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Testing on Cores from Concrete Roads

Parvez Khan[1] and Shrikant M. Harle[2]
[1]B.E. Final Year Student, [2]Assistant Professor, Department of Civil Engineering, Prof Ram Meghe College of Engineering and Management, Badnera, Maharashtra, India

***Corresponding author**
Shrikant M. Harle

Email:
shrikantharle@gmail.com

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Abstract: This study presents the information and conclusions about numerous tests – destructive and non-destructive – on concrete core specimens. The main focus is made on basic tests namely density test, water absorption test, rebound hammer test, ultrasonic pulse velocity test, and compression test. All test aim to provide us a comprehensive and sufficient data for assessing the 'quality' and 'strength' of concrete core specimens. The details all the necessary and essential points commencing from the preparation of core specimens, as per various nationally and internationally accepted design codes for concretes, ranging from procedures of tests, leading to final conclusions and findings of core strength and quality and their correlations. Comparative study of block concrete pavements and in-situ concrete pavements are briefly made and their strengths and quality are assessed. Basic requirements for ideal core dimensions are also explained. Also, two specimen cores from PCCBP (Plastic Cell filled Concrete Block Pavement) were tested for density test and water absorption test. Their inferences are also mentioned in conclusion section of the study.
Keywords: concrete core specimens, hammer test, concrete pavements, PCCBP

INTRODUCTION

The introductory part explains about various tests made on cores, their need, and their inferences. Starting from the basics and known facts, it gives all details of tests that can be performed on concrete cores. Also, water absorption and density tests are done on PCCBP cores. They are explained in discussion and conclusion.

General

Assessment of in-situ concrete strength in structures is always a challenge for engineers. How to exactly deal with it has always been the matter of concern. In the current methodology, nondestructive techniques (NDT) are combined with destructive techniques (coring tests) in order to implement a relationship "conversion model" between the compressive strength and NDT measurements [1]. The Compressive strength of concrete is surely one of the prominent factors that affect the overall safety of a RC structure. Any assessment begins with a survey of the structural system and of the existing documentation, which may contain information also on the materials that had been used for the construction. However oftentimes these documents have been lost or may be unreliable, so that an experimental evaluation of the material properties is almost always required. The assessment of in situ concrete compressive strength is typically performed extracting concrete cores from the structure and then by testing them in compression testing machines. All existing standards implicitly assume that the measured core strength values are independent one to each other, even though it is reasonable to think that in situ concrete strength is actually a realization of a random field with a certain correlation function [2].

The concrete blocks can be either precast or cast in situ. A precast concrete block pavement consists of individual blocks of hand held size units laid on a thin bed of sand, called bedding sand, flanked by edge restraints on either side of the pavement. The blocks are separated by about 2 to 4 mm and the gaps are filled with jointing sand. A granular or cement bound subbase is provided below the bedding sand to lower the stress on the subgrade. The cast in-situ type of pavement consists of a formwork of polyethylene cells 150 mm by 150 mm in size with thicknesses varying from 50 to 150 mm or greater. The plastic cells are stretched over the carriageway under tension, filled with concrete, and compacted. During compaction, the cell walls get deformed bringing about interlocking among the concrete blocks [3].

LITERATURE SURVEY

Alwash, *et al.* studied reliability of assessing the concrete strength using NDT measurements (rebound hammer test in particular). Two estimated quantities (mean strength and strength variability) had been the target of the assessment using two model identification approaches: regression and bi-objective. The effects of several factors on the reliability of assessment were analyzed. These were: within-test variability of rebound measurements, true concrete strength variability, number of test locations used to identify the model between strength and rebound measurement NC (number of cores in the case of real structure), way of selection the NC test locations (random or conditional), and the model identification approach (regression or bi-objective) [1].

Bonfilgli, *et al*. analysed the influence of spatial correlation of core strength measurements upon assessment of strength of in-situ concrete. The results seem suggesting that in presence of even a modest correlation there exist a minimum core inter-distance, depending on the degree of correlation, below which the accuracy cannot improve anymore. This observation may have practical consequences on the estimation of the desired number of cores to extract in real world scenarios [2]. Ryntathiang; *et.al*. Described the findings of a study carried out for evaluating the performance of cast in situ concrete block pavements for low volume roads. Cast in situ concrete blocks can provide dust-free, low maintenance, and cost effective pavements in rural areas. CIS CBP are found to have better rutting resistance than the precast CBP[3].

Yendrembam Arunkumar Singh investigated the assessment of structural behaviour of different thickness of PCCBP over WBM sub-base layer course 100 mm thick, suggesting that PCCBP can be a good alternative for strengthening the existing bituminous pavements [4]. Mustafa Tuncan, *et.al*. Estimated concrete strength gained from compression tests conducted on cores having a diameter considerably smaller than the recommended one of 100 mm. They examined the results of tests applied on the 69 and 46 mm diameter cores [5]. Mahdi Shariati, *et al*. "Assessing the strength of reinforced concrete structure through ultrasonic pulse velocity and rebound hammer tests" Scientific Research and Essays Vol.6(1),pp.213-220, 4 January,2011 [7]. Kaushal Kishore gave well-established method, enabling visual inspection of the interior regions of a member to be coupled with strength estimation for the examination and compression testing on cores cut from hardened concrete [8].

IS: 456-2000, Plain and reinforced concrete – Code of Practice (Fourth Revision) BIS, New Delhi specified that - the points from which cores are to be taken and the number of cores required - shall be at the discretion of the engineer-in-charge, however fewer than three cores should be tested[9]. IS: 516-1959, Method of test for strength of concrete, BIS, New Delhi described the method of preparation and testing of cores. Cores to be tested for compression strength shall have ends that are reasonably even, perpendicular to the axis and of the same diameter as the body of the specimen [10].

ASTM: C42, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete preferred that the length of the capped or ground specimen should be between 1.9 and 2.1 times the diameter. If the ratio of the length to the diameter (L/D) of the core exceeds 2.1 reduce the length of the core so that the ratio of the capped or ground specimen is between 1.9 and 2.1. Core specimens with L/D ratio equal to or less than 1.75 require corrections to the measured compressive strength. A strength correction factor is not required for L/D ratio greater than 1.75. A core having a maximum length of less than 95% of its diameter before capping or a length less than its diameter after capping or end grinding shall not be tested[10]. BS 1881: Part 120: 1983, British Standard: Testing concrete, Part 120: Method for determination of the compressive strength of concrete cores describes a method for taking cores from concrete and preparing them for testing and for the method for determining their compressive strength, and gives their apparatus details [11].

THEORETICAL ASPECT

The standard cylinder and cube strengths of the concretes produced from crushed limestone aggregate were somewhat higher than those of the concretes produced from natural aggregate, although the w/c ratios of the natural aggregate concretes were lower than that of crushed limestone aggregate [5].

The way of selection the NC test locations may also play a role on the reliability of assessment. These NC locations can be defined in accordance with certain conditions applied on the NDT results ''conditional selection". The idea of the conditional selection is to select the NC test locations that cover, as much as possible, the whole range of the NDT measurements distribution [9].

Core drilling

A core to be tested for strength shall not be removed from structure until the concrete has become hard enough to permit its removal without disturbing the bond between the mortar and the coarse aggregate. Normally the concrete shall be 14 days old before the specimens are removed. It is preferred the concrete should be 28 days old for drilling cores. A core is usually cut by means of a rotary cutting tool with diamond bits. The concrete core drilling machine is portable, but it is heavy and must be firmly supported and braced against the concrete to prevent relative movement which will result in a distorted or broken core, and a water supply is also necessary to lubricate the cutter. Handheld equipment is available for cores up to 75 mm diameter. If the ends of the cores do not conform to the perpendicularity and plainness requirements, they shall be sawed or ground to meet those requirements or capped as per standard procedure.

Capping

Unless their ends are prepared by grinding, cores should be capped with high alumina cement mortar or sulfurs and mixture to provide parallel end surfaces normal to the axis of the core. Other materials should not be used as they have been shown to give unreliable results. Caps should be kept as thin as possible, but if the core is hand trimmed they may be up to about the maximum aggregate size at the thickest point.

It is essential that the cap be thin, preferably 1.5 to 3 mm. The capping material must be no weaker than the concrete in the specimen [10].

Non-destructive tests

Rebound hammer test

This test relates the compressive strength of concrete with its surface hardness. The rebound hammer measures the elastic properties or strength of concrete in terms of surface hardness and penetration resistance. The test hammer hits the concrete with a particular defined energy and its rebound (moving back after impact) depends upon hardness of concrete.

Water absorption test

The percentage of water absorbed in core specimens is to be found out in this test. For this test, specimens are dried in an oven for a defined time and a defined temperature, and then placed in desiccator to cool. Immediately, after cooling specimens are weighed.

Ultrasonic pulse velocity test

An ultrasonic pulse velocity test is an in-situ, nondestructive test to check the quality of concrete and natural rocks. In this test, the strength and quality of concrete or rock is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure or natural rock formation. This test is conducted by passing a pulse of ultrasonic wave through concrete to be tested and measuring the time taken by pulse to get through the structure. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids.

METHODOLOGY

- Density of cores

Apparatus: Weighing Machine, Ruler, Cores

Procedure:

- Firstly the weight of cores was measured using weighing machine.
- Then Diameter and Height were measured.
- Then densities were measured using following formula:

$$\text{Density} = \text{Mass/Volume} = \text{Mass} / (\pi D^2/4).h \qquad \dots (4.1)$$

Water Absorption Test

Apparatus: Weighing Machine, Absorbent Cloth, Oven, Distilled Water

Procedure:

- Firstly dry weight of cores was taken (W_1).
- Cores were placed in oven at 105°C for 72 hours.
- After 72 hours cores were removed from oven carefully and placed in distilled water for 24 hours.
- Then cores surface was cleaned using absorbent cloth.
- Now cores were weighed again. (W_2)

$$\% \text{ absorbed water} = (W_2 - W_1)/W_1 \times 100 \qquad \dots (4.2)$$

- Rebound Hammer Test:

This test relates the compressive strength of concrete with its surface hardness.
Working Principle:

The rebound of rider weight from the plunger due to hammering action is measured. This distance of ground of rebound of rider weight is measured on a scale, which is proportional to the surface hardness of concrete [6].

Procedure

- First of all clean and dry the surface of concrete core.
- The point of impact should be at least 20mm away from any edge or shape discontinuity.
- For taking a measurement the rebound hammer should be held at right angle to the surface of concrete core.
- The test can thus be conducted horizontally on vertical surface or vertically upward or downward on horizontal surface.
- Rebound hammer is conducted around all the points of observation on all accessible surfaces of pavement.

Cost of operation

Rebound Hammer: 10,000/-
Digital rebound hammer: 2,50,000/-
Rebound Hammer is also called as *Schmidt Hammer*.

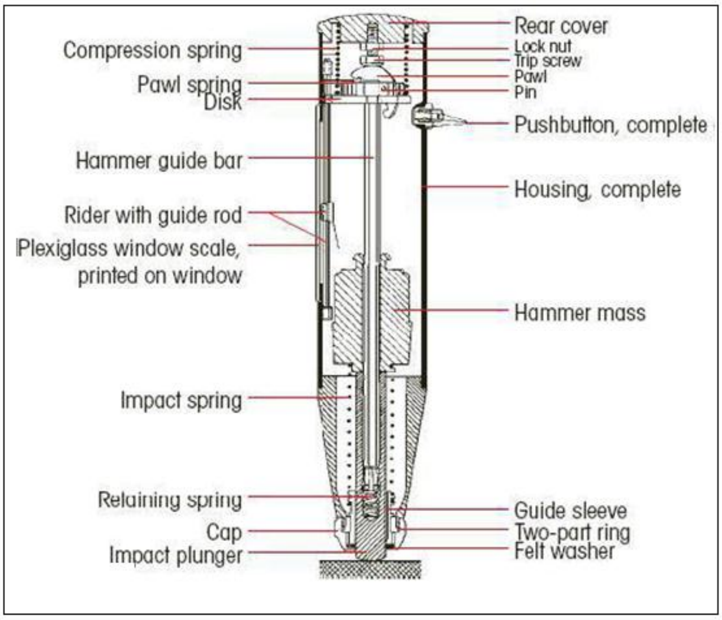

Fig-1: Rebound Hammer [6]

- **Factors affecting the rebound hammer test**

The rebound numbers are influenced by a number of factors like types of cement and aggregate, surface condition and moisture content, age of concrete and extent of carbonation of concrete.

- **Type of Cement**

Concretes made with high alumina cement can give strengths 100 percent higher than that with ordinary Portland cement. Concretes made with supersulphated cement can give 50 percent lower strength than that with ordinary Portland cement.

- **Type of Aggregate**

Normal aggregates such as gravels and crushed rock aggregates give similar correlations, but concrete made with lightweight aggregates require special calibration.

- **Surface Condition and Moisture Content of Concrete**

The rebound hammer method is suitable only for close texture concrete. Open texture concrete typical of masonry blocks, honeycombed concrete or no-fines concrete is unsuitable for this test. All correlations assume full compaction, as the strength of partially compacted concrete bears no unique relationship to the rebound numbers. Troweled and floated surfaces are harder than moulded surfaces, and tend to overestimate the strength of concrete.

A wet surface will give rise to underestimation of the strength of concrete calibrated under dry conditions. In structural concrete, this can be about 20 percent lower than in an equivalent dry concrete.

- **Curing and Age of Concrete**

The relationship between hardness and strength varies as a function of time. Variations in initial rate of hardening, subsequent curing and conditions of exposure also influence the relationship. Separate calibration curves are required for different curing regimes but the effect of age can generally be ignored for concrete between 3 days and 3 months old.

- **Ultrasonic Pulse Velocity Test**

Working Principle

Pulse velocity method is the relation between time taken for the pulse of ultra sonic sound to travel through concrete and coming back and the compressive strength of concrete [6].

Procedure

In this test method, the ultrasonic pulse is produced by the transducer which is held in contact with one surface of the concrete member under test. After traversing a known path length in the concrete, the pulse of vibrations is converted into an electrical signal by the second transducer held in contact with the other surface of the concrete member and an electronic timing circuit enables the transit time (T) of the pulse to be measured. The pulse velocity (V) is given by:

$$V = L/T \qquad \dots (4.4.1)$$

Pulse velocity measurement made on concrete structure may be used by placing the two transducers.

- Opposite faces (direct transmission)
- Adjacent faces (semi-direct transmission)
- The same face (indirect or surface transmission).

The maximum pulse velocity is transmitted at right angles to the face of the transmitter. The direct method is the most reliable one from the point of view of transit time measurement. Also, the path is clearly defined and can be measured accurately, and this approach should be used wherever possible for assessing concrete quality.

Factors affecting the measurement of pulse velocity

- **Surface Conditions and Moisture Content of Concrete**

Smoothness of contact surface under test affects the measurement of ultrasonic pulse velocity. For most concrete surfaces, the finish is usually sufficiently smooth to ensure good acoustical contact by the use of a coupling medium and by pressing the transducer against the concrete surface. When the concrete surface is rough and uneven, it is necessary to smoothen the surface to make the pulse velocity measurement possible.

- **Temperature of Concrete**

Variations of the concrete temperature between 5 and 30°C do not significantly affect the pulse velocity measurements in concrete. At temperatures between 30 to 60°C there can be reduction in pulse velocity up to 5 percent. Below freezing temperature, the free water freezes with- in concrete, resulting in an increase .in pulse velocity up to 7.5 percent.

- **Effect of Reinforcing Bars**

The pulse velocity measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plain concrete of the same composition. This is because, the pulse velocity in steel is 1.2 to 1.9 times the velocity in plain concrete and, under certain conditions, the first pulse to arrive at the receiving transducer travels partly in concrete and partly in steel.

Table-1: Quality of Concrete based on pulse velocity [6]

Sr. no.	Pulse velocity (km/sec) 'v'	Quality of concrete (Grading)
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful

- **Compression Test**

Compressive Strength Test on Drilled Concrete Cores is required to determine the strength of hardened concrete in structure.

Procedure

- Placing the core in the testing machine. Wipe the bearing surfaces of the testing machine and of any auxiliary platens clean and remove any water, loose sand or other material from the ends of the core. Centre the core carefully on the lower platen of the machine. Wherever possible use a jig to align the specimen, do not use any packing other than auxiliary steel plates between the ends of the core and the platens of the testing machine.
- Loading. Without shock apply and increase the load continuously at a constant rate within the range of 0.2 N/(mm2.s) to 0.4 N/(mm2.s) until no greater load can be sustained. On manually controlled machines as failure is approached the load indicator pointer will begin to slow down; at this stage operate the controls rapidly and smoothly to maintain as far as possible the specified loading rate.
- Record the maximum load. Normal failures are reasonably symmetrical. Note any unusual failures and the appearance of the concrete.
- Calculate the compressive strength of each core by dividing the maximum load by the cross-sectional area, calculated from the average diameter. Express the results to the nearest 0.5 N/mm^2.

For cores free of reinforcement- Calculate the estimated in-situ cube strength to the nearest 0.5 N/mm^2 from the equation

$$\text{Estimated cube strength} = \{D/(1.5 + 1/\lambda)\} \times (\text{compr. Strength})$$

Where;

D is 2.5 for cores drilled horizontally (for precast units perpendicular the height when cast); or 2.3 for cores drilled vertically (for precast units parallel to height when cast);

NOTE. It should be noted that in-situ strengths estimated from the above formula cannot be equated to standard cube strength. For cores with reinforcement perpendicular to the core axes: Calculate the estimated in-situ cube strength by multiplying the strength obtained from the formula in above equation by following factor:

$$1.5\ (\phi_r\, d / \phi_c\, l) \qquad \ldots(4.4)$$

where;

ϕ_r is the diameter of the reinforcement;

ϕ_c is the diameter of specimen;

d is the distance of axis of bar from nearer end of specimen;

l is the length of the specimen after end preparation by grinding or capping.

Correction factor

Table-2: Performa for concrete test [7]

L/D RATIO	ASTM C-42	IS: 516
2	-	1
1.75	.98	.97
1.5	.96	.95
1.25	.93	.92
1	.87	.89

Fig-2: Compression Testing Machine

CALCULATIONS

Density of cores

Calculations of density test are discussed in following table:

Table-3: Observation Table for Density Test

	Core 1	Core 2
Weight	1050 gm	1964 gm
Diameter	6.7 cm	9.3 cm
Height	11.5 cm	12.3 cm
Density	2.58 g/cm^3	2.35 g/cm^3

5.2) Water Absorption Test:

Core 1:

W_1 = 1050 gm $\quad$ W_2 = 1100 gm

% absorbed water = $(W_2 – W_1)/W_1$ x 100
% absorbed water = {(1100 – 1050)/1050} x 100
= 4.76 %

Core 2:

W_1 = 1964 gm $\quad$ W_2 = 2070 gm

% absorbed water = $(W_2 – W_1)/W_1$ x 100
% absorbed water = {(2070 – 1964)/1964} x 100
= 5.39 %

Fig-3: Cores from PCCBP

Fig-4: Cores placed in water for 24 hours

Fig-5: Cores after water absorption

CONCLUSIONS

- Density test shows the fillingness and amount per unit size of core. The density of the two cores from PCCBP was found to be 2.58 g/cm³ & 2.35 g/cm³.
- Water Absorption Test gives the percentage of water absorbed in the cores. The cores from PCCBP absorbed 4.76% & 5.39% water.
- The Rebound Hammer Test gives convenient and rapid indication of compressive strength of concrete. It also purposes to assess the uniformity and quality of concrete.
- The Ultrasonic Pulse Velocity Test checks the quality of concrete analyzing the cavities and homogeneity of concrete.
- The Compression Test gives the compressive strength of concrete.
- The DT & NDT are useful for assessment of quality and strength of concrete.

REFERENCES

1. Alwash, M., Breysse, D., Sbartaï, Z. M., Szilágyi, K., & Borosnyói, A. (2017). Factors affecting the reliability of assessing the concrete strength by rebound hammer and cores. *Construction and Building Materials*, *140*, 354-363.
2. Bonfigli, M. F., Materazzi, A. L., & Breccolotti, M. (2017). Influence of spatial correlation of core strength measurements on the assessment of in situ concrete strength. *Structural Safety*, *68*, 43-53.
3. Ryntathiang, T. L., Mazumdar, M., & Pandey, B. B. (2005). Structural behavior of cast in situ concrete block pavement. *Journal of transportation engineering*, *131*(9), 662-668.
4. Singh, Y. A. (2011). *A Study on Plastic Cell Filled Concrete Block Pavement for Low Volume Rural Roads* (Doctoral dissertation).
5. Tuncan, M., Arioz, O., Ramyar, K., & Karasu, B. (2008). Assessing concrete strength by means of small diameter cores. *Construction and Building Materials*, *22*(5), 981-988.
6. Shariati, M., Ramli-Sulong, N. H., KH, M. M. A., Shafigh, P., & Sinaei, H. (2011). Assessing the strength of reinforced concrete structures through Ultrasonic Pulse Velocity and Schmidt Rebound Hammer tests. *Scientific Research and Essays*, *6*(1), 213-220.
7. Kishore, K. (1995). Synthesis and characterization of photo-crosslinkable main-chain liquid-crystalline polymers containing bis (benzylidene) cycloalkanone units. *Polymer*, *36*(9), 1903-1910.
8. Code, I. S. Plain and reinforced concrete-Code of practice. *New Delhi*.2000.
9. Senthamarai, R. M., & Manoharan, P. D. (2005). Concrete with ceramic waste aggregate. *Cement and Concrete Composites*, *27*(9), 910-913.
10. Yi, S. T., Yang, E. I., & Choi, J. C. (2006). Effect of specimen sizes, specimen shapes, and placement directions on compressive strength of concrete. *Nuclear Engineering and Design*, *236*(2), 115-127.
11. ftp://law.resource.org/pub/in/bis/S03/is.13311.1.1992.pdf : IS 13311 - 1992