Faculty of Engineering and Technology

Civil Engineering Department

Construction Materials Laboratory

ENCE215

Experiment # 6

" Non-destructive test: Hammer, Ultrasonic and core testing"

Instructors :-

Dr. Nizar Assi.

Eng. Yasser Saad

Done By Group #C :-

Mojahed Sabbah 1171996

Date of performing the experiment: 5-11-2014

Date of submitting the experiment: 20-11-2014

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- **Introduction**

Background information

It has become elementary that concrete is recognized by its strength, were this property of is the most relevant to engineers when designing structures and constructions using concrete. The direct way to measure the strength of concrete is by crushing standard specimens under standard circumstances, and this method lies under the category of destructive concrete testing. However, this could be impossible if testing concrete's strength in already preexisting structures is desired. If the latter is the case engineers resort to conduct indirect tests ' Non-destructive tests ' on these structures, were the structural element to be tested is preserved after testing. These tests were invented based on experimental procedures and correlating empirical results with actual direct strength. In addition, this method of testing is advantageous if the cubes (or any other specimen) taken from site fail the direct crushing test, so before judging that the project should be destroyed, it is a must to examine the project by non-destructive methods.

One of the most common non-destructive tests is the Schmidt hammer or the Rebound hammer test, where it is performed using a special mechanical hammer consisting from an inside standard mass attached to a spring and a plunger, when the plunger is pressed against the concrete's surface the spring and the mass are released to hit the surface of concrete, after the impact the mass rebounds and the pointer moves on the graduated scale on the hammer, this obtained value is called the ' rebound index '. If the concrete to be tested is stiff and strong it will not absorb high amount of energy and the mass rebounds to a high instinct giving a higher rebound index, while if the concrete is weak and has low stiffness, it will be able of absorbing high amount of energy, which gives lower rebound index. It is crucial to pay attention to the orientation of the hammer when performing the test, since each orientation angle is differently correlated to the strength of concrete. After the rebound indices are obtained the strength could be evaluated using curve from graph (1) in the references section.

Another important method of non-destructive testing is the ' Ultrasonic Pulse Velocity Test '. This test is mainly used for determining the quality of concrete. The basic principle of the test is to transmit a wave through concrete, and see how fast it travels. The faster the pulse travels through concrete the stronger it is expected to be, since higher velocity indicates internal uniformity of concrete, while if the pulse travels slow inside concrete, it is an indication of low uniformity of concrete or the presence of voids or internal cracks (waves travel faster through solids than gas or air). To proceed in this test, an ultrasonic pulsing device is needed, it consists of an electrical pulse generator, an amplifier , an internal timing circuit and two transducers (transmitter and receiver). The transducers are put on the element, the pulse generator sends an ultrasonic wave starting from the transmitting transducer, when the wave is received by the other transducer, the time of travel measured by the internal timing circuit is displayed on the screen's device, the velocity is calculated by dividing the distance between the two transducers over the time of travel. By plugging this calculated velocity into the curve in graph (2) the compressive strength is evaluated. There are three arrangements to place the transducers, the direct method where the two transducers are placed in the opposite directions and both have the same line of action. The semi direct method, were the one of the transducers is placed on the side surface of the element, and the other is placed on the top or bottom of the element (perpendicular lines of action). The last method is the indirect, where both transducers are placed on the same surface with a distance between them (parallel lines of action).

The last non-destructive testing method involved in this experiment is the ' core testing '. as mentioned earlier, when testing the direct compressive strength of specimens by crushing fails to achieve the specified strength, it is important to examine an actual sample from the structural element itself. This is done by collecting different core (cylindrical) samples of the structure using a drill cuter and crushing them directly using the compressive crushing machine. The reason behind this procedure is that even if the original specimens fail that doesn't mean that the structure would fail too, it might be that these specimens are not representative of the structure due to many reasons such as bad preparation of samples or poor laboratory conditions, hence the cores are taken since they are considered representative of the actual structure.

Attention should be paid that these testing methods were designed for plain concrete, and they would give inaccurate readings in case the tested concrete is reinforced, so a metal detector should be used in order to avoid testing reinforced regions.

Purpose

The goal of this experiment is to evaluate the strength of concrete specimens indirectly using three non-destructive testing approach (Schmidt hammer, Ultrasonic Pulse Test and the Core Test).

- **Hypotheses**

These experiments were based on completely empirical relations and statistical analysis, thus the values of strength are very approximate and might differ largely from actual strength measurements.

Formulas:

1) $\rho = \frac{W_{SSD}}{W_{SSD} - W_{Sub}}$

Where:

ρ: density of the specimen.

W_{SSD}: saturated surface dry weight of the specimen.

W_{sub}: water submerged weight of the specimen.

2) $V = \frac{D}{\Delta t}$

Where:

V: pulse velocity.

D: distance between the centers of transducers.

Δt: pulse's time of travel.

3) For the indirect arrangement the distance is calculated using Pythagorean theorem.

4) cubical strength = $\frac{cylindrical\ strength}{0.8}$

- **Procedure**

a) Schmidt hammer

1- Specimens of hardened concrete were already prepared in the lab (10mm cube, 150mm cube, 150mm *300mm cylinder, 100mm*100mm*500mm prism).
2- The Schmidt hammer was placed vertically downward (angle = -90^o) on the top face of the 10mm cube, and the hammer was moved vertically downward until the plunger released the mass and a high sound of impact was heard.
3- Just right after the impact and before moving the hammer, the lock button was pressed to maintain the measurement.
4- The same procedure was repeated on five different points of the same cube and five different rebound indices were recorded.
5- The same procedure was followed with the large cube, the cylinder and the prism.
6- For the sake of comparison another five measurements were taken horizontally for the large cube (angle = 0^o).

b) Ultrasonic

1- The transducers of the ultrasonic device were covered by grease (prevents distraction of pulses).
2- The device was calibrated using a calibrating rod.
3- A thin circular layer of grease was spread on each specimen at the area where the transducers are to be placed.
4- For the small cube direct measurement were taken by placing the transducers oppositely on each lateral side, and then the device was turned on, the time was recorded.

5- For the large cubes direct measurement were taken as in step 2, besides to semi direct measurement were one transducer was placed at the centre of the top surface, and the other was placed at the centre of the lateral surface, the time displayed on the screen was recorded.

6- For the cylinder only direct measurement was taken same as for the small cubes.

7- For the prism direct measurement was taken, in addition to indirect measurement where the transducers were both placed at one of the (100mm * 500mm) surfaces with a dividing distance.

8- The pulse was turned on and the time was recorded, also the distance between the centres of the transducers was measured.

c) Core test

1- A cylindrical core was drilled from a large cube using the core cutter drill.

2- The core was cured in water (fully submerged) for seven days.

3- After the seventh day the core was taken out of water, then it was weighed on the balance at saturated surface dry condition, also it was weighed when submerged in water.

4- Visual inspection was carried on the core to make sure that the core was in acceptable condition (no huge cracks or large voids).

5- The maximum void size and the maximum aggregate size were measured.

6- The dimensions of the core were measured using the calliper.

7- Then the sample was crushed using the compressive machine and the strength was calculated.

- **Instruments**

Apparatus and Tools:

fig(1): Ultrasonic device

fig(2): calibrating rod

fig(5): compressive machine

fig(6): core cutting drill

fig(3): grease

fig (4): Shmidt hammer

fig(7): balnce

fig(8): caliper

- **Data & Calculations:**

<table>
<tr><td colspan="6">Table(1): Rebound indices and associated compressive strength</td><td></td></tr>
<tr><td>specimen</td><td>Angle (^o)</td><td>Readings</td><td>Best three readings</td><td>Strength (MPa)</td><td>Average Strength Of cylinder (MPa)</td><td></td></tr>
<tr><td>Cube (10mm)</td><td>-90</td><td>36
35
35
34
39</td><td>36
35
35</td><td>37
34
34</td><td>35</td><td></td></tr>
<tr><td>Cylinder</td><td>-90</td><td>31
31
21
32
28</td><td>31
31
32</td><td>26
26
28</td><td>26.7</td><td></td></tr>
<tr><td>Cube (150mm)</td><td>-90</td><td>32
26
28
30
27</td><td>26
28
27</td><td>20
24
22</td><td>22</td><td rowspan="2">20.9</td></tr>
<tr><td>Cube (150mm)</td><td>0</td><td>20
29
32
30
26</td><td>28
30
32</td><td>17
19
23</td><td>19.7</td></tr>
<tr><td>Prism</td><td>-90</td><td>30
36
33
33
37</td><td>30
30
33</td><td>26
26
30</td><td>27.3</td><td></td></tr>
</table>

<table>
<tr><th colspan="6">Table(2): ultrasonic pulse time, velocity and associated strength</th><th></th></tr>
<tr><th>Specimen</th><th>Arrangement</th><th>D (cm)</th><th>Δt (μ.s)</th><th>V (Km/s)</th><th>Strength (MPa)</th><th></th></tr>
<tr><td>Cube 10mm</td><td>Direct</td><td>10</td><td>23.5</td><td>4.26</td><td>32</td><td></td></tr>
<tr><td>Cube 150mm</td><td>Direct</td><td>15</td><td>38.8</td><td>3.87</td><td>21</td><td rowspan="2">20</td></tr>
<tr><td>Cube 150mm</td><td>Semi direct</td><td>10.6</td><td>28.8</td><td>3.68</td><td>19</td></tr>
<tr><td>Cylinder</td><td>Direct</td><td>30</td><td>91.6</td><td>3.28</td><td>14</td><td></td></tr>
<tr><td>Prism</td><td>Direct</td><td>50</td><td>116.6</td><td>4.29</td><td>33</td><td rowspan="2">28.5</td></tr>
<tr><td>Prism</td><td>Indirect</td><td>38.5</td><td>96.4</td><td>3.99</td><td>24</td></tr>
</table>

Table(3): Core test data

SSD weight (gm)	1515
Submerged weight (gm)	870.5
Volume (cm^3)	644.5
ρ (gm/cm^3)	2.35
Length of specimen (L) (mm)	149
Diameter of specimen (d) (mm)	74.5
Max size of voids (mm)	6
Max size of aggregates (mm)	33
Cross sectional area (cm^2)	43.57
L / d	2
Failure force (KN)	112.2
Cylindrical strength (MPa)	25.75
Cubical strength (MPa)	32.19

- **Results & Conclusion**

1) The small cubes gave strength of 35 MPa using the hammer test and 32 MPa using the ultrasonic test, and these values are considered close to each other.
2) The large cubes gave strength of 20.9 MPa using the hammer test and 20 MPa using the ultrasonic test, and these values are considered close to each other.
3) The cylinder gave strength of 26.7 MPa using the hammer test and 14 MPa using the ultrasonic test, these values are highly deviated.
4) The prism cubes gave strength of 28.5 MPa using the hammer test and 27.3 MPa using the ultrasonic test, and these are considered close to each other.

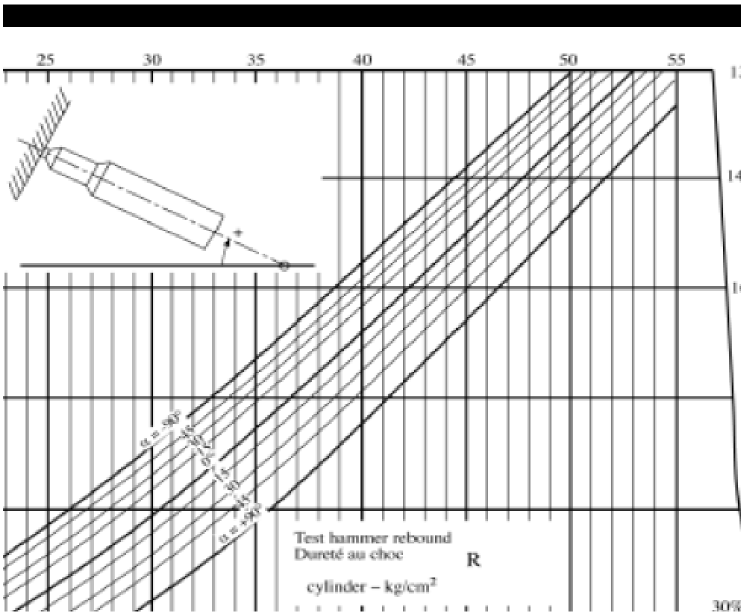
It is noticed that the strength obtained by both ways could be considered satisfactory, even though errors are highly present in the experiment, some are:

1- The hammer measures the hardness of concrete only on the surface (3cm deep).
2- If the point to be tested with the hammer is right over an aggregate a false higher strength is measured.
3- Excessive grease affects the pulse velocity.
4- Poor arrangement of transducers.
5- Maladjustment of the core drill.

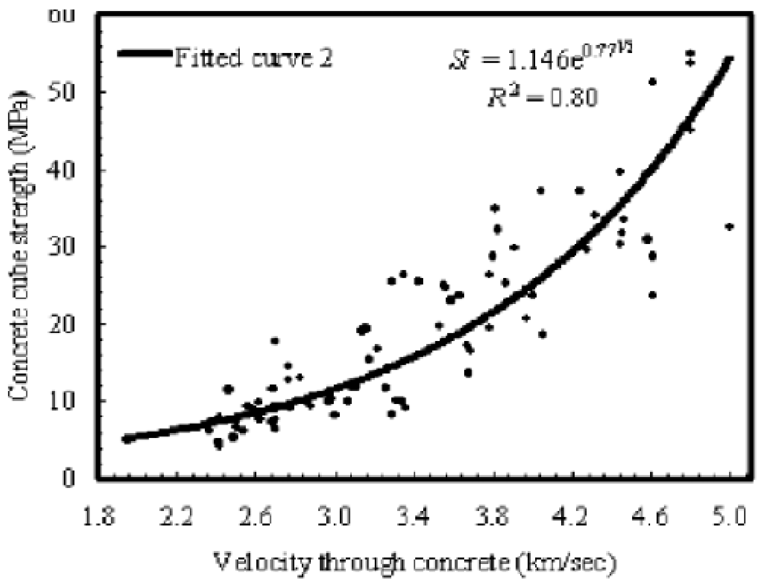
In this experiment it is all about approximation since all the curves are based on empirical results and that's why results could be accepted despite large errors.

- **References**

Materials for civil and construction engineers, Michael S. Mamlouk, John P. Zaniewski.



graph(1): compressive strength V.S rebound index



graph(2): compressive strength V.S pulse velocity