IMPACT-ECHO TECHNIQUE FOR DETECTING THE CRACKS PROPAGATION IN CONCRETE PLATES

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Introduction

Pulse wave propagation has a key role in detecting a variety of defects in concrete structures including cracks, voids, determining the depth of surface-opening cracks, and delaminations in the concrete plates. Early detection of damage can save lives and costly repairs. The information obtained from the inspection is generally used to plan and design maintenance activities, and increase the safety.

Impact-echo technique, which is based on the use of impact-generated stress (sound) waves, is employed to assess the integrity of the structure or to determine the location of flaws.

The advantages and limitations of using the impact echo method were described through representative examples [1]. The impact echo technique was successfully utilized in detecting various defects in reinforced and prestressed concrete members [2-3].

In this study, a thick high strength concrete (HSC) plate used for offshore applications was nondestructively evaluated in the laboratory using the impact-echo technique. Impact-echo tests were performed concurrently with dynamic load test. That enables continuous inspection of the structure as well as the capability to detect locally damaged and overstressed spots. Finite element analysis FEA was conducted to simulate the effect of the crack propagation on the spectral response of the thick concrete plate was investigated.

Through the use of this method, operators of such structures will be able to maintain safe and economic operation of their facilities. Maintenance and shutdown cost will be reduced. In addition danger to human life and the environment will be reduced.

Experimental Program

Concrete Slab: A Two-way reinforced concrete plate was cast, instrumented, and tested in the current investigation. The test plate had a total thickness of 200 mm. The tested slab was square with a side dimension of 1900 mm in both directions and was simply supported along all four edges with the corners free to lift. The plate was tested in a vertical position in order to detect and mark the cracks as they develop, as presented in Fig. 1.

Fig. 1 Reinforced concrete slab and test setup

Load Testing: The load was applied to the plate concentrically through the column stub. The test was carried out using a closed-loop (MTS) testing machine with a maximum capacity of 670 kN in displacement control mode. In this test, the concrete plate was loaded in ten load-sets, each load-set was repeated four times to allow enough time for monitoring and marking flexural cracks, as shown in Fig. 2.

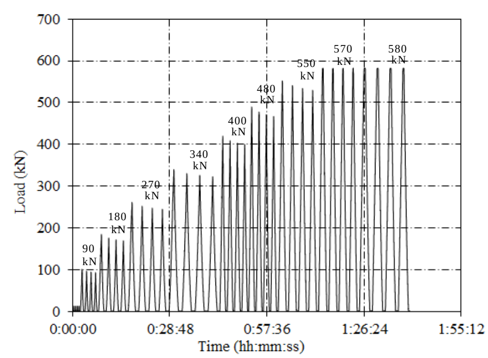

Fig. 2 Loading profile for cyclic loading test

Methodology: Impact-echo tests were performed to non-destructively assess the change in condition of reinforced concrete slab specimen subjected to cyclic load. This technique was performed concurrently with dynamic load tests in the laboratory. Impact-echo tests were first performed to assess the initial condition throughout the slab by analyzing the variation in the apparent P-wave velocity (C_p). Then, impact-echo tests were performed concurrently with a cyclic load test. The change in the apparent P-wave velocity was monitored and the shift of the first mode frequency present in each response spectrum was captured.

Damage Assessment of Dynamically Loaded Slab

Initial Condition: Impact-echo tests were first performed to assess the initial condition. In general, the wave velocity C_p ranged from 4272 to 4388 m/s before the application of the cyclic load. These values were within the acceptable velocity range for normal concrete quality.

Condition after Cyclic Loading Set 4 (Load Level = 270 kN): The wave velocity ranged from 4125 to 4337 m/s. The reduction in average wave velocity C_p over corner area of the slab was 0.8 %, indicating that the slab over that area was relatively intact and the corner area of the slab close to the support did not show a notable reduction in the slab stiffness at that level of the cyclic load. However, the reduction in the average wave velocity C_p over the central area of the slab was approximately 3.5 %, as shown in Fig. 3. The central area represents the zone of maximum stresses, and some flexural cracks propagated over this area. The reduction in the measured C_p velocity reflected the stiffness degradation and cracks development in this zone, as illustrated in Fig. 3.

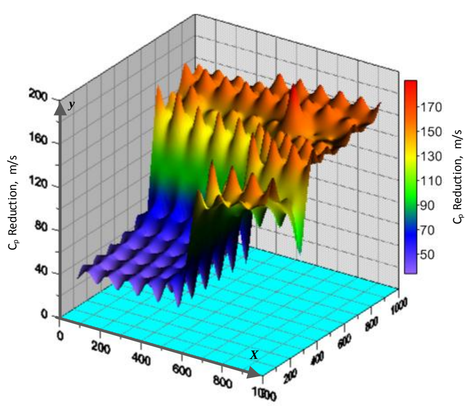

Fig. 3 The reduction of C_p due to the cyclic load application (P = 270 kN)

Condition after Cyclic Loading Set 7 (Load Level = 480 kN): The wave velocity ranged from 3657 to 4190 m/s at this level of cyclic load. Cracks of higher depth developed parallel with the progression of new cracks over the central area of the concrete plate, that reflected by the obvious reduction in the measured C_p velocity (12.3 %) over that area, see Fig. 4.

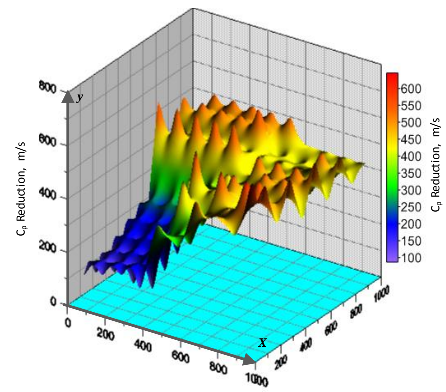

Fig. 4 The reduction of C_p due to the cyclic load application (P = 4800 kN)

Finite Element Modeling of Cracked Concrete Plate

The effect of the cracking propagation on the spectral response was investigated in the current study. A vertical crack was introduced at a distance of 475 mm from the left support. The height of the vertical changed from 75 mm [Fig. 5(a)] to 150 mm [Fig. 5(b)]. The results of the finite element modeling showed a continuous decrease of the mode of vibration as the height of the crack increased.

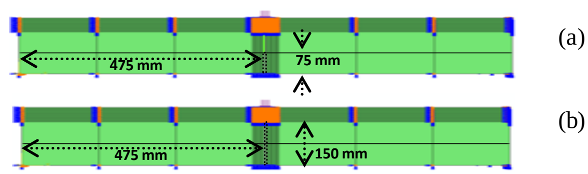

Fig. 5 The influence of the crack height on the spectral response

Conclusion

Impact Echo Technique provides a valuable aid to the interpretation of the cracking response of the concrete structures. These results can be used by bridge and offshore inspectors to assess the concrete condition to help identifying problems before significant damage accumulate.

References

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