Journal of Advanced Engineering Research
ISSN: 2393-8447
Volume 10, Issue 2, 2023, pp.163-167

Non-destructive evaluation of thick concrete components using the impact-echo method

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ABSTRACT

Condition assessment of concrete structures is an important area of research. The impact echo method is one of the advanced non-destructive methods used to assess concrete integrity and identify internal defects in concrete. The method is based on the principle that transient stress waves transmitted into the concrete will get reflected by the internal flaws and back wall. This method is used to detect defects or to evaluate the thickness of sections of concrete structural elements.

In the present work, Impact echo testing has been carried out for the identification of defects in an in-house laboratory structure. For the investigation, a test floor, reaction wall and one column from the CSIR-Structural engineering research centre (CSIR-SERC) have been assessed using the impact-echo method. A one-inch grid has been adopted, data is collected along the grid line and processed using impact-echo software. From the results, it has been observed that there are no defects along the investigated grid line on the test floor. Similarly, the reaction wall and column results also indicate that the concrete is free from defects. The preliminary investigation has indicated that the structural members are made of good-quality concrete and no defects have been identified. Further, an extensive investigation needs to be carried out to identify the presence of defects in the structure.

KEYWORDS – Impact echo method, thick concrete structures, non-destructive evaluation

1. INTRODUCTION

In the present day, it is necessary to access the integrity of a structure to reduce repair cost, and structure downtime and also for saving lives, The evaluation of structures can be carried out by using Non-destructive methods. Non-destructive methods are very popular these days, and also very helpful to us for detecting defects, voids, and delamination etc., Non-destructive testing (NDT) methods have evolved from methods like rebound hammers, ultrasonic pulse velocity tests to developed modern methods like ground penetrating radar, ultrasonic pulse-echo and impact echo. Currently, non-destructive testing (NDT) techniques rely on the propagation of elastic waves to determine the depth and locate defects within concrete structures. Ultrasonic and impact echo methods are commonly used for thicker concrete structures. However, ultrasonic testing requires access to both surfaces and proper transducer alignment, which can be challenging. To address these limitations, impact echo testing was developed. This technique only requires a single surface, can identify defects and determine concrete thickness. This study uses impact echo to detect defects in a reinforced concrete wall, and horizontal floor at CSIR-SERC. Previous studies on impact echo have mainly focused on concrete structures with thickness of 150-500mm, but this study tests structures with thicknesses of 500-1000mm.The study evaluates the structural integrity of the reaction wall, test floor and column.

2. METHODOLOGY

The impact echo technique operates by inducing brief mechanical impacts that create stress waves, which are then detected by a transducer as surface displacement caused by the arrival of reflected stress waves. The mechanical impact generates vibrations at various frequencies that can be used to assess the structure's integrity. The transducer measures the displacement, which is recorded and stored as a time-domain waveform. The data analysis process involves using the fast Fourier transform to convert the time-domain waveform into an amplitude spectrum as shown in Fig.1

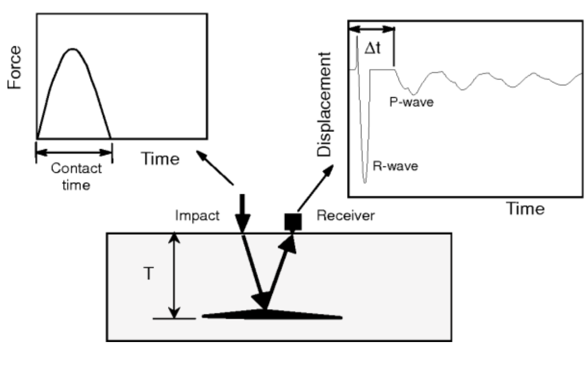


Fig.1. Impact Echo Instrument

The impact echo method has three basic components as shown in Fig. 2:

1. Mechanical impactors (hammers with steel spheres) of different sizes to produce impact, proportional to the size of the structural element (steel spheres)
2. A transducer for receiving surface displacements
3. Data acquisition system to receive, process and transmit waveforms

Fig.2. Parts of Impact Echo

Initially, steel spheres are used as impactors for producing impacts. Further, development in the method led to the use of steel balls attached to the steel rods.

3. EXPERIMENT INVESTIGATION

The impact-echo equipment used during the experiment is shown in Fig. 2. The impact-echo equipment includes the following items

1. Steel balls
2. Data acquisition system
3. A cable that connects transducers to the data acquisition system

The impact-echo technique typically involves collecting data at specific points on the test structures. As such, marking a grid on the structures beforehand is necessary to facilitate the data collection process. In this study, a 1-inch (2.5cm) grid was utilized for all the test structures. Before testing a structure, it is crucial to assess the functionality of the different impactors. This is especially important for thick structural components. Therefore, all impactors were tested for their effectiveness, and it was found that the impactor size is a critical factor affecting the impact-echo test results. Selecting the appropriate impactor size is crucial for the success of the tests, and the 16mm steel ball impactor was found to be effective for evaluating thick structural elements based on preliminary investigations and prior experience.

Considering the distance between the impact point and the transducer position is another crucial factor. Based on research, an impactor-receiver spacing of 50mm (2 in.) and an impact duration of around 40µs are effective. During the investigation, the following test procedure was conducted at each girder point:

1. Expected frequencies for reflections from the concrete, were assessed through trial and error
2. Five trials were performed on each grid point of the specimen
3. The results were analysed, and
4. The data was plotted to identify differences in frequency variations between the solid and cracked surfaces.

4. SPECIMEN DETAILS AND GRID MARKING

The concrete structures used in this study are

(i) Reaction wall – 6m x 7m x 0.75m
(ii) Test floor – 8m x 30m x 1m
(iii) Column – 1m x 0.5m

In the reaction wall, floor and column grid lines are marked every 2.5cm along X- and Y- directions (as shown in Fig. 3). The data is collected at all grid points. At every grid point, five data are collected. after collecting all data, the processing is done.

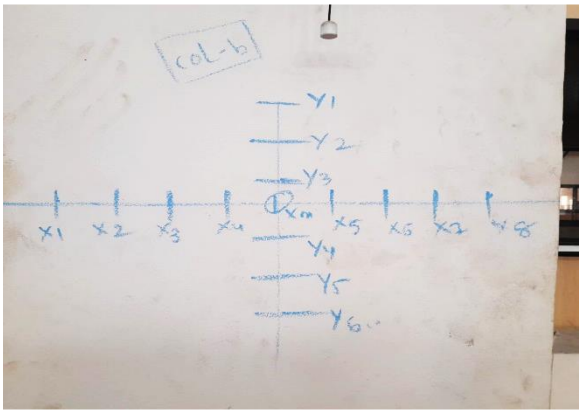
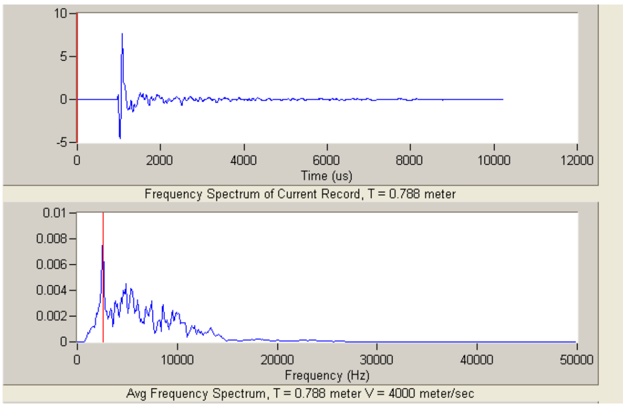


Fig.3. Grid marking

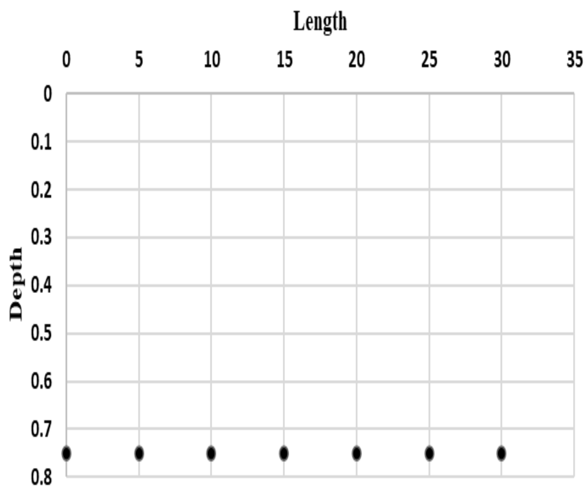
RESULTS AND DISCUSSIONS

The structural members i.e., test floor, column and reaction wall, were tested using the impact echo method to identify defects. The data collected on the structural members were analyzed by using "Olson impact-echo instrument". Collecting and processing of data could be carried out with the tailor-made WinTFS software. The present work presents four graphs that show the presence or absence of defects in those four structural members (i) reaction wall (ii) floor (iii) column-lengthwise (iv) column–breadth wise

Based on the data collected using the IE instrument, the graph plotted for all four structural members as shown in Fig. 4-7,



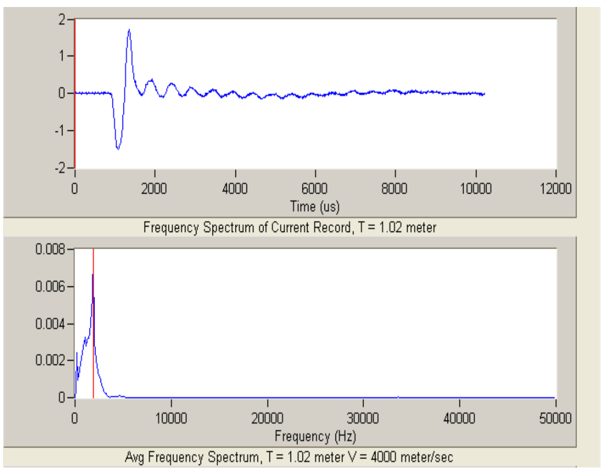
a. Signal and frequency spectrum



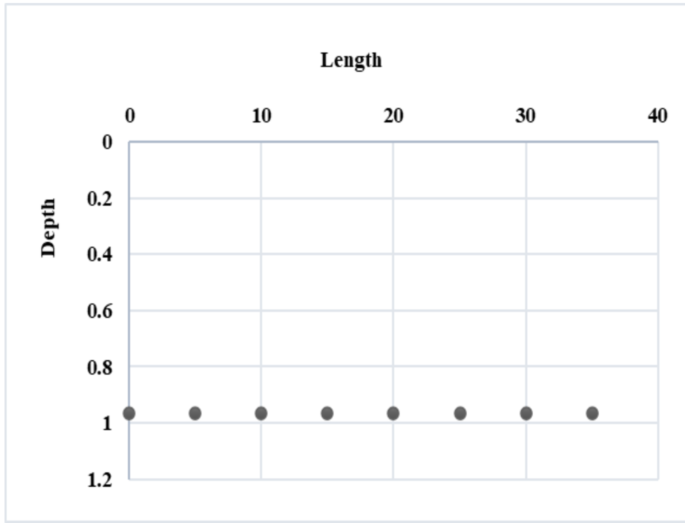
b. B-scan image indicating the depth

Fig. 4. IE results of the Reaction wall

Experiments were conducted on the reaction wall along multiple grid lines on both the x and y-axis. The graph displayed shows the results of these experiments, indicating that the reaction wall is defect-free and possesses uniform thickness across the tested region.



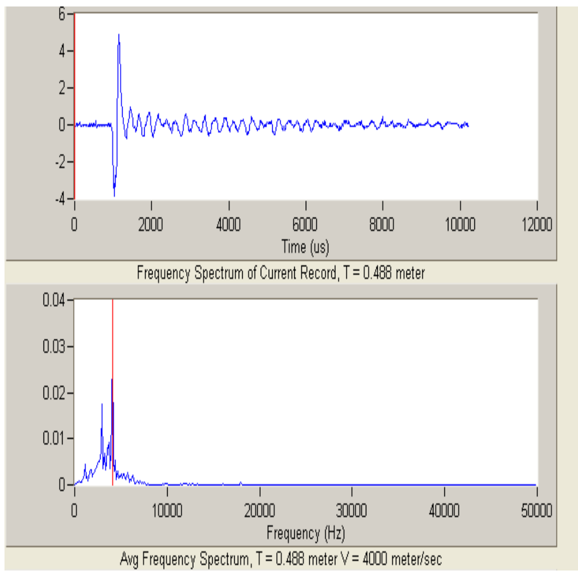
a. Signal and frequency spectrum



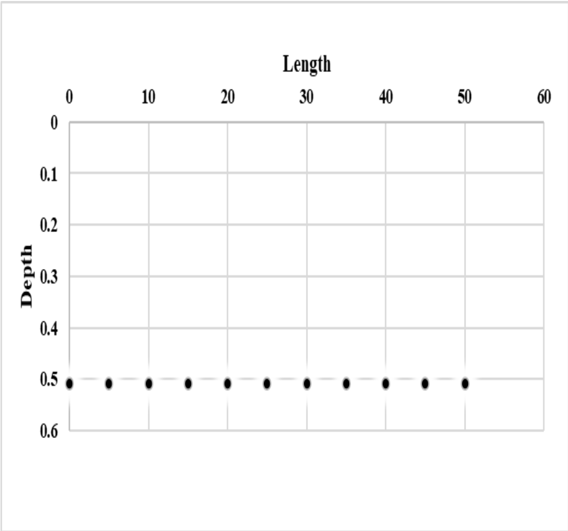
b. B-scan image indicating the depth

Fig. 5. IE results of Test floor

Tests were performed on the test floor across numerous grid lines on both the x and y axes. The displayed graph illustrates the outcome of these tests, revealing that the test floor is free from defects and has a uniform thickness throughout the tested area.



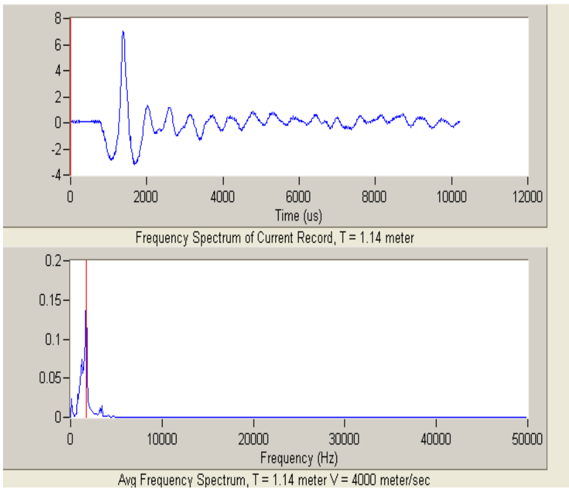
a. Signal and frequency spectrum



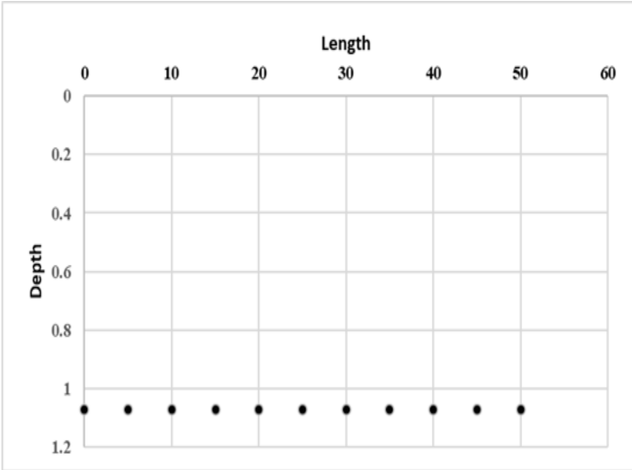
b. B-scan image indicating the depth

Fig.6 IE results of column (width)

Experiments were conducted on the column across multiple grid lines on both the x and y axes. The graph presented shows the results of these tests, indicating that the column is defect-free and has a consistent thickness throughout the tested region.



a. Signal and frequency spectrum



b. B-scan image indicating the depth

Fig.7 IE results of column (breadth)

Tests were carried out longitudinally along the grid lines of the columns, and the resulting data was gathered and analyzed. The findings suggest that the columns are free from defects in the tested areas

CONCLUSIONS

In the present work, three concrete members have been chosen for the identification of defects by using the impact echo technique. The experiments were performed. the frequency is consistent for all points along the grid line for the reaction wall. that indicates that the reaction wall is free from defects. Experiments were conducted on both the columns and test floor, and the findings indicate that they do not have any defects, which aligns with the results obtained for the reaction walls. These results apply only to the specific region that was studied, and further evaluations are necessary for other locations.

ACKNOWLEDGEMENTS

The authors express their gratitude to SERC for offering the platform to conduct this study. The publication has been authorized by the Director of CSIR-SERC, Chennai.

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