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Review on Impact Echo Technique for Concrete Exposed to High Temperature

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Abstract - *Impact echo is a non-destructive method for evaluation of concrete based on the stress waves generated by impact which transmits through the structure and gets reflected by internal flaws. Impact echo can be used to measure the thickness in concrete slabs and plates approved by (ASTM Standard C 1383-98a, and I.S 15987: 2013). It is preliminary used to determine the extent of flaws such as voids, honeycombing, cracks, delamination and debonding in plain, reinforced and post tensioned concrete structures. Impact echo is a reliable method for locating variety of defects. Recently, Impact echo method is estimating its application in determining the dynamic modulus of elasticity as well as the assessment of thermally deteriorated concrete.*

Key Words: **Impact-echo, Stress waves, thermally deteriorated concrete**

1.INTRODUCTION

Concrete is a heterogeneous mixture of aggregates, cement and water, and a noncombustible material. In spite of the fact that concrete is noncombustible, it experiences the negative effect on mechanical properties when exposed to high temperatures during fire. The increase in temperature affects the cement paste as well as aggregates. It is well known that during heating, Aggregate grains expand and the cement paste experiences shrinkage. Change in volume over time which decreases the dimension of concrete is known as shrinkage. The shrinkage of cement paste is related with evaporation of water from pores during heating process as a well as with dehydration of hydrates i.e (C-S-H gel) Aggregates normally occupy 40–60 % of the volume in concrete, the behavior of concrete at high temperatures is strongly dominated by properties of the aggregate used.

When concrete is exposed to high temperature it degrades the Physical (evaporation), Chemical (dehydration) and Mechanical (compressive strength, damage, spalling, cracking) properties. The main changes occur primarily in the hardened cement paste. As the temperature increases in concrete to 100°Cfree water from the capillary pore system of hardened cement paste will be evaporated. In the range of 100 °C- 400 °Cthe cement paste loses physically bond water, while at temperatures above 400 °Cchemically bound water will be lost and explosive Spalling is observed. At 800 °Ctotal loss of water of hydration. After 1200 °Cconcrete starts to melt. From 600 °C- 1400 °Cconcrete structurally is not useful.

When concrete is exposed to fire it has non-uniform properties in the cross section of members. The degradation mainly occurs at near-surface layer. Due to change in temperature corresponding to strains creates incompatibility between cement paste and aggregates which leads to microcracks. Since the microcracks has a significant effect in defining the true strength of material it is necessary to analyze the damage severity. To take a decision on the possibility of further operation of facility after fire accident, Post fire assessment of concrete quality is relevant. Ensuring the safety of concrete structures, early detection of internal defects and accurately characterizing defect is important.

1.1 NON-DESTRUCTIVE TEST:

Over all these years, number of non-destructive techniques have been developed and applied for detecting the internal flaws and defects of concrete structures. Non-Destructive testing is carried out to predict the lifetime of structure and risks connected with the further usage of it. The most important advantage of NDT is that after testing, the structure remains undamaged. The NDT methods include Rebound Hammer test, ultrasonic pulse velocity, ground penetration radar, impact echo, etc. Among these different techniques Impact-echo (IE) method is most popular one to detect the cracks and delamination of concrete structures. The impact echo method was invented at U. S. National Bureau of standards (NBS) in 1980, and developed at Cornell University, New York from 1987-1997. The first successful attempt of this method was in geotechnical engineering which evaluated the integrity of concrete piles and caissons.

How Impact Echo Works: An impact produced by steel ball against the concrete structure, is used to generate the stress waves that propagates into structure and gets reflected by internal flaws and defects. The displacements which are caused by the reflection of these stress waves are obtained from the transducers which is adjacent to the impactor. The resulting displacement versus time is recorded in time domain, which are transformed to frequency domain by Fast Fourier Transform technique which gives the plot of amplitude versus frequency. Multiple reflections of stress waves on surface are used to determine the location of flaws

and integrity of structure. As it produces the waveforms it has the patterns which provides the information about the location of flaws, or the dimension of cross section of structure. Impact-echo test has distinctive waveforms for solid structures and are easily recognized. The patterns get changed and disrupted, if flaws are present. The waveforms provide the qualitative information about the existence and location of flaws. (See Fig. 1)

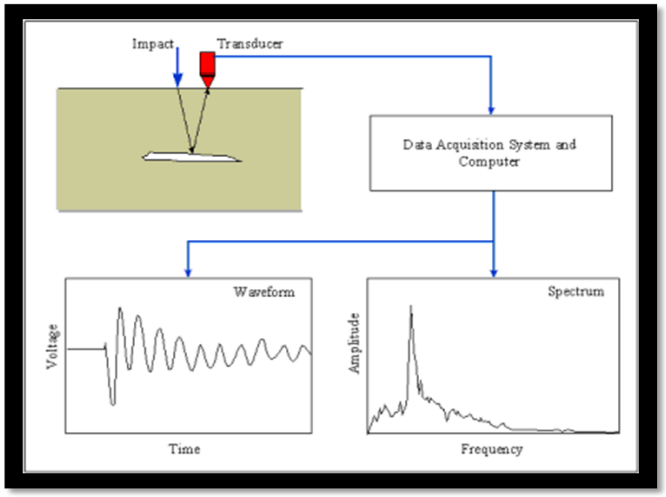

Fig. 1: Schematic of Impact Echo Method

Components of Impact- Echo

- **Impactor**- The steel ball of 8 mm in diameter and attached to the steel spring. The impactor has spherical tip. It produces an impact with sufficient energy to produce surface displacement

- **Transducers**- It should be capable of detecting the small displacement which corresponds to impact generated by the impactor. The transducers tip shall be placed about 300 mm apart

- **Data-Acquisition System**- It is hardware and software that allows one to measures the data record it and after processing we get the output from transducer. It has a portable computer with 2 channel DAS card. The sampling rate for each channel shall be 500 kHz with interval of 2 μs

- **Cables and Connectors**- Connectors must be of high quality and tightly connected to cable. Cables are used to connect the transducers to DAS

The transducer is held on the concrete surface and steel impactor is impacted within the distance of 0.4T(T= thickness of concrete surface)

1.2 BENEFITS OF IMPACT ECHO

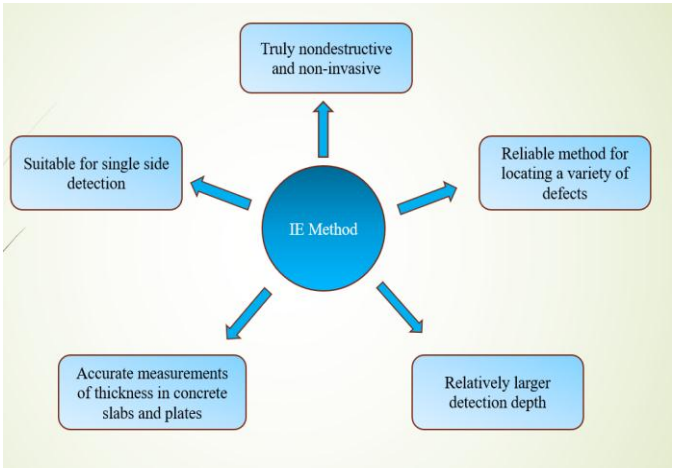

Fig. 2: Advantages of Impact Echo Method

2. REVIEW OF LITERATURE

Julia Wróblewska & Robert Kowalski (2020) has studied laboratory and in situ (non-destructive and semi-destructive tests) in application to reinforced concrete structures after fire. One of the most important phenomena affecting the load-bearing capacity of these structures is the reduction in concrete strength at high temperature and after cooling. Traditional test methods, commonly used in normal conditions (e.g. destructive test on core specimens), usually do not take into account the non-uniformity of concrete after a fire. Therefore, other methods are proposed to determine the depth of the damaged concrete in the external layers of a given structural member

Richard Dvořák1 et al. (2017) investigated the use of Impact-echo acoustic method for testing concrete which is degraded by high temperature. It has also studied the feasibility of concrete composite material of aggregates and Portland cement by means of acoustic method. Results are compared with traditional parameters. The obtained results show the frequency which is obtained from the testing of impact echo.it concluded that impact echo is a convenient tool to assess the life and quality of structure.

Miroslav Lunak, et al. (2016) carried out non-destructive test to assess the risk related to structure and predict the lifetime. The main advantage of this NDT is that after testing structure remains undamaged. The new method introduced in this paper is impedance spectroscopy which employs the impedance characteristic frequency dependent on analysis the properties of cement and non- cement material. After any case of fire loading, it is required to verify structure's condition. One way how to assess the risks connected with further usage of the structures after being exposed to the fire is the non-destructive testing. This paper is dealing with

non-destructive measurement of changes of electric parameters of the cement-based mortars subjected to the high temperatures The results which are obtained shows the frequency inspection carried out by means of impact- echo. The principle of mentioned method is based on dielectric studying the dielectric losses versus frequency plots.

Katarzyna Krzemien and Izabela Hager (2015) investigated the the nature of elastic wave transition obtained in the time domain and the wave propagation velocity for the impact-echo method employed on the surface of concrete cubes 0.15 *0.15 * 0.15 m3 subjected to heating in the temperature range of 200–1000 C. The relations between the characteristics of the obtained impact-echo signal and the mechanical properties of concrete subjected to high temperature were presented as regression curves. The paper proposes certain formulas to be employed while assessing fire-damaged concrete element.

Jing-Kui Zhang et al (2016) carried out study on full condition assessment of concrete elements by introducing advanced machine learning techniques for performing comprehensive analysis and pattern recognition of IE signals. Specifically, we use wavelet decomposition for extracting signatures or features out of the raw IE signals and apply extreme learning machine, one of the recently developed machine learning techniques, as classification models for full condition assessment. To validate the capabilities of the proposed method, we build a number of specimens with various types, sizes, and locations of defects and perform IE testing on these specimens in a lab environment. Based on analysis of the collected IE signals using the proposed machine learning based IE method, we demonstrate that the proposed method is effective in performing full condition assessment of concrete elements or structures.

Xiaobin Lu et al (2013) evaluated that dynamic modulus of elasticity can be determined by impact echo method. P-wave speed obtained from impact echo on standard specimen which corresponds with theoretical 1D p-wave speed. Dynamic modulus of elasticity can be calculated from the resonant frequency obtained from Impact echo test.

M. Koabaz et al. (2012) characterized fire damaged concrete by impact echo method. Concrete which is exposed to high temperature experiences the more or less heavy damage which compromises the mechanical properties and stability. The assessment of fire damaged concrete is important to determine the repairs and reconstruction of structure. Very strong correlation between E_{static} and $E_{dynamic}$ obtained

Gabriella Epasto et al. (2009) evaluated fire-damaged concrete using impact-echo method. The impact echo technique and new signal procession method was introduced. Cores and X ray diffraction analyses was also done to assess the fire damaged concrete at various depths. The results obtained from impact echo is in time domain which is processed in frequency domain by continuous wavelet transform (CWT). The results were evaluated to check how fire affects the reinforced concrete building. The results were reflected in the form of scalogram.

Ufuk Dilek and Michael L. Leming (2007) this study compared results of in situ pulse velocity and impact-echo testing with dynamic elastic modulus and air permeability index test results of 25 mm 1 in.thick disks sawed from concrete cores removed from selected areas of the damaged slab. Both the NDE techniques and the laboratory testing of thin disks identified the presence of damage as a result of the fire. Analysis of the relatively thin concrete specimens permitted assessment of the presence and degree of damage in thin layers, and provided important and useful data on concrete properties for engineering assessment. The findings highlighted a shortcoming of using conventional strength testing alone on investigations involving relatively thin layers of damage and pointed out several key limitations in the use and interpretation of nondestructive evaluation and associated analysis in a field assessment project.

Angel Di Maio (2002) carried out Non-Destructive Tests for the Evaluation of Concrete Exposed to High Temperatures. This paper represents the study of nondestructive testing on concrete which were exposed to high temperature. The analysis is based on the modulus of elasticity, strength and ultrasonic pulse velocity. The obtained results is conclude that UPV is a good tool for estimation of static modulus of elasticity on concrete which are exposed to high temperatures.

In accordance with the above literatures, standard ASTM C (1383) - 98 a, procedure B for testing of impact echo is followed. Experience is needed to in setting up optimal testing parameters, recognizing valid record waveforms and analyzing test results.

3. CONCLUSIONS

- The review of literature study elaborates the post fire assessment on normal and High strength concrete using Impact echo techniques and there is limited study on thermally deteriorated Geopolymer concrete.
- Hence, there is a scope to work on thermally deteriorated geopolymer concrete, to get the better understanding of the feasibility of Impact–echo techniques.
- The correlation between Impact–Echo method with different nondestructive techniques is necessary for the assessment of thermally deteriorated Geopolymer concrete.

REFERENCES

1. Wróblewska, J., & Kowalski, R. (2020). Assessing concrete strength in fire-damaged structures. *Construction and Building Materials*, *254*, 119122.

2. Dvořák, R., Luňák, M., Chobolac, Z., Hela, R., & Bodnárová, L. (2017, April). Impact-Echo Method Used to Testing of High Temperature Degraded Concrete Composite of Portland Cement CEM I 42.5 R and Gravel Aggregate 8/16. In *Second International Conference on Mechanics, Materials and Structural Engineering (ICMMSE 2017)* (pp. 196-200). Atlantis Press.

3. Lunak, M., Kusak, I., & Stefkova, D. (2016). Comparison of results of impedance spectroscopy methods with results of impact-echo method in investigation of high-temperature-degraded concrete. *Procedia Engineering*, *151*, 265-270.

4. Krzemień, K., & Hager, I. (2015). Post-fire assessment of mechanical properties of concrete with the use of the impact-echo method. *Construction and Building Materials*, *96*, 155-163

5. Zhang, J. K., Yan, W., & Cui, D. M. (2016). Concrete condition assessment using impact-echo method and extreme learning machines. *Sensors*, *16*(4), 447.

6. Lu, X., Sun, Q., Feng, W., & Tian, J. (2013). Evaluation of dynamic modulus of elasticity of concrete using impact-echo method. *Construction and Building Materials*, *47*, 231-239.

7. M. Koabaz et al, "Characterization by the Impact-Echo Method of the High Temperature-Induced Damage on Concrete Specimens", (2012)

8. Epasto, G., Proverbio, E., & Venturi, V. (2010). Evaluation of fire-damaged concrete using impact-echo method. *Materials and structures*, *43*(1), 235-245.

9. Dilek, U., & Leming, M. L. (2007). Comparison of pulse velocity and impact-echo findings to properties of thin disks from a fire damaged slab. *Journal of Performance of Constructed Facilities*, *21*(1), 13-21.

10. Di Maio, A., Giaccio, G., & Zerbino, R. (2002). Non-destructive tests for the evaluation of concrete exposed to high temperatures. *Cement, Concrete, and Aggregates*, *24*(2), 58-67.

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