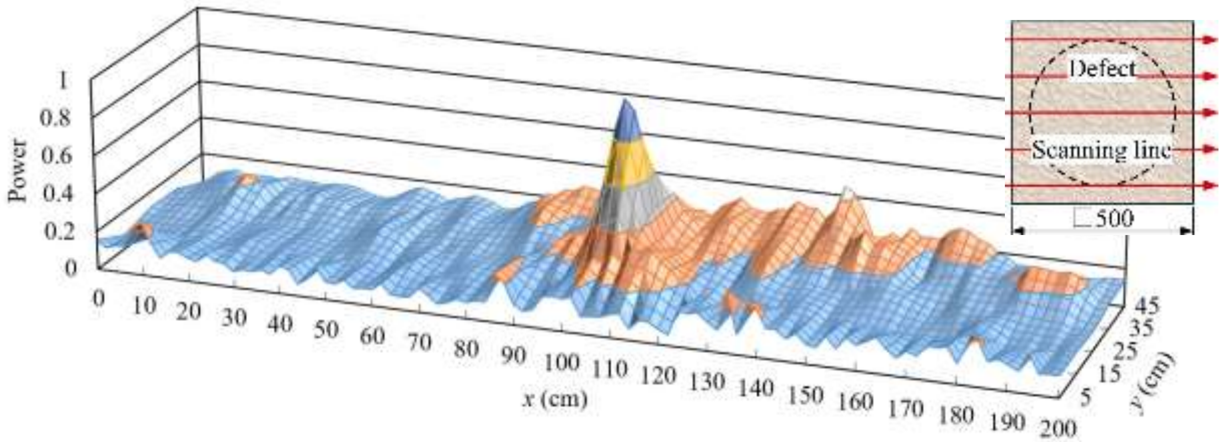

Fig. 8: Acoustic power distribution in a running test.

As can be seen in Fig. 8, the acoustic power correctly spikes indicating a defect. In addition, the counter line of the acoustic power at 0.3 accurately indicates a 'circular' defect. So, the 400 mm defect can be clearly detected using 100 mm intervals.

4. Conclusion

Water Jet Impact Acoustic Method has been developed. The apparatus of the Water Jet Impact Acoustic Method was mounted on a vehicle and detected a defect with a diameter of 400 mm in a concrete specimen while in motion. According to the results, we conclude as follows;

(1) The impact of a water jet on a sound concrete surface has virtually no acoustic power between 0 kHz and 2.0 kHz.
(2) The optimal power range of acoustic frequency in order to detect defects in concrete structures is between 0 and 2.0 kHz.
(3) A 400 mm circular defect can be successfully detected using a water-jet at up to 100 mm intervals.

Acknowledgements

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