A partially destructive method for testing In-situ strength of concrete

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Abstract. Core test is commonly required in the area of concrete industry to evaluate the In-situ compressive strength of concrete and sometimes it becomes the unique tool for safety assessment of existing structure. Core test is therefore introduced in most of the codes. The current method of core testing involves the use of compression tests on cylindrical specimens obtained from cores drilled in-situ. The cores are damaged during extraction, transportation, more time and money involved during sawing and capping and sometimes cores are misplaced and also there is misinterpretation of strength due to variation in site and laboratory conditions. In order to overcome the difficulties, a new machine which simplifies the entire tedious testing process has been developed and used in this research work for testing of concrete strength within the structure. The principle of the machine is to test the un-extracted core with lesser diameters within the site for its Compressive strength. To test the reliability of the machine, cores of different diameters and L/D ratios were tested both by conventional method and newly developed machine and Comparative statistical analysis such as Student’s t-test analysis is done to check the homogeneity of data and the general similarity between the results of Conventional method and the newly developed machine. Nearly 54 core samples of 24mm, 36 samples of 42mm and 36 samples of 67mm diameter of L/D ratios 1.0, 1.5, 2.0 were tested. The statistical analysis like Student’s t-test proved that there is no considerable difference in the newly developed method and the conventional method of concrete core testing.

1. Introduction

The estimation of In-situ concrete strength is most frequently faced whenever it is needed to assess the strength of a structure. Hence research in this field was very wide and many varieties of destructive and non-destructive testing methods were developed. Many codes provide various methods for In-situ strength testing of concrete. However, these codes also given limitations for few methods like UPV could not provide direct strength of concrete but it relates with homogeneity and porosity of concrete and the Rebound hammer indicates approximate strength based on surface hardness of Concrete. Hence there has been an extensive need of a direct test with minimum limitations to test the in-situ strength of concrete. Generally majority of concrete consultants prefer to use Core testing as per different codes like, [1] and [2] which involves testing of cylindrical specimens obtained from concrete structures.

However, the core strengths obtained by this method is affected by many factors which have been discussed by many authors. The most discussed factors among them are Height to diameter ratio (H/D), Diameter of the core, direction of drilling etc. Various authors [3] [4] studied on cores of H/D
ranging from 0.75 to 2 and have found that compressive strength of core samples decreases with increase in H/D. Various codes have provided correction factors for correcting the concrete strengths of cores with H/D < 2. From reference [5] it was found that cores with H/D less than 1 are unreliable due to large variability in results.

It has also been observed that core diameter is equally important as H/D ratio. The impact of core diameter has been mentioned in the research by [6] [3] [7] [4]. They tested core diameters ranging from 25mm to 150mm and observed that the compressive strength of concrete is increasing with the increase in diameter. Although the strength of cores is following a pattern according to diameter, the change is variance of results has been observed by some authors [5] [8] [9] [10] they observed that the Coefficient of variance of compressive strength results increases with decrease in core diameter. Apart from H/D and diameter, strength change has been observed in some other factors like Direction of drilling, moisture condition, and presence of reinforcement and effect of drilling damage.

2. Research significance

The machine is designed in such a way that the cores can be tested within site. Thereby reducing the time and money required for transportation, trimming and capping unlike standard method. The In-situ compression testing machine has been tested and data obtained is compared with the data of standard method using statistical tools and proved no difference. This invention can reduce the damage occurred to the structure due to drilling of large diameter cores and reduces the time and money required for transportation, sawing, capping etc. The typical drawing and description of In-situ compression testing machine has been given in following sections.

3. Materials and Methods

The materials and methodologies followed in this research has been discussed in this section

3.1 Casting of concrete bed

For testing the concrete both by standard method and In-situ methods a concrete bed of M25 strength has been designed and laid at the site.

3.2 Description of in-situ compression testing machine

The In-situ compression testing machine is a device for measuring the compressive strength of hardened concrete within the structure. The instrument includes a base, inverted U shaped frame made of mild steel angular channels of sufficient strength, anchor fasteners 4 no’s, a hydraulic cylinder, a threaded screw to move the hydraulic cylinder up and down, a loading assembly to apply pressure on the fluid in hydraulic cylinder, a ram, a pressure gauge calibrated to show the load transferred. The device is placed on the concrete surface in such a way that the piston exactly sits on the un-extracted core which is cut and left in the concrete structure. Proper care is to be taken by placing metal plates of diameter equal to the core which is being tested to ensure proper load dispersion. Once the device is placed, markings are done at the holes which are provided for anchor fasteners. Holes are then drilled in the particular places and the anchor fasteners are installed to hold the device in position and to take the reactions exerted by the piston.

Once the device is fixed, the pressure is to be applied on the liquid in the hydraulic cylinder which transfers the pressure to the piston. The piston then starts applying load on the concrete core. The corresponding pressure is also transferred to the pressure gauge through the hose which is connected from the hydraulic cylinder to the pressure gauge. Hydraulic hose pipes are connected to both the hydraulic cylinder of the pumping assembly and to the calibrated gauge which shows the pressure applied in kilo Newton, through which the load applied can be known. The pressure gauge has two indicators, a main needle which moves corresponding to the pressure applied, and the needle follower is an indicator which follows the main indicator till the failure load. The picture of the In-situ compression testing machine has been given in Figure 1. Once the concrete under the ram fails, the main indicator comes back to zero and the needle follower stays at the point where the concrete has failed. By this we can find out the load at which the concrete is failing and thereby the compressive
strength of concrete, without the need of bringing the core to the laboratory by extracting the core from the site.

**Figure 1.** In-situ compression testing machine.

### 3.3 Methodology

#### 3.3.1 Standard core test according to IS 516-1959

The cores samples of different diameters 24mm, 42mm, and 67mm and H/D ratios of 1.0, 1.5 and 2.0 ratios are drilled using portable core cutter having rotary cutting tool with diamond bits and collected from the site. The cores were not cured to match with the site conditions. Then they are sawed to required lengths. After sawing the core samples to the required dimensions, capping is done to smoothen the irregularities using molten sulphur as given in the code. The dimensions and weight of the samples after capping is noted and samples were tested in CTM. The core strength of a cylinder is calculated by dividing crushing load by its area.

#### 3.3.2 Compressive Strength Testing of Concrete Cores using In-situ compression testing machine

Since the diameter chosen is lesser, the load at which the specimen fails will also be lesser, thereby reducing the required capacity of the cutting and testing devices. Hence small cores has been chosen for this particular research and the idea of testing the samples within the site has been developed. The diameters of cores chosen for the research were 24, 42 and 67 mm and the design strength of concrete to be tested is 25 MPa, hence the required capacity of the testing device is reduced. Thereby making it easier to transport to site. So, the hydraulic testing device of 100 KN capacity as explained in section 3.2, has been transported to site. By using this device, the stages of standard method which causes delays and errors are eliminated and the entire process was replaced with this in-situ testing system which finishes the testing process in a single stage eliminating the limitations which earlier testing method was facing, like misinterpretation of strength due to sawing, capping and damage of cores during extraction, misplacement of specimens during transportation, variation in results due to site and laboratory conditions and manipulations which may take place due to time lag etc. The different combinations of core samples of diameter 24, 42, and 67mm and H/D ratios of 1.0, 1.5 and 2.0 were
chosen. 9 samples of 24 mm and 6 samples of both 42 and 67mm diameter cores for each H/D ratio were chosen for the research.

In the In-situ compression test method, the equal number of cores as tested in Standard method of different L/D ratios 1.0, 1.5, 2.0 and diameters of 24mm, 42mm, and 67mm are carefully drilled, the core samples were drilled but not extracted from the site. Care was taken such that the L/D ratios is maintained. The In-situ compression testing machine is then taken to the site. The device is placed in such a way that the loading ram is eccentrically placed on the core sample which is left within site. The Compression Load cell of 10 Tonne ($10\, T$) capacity is then placed between the loading ram of the device and the core sample for more accuracy. Cores of different diameters were tested using metal plates of corresponding diameter. Holes are drilled for the anchor fasteners using hammer drilling machine at the necessary locations in the concrete. The anchor fasteners as shown are dropped in the holes drilled. As the bolts are inserted into the fasteners and tightened, the anchor fasteners inside expands and anchors well inside the concrete element. Then the device is tightened thoroughly. Now the device is ready to take the reactions exerted by application of load on the core sample. Load is applied on the core sample gradually, and the load at which the sample fails is then noted. Various trend graphs are prepared from the tests results.

4. Results and Discussion

The data obtained from both standard and In-situ methods are tested with Student’s T-test. The data is tabulated as given in table 1. The Student’s T test has been checked for every combination of core diameter and H/D ratio between the mean values obtained from both standard method of core testing as per IS 516- 1959 and the In-situ method. The results indicated that there has been no significant difference between the mean values of both the methods.

| L/D Ratio | Core diameter (mm) | Core strength | Students t Stat value between both standard and In-situ method | t Critical | t Stat < t c | P Value | P > 0.05, O.K |
|-----------|--------------------|---------------|---------------------------------------------------------------|------------|------------|---------|----------------|
| 1         | 67                 | 27.78         | 28.98                                                         | 0.842      | 2.262      | O.K     | 0.422          |
| 1         | 42                 | 27.39         | 27.19                                                         | 0.169      | 2.228      | O.K     | 0.869          |
| 1.5       | 24                 | 26.08         | 25.15                                                         | 2.122      | 2.131      | O.K     | 0.051          |
| 1.5       | 67                 | 24.15         | 25.97                                                         | 0.985      | 2.228      | O.K     | 0.354          |
| 1.5       | 42                 | 23.82         | 23.34                                                         | 0.389      | 2.228      | O.K     | 0.706          |
| 2         | 24                 | 22.11         | 22.97                                                         | 1.101      | 2.145      | O.K     | 0.289          |
| 2         | 67                 | 23.07         | 23.33                                                         | 1.114      | 2.228      | O.K     | 0.842          |
| 2         | 42                 | 22.31         | 22.38                                                         | 1.054      | 2.228      | O.K     | 0.963          |

The comparative graph of the strength values of both the methods along with the trend line followed by results is given in Figure 2. It has been observed from the graph that both standard and In-situ methods results following almost the same trend line. Hence we can infer from the graph that the In-situ compression testing machine can be used for core testing in the site.

The mean values of the core strength results of both standard method and In-situ method were plotted against the H/D ratio and Core diameter as shown in figure 2. It has been observed from the figures that the core compressive strengths are decreasing as the H/D ratio increases for a given...
diameter and core strengths are decreasing as the diameter increases for a given H/D ratio, in both methods.

It is observed from the data that the standard deviation of the data is increasing significantly as the diameter of the core is decreasing. This variability may be due to variability of coarse aggregate position in core samples. The standard deviation values of both standard and In-situ methods are given in Table 2.

Figure 2. Core compressive strengths of both methods along with trend lines followed.

Table 2. Standard Deviation of core compressive strength results.

| H/D Ratio | Diameter of the Core (mm) | Standard deviation of Standard method | Standard deviation of In-situ method |
|-----------|---------------------------|--------------------------------------|-----------------------------------|
| 1         | 67                        | 1.75                                 | 1.67                              |
|           | 42                        | 1.92                                 | 2.12                              |
|           | 24                        | 2.77                                 | 3.02                              |
| 1.5       | 67                        | 1.51                                 | 1.24                              |
|           | 42                        | 1.89                                 | 2.36                              |
|           | 24                        | 3.11                                 | 3.50                              |
| 2         | 67                        | 1.51                                 | 1.47                              |
|           | 42                        | 2.43                                 | 2.19                              |
|           | 24                        | 2.69                                 | 3.34                              |

5. Conclusions
1. The Student’s T-test values indicated that there is no significant difference between the mean strength values of both standard and In-situ methods at a confidence level of 95%. Hence the In-situ compression testing machine can be used for strength testing of hardened concrete on site.
2. The core compressive strength increased as the H/D ratio decreased for a given core diameter.
3. The core compressive strength increased as the diameter increased for a given H/D ratio.
4. The standard deviation of the strength results increased with the decrease in core diameter irrespective of H/D ratio.
5. Cores of smaller diameters can be used for strength testing of concrete which facilitates the use of more practical machinery both for cutting and testing

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