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"Study on Specimen Shape and Size Effect on the Compressive and Split Tensile Strength of High Strength Concrete"

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Abstract—*In this paper, the results of investigation on the influence of shape and size of the specimen on the Compression and Split Tensile strength of concrete were reported. Tests were carried out using circular specimen having constant diameter and varying length to diameter ratio between two grades of concrete of 40 and 60 MPa . It was found from the test that the variation of compressive strength with specimen length to diameter ratio was almost lean at both 7 days and 28 days for two grades of concrete studied. Therefore linear variation of correction factor for specimen aspect ratio as suggested in IS-516:1959 seem to be appropriate for even high strength concrete such as M40 and M60 grades. However the split tensile strength shows drastic variation with respective to specimen aspect ratio and therefore linear variation of correction factor cannot be used. Results also show that as specimen height increases the compressive strength decreases whereas the split tensile strength increases with increase in length with a given diameter.*

Keywords: *high strength concrete, compressive strength, split tensile strength, size effect, shape effect, aspect ratio.*

1. INTRODUCTION

Concrete, has become one of the most important construction material from centuries because of its ability to withstand different loads on structures. Like other construction material, for controlling the quality of concrete, there are lot of experiments, each one designated to specify different properties of concrete. Among these experiments, the one which are designated to evaluate the resistance of concrete against loads are more common. Compressive Strength test and Split Tensile strength test are two of the most important experiments carried out. The size and shape of compressive strength test specimens of concrete varies from one country to another. Cylinders are used in the United States of America, Canada, France, Australia, etc. whereas cubes are the standard shape used in the United Kingdom, Germany, and many other European countries. There are several countries where tests are conducted on both cubes and cylinders. Commonly used standard sizes are 150x150x150mm and 150 x 300mm for cubes and cylinders respectively. However the advantages like easy handling, necessitating lower capacity of test machines, usage of less concrete, etc. offered by smaller specimens have caused them to be used more frequently.

2. OVERVIEW OF THE EXPERIMENTAL PROGRAM

The experimental program was conducted to study the size and shape effects on Compressive Strength test performed on High-Strength Concrete (HSC) specimens. Specifically we intend to disclose the influence of sizes in cubes and the relationship between Compressive Strength and Split Tensile strength obtained from standard cylinder sizes (75x150, 100x200, 150x300) and the strength of cube specimens and whose length to diameter ratio is less than two (l/d<2). We also study the variation of crack pattern and the mechanical behaviour for different size and shape of specimens.

3. MATERIALS

In this context the basic tests are carried out on Ordinary Portland Cement (OPC) of 53 grade, Fine Aggregate, Coarse Aggregate and the results for Setting Time, Normal Consistency, Specific Gravity, Bulk density and Water absorption are recorded as per Indian specifications. Results are tabulated bellow

Table 1: Details of basic tests

Tests on cement	
Normal consistency	30 %
Initial setting time	145 min.
Final setting time	265 min.
Specific gravity	3.15
Properties of fine Aggregate	
Bulk density	1726 kg/m^3
Specific gravity	2.6
Water absorption	1 %

Properties of coarse Aggregate	
Bulk density	1638 Kg/m^3
Specific gravity	2.64
Water absorption	1.62 %

4. CONCRETE MIX DESIGN

As per IS-10262:2009 and ACI-211.4R (Recommended guidelines for concrete mix design) mix design was carried out for M40 and M60 concrete.Table2 shows the mix proportions for ingredients required for m^3 of concrete

Table 2: Quantity of materials for cubic meter of concrete

Mix proportion for M40	
Cement	492.5 kg/m^3
Fine aggregate	804.98 kg/m^3
Coarse aggregate	1024.53 kg/m^3
Water	197 kg/m^3
Mix proportion for M60	
Cement	504.21 kg/m^3
Fine aggregate	683.24 kg/m^3
Coarse aggregate	1108.13 kg/m^3
Water	141.61 kg/m^3
Super plasticizers	4.66 kg/m^3

Table 3: Ratio Of Mix Proportion 1m^3 Concrete

Mix proportion for M40	1:1.63:2.08:0.4
Mix proportion for M60	1:1.35:2.19:.29:0.8

5. EXPERIMENTAL WORK

To study the size and shape effect of test specimens on the compressive and split tensile strength in detailed experimental program has been proposed. Table 4 shows the details of the specimens casted to study. The details of the companion plan concrete specimens are given.

Table 4: Details Of Specimens

Specimen shape	**l/d ratio**	**Dimensions(mm)**
Cylinder	0.83 1.38 1.66 1.94 2.22	180x150 180x250 180x300 180x350 180x400
Cylinder	2.0	75x150 100x200 150x300
Cube		150X150X150

6. METHOD OF TESTING

Tests were performed on a 200t- capacity testing machine. Loading rate was adjusted for all specimens to be 0.2MPa/s. the spherical bearing block of the test machine was changed depending on the size of the specimen. Diameters of the upper bearing blocks used are given in table 4.

7. CASTING AND TESTING

The details of the specimens cast are given in Table 5.

Table 5: Specimens Test For Compressive And Split Tensile Strength

Specimen type	**Specimen size(mm)**	**No.of specimens**	
		7days	**28days**
Cube	150x150x150	5	5
Cylinder	75x150 100x200 150x300	5 5 5	5 5 5
Cylinder	180x150 180x250 180x300 180x350 180x400	5 5 5 5 5	5 5 5 5 5
TOTAL		**45**	**45**

Fig. 1: Photograph of casted specimens

Fig. 2. Photograph of during testing specimes

Fig. 3: Photograph indicating crack pattern specimen

8. RESULTS

The results of the experimental program conducted to understand the size and shape effect on the compressive strength and split tensile strength of concrete is analyzed in detail. Tables 6,7,8 and 9 present the results of axial compression tests conducted on concrete specimens.

Table 6: Compressive Strength(M40)

Specimen type	Specimen size(mm)	Average 7-days comp.strength (MPa)	Average 28-days comp.strength (MPa)
Cube	150x150x150	35.653	47.902
Cylinder	75x150	20.023	26.10
	100x200	26.694	34.74
	150x300	27.537	35.20
Cylinder	180x150	29.104	35.203
	180x250	21.624	27.365
	180x300	19.076	25.436
	180x350	14.628	21.701
	180x400	12.950	19.251

Table 7. Split Tensile Strength(M40)

Specimen type	Specimen size(mm)	Average 7-days Split Tensile (MPa)	Average 28-days Split Tensile (MPa)
Cylinder	75x150	2.598	3.174
	100x200	2.701	3.343
	150x300	3.215	4.115
Cylinder	180x150	2.106	2.608
	180x250	2.533	3.013
	180x300	2.885	3.310
	180x350	3.115	3.924
	180x400	3.549	4.348

Table 8: Compressive Strength(M60)

Specimen type	Specimen size(mm)	Average 7-days comp.strength (MPa)	Average 28-days comp.strength (MPa)
Cube	150x150x150	55.362	63.754
Cylinder	75x150	28.763	35.044
	100x200	39.511	45.196
	150x300	40.910	50.939
Cylinder	180x150	50681	59.654
	180x250	38.702	47.345
	180x300	33.214	41.404
	180x350	28.323	36.552
	180x400	22.560	29.360

Table 9: Split Tensile Strength(M60)

Specimen type	Specimen size(mm)	Average 7-days Split Tensile (MPa)	Average 28-days Split Tensile (MPa)
Cylinder	75x150	4.676	5.582
	100x200	4.753	5.924
	150x300	5.346	6.292
Cylinder	180x150	2.979	3.523
	180x250	4.296	5.146
	180x300	4.343	5.229
	180x350	4.898	5.430
	180x400	5.389	6.342

In this experimental investigation, compressive strength for cube and splitting tensile strength,compressive strength test was performed on cylindrical samples, cured in water, at the age of 7 days, 28 days.In the following figures compressive strength vs specimen size and splitting tensile strength vs specimen size is shown.

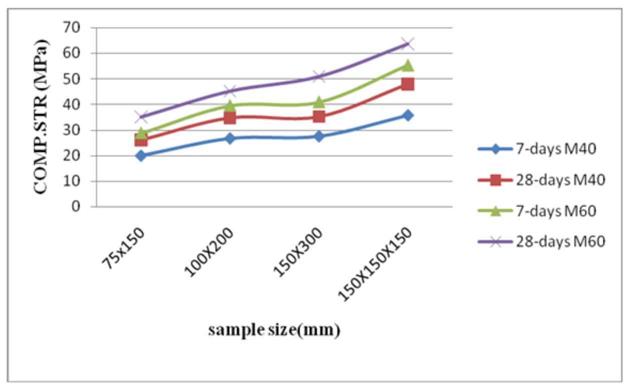

Fig. 4: Compressive strength vs sample size

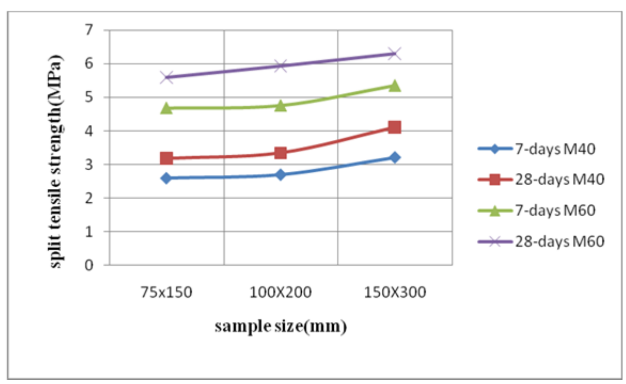

Fig. 5: Split tensile strength vs sample size

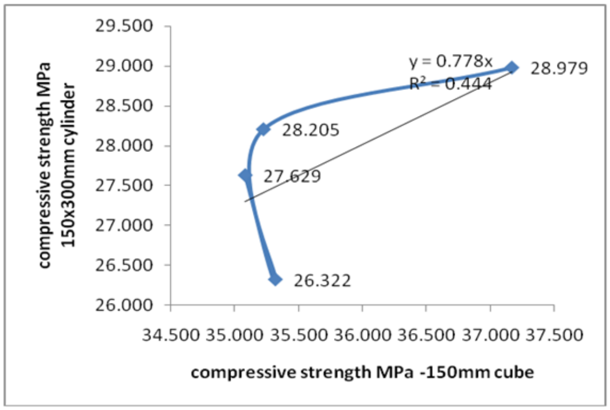

Fig. 6. Compressive strength MPa-150x300mm cylinder vs compressive strength MPa -150mm cube

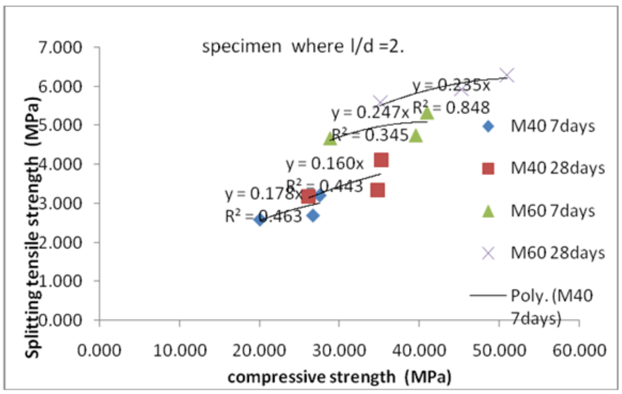

Fig. 7. Splitting tensile strength (MPa) vs compressive strength (MPa) where l/d =2.

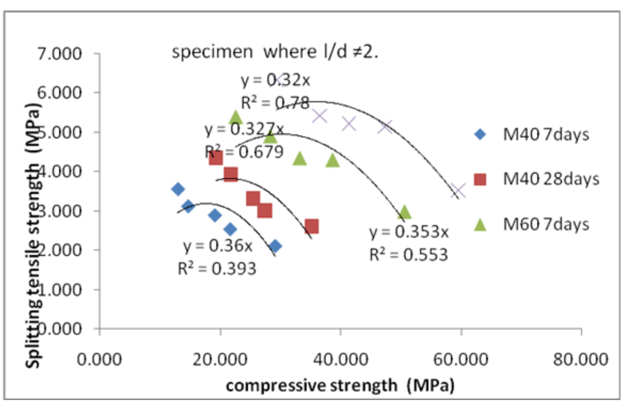

Fig. 8. Splitting tensile strength (MPa) vs compressive strength (MPa) where l/d ≠2.

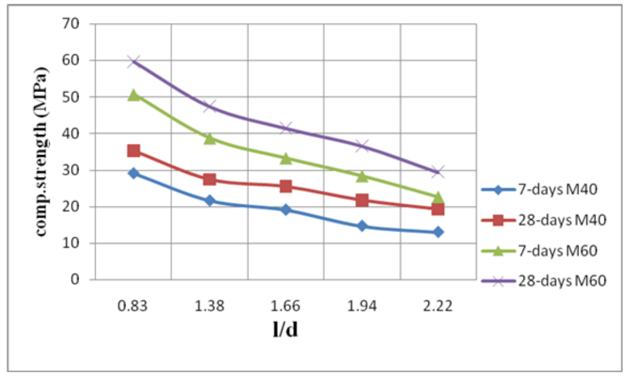

Fig. 9. compressive strength (MPa) vs l/d.

To understand the behaviour of slenderness ratio (H/D ratio), are plotted for compressive strength with respect to the slenderness ratio and Splitting tensile strength with respect to the l/d (in compressive strength small specimen give higher strength and large specimen have higher strength in split tensile strength).

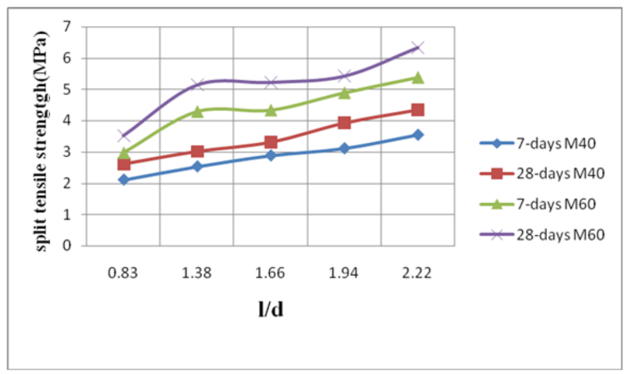

Fig. 10.Splitting tensile strength (MPa) vs l/d.

It can be noticed that as the sample size increases compressive strength also increase but 100x200 is less shape effect seen. In split tensile same size get more shape effect.

The dashed lines in each Fig. are the line with the equation of y=x, having the slope of 45°. The line has been plotted in order to compare different trend lines with each other. by increasing splitting tensile strength, the deviation from the line of y=x increases for in lower strengths, tensile strength of cylinder 150×300 mm and cylinder 100×200 mm are almost equal but at higher strengths, the strength of cylinder 100×200 mm is obviously higher than the strength of cylinder 150×300 mm. It can be noticed that where l/d =2 Slope are not high but in the case of l/d≠2 are higher.

9. CONCLUSIONS

If the tensile strengths of all shapes of specimens are considered, the slope of the graph of split tensile strength vs. compressive strength will have an increasing trend. And it can be seen that as l/d ratio increases noteded that less size shape effect in the compressive strength where as in split tensile strength have more size shape effect.

Results also show that as specimen height increases the compressive strength decreases whereas the split tensile strength increases with increase in length with a given diameter.

By changing mix design, and reducing the water/cement ratio, hardened density of concrete samples increases due to having stronger bonds. However, using high grade cement can cause disruptions in the increasing trend. Effect of size and shape of specimens on split tensile strength are more pronounced at higher strengths. Compressive strength results were strongly influenced by their specimen sizes and wall effect.

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