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Experimental Study on Corelation between Specimen Size and Compressive Strength of Concrete

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Abstract:- Concrete's compressive strength is perhaps the most relevant material factor to take into account while designing structural elements. However, using this value has become challenging because control specimen sizes vary from nation to nation. Many studies were conducted in past to analyse the specimen size and shape effects on the compressive strength of concrete. The previous investigations were conducted on different sized cylinders and cubes. The mechanical strength values of the specimens were observed to be decreased than the bigger specimen. In the present study efforts are made to study the effect on cube compressive strength for 150mm and 300mmspecimen size for a uniform concrete mix.

I. INTRODUCTION

The most crucial concrete activity is the result of the compressive strength test. It is critical to obtain precise concrete strength values in order to assure the safety of completed designs [1,2]. Cylinders and cubes are the most common specimens used for compressive strength tests of concrete around the world. [3].Concrete compressive strength test specimens vary in size and shape from region to region. The United States, Canada, France, Australia, and other countries use cylinders, but the United Kingdom, Germany, and many other use cubes. Tests on both cubes and cylinders are conducted in a number of nations. For cubes and cylinders, the most common standard sizes are 150mm and 150 x 300mm, respectively. Smaller specimens, on the other hand, have become more popular due to advantages such as ease of handling, the need for smaller capacity testing equipment, the use of lesser concrete, and so on. While there has been a lot of research on this topic for normal strength concretes, there are only few studies stretching back to 1925 [1].Only a few researches investigated the impact of sample size and shape on high strength concrete have been published.

For normal strength concrete, Gonnerman investigated the size effect on cylinders, prisms, and cubes of different size. He discovered that compressive strengths increased as the size of concrete examples in cylindrical shapes with the same slenderness ratio decreased.[6]. This is due to an increase in the number of micro structural deficiencies in large specimens. [7].

The study yielded a number of empirical models, the most important of which was developed by Neville. The model is based on the specimen's strength and certain of its characteristics, such as volume (V), longitudinal dimensions (d), and h/d ratio. The role of size and shape on conventional concrete strengths can be predicted using this model based on experimental results. For typical concretes, the conversion factor for 150 mm and 100 mm sized cubic specimens ranges from 0.89 to 1.29 [8,9]. Some other research examined at the compressive strength of concrete specimens of various sizes and maturities. The compressive strength of the 100 mm cubic specimen was roughly 5% to 6% higher than that of the 150 mm cubic specimen, according to the test results.

Compressive strength values alter as the size of a concrete specimen changes, which is very well recognized. Because of their various geometries, these changes in the specimen's strengths are not constant. It was also discovered to be more obvious in high-strength concrete [11]. Many previous studies were focused on investigating corelation between compressive strength and standard specimen sizes for normal concrete. The objective of the present work was to experimentally investigate the effect of change in specimen size on compressive strength of concrete.

II. EXPERIMENTAL WORK

The present study includes total 03design mixes for characteristic strength of M15 grade of concrete. The PPC (Portland Pozzolana Cement), crushed rock as coarse aggregate, river sand as fine aggregate and PC based superplasticizer is used for mix proportioning. Cube specimen size 150mm and 300mm were casted for every trial and the compressive strength of concrete was determined at 28 days, 56 days and 112 days of curing age of concrete.

III. MATERIALS

A. Cement

Pozzolana Portland Cement with fly ash as constituent, having thirty two percent by mass of cement confirming to IS 1489-1991 (Part-1) is used to prepare SCC mixes [12]. Test values for Blaine's fineness and specific gravity were 400 m^2/kg and 2.92 respectively.

Chemical Composition (% by wt.)	PPC
Loss of Ignition (LOI)	2.20
Insoluble residue (IR)	28.69
Silica	24.15
Mix Oxide as R_2O_3	17.82
Fe as Fe_2O_3	3.59
Al as Al_2O_3	14.23
Calcium Oxideas CaO	49.85
Magnesium Oxide	1.34
Total Sulphur Content	2.10
Percentage of sodium oxide (Na_2O) - 'a'	0.34
Percentage of Na_2O equivalent to the K_2O - 'b'	0.66
Total water-soluble alkali (a + b)	1.0
Total Chlorides	0.012

Table 1: Chemical composition of Pozzolana Portland Cement (PPC)

B. Aggregates

Gradation analysis for fine aggregate and coarse aggregate conforming to IS 383:2016 (Reaffirmed 2021) graphically represented as Fig.2 [13]. As per gradation fine aggregate (river sand) is observed of zone-II. Crushed stone of maximum nominal size 20mm and 10mm are used as coarse aggregate. The determined values of specific gravity of maximum nominal size 20mm, 10mm and sand was 2.66, 2.65 and 2.60 respectively.

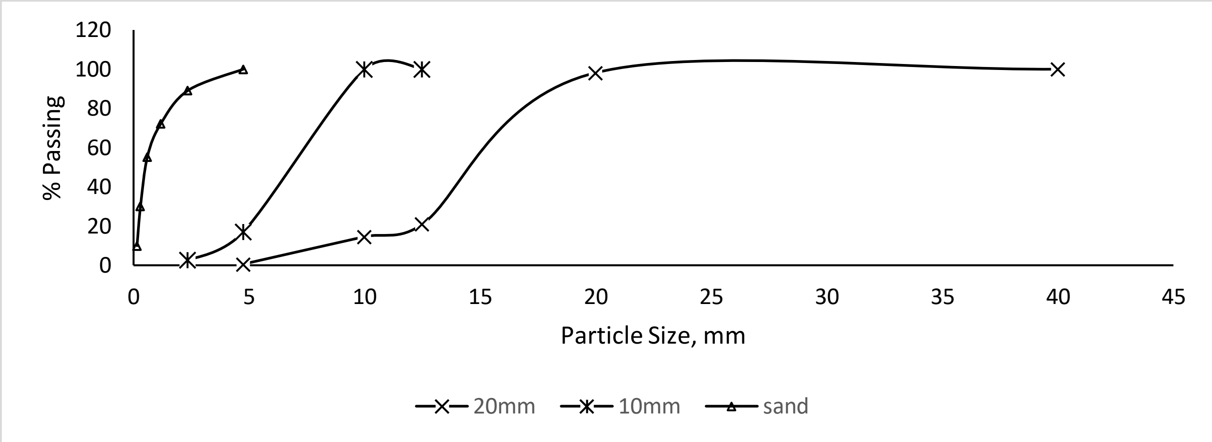

Fig. 1: Gradation curve for coarse and fine aggregate

C. Super plasticizer

A new generation modified polycarboxylicether based super plasticiser consists of high-performance carboxylic ether polymer with long side chains, free of chloride and having low alkali is used in experimental program. The measured value of specific gravity is 1.04 and of solid content is 28.17 percent. The super plasticizer is used to improve upon the fresh properties of concrete mixes and optimum dosage of super plasticizer is obtained through trials.

IV. METHODS

A rotating drum tilting type mixer having capacity of 100Litre was used for mixing all the materials. The feeding sequence in drum was coarse aggregate, fine aggregate, and PPC; these materials were thoroughly mixed in dry state approximately for 2 minutes. Thereafter 75 percent of total water was added into drum and later balance 25 percent water with superplasticizer was added while the mixture was in operation. Subsequent mixing of 5 minutes produced a homogenous mix. As soon as the design mix was prepared fresh properties test i.e., slump test was performed. To determine the hardened properties i.e. compressive strength cube specimen of 150 mm and 300 mm size were prepared. The mix proportions details are given in table 2 as under:

Mix (M15A20)	Cement (kg)	Sand (kg)	CA 20mm (kg)	CA 10mm (kg)	Water (kg)	Admixture (kg)
M-1	260	632	818	545	169	2.08
M-2	250	632	818	545	165	2.0
M-3	270	632	818	545	170	2.1

Table 1: Concrete Mix Proportions

In the present study the observations of mix-1 are taken into the considerations to analyse the effect of cube specimen size on compressive strength.

V. METHOD OF TESTING

Tests were performed on a 200tcapacity compressive strength testing machine. Loading rate was adjusted for all specimens to be 140kg/cm^2/min. The spherical bearing block of the test machine was changed depending on the size of the specimen. The dimensions were in accordance with IS 516. Compressive strength of one set i.e., three numbers of cubes per trial for 150mm and 300m cube size was determined for 28 days, 56 days and 112 days of curing age.

Fig 2: Testing of cube specimen in CTM and curing of concrete cubes

VI. RESULTS AND DISCUSSION

Compressive strength test results obtained from the experimental study are given in Figure 2, Figure3 and Figure 4, as an average strength values of at least 30 samples consisting of average compressive strength for three set of cube specimen for each period, and the correlation between strength and sample size as aspect ratio is given in Figure 5, Figure 6 and Figure 7. According to the results, 150 mm cubic concretes in Mix-1 are higher at 8-15% ratios than 300 mm cubic concretes.

The results are consistent with the literature for large specimens i.e., specimen size more than 150 mm the larger the volume of the concrete subjected to stress, the more likely it is to contain an element of a given low strength. As a result, the measured strength of the specimen decreases with increase in its size [14].

Considering the age-based comparison of test results, the 28 days test results showed that compressive strength of all samples for 150mm specimen size is more than that of 300mm specimen sized samples.

Similarly, the 56 days and 112 days test results for 150mm and 300mm specimen size

Are indicative of the similar trends where smaller specimen size has resulted into better compressive strength as suggested by various previous studies.

On the other hand, with the same reasoning, the smaller specimens should result in higher apparent strengths but the contradiction in past studies for smaller specimens were attributed to the “wall effect”: The quantity of mortar required to fill the space between the particles of the coarse aggregate and the wall of the mould is greater than that necessary in the interior of the mass and therefore in excess of the mortar available even in a well-proportioned mix [15].

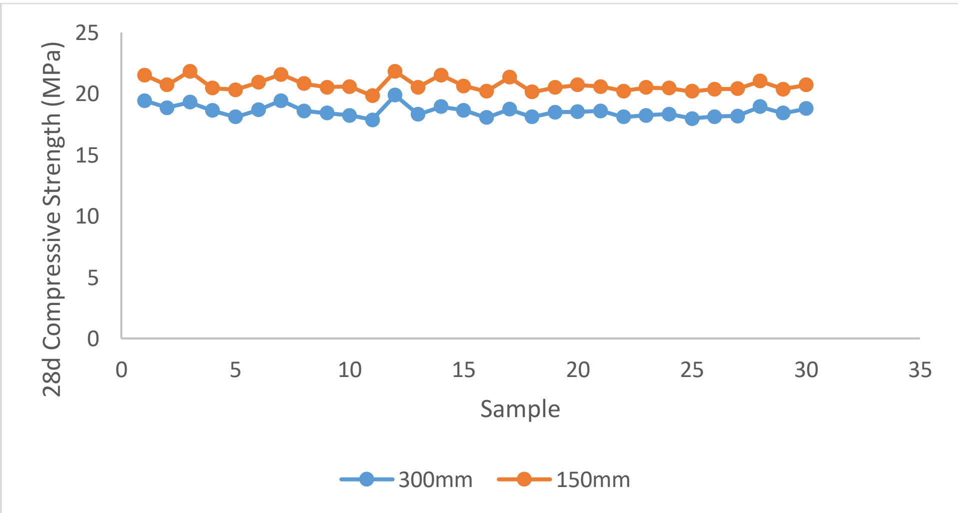

Fig. 3: Variation of 28 days compressive strength for 150mm and 300mm specimen size

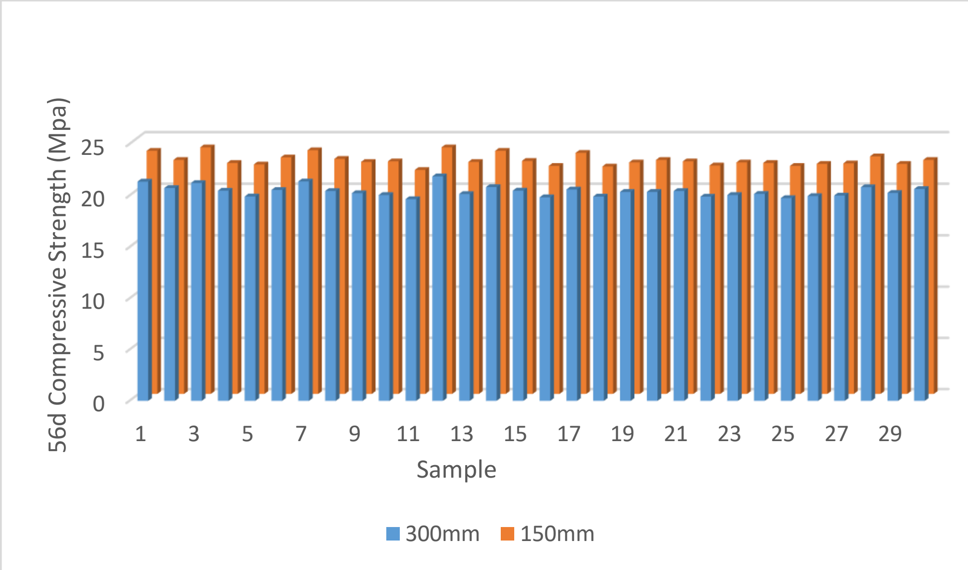

Fig. 4: Variation of 56 days compressive strength for 150mm and 300mm specimen size

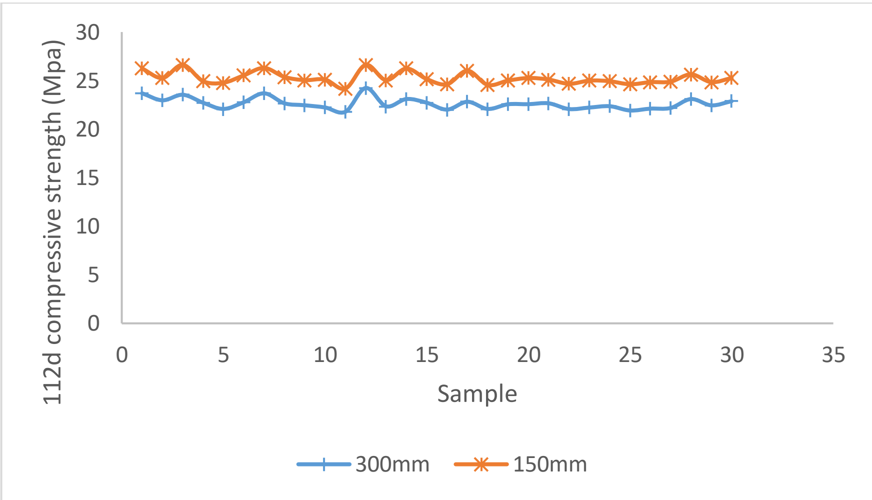

Fig. 5: Variation of 112 days compressive strength for 150mm and 300mm specimen size

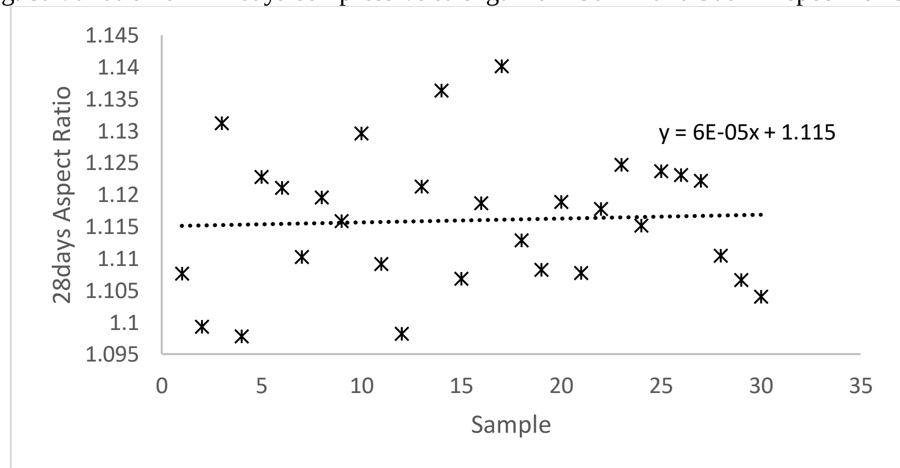

Fig. 6: Aspect Ratio for 28 days compressive strength for 150mm and 300mm specimen size

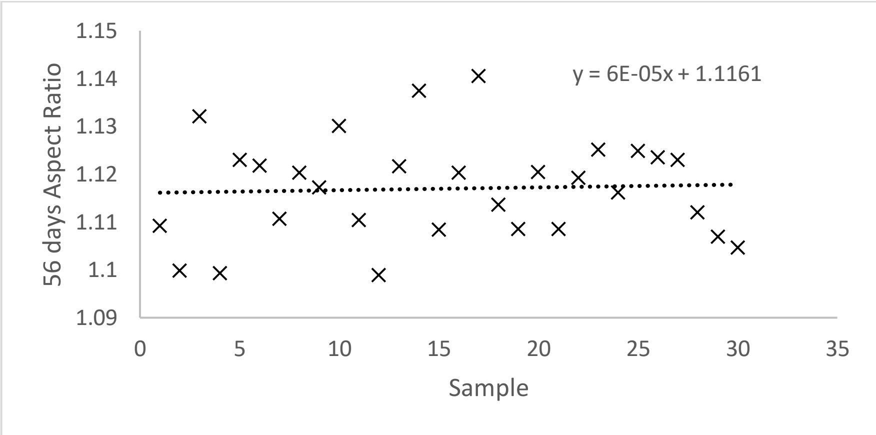

Fig. 7: Aspect Ratio for 56 days compressive strength for 150mm and 300mm specimen size

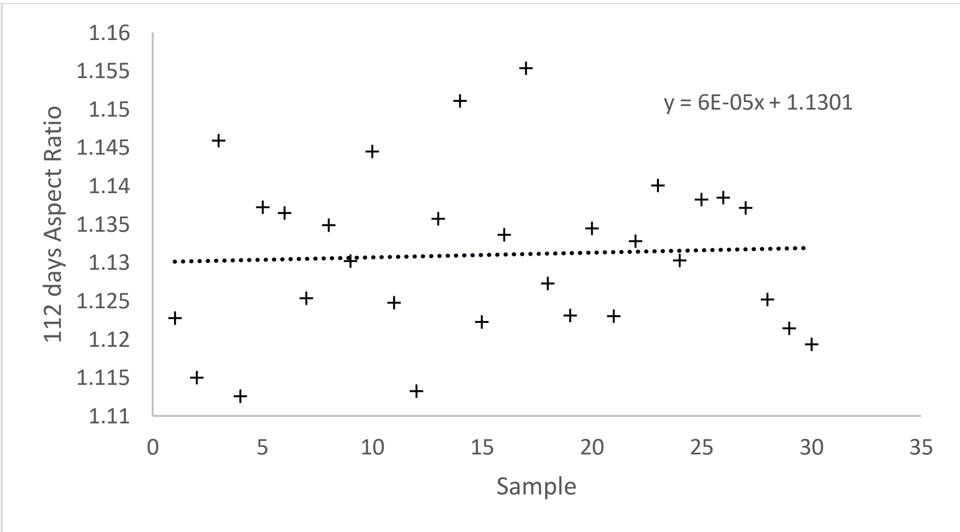

Fig. 8: Aspect Ratio for 112 days compressive strength for 150mm and 300mm specimen size

The results of Figures 2,3, and 4 show that the compressive strength of concrete specimens reduces as its size increased. This intended pattern is consistent with the large number of studies [15]. The best reason seems to be that as the volume of concrete increases, the flaws and deficiencies become more visible. The number of micro-cracks or other defective elements that may be present in the sample significantly increases as sample sizes grow. As a result, smaller samples yield better compressive strength values [16].

VII. CONCLUSION

The effect of samples of various sizes and geometries on compressive strength has been examined in previous studies. The influence of specimen size with the same geometry but varied sizes on compressive strength was explored in this study, which took the most commonly used concrete grade into consideration. The following are the outcomes:

- The cube compressive strengths of 150 mm specimens are more than those of 300 mm cube specimens. As a result, 150 mm cube specimen can be utilized in different applications.
- In experimental tests, it has been discovered that as the sample size increases in concretes with the same geometry, the compressive strength decreases.
- It was discovered that the compressive strength values tested on samples of various sizes have a linear relationship with aspect ratio of 150mm and 300mm cube for 28 days, 56 days and 112 days.
- In terms of lower capacity compression testing apparatus on construction sites, convenience of sample handling and transfer, and lesser amount of concrete loss, 150 mm cube samples in quality control is advantageous.

Based on the above findings, a 150 mm cubic specimen can be used for determination of compressive strength with aggregate size up to 20mm.

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