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A Study on Cube and Cylinder Strength of Brick Aggregate Concrete

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Abstract: *Concrete is unique and extensively conducive construction material by virtue of its excellent compressive strength, which is one of the most important and useful properties of concrete. In most structural applications, concrete is employed primarily to resist compressive stresses, which depends on plenty of factors like properties of ingredients, design method of preparation, curing conditions etc. Generally, compressive strength of concrete is referred to either cube strength or cylinder strength. The compressive strength of concrete is determined by testing cubes or cylinders made in laboratory or field or cores drilled from hardened concrete at site or from the non-destructive testing of the specimen or actual structure. The main objective of this research was to make comparison of strength between cube and cylinder using brick aggregate concrete. For this purpose, nine sets of mix proportions were made and studied the variation of strength between cube and cylinder. Along with this, variation of strengths between standard and small cylinders was also observed. Moreover, concrete was designed for two specified compressive strengths (3000 psi and 4500 psi) by American Concrete Institute (ACI) mix design procedure. Then it was casted and tested in laboratory with proper care. From the analysis of the test results, it had been found that cylinder strength was approximately 86 to 90 percent of cube strength and small cylinder strength was approximately 91 to 94 percent of standard cylinder strength.*

Keywords: *ACI method, Compressive strength, Cube, Cylinder, Water Cement ratio.*

I. Introduction

Introduction to concrete as building material indeed marked as epoch in the history of civilization. Concrete has been used as building material for centuries. It is by far the most widely used construction material today. We can hardly find any aspect of our daily lives that does not depend directly or indirectly on concrete. We may live, work, study, or play in concrete structure to which we drive over concrete roads and bridges. Our goods may be transported by trucks travelling on concrete super-highways, by trains that run or rails supported on concrete sleepers, by ships that moor at concrete piers and harbors protected by concrete breakwater, or by airplanes landing and taking off on concrete runways. Water for drinking and raising crops is stored behind massive concrete dams and is distributed by systems of concrete waterways, conduits and pipes. The water thus stored may also be used to generate electric power.

The various unique properties of concrete have marked its superiority over many other construction materials. The versatility and mouldability of concrete, its high compressive strength, and the discovery of reinforcing and prestressing techniques, which helped to make up for its low tensile strength, have contributed largely to its widespread use. The cheapness, durability, exclusive resistance to weather, fire, and water and corrosion make concrete a particularly suitable and unique material for road construction, bridges, building and dams, for the foundations, framework, floors and roofs of large buildings of all kinds and for structures in collieries and industrial plants. Hence it has proved itself conducive to form the basis of modern engineering as well as having a greater influence on dramatic impact of technology.

The strength of concrete depends on a multitude of factors, and may vary within very wide limits with the same production technology (identical composition, properties and curing). Primarily it depends on:-

- Its age and curing conditions
- The shape and dimensions
- The nature of the stressed state
- Climatic conditions etc.

Difference between the strength and actual strength to a great extent is a frequent occurrence due to lack of proper designing for the service conditions, proper handling and curing. The successful use of concrete depends on the intelligent application of its properties. For this reason, a thorough understanding of the material properties of the concrete is essential to get the material of required quality and durability. Moreover, unlike the

rest of the world in a developing country like Bangladesh, the typical use of locally produced broken bricks aggregates and coarse Sylhet sands as the filler material in the production of concrete demands special attention of the researchers in regard to its method of preparation, compaction, strength and durability as all the design charts used in practice are based on the stone aggregate concrete, which is very rare in Bangladesh. The purpose of this study was therefore to select the optimum proportions of cement, water and brick aggregates to produce a concrete that satisfies the requirements of strength, workability, durability and economy in context to Bangladesh. Mix design methods are useful as guides in the initial selection of these proportions. The prime objective of this research was to compare the cylinder strength and cube strength of brick aggregate concrete.

II. Methodology Of The Research:

The research was executed by the method given by American Concrete Institute (ACI) to design the mix for its magnitude of acceptance throughout the work, practical applicability and easy procedure. The main objective of this study was to compare the compressive strength of cube with cylinder for brick aggregate concrete. In attaining the aforementioned objective, the following activities were undertaken:

- A through survey of the related literature was carried out. The properties of the constituent materials of concrete, methods of different types of mix design were covered in this review.
- Laboratory tests were done to obtain the information required for the design of concrete. Information about bulk specific gravity of sand and brick aggregate, bulk unit weight of sand and brick aggregate, fineness modulus of sand etc was obtained through different laboratory tests.
- During the research work, cubes and cylinders were simultaneously casted, cured and tested. For this reason, no other factors were considered in verifying cube strength and cylinder strength.
- Finally, a suggestion for future study/research was also offered.

III. Design Of Concrete Mix Of Specified Compressive Strength

Two concrete mixes were designed for specified compressive strength according to ACI method. Then specimens (cylinder & cube) of standard size were prepared and tested in the laboratory. The laboratory test results of nine cylinders (6"x12") and 9 cubes (6"x6"x6") for each ratio (cement: fine aggregate: coarse aggregate: water) at different days were taken. This test data were indicated as average strength of three specimens both cylinder and cube for each ratio. The average strength of cylinder and cube were listed Table 1.

Table 1: Compressive strength of Cylinder and Cube

Specified Strength (psi)	Ratio (wt.)	w/c	Cement Brand	Slump (inch)	Age (day)	Compressive strength (psi)		Unit Wt. (lb/ft^3)	Mode of failure
						Cylinder	Cube		
3000	1:2.21:2.92	0.55	Brand 'B'	1.75	3	2080	2530	143.8	Combined
					7	2690	3530		
					28	3590	4610		
4500	1:1.4:2.02	0.38	Brand 'B'	0.75	3	4030	4100	135.7	
					7	4610	4730		
					28	5370	6180		

The concrete was designed for the compressive strengths of 3000 psi and 4500 psi at 28 days. At the end of 28 days, the cylinder strength and cube strength for compressive strength 3000 psi were found to be 3590 psi and 4610 psi respectively. It was found for compressive strength 4500 psi to be 5370 psi and 6180 psi respectively. In both cases, the obtained cylinder strength was 20% more than the specified compressive strength and no test data had fallen below the specified compressive strength.

IV. Results Of Compressive Strength Test Of Cylinder And Cube:

Compressive strength is determined using 150 mm x 300 mm (6"x6") cylinders in the US and 150 mm (6") cubes in the UK, although standards permit the use of smaller specimens depending on the maximum size of aggregate. In the laboratory, two types of cylinders: (4"x8") and (6"x12") and one type cube (6") were used. The following ingredients were used for making concrete:

a. Ordinary Portland Cement available in Bangladesh
b. Natural sand
c. Brick aggregate
d. Water of good quality

The laboratory test result of 9-cylinders (6"x12") and 9-cubes (6") for each ratio (Cement: Fine Aggregate: Coarse Aggregate: Water) at different days were properly taken. This test data was indicated as

average strength of 3-specimens both cylinder and cube for each ratio. The average strength of cylinder (6"x12") and cube (6") were listed in Table 2.

Table 2: Compressive strength of Cylinder and Cube

Ratio (by weight)	w/c ratio	Slump (inch)	Cement Brand	Age (days)	Compressive strength (psi)		Mode of Failure	Comment
					Cylinder	Cube		
1:2:4	0.45	0.50	Brand 'A'	3	2010	2240	Combined	Cube strength is 15.12% more than Cylinder strength averagely
				7	2490	2890		
				28	3540	3950		
	0.50	0.75		3	1860	2150		
				7	2440	2800		
				28	3300	3780		
	0.60	1.00		3	1570	1870		
				7	2070	2440		
				28	2840	3270		
1:1.75:3.5	0.45	0.50	Brand 'B'	3	2180	2430		Cube strength is 10.63% more than Cylinder strength averagely
				7	2780	3100		
				28	3860	4130		
	0.50	0.75		3	1740	1960		
				7	2270	2540		
				28	3180	3430		
	0.60	1.00		3	1480	1640		
				7	1940	2210		
				28	2680	2910		
1:1.5:3	0.45	0.50	Brand 'B'	3	2420	2810		Cube strength is 12.00% more than Cylinder strength averagely
				7	3230	3500		
				28	3930	4180		
	0.50	0.75		3	1960	2310		
				7	2660	2970		
				28	3560	3900		
	0.60	1.00		3	1290	1540		
				7	1830	2040		
				28	2600	2790		

4.1 Comparison of Strength between Cylinder & Cube at different Water Cement ratio:

Compressive strength of both cylinder and cube increases with the decrease in water cement ratio. From test data it was found by plotting compressive strength vs. water cement ratio. In this research, work water -cement ratio was randomly selected. Then the compressive strength of the specimens was determined. The compressive strength vs. water cement ratio curves were shown in Figure 1, Figure 2 and Figure 3.

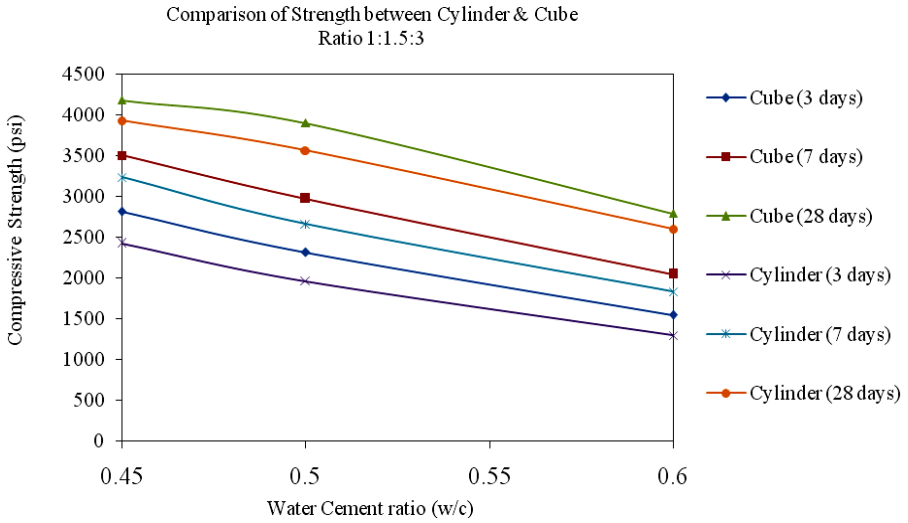

Figure 1: Comparison of compressive strength of concrete between cylinder and cube at different water cement ratio.

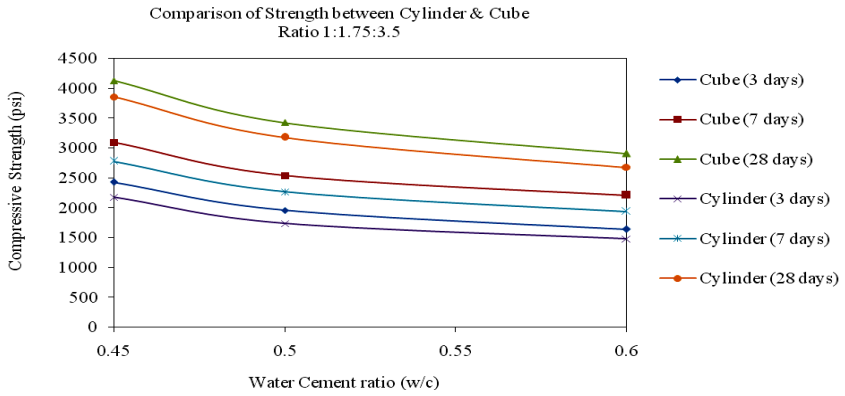

Figure 2: Comparison of compressive strength of concrete between cylinder and cube at different water cement ratio.

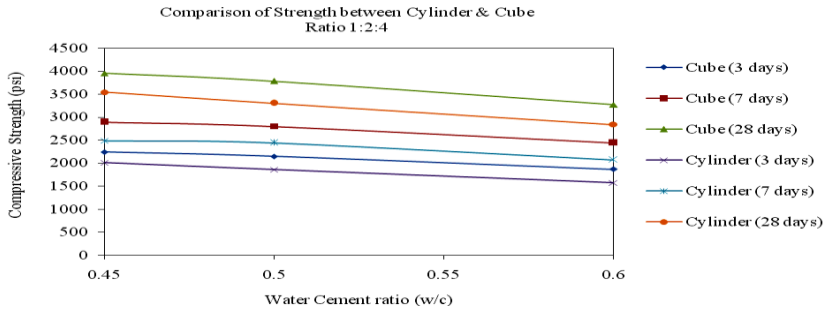

Figure 3: Comparison of compressive strength of concrete between cylinder and cube at different water cement ratio.

4.2 Comparison of Strength between Cylinder & Cube at different days:

Compressive strength of both cylinder and cube increases with days. From the test data, it was found by plotting compressive strength vs. age. In this research work, water-cement ratio, cement, fine aggregate and coarse aggregate were randomly selected. Then compressive strength of the specimens was determined. The compressive strength vs. age curves were shown in Figure 4, Figure 5 and Figure 6.

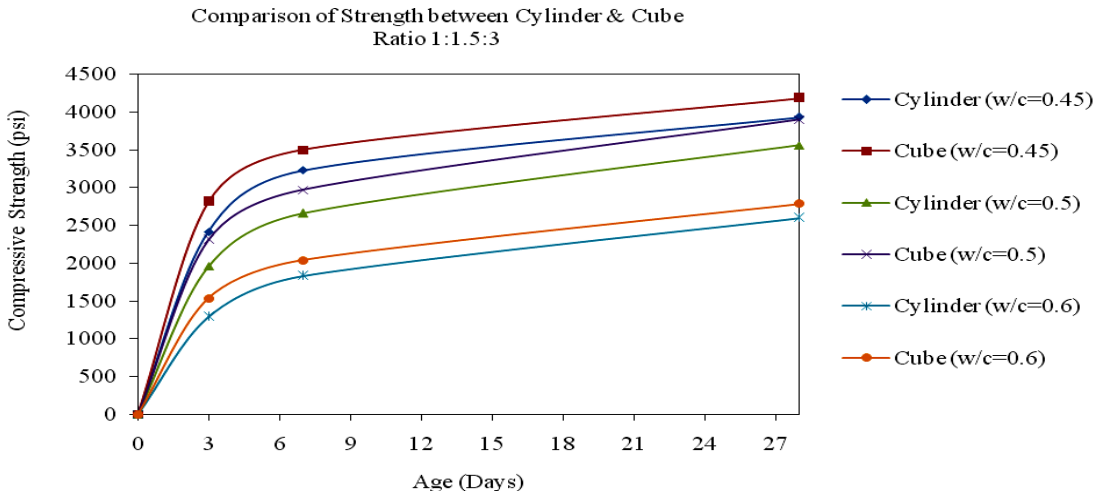

Figure 4: Comparison of compressive strength of concrete between cylinder and cube at different days.

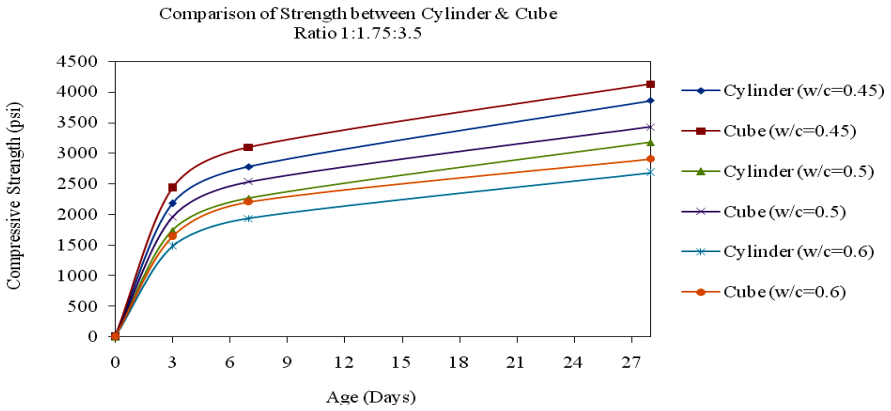

Figure 5: Comparison of compressive strength of concrete between cylinder and cube at differnent days.

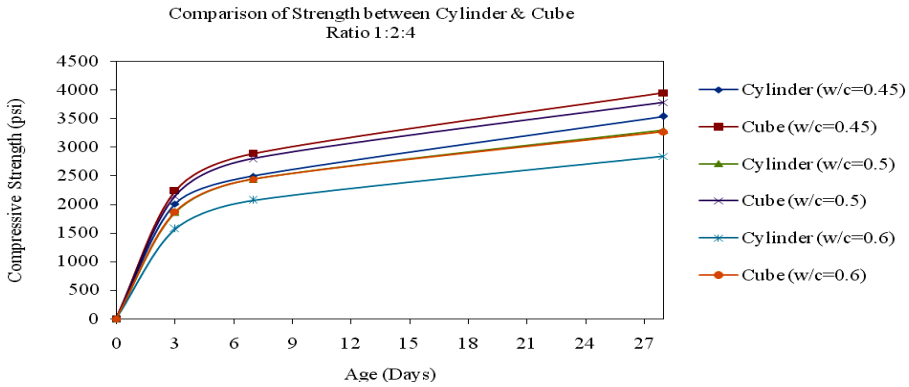

Figure 6: Comparison of compressive strength of concrete between cylinder and cube at differnent days.

4.3 Comparison of Strength between Cylinder & Cube with richness of Cement:

Compressive strength of both cylinder and cube increases with the increase of cement. From the test, data it was found by plotting compressive strength vs. water-cement ratio. In this research work, we randomly selected water-cement ratio, cement, fine aggregate and coarse aggregate. Then compressive strength of the specimens was determined. The compressive strength vs. water-cement ratio curves were shown in Figure 7, Figure 8 and Figure 9.

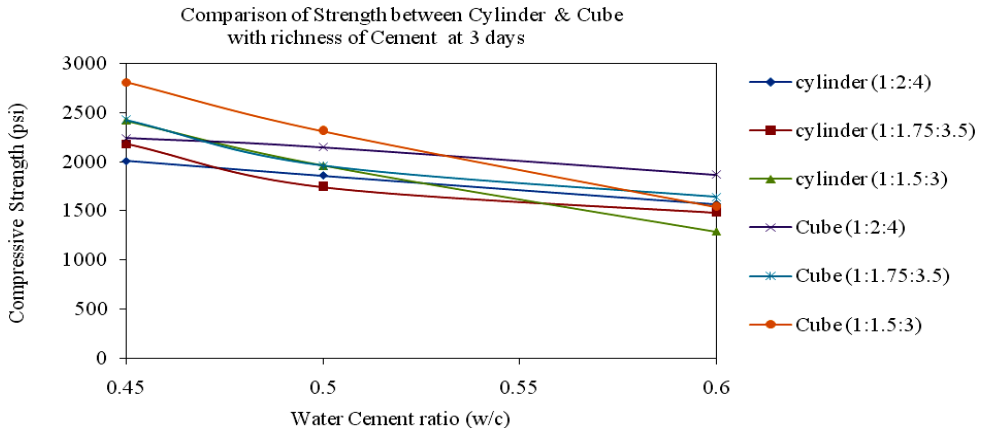

Figure 7: Comparison of compressive strength of concrete between cylinder and cube with richness of cement at 3 days.

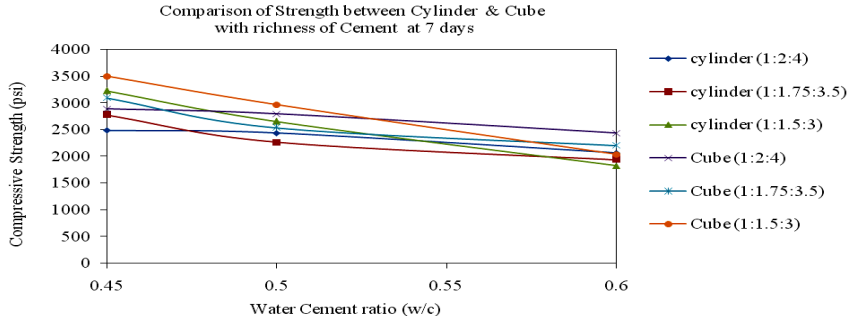

Figure 8: Comparison of compressive strength of concrete between cylinder and cube with richness of cement at 7 days.

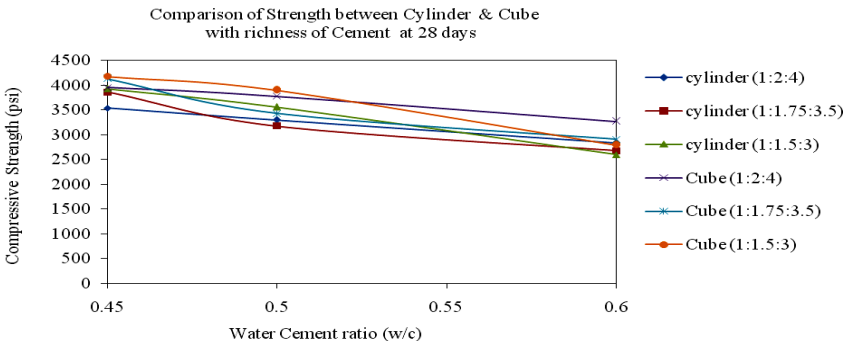

Figure 9: Comparison of compressive strength of concrete btween cylinder and cube with richness of cement at 28 days.

4.4 Comparison of Strength between small cylinder and standard cylinder:

The laboratory test results of nine small cylinders (4"x8") and 9 standard cylinders (6"x 12") for each ratio (Cement: Fine Aggregate: Coarse Aggregate: Water) at different days were properly taken. This test data were indicated as average strength of three specimens both cylinders for each ratio. The average strength of standard cylinder (6"x 12") and small cylinder (4"x8") were listed Table 3. A comparison of strength with age and water-cement ratio between small cylinder and standard cylinder was shown in Figure 10 and Figure 11 respectively.

Table 3: Compressive strength of small cylinder and standard cylinder

Ratio (by weight)	w/c ratio	Slump (inch)	Cement Brand	Age (Days)	Compressive strength (psi)		Mode of Failure	Comment
					Cylinder (4"x8")	Cylinder (6"x12")		
1:2:4	0.45	0.50	Brand 'A'	3	1940	2010	Combined	Small cylinder strength 7.40 % less than standard cylinder
				7	2270	2490		
				28	3190	3540		
	0.50	0.75		3	1790	1860		Small cylinder strength 8.03 % less than standard cylinder
				7	2210	2440		
				28	2940	3300		
	0.60	1.00		3	1510	1570		Small cylinder strength 9.70 % less than standard cylinder
				7	1860	2070		
				28	2140	2840		

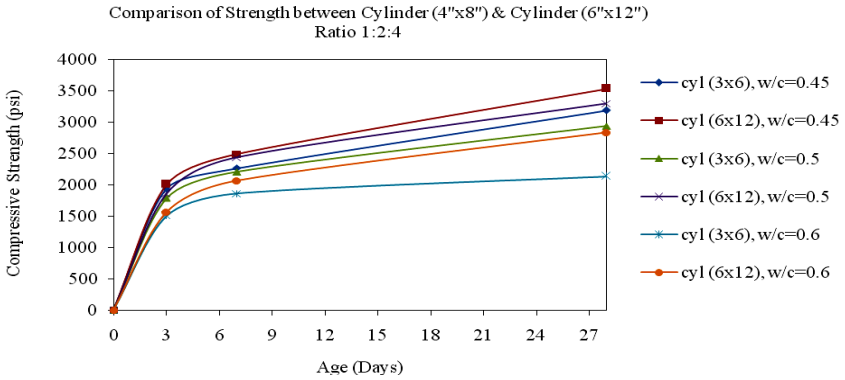

Figure 10: Comparison of compressive strength of concrete between small cylinder and standard cylinder at different days .

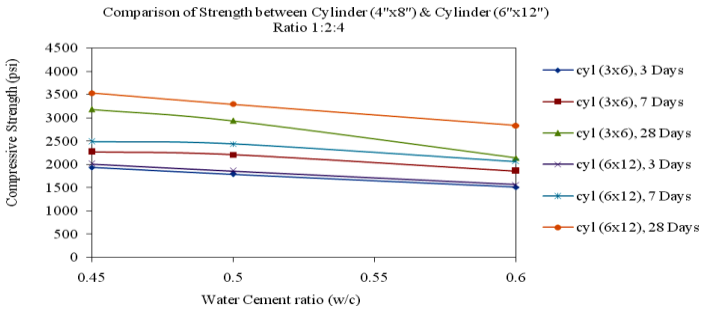

Figure 11: Comparison of compressive strength of concrete between small cylinder and standard cylinder at different water cement ratio .

V. Conclusion And Recommendation:

The prime objective of this research work was to study of cylinder and cube strength of brick aggregate concrete. From the experimental data and graphs, the following conclusions were made:

a) The cube strength was approximately 1.15 times the cylinder strength.
b) The standard cylinder strength was approximately 1.07 times the small cylinder strength. Since, both standard cylinder (6"x12") and small cylinder (4"x8") were tested in the same testing machine having large end platen – due to this large end platen effect, this 7% difference in compressive strength was observed.
c) Compressive strength increases with the increase of Aggregate/Cement ratio for constant water/cement ratio.
d) Compressive strength increases with age. This rate of gain of strength was sharp upto first three days and then for the next four days (i.e. from three to seven days), this strength achievement rate was slower than that of the first three days. For the next twenty one days (i.e. from seven to twenty eight days) this strength gaining was flatter than the previous range of days as stated.
e) Small cylinder strength behaves almost similarly with standard cylinder strength.
f) Strength gain at
   3 days = 60% of 28-days strength
   7 days = 78% of 28-days strength
g) Failure mode of both cylinder and cube was non-explosive and combined.
h) The experimental data showed that there was no definite relationship between the strength of the two shapes of the ratio of cylinder/cube strength. It depended primarily on the level of strength of concrete and was higher when the strength of concrete was higher.

Concrete is a vast field of research involving numerous unsolved question and problem of qualification properties. However, from the practical point of view, the strength of concrete is the primary interest to the engineers. In relation to concrete strength only, further studies can be made and some suggestions, especially suitable for Bangladesh, are presented here.

a) More detail and extensive study can be made to develop statistical patterns of strength variation between cylinder and cube strength. Results of previous studies will help a great deal in this regard.
b) Statistical analysis of the gain of strength after 28 days may be of practical worth in some cases. Hence, again previous investigation will prove to be valuable and helpful.

c) In the research work, it was found that the aggregate property should have been tested for the confirmation of the aggregates effect on the strength of concrete. So, in future stone aggregate as well as brick aggregate can be simultaneously tested and the test results can be put into the codes for future reference.
d) In Bangladesh, now-a-days concrete making plants have been started where concrete of desired strength are prepared and transported to the site using admixture to delay the setting time, but most often concrete is mixed manually or using small machine on site. Comparison of hand-mixing to machine-mixing to find the influence of the mixing technique on concrete strength may reveal some quantitative information.

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