Correlation Curves to Characterize Concretes by Means of Non-Destructive Tests

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Abstract—There are many technologies available for supervising and investing quality of concrete. These methods are not only limited to laboratory test but also in-situ tests are available for previously constructed structures. Now a day, numerous NDT methods are available for finding the strength and other features of concrete such as CAPO test, rebound hammer test, ultrasonic pulse velocity test etc. Out of these NDT test ultrasonic pulse velocity method (UPV) and rebound hammer (RH) are extensively accepted by researchers and engineers as they are relatively simple to perform and identify the readings. Though, the analysis of test data is not simple, because the results are significantly influenced by environmental exposure to which structure it is rendering. So, it is needed to establish a correlation between outcomes of these techniques and actual strength of concrete structures before assessing the strength of existing structures. In the present research, a correlation has been recognized between compressive strength of concrete structures and NDT results.

Key words: NDT Techniques, Ultrasonic Pulse Velocity Method, Rebound Hammer, Correlation Curves

I. INTRODUCTION

Concrete is a blend of aggregate and cement paste, this paste combines with aggregates. Superiority of concrete depends upon the quality of constituents. It is the most frequent utilized materials by the construction industries. Compressive strength of concrete is one of the important factor to assess the overall supremacy of concrete as other mechanical prosperities are directly associated to the compressive strength [5].

Quality assessment of concrete in structures is frequently performed by testing standard specimens. Thus, the direct determination of concrete strength requires preparation and testing of prepared samples. The standard test method gives an idea about the potential concrete strength. Though, the standard tests results may not be same as that of actual concrete strength since the compaction and curing regimes applied in situ and in standard technique are fairly different. Consequently, non-destructive tests are extensively utilized to evaluate the strength of concrete in structures. Besides, as the name indicates, non-destructive tests do not make any damage or harm to the concrete and neither influences the behavior of structure. These methods can also be utilized for the well-organized planning of the construction works in huge infrastructure projects, in which it may be required to know strength of concrete structures in order to determine the removal time of formwork, the stressing or releasing time for the wires in pre-stressed members, the loading time for the system in post-tensional elements or the time for opening the structure to service safely. There are various non-destructive techniques available in order to evaluate the strength of concrete structures.

II. REBOUND HAMMER & ULTRASONIC PULSE VELOCITY TEST

- Rebound hammer test is done to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) - 1992. The hammer can be used in different positions (horizontal, vertically overhead or vertically downward) as well as at any transitional angle, but it should be perpendicular to the surface under test.
- Pulse Velocity technique is a suitable technique for examining structural concrete. The fundamental principle of evaluating the quality of concrete is that relative higher velocities are achieved when the superiority of concrete in terms of homogeneity, density and consistency is excellent. In case inferior quality of concrete, lesser velocities are found. If there is a void, fracture or flaw within the concrete which appears in the way of diffusion of the pulses, the pulse strength is attenuated and it passes around the discontinuity, thereby making path length longer. Consequently, lower velocities are obtained. The actual pulse velocity obtained depends primarily upon the material and the mix proportion of the concrete. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity.

III. LITERATURE REVIEW

Several researchers used different NDT equipments in order to assess the condition of RC structures. Palermo et al. (2018) worked on non-destructive testing methodology for damage evaluation of RC structures after seismic events. In this research, ultrasonic and sonic wave propagation in the solid matter was used in order to identify and investigate the modifications stimulated by the seismic load on RC structures. The adopted methodology was experimented through live shaking tests reproducing numerous earthquakes. Table shaking tests were executed at ENEA Casaccia Research Centre on a full-scale 2-storey RC frame building designed under the current Italian code (NTC2008). Among the applied NDT techniques, direct and indirect sonic methods, as well as partial and complete methods for ultrasonic tomography application was explored.

Stergiopoulou et al. (2008) showed a procedure for NDT of urban concrete infrastructures by means of UPV measurements, and applied to concrete garages. UPV has been used as an indicator of concrete quality.

A steel bridge using several NDT methods has been inspected by Rens and Kim (2007), the methods used are such as visual inspection, hammer sounding, UPV testing including tomographic imaging, Schmidt hammer; Outcomes
of NDT had been used to determine areas, to be checked with local destructive tests such as: compressive strength, chloride testing and Petrographic testing. Magnetic concrete covermeters are widely used to estimate the cover to steel bars.

A case study of deteriorated water tanks located in the semitropical region of India has been done by Bhadauria and Gupta (2007). Factors measured are concrete cover, compressive strength, carbonation depth, chloride concentration etc. NDT methods used are, Cover-meter, Phenolphthalein indicator test, Quantab test, Potentiometric titration, Schist’s hammer test and UPV test.

Dias and Jayanandana (2003) used nondestructive techniques such as visual inspection, perusal of drawings, ultrasonic pulse velocity measurements, Cover-meter surveys and core testing for the condition evaluation.

Rufino & Relunia (1999) observed that nondestructive testing of concrete is extremely complex and it is difficult to setup experimental procedures and to study the obtained data. However, latest study and research activities have revealed the different methods of NDT, like the electromagnetic method, ultrasonic pulse velocity test, pulse echo/impact echo test, infrared thermography, radar or short pulse radar techniques, neutron and gamma radiometry, radiography, carbonation test and half-cell potential method available for NDT of concrete structures.

IV. EXPERIMENTAL RESULTS

On the basis of data obtained from testing cubes of different grades. Correlation curve on crushing strength test, rebound hammer and UPV test has been made.

in table 1. It has been noted that results obtained from above eqns. are almost same.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Rebound Number</th>
<th>UPV (km/s)</th>
<th>Compressive strength (Rebound eqn.) in Mpa</th>
<th>Compressive strength (UPV eqn.) in Mpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure 1</td>
<td>27</td>
<td>3.84</td>
<td>28.568</td>
<td>29.61456</td>
</tr>
<tr>
<td>Structure 2</td>
<td>24</td>
<td>3.44</td>
<td>25.709</td>
<td>25.62096</td>
</tr>
<tr>
<td>Structure 3</td>
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<td>3.78</td>
<td>28.568</td>
<td>29.01552</td>
</tr>
<tr>
<td>Structure 4</td>
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<td>3.78</td>
<td>26.662</td>
<td>29.01552</td>
</tr>
<tr>
<td>Structure 5</td>
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<td>3.24</td>
<td>22.85</td>
<td>23.62416</td>
</tr>
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<tr>
<td>Structure 7</td>
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<td>3.61</td>
<td>25.709</td>
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</tr>
<tr>
<td>Structure 8</td>
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<td>29.521</td>
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<td>Structure 9</td>
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<td>3.01</td>
<td>19.991</td>
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<tr>
<td>Structure 10</td>
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<td>3.79</td>
<td>31.427</td>
<td>29.11536</td>
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<tr>
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<td>30.474</td>
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<tr>
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<td>Structure 13</td>
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<td>29.521</td>
<td>29.11536</td>
</tr>
<tr>
<td>Structure 14</td>
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<td>3.85</td>
<td>30.474</td>
<td>29.7144</td>
</tr>
</tbody>
</table>

Table 1: Data Obtained through In-Situ Testing of Structures

![Image](image1.png)

Figure 1 – Crushing Strength vs Rebound Number

![Image](image2.png)

Figure 2 – Crushing Strength vs Ultrasonic Pulse Velocity

Field survey has been done in order to obtain data for assessing the values of compressive strengths and shown

V. CONCLUSION

1) Correlation curves are generally provided with NDT equipments in order to calculate the desired values through in-situ obtained results. Though, local
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conditions may the affect in-situ results. In the present work local correlation curves and equations for rebound hammer and UPV equipments have been developed.

2) Following equations have been developed for Rebound hammer and UPV equipments.

\[ f = 1.317 \times N^{0.825} \]  (Rebound eqn.)
\[ f = 1.423 \times V^{1.688} \]  (UPV eqn.)

3) 15 existing structures have been examined to find the in-situ strength for validation of equations developed. Results obtained by using field data and above two equations were compared in fig. 5.9.

4) Equations show a high degree of accuracy having regression coefficient 0.837.

5) For evaluating the in-situ condition of existing structures NDT methods are most suitable techniques.

6) NDT methods assess the structure without harming its future usefulness.

REFERENCES


