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Efficiency of Ultrasonic pulse velocitytest in life of concrete structure

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Abstract: *Concrete is a basic material used for almost all the engineering projects. Concrete is a composite material, amalgamation of water, cement and aggregates. The concrete comprises of many influential building variables, such as the water/cement ratio, aggregate type and size, humidity and type of cement used in the process. Improper mixing, errors in preparation, excess of admixtures, inadequate workability, honeycombing are some of the major drawbacks of concrete while constructing a concrete structure. All these factors directly affect the quality of concrete and the compressive strength of the concrete. We find it always necessary to detect such trouble causing elements in the structure and to rectify them for long life of concrete structure. UPV test is one of the major tests practiced in order to assess the condition of a structure. This study thoroughly deals with the concept, methodologies, functioning, result of UPV test in understanding the condition of a structure.A random structure is taken and analysed with the Non-destructive testing (UPV), after the repair works carried out as per the analysis of UPV test, the structure is again taken under condition assessment test. The results of both Pre and Post Retrofitting of the RCC structure has been discussed in this paper.*
Keywords: *UPV, NDT, RCC, Pulse Velocity, Retrofitting.*

I. Introduction

NDT is basically an evaluation of condition of concrete in the structure. This has been a vital tool because these methods do not affect the appearance and the performance of the analysed structures. The method allows doing the tests at the same place, making possible a continuous monitoring in the structures and a determination of possible variations during a period of time. Once the structures are monitored, the life-time can be predicted, and consequently, the treatment and the recovery become more easy and economic.

The NDT application in India has grown during the last few years. However, the routine procedures are not well known in the civil engineering area. The NDT methods are not reliable to measure the structure strength, but they are useful to analyse the concrete properties and to determine its homogeneity. The correlation between the NDT and the structure strength can be established. The correlations are particular for a certain type of concrete and must be used with caution. Concrete properties can vary considerably depending on the nature and proportions of its materials, the construction methods and the loading and environmental conditions. In order to prevent and control the concrete deterioration, it is interesting to establish continuous monitoring strategies, which might be a powerful tool to increase the service life of concrete. This implies the development of control methods which are able to determine the quality and the condition state of concrete.

UPV methods can play an important role in this area, since they allow us to monitor the density and homogeneity of the material, providing information about the strength evolution and about the existence of internal flaws and defects. The UPV methods have been used in inspection operations and monitoring of concrete structures. This test allows to measure and to control a series of basic parameters to determine the concrete quality. However, interpreting the result of this type of test need to be made in a criteriously form and demand a specific knowledge of the influential factors.

A series of comparison between pre and post repairing results of UPV test demands some active importance to this test in civil engineering. This study completely indicates the benefits of UPV for condition assessment of concrete structures.

II. Ultrasonic Pulse Velocity

UPV is a mechanical assembly which is used for over a decade now in India to assess inside condition of a solid material. It is developed over the years and has been in use for several years in civil engineering field for condition assessment of any concrete structure. It is also taken under the Indian Standard for Non-destructive testing method by the civil engineering council and advisory committee of civil engineers in India. (IS- 13311 Part-I).Among the available methods of NDT, the UPV methods can be considered as one of most promising methods for evaluation of the concrete structures, once it makes possible an examination of the material homogeneity. It is possible to obtain a total control of a structure, using the properties variations with the time. The UPV methods make possible the continuous evaluation of concrete conditions during entire service life of structure. The UPV results can be used for diagnosis, prognosis and quality control of concrete structure. The

method is based on high frequency sound wave propagation which passes through the material. The speed of the wave varies in function of the density of material, allowing the estimation of the porosity and the detection of discontinuities.

The basic idea is to project the sound inside a material and measure the time necessary for the wave to propagate through it. Once the distance is known, it is possible to determine the average pulse velocity, which will depend on several factors such as the nature of the material and the presence of water in the pores, among others. The method is normally based on the use of portable equipment, composed by the source/detector unit and the surface transducers, which works in the frequency range of 25 to 60 kHz. The ultrasonic pulses depend on the density and elastic properties of the material.

III. Technical Approach Of Device

The ultrasonic pulse velocity measurement technique involves determination of velocity of ultrasonic pulse through concrete. The velocity of these pulses depends upon the density and elastic properties of the material. The quality of some materials is sometimes related to their elastic stiffness so that measurement of ultrasonic pulse velocity in such material can often be used to indicate their quality as well as to determine their elastic properties.

The pulse is generated by electrical pulse generator with the assistance of a 12 volts - 7.2 Mah battery. Transducers are held as a subject of transmitting and receiving agents of pulse in the assembly. Amplifier enhances the signal strength of the pulse; better indications for the transducers are being produced through the amplifier. The period of covering a distance from a transmitting end to receiving end in a solid material is shown by the electronic timing device.

The pulse velocity is determined by the equation:

$$\text{Pulsevelocity} = \frac{\text{PathLength}}{\text{TransitTime}}$$

Velocity of the pulse generated has to be determined once it is propagated, as the whole idea of detecting defects in a solid material or concrete is based on the velocity at which the pulse travels through concrete. The path length describes the distance of the transmitting end to the receiving end of the solid material, and transit time is the time elapsed to cover the particular path length. Both of this quantities are measured to determine the pulse velocity.

IV. Methodology

The instrument indicates the time taken for the earliest part of the pulse to reach the receiving transducer measured from the time it leaves from a suitable point on the surface of the material. The method of application of the UPV consists of three methods. The basic process of the method involving application of UPV is to setup the assembly (UPV) to work in order to get appropriate results.

As per IS 13311 (Part I) 1992

Sr No.	U.P.V. (km/sec.)	Quality of Concrete for Direct Method
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3km/sec.	Doubtful.

Note: - Readings of semi direct & indirect methods are less than direct method generally by 1km/sec

Pulses are not transmitted through large air voids in a material and if such a void lies directly in the pulse path, the instrument will indicate the time taken by the pulse, which followed quickest rout. It is thus possible to detect large voids when grid of pulse velocity measurement is made over a region in which voids are located.

In order to detect flaws and to process safe working functions there are three methods or patterns of testing a concrete structure by UPV. [5]

1. Direct method
2. Indirect method
3. Semi-direct method

1.1 Direct method is the most accurate and promising method of the UPV test. Appropriate results and exact evaluation of the structure can be obtained by this method. It is generally practiced where both the phase of the structural members exactly opposite to each other are approachable by the device. Direct method comprises of exact path length of the column or beam or any structural member. The path length in direct method is considered as the width of the structural member.

1.2 Indirect method is used where only one phase of the structural member is available and visible. Structures such as R.C.C chimney and cement silo and residential buildings where all structural members are uniformly built in, these are the places where indirect method is practiced more often. Path length in indirect method is taken in between 100 to 200 mm.

1.3 Semi-direct method is practiced where two phases adjacent and not exactly opposite two each other are available. Path length in such case is calculated using Pythagoras theorem. It is not used more often in order to obtain exact results and comparative to direct method.[7]

V. Experimental Representation

As a part of the study, experiments are carried out to enhance the presumption of this paper that UPV results are considered in order to edge pass the life of concrete structure.

A random school building is taken for analysis. Analysis of complete structural members were carried out with UPV test. The work has been Approached as per the standard specifications given in IS 13311 (1992 part-1).

The main objective of this paper is to show efficiency of the UPV test in concrete structure and for detecting flaws in concrete structures so that appropriate measures can be uplifted in order to increase the life of that structure. The comparison of the results before retrofitting and after retrofitting has been put forth in order to showcase the significance of UPV. For the prospect of better understanding, some selected columns of ground floor has been included in this study.

The results shows clear case of doubtful quality of concrete in each and every vertical structural element (according to IS 13311, 1992-1).

The generalize and accurate approach is the direct method of testing the structural components of the structure, and hence the direct results has been taken considering the accuracy of results.

Deficiencies like voids, air gaps, corroded reinforcements, less uniformity, hollow spaces and structural cracks or other changes in concrete which are the results of frost, fire, chemical vicinity, environmental dysfunction or other imperfections, can be considered for retrofitting of the structure. The result indicates clear flaws in the concrete of the vertical structural member of the structure. With these results, the structural engineer suggested that the structure should be retrofitted in order to avoid collapse and to increase the life of the structure and to rectify the flaws that are developed over the years in the concrete.

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VI. Remedial measures and recommendations for retrofitting of the structure

1. As per the UPV report all the structural members need grouting at every junction point of the structural member. Grouting should be carried out as per the specifications.
2. Grouting for cracks less than 10 mm wide: All the cracks less than 10 mm wide should be grout with non-shrink free flow low viscosity solvent free epoxy grout.
3. All the vertical structural members should be jacketed and retrofitted. As per the UPV report, huge amount of honeycombing and major structural cracks and voids are detected. Columns need to be jacketed as per the specifications of jacketing for existing columns.

The above measures were suggested by the experts after going through the NDT report.After the processing of the above measures on the structure were done, for further completion of the study, the complete structure which is now been retrofitted by standard specifications is again taken for analysis by UPV test. Analysis of each and every structural members was carried out. The structural members of ground floor which were analysed before retrofitting was again analysed.

UPV Results before and after the Retrofitting and grouting in the structural members of ground floor.

Sr no.	Structural component	Particular	Pre-Repaired				Post-Repaired			
			Path length (L)	Time interval (Micro sec.)	Velocity Km/sec	Avg. velocity	Path length (L)	Time interval (Micro sec.)	Velocity Km/sec	Avg. velocity
1.	C1 (G.F)	Direct	230	140	1.64		280	79	3.54	
2.	C2 (G.F)	Direct	230	122	1.88		280	66	4.24	
3.	C3 (G.F)	Direct	230	81	2.83		280	68	4.11	
4.	C4 (G.F)	Direct	230	95	2.42		280	63	4.44	
5.	C6 (G.F)	Direct	230	107	2.14	2.10	280	49	5.71	4.37
6.	C7 (G.F)	Direct	230	92	2.50		280	59	4.74	
7.	C8 (G.F)	Direct	230	89	2.58		280	53	5.28	
8.	C10 (G.F)	Direct	450	174	2.58		500	127	3.93	
9.	C11 (G.F)	Direct	230	114	2.01		280	71	3.94	
10.	C12 (G.F)	Direct	230	498	0.46		280	75	3.73	

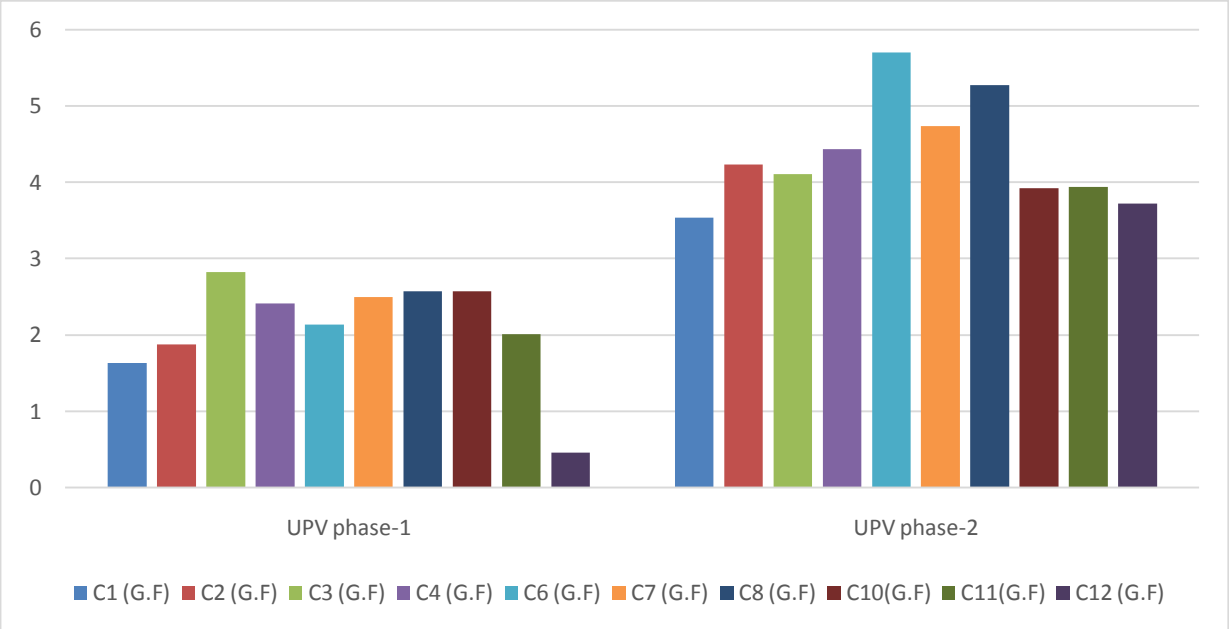
Note: - Readings of semi direct & indirect methods are less than direct method generally by 1km/sec.

The results shows clear case of doubtful quality of concrete in each and every vertical structural element (according to IS 13311, 1992-1).

The results of the ground floor columns after the retrofitting work are completely in contrast to the results obtained on the columns before the retrofitting and grouting. This result indicates excellent quality of concrete (acco.IS13311 Part-1).

VII. Graphical Representation

The graphical representation of the velocities of UPV test on each of the 12 columns of the ground floor pre and post retrofitting are shown.The graphical representation made it quite convincing that the use of UPV has proved to be a valuable as non-destructive equipment in order to detect flaws and assess the life and condition of the concrete structure. Efficiency of UPV has been put forth through this study.



Graphical representation of the UPV results of ground floor vertical structural members.

UPV Phase – 1 – Pre - retrofitting
UPV Phase – 2 – Post- retrofitting

VIII. Conclusion

The test results ends with a convincing graphical representation of two of the velocities of each floor before and after retrofitting and grouting repair work. UPV results for velocities of after repair works are relatively indicating a well nourished or good quality of concrete as compared to velocities of the test conducted before the repair works.The difference between the velocities in the graphs is stating that the UPV test is liable in detecting the flaws like structural cracks, voids, honeycombing and many more structural deficiencies in concrete structures.Complications and problems in the concrete structures can be detected and can be studied on for the repair works. The test results comprises the efficiency of UPV test throughout the technical paper.UPV test can be considered the best in obtaining the accurate condition of the concrete in concrete structures.The experiment carried out just portrayed the significance UPV test brought to the life of the structure. Before the application of an kind of repair work, it was thoroughly analysed and the structural calamities were brought in front with the help of the UPV test and on the base of those results the structure is retrofitted and repaired by Grouting in structural cracks and jacketing the vertical structural members.This paper technically proves the efficiency of UPV test in the life of any concrete structure.

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