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Strength Conversion Factors for Concrete Based On Specimen Geometry, Aggregate Size and Direction of Loading

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Abstract: The main goal of this study is to find out the effect of effect of specimen shape and size, aggregate size and directions of loading and placement on the compressive strength of M20, M40, M60 and M80 grades of concrete. During the experimental study, different shaped and sized concrete specimens of different concrete mix designs were tested for compressive strength at 28 days. For casting the concrete samples, totally four different moulds were utilized, which were two different sizes of cubes and two different sizes of cylinders. The cubic moulds were 100 and 150 mm. The cylindrical moulds were 150×300 and 100×200 mm. So the relationship between size and shape effect on compressive strength of concrete samples is evaluated. Casted cubes and cylinders are tested for the compressive strength under axial compression on completion of 28 days as per IS: 516-1999.In this study, the effect of specimen sizes, specimen shapes, and placement directions on concrete compressive strengths for various grades widely used is evaluated. In addition, correlations between compressive strengths with size, shape, and placement direction of the specimen are investigated. It was found that with the increase of the size of the concrete specimen, compressive strength tends to decrease. The effect of grade of concrete on the shape effectof the compressive strength decreases as the specimen size increases regardless of strength level. Conversion factors of 0.80 to 0.90 were suggested for converting compressive strength of cylinders to compressive strength of cubes. For cubes, when the placement direction is parallel to the loading direction, the compressive strength is higher than the normal case. As aggregate size increases, compressive strength is found to be increasing.

Index Terms- specimen shape and size,Conversion factors, strength correction factors, aggregate size, loading direction.

I. INTRODUCTION

Determining the compressive strength of concrete is one of the most crucial stages of construction works as the mechanical and durability properties of the concrete depends on the compressive strength of the concrete.

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To maintain a control on the quality of concrete, concrete samples are casted in various moulds according to various standards adopted in various countries. On the other hand, it is known that different shapes and sizes of concrete samples can cause variations in results of compressive strength.

This paper is focused to study the effect of specimen sizes and shapes on compressive strength of concrete. Many previous studies and experimental investigations have been conducted in order to find out how changing specimen shape and size could influence the results. In this study conversion factors are proposed to convert the compressive strength results of different specimens based on size, shape, aggregate size and placement direction. For most countries, sizes and shapes of test specimens to determine the compressive strength of the concrete are different. However, commonly used specimens are cylinders and cubes. Due to the differences in the shape, height/diameter ratio, and end restraint due to the machine platens, cylinder and cube strengths obtained from the same batch of concrete could differ.

II. OBJECTIVES OF THE PRESENT WORK

1. To evaluate the effect of specimen shape and size on the compressive strength of M20, M40, M60 and M80 grade concretes.
2. To suggest strength conversion factors for M20, M40, M60 and M80 grade concrete specimens of different shapes and sizes.
3. To compare the compressive strengths of concrete cubes of M20, M40, M60 and M80 grades when subjected to loading parallel and perpendicular to the placement of concrete.
4. To evaluate the effect of aggregate size on the compressive strength of M20, M40, M60 and M80 grade concrete specimens of different shapes and sizes.

III. MIX PROPORTIONS

The mix proportions of M20 and M40 grade concrete are designed using IS: 10262-2009 and mix proportions for M60 and M80 grade concrete are designed using Entroy and Shacklock's empirical graphs. The mix proportions and materials required for one cubic meter are given in table 1 below.

TABLE 1: MIX PROPORTIONS AND QUANTITIES PER 1 CU. M. OF M20, M40, M60 AND M80 GRADE CONCRETES

Grade of the Concrete	Mix proportions	Cement kg/m^3	Micro-silica kg/m^3	Fly ash	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water L
M20	1: 2.90: 3.14: 0.54	320.4	-		927.3	1005.4	173 L
M40	1: 2.25: 2.56: 0.42	390.7	-		876	999.7	164.1 L
M60	1:1.60:1.84:0.26 (Micro Silica - 6% bwc*) (Superplasticizer(SP) – 1% bwc*)	436	27.8	50.34	819.9	948	130.6 L
M80	1:1.12:1.40:0.23 (Micro Silica - 10% bwc*) (Superplasticizer(SP) – 1.2% bwc*)	451.8	50.2	155.2	732.3	914.1	115.5 L

*bwc-by weight of cement

IV. LATERAL SURFACE AREA/VOLUME RATIO

The table 2 presents the lateral surface/volume ratio and load application area for different concrete specimen shapes and sizes.

TABLE 2: LATERAL SURFACE/VOLUME RATIO AND LOAD APPLICATION AREA FOR DIFFERENT SPECIMENS

Sample type and size in mm	Lateral surface area/volume ratio (mm^{-1})	Area on which load applied mm^2
Cyl.100×200	0.050	7850
Cyl.150×300	0.033	17662.5
Cube 100	0.060	10000
Cube 150	0.040	22500

V. EFFECT OF SPECIMEN SHAPE AND SIZE ON COMPRESSIVE STRENGTH OF CONCRETE

The figure 1 presents variation of compressive strength of various grades of cylindrical and cube concrete specimens.

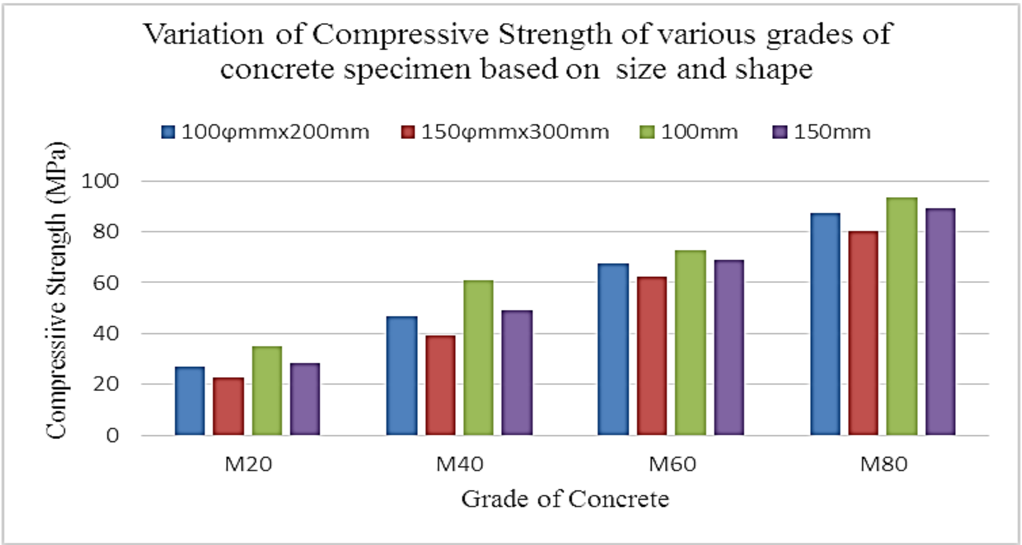

FIGURE 1: VARIATION OF COMPRESSIVE STRENGTH OF VARIOUS GRADES OF CYLINDRICAL AND CUBE CONCRETE SPECIMENS

VI. COMPRESSIVE STRENGTH CONVERSION FACTORS

The table 3 presents the compressive strength conversion factors based on various shapes and sizes of specimens of M20 and M40 grade.

TABLE 3: COMPRESSIVE STRENGTH CONVERSION FACTORS OF CYLINDRICAL AND CUBE CONCRETE SPECIMENS OF M20 AND M40 GRADE

		Cylinder		Cube	
		100ϕmmx200mm	150ϕmmx300mm	100mm	150mm
Cylinder	100ϕmmx 200mm	1.00	1.16	0.84	0.95
	150ϕmmx 300mm	0.86	1.00	0.70	0.80
Cube	100mm	1.19	1.43	1.00	1.24
	150mm	1.05	1.25	0.80	1.00

The table 4 presents the compressive strength conversion factors of cylindrical and cube concrete specimens of M60 and M80 grade.

TABLE 4: COMPRESSIVE STRENGTH CONVERSION FACTORS OF CYLINDRICAL AND CUBE CONCRETE SPECIMENS OF M60 AND M80 GRADE

		Cylinder		Cube	
		100ϕmmx 200mm	150ϕmmx 300mm	100mm	150mm
Cylinder	100ϕmmx 200mm	1.00	1.05	0.90	0.98
	150ϕmmx 300mm	0.95	1.00	0.89	0.90
Cube	100mm	1.11	1.12	1.00	1.05
	150mm	1.02	1.11	0.95	1.00

To convert compressive strength of the specimen to the strength of other specimens (with different cross sectional area), the specimen's compressive strength should be multiplied by the values which were obtained from the table 5.

TABLE 5: COMPRESSIVE STRENGTH MULTIPLICATION FACTORS OF CYLINDRICAL AND CUBE CONCRETE SPECIMENS OF DIFFERENT GRADE CONCRETES

		Cylinder		Cube	
		100ϕmmx200mm	150ϕmmx300mm	100mm	150mm
Compressive Strength	M20	0.95	0.80	1.24	1
	M40	0.95	0.80	1.24	1
	M60	0.98	0.90	1.05	1
	M80	0.98	0.90	1.05	1

VII. EFFECT OF LOADING AND PLACEMENT DIRECTIONS ON COMPRESSIVE STRENGTHS

The table 6 presents the compressive strengths based on loading and placement directions.

TABLE 6: COMPRESSIVE STRENGTHS BASED ON LOADING AND PLACEMENT DIRECTIONS FOR DIFFERENT GRADE CONCRETES OF VARIOUS SPECIMEN SIZES

Specimen shape	Specimen size (mm)	Grade of the concrete	Compressive Strength (MPa)	
			Placement direction parallel to loading direction	Placement direction perpendicular to loading direction
Cube	100	M20	36.90	35.14

		M40	64.17	61.11
		M60	83.35	72.48
		M80	107.61	93.57
	150	M20	29.76	28.34
		M40	51.74	49.28
		M60	79.38	69.03
		M80	102.48	89.11

VIII. EFFECT OF COARSE AGGREGATE SIZE ON COMPRESSIVE STRENGTHS OF CONCRETE

The table 7 presents the compressive strengths of various grades of concrete specimens of different size and shape made with 20mm and 10mm coarse aggregate.

TABLE 7: Compressive Of Various Grades Of Concrete Specimens Of Different Size And Shape Made With 20mm And 10mm Coarse Aggregate

Specimen shape	Specimen size (mm)	Grade of the concrete	(20mm CA) Compressive Strength (MPa)	(10mm CA) Compressive Strength (MPa)
Cylinder	100×200 (diameter ×length)	M20	26.92	24.23
		M40	46.82	42.14
		M60	67.65	60.89
		M80	87.33	78.60
	150×300 (diameter ×length)	M20	22.67	20.40
		M40	39.42	35.48
		M60	62.13	55.92
		M80	80.20	72.18
Cube	100	M20	35.14	31.63
		M40	61.11	55.00
		M60	72.48	65.23
		M80	93.57	84.21
	150	M20	28.34	25.51
		M40	49.28	44.35
		M60	69.03	62.13
		M80	89.11	80.20

IX. DISCUSSIONS

The cube with a 100mm size had the highest compressive strength of all. For this reason, that size of test cube should be more representative, and any cube size below 100 mm cube seems to be unsuitable for testing the compressive strength of concrete.The ratio of the cube strength to cylinder strength with increasing compressive strength of concrete decreases progressively from 1.24 to 1.05. Above-mentioned 1.24 and 1.05 are the ratios corresponding to the cylinder compressive strengths of 20-40 MPa and 60-80MPa, respectively

The compressive strength was insignificantly affected by changing l/d ratio as the strength of concrete increases. For high-strength concrete (HSC), the influence of specimen shape is not so significant.

For cubes, size effect difference with placement direction is insignificant. This is because the failure of cubes occurs not due to lateral expansion but due to crushing and the lateral expansion is restrained due to the end restraint occurred by the machine platens.

For cubes, when the placement direction is parallel to the loading direction, the compressive strength is higher than the normal case. HSC shows more brittle behavior than NSC. This means that the size of fracture process zone and the size effect of HSC, respectively, are smaller and more apparent than NSC. For cubes, because the face of casting is rough compared to the other faces. When load acted on it, it doesn't share the load uniformly and hence the face other than the face of casting is tested. Casting face with the load uneven may cause the cracks prior giving the low compressive strength. In the uniaxial compression test, smaller contact area between the specimen surface and steel platen of test machine resulting in lower friction-based shear forces in small specimens.It has been observed that the restraining effect due to friction between the specimen and the platens extends over the entire height of the cube. But in the case of the cylinder, it remains unaffected. Hence, it is clear that the total stress that will be created in the cube will be higher compared with the cylinder specimen. This will result in a higher value of the compressive strength in cubes than the cylinder even by employing the same concrete mix.

X.CONCLUSIONS

The current work investigated a narrative approach of finding the effect of specimen shape and size, aggregate size and directions of loading and placement on the compressive strength. Based on the results reported in this work and key findings during the experimental investigations, the following conclusions are drawn:

1. With increase of the size of the concrete specimen, compressive strength tends to decrease. The cube with a 100mm size had the highest compressive strength of all.
2. The effect of grade of concrete on the shape effect of the compressive strength decreases as the specimen size increases regardless of strength level. More specifically, for M60 and M80, the difference of compressive strengths between cylinders and cubes is more rapidly disappeared than that of M20 and M40 grades of concrete.
3. Conversion factors of 0.80 to 0.90 were suggested for converting compressive strength of cube to compressive strength of cylinder. The ratio of the cube strength to cylinder strength with increasing compressive strength of concrete decreases progressively from 1.24 to 1.05. Above-mentioned 1.24 and

   1.05 are the ratios corresponding to the cylinder compressive strengths of 20-40 MPa and 60- 80MPa, respectively
4. For cubes, when the placement direction is parallel to the loading direction, the compressive strength is higher than the normal case. For normal strength concrete (NSC) (M20 and M40 grades), the size effect difference with displacement direction is not distinct compared to high strength concrete (HSC) (M60 and M80 grades).
5. To study the wall effect, compressive strength results of different specimens have been plotted against surface/volume ratio of samples. By increasing the ratio of lateral surface to volume, compressive strength has a steady decreasing trend. Increasing the ratio of surface/volume, in fact means that for each cubic meter of the specimens, there is an increasing amount of surface area. As a result, specimens with higher ratio of surface area/volume are willing to have less compressive strength.
6. Compressive strength results were strongly influenced by their specimen sizes and wall effect. When the concrete bonds are weaker, the results of compressive strengths seem to be more uniform, since the compressive strength of the samples are controlled by their bonds' strength.
7. By decreasing the ratio of lateral surface/volume of specimens, the compressive strength increases.
8. The cylinder specimen indicated a small change in compressive strength when the l/d ratio changed from 1.0 to 2.0; compared to cubes. In fact, compressive strength for cylinder increased as l/d increased; whereas for cube, there was a reduction in compressive strength.
9. As aggregate size increases, compressive strength is found to be increasing.

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