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Properties of Brick Aggregate Concrete as Influenced by the Strength of Brick

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ABSTRACT

The principal aim of this study was to research the influence of the strength of brick on the properties of brick aggregate concrete. In doing that the water-cement ratio by weight and curing period of concrete for all specimens was kept fixed. The sort of brick as a source of coarse aggregate was the sole variable during this study. Three varieties of brick were utilized during this study to vary the strength of aggregate. These are picked first-class brick and second class brick. The mix ratio by volume were 1:1.25:2.5 & 1:1.5:3.0. The fineness modulus of combined sand (50% Sylhet +50% Local) was 1.88. Tests were administered on cylinder and prism specimens. Emphasis was given to studying the fundamental properties of hardened concrete like compressive strength, modulus of elasticity, and tensile strength. Attempts were made to form a relation between the properties of concrete and also the strength of bricks.

The test results have shown that the properties of concrete the compressive strength, f'c; modulus of rupture, fr; split tensile strength, fsp and modulus of elasticity, Ecinitially increases at the subsequent rate with the increase of the strength of brick, and then the rate decreases.

***KEYWORDS:** Mix Ratio, Fineness Modulus, Compressive Strength, Modulus of Elasticity, Tensile Strength*

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I. INTRODUCTION

Brick is a man-made reasonably stone product of clay whose chief characteristics are plasticity when it's wet and stone-like hardness after being heated to high temperatures. Brick is that the most ordinarily used artifact and used for constructing walls, columns, roofs, paving floors, etc. Concrete is a synthetic stone obtained carefully proportioned mixture of cement materials, fine aggregate & coarse aggregate. In Bangladesh, stone chips (crushed stone) and brick chips (crushed bricks), surki and sand are generally used as coarse aggregate and fine aggregate respectively. In regions like Bangladesh and parts of the state, India where natural rock deposits are scarce, burnt-clay bricks are extensively used for concrete making and performances of such concrete are quite satisfactory. Here, construction of rigid pavements, small to medium span bridges and culverts and build up to 6 stories high using brick aggregate concrete is sort of common. So, an understanding of the properties of brick and properties of concrete made with brick chips is important to research the failure and distress of concrete. These properties are often divided into two main groups. Properties of fresh concrete are workability, cohesiveness, plasticity and consistency and other properties of hardening concrete which are durability, strength, modulus of elasticity. The strength is that the most significant and desirable properties of concrete. The strength of concrete varies on several factors like the standard of materials, the proportion of mixture, workability, proper compaction and curing. In most structural applications concrete is specially to resist the compressive stresses because concrete is so strong in compression and weak in tension. That's why; the compressive strength of brick's additionally as concrete is that the most important over tensile strength.

In Bangladesh scarcity and high cost of natural aggregate have led to the utilization of brick aggregate as substitutes for concrete making. So, it's necessary to develop and investigate the properties of the concrete cast with brick chips as coarse aggregate. The study was aimed primarily at generating information on the essential properties of brick mainly compressive strength, including the whole stress-strain response of concrete made with three different types of crushed bricks as coarse aggregate. The main objectives of this study are to investigate the influence of the strength of brick on the properties of concrete and also, to get the relation between properties of brick aggregate concrete (f'c, fr, fsp and Ec) and therefore the crushing strength of bricks.

II. LITERATURE REVIEW

In our country, it's well-known that brick chips are very widely employed in ordinary construction for its availability and economy. So it's necessary to analyze the properties of concrete using bricks of various strengths. Some work has been meted out into the change of using crushed brick as an aggregate in concrete but most of the research dates back to only after World War- II. Only a little amount of labor has been administered out using the kinds of brick that are commonly employed in construction today and there's little knowledge on the topic within the UK and other countries.

A review of the literature reveals that Akhtaruzzaman and Hasnatdole out some research using well-burnt brick as coarse aggregate in concrete. The study was limited to four mixes, proportioned in accordance with road note 4, to realize target cylinder compressive strengths from 2000to5000psi for the resulting concrete. They need reported that the obtained compressive strengths exceed the corresponding target strengths for all the mixes. Also compared with the predictions of the equations recommended within the 1977 ACI code, these results exhibited approximately 10 to 12% higher modulus of rupture and split tensile strength than those of conventional concrete. However, the modulus of elasticity recorded for brick aggregate concrete was approximately 30% lower.

Ali R.Khaloo used crushed clinker bricks because the coarse aggregate in concrete. He stated only a 7% loss in concrete compressive strength associated with concrete prepared with ordinary aggregates. In contrast to the current decrease strength, there's a decrease within the unit weight of crushed brick concrete of 9.5%.

Another review of the literature reveals that the study reported by Mansur et.al.(1999), in keeping with them the suitability of crushed clay bricks as a coarse aggregate for concrete has been assessed by comparing its basic properties thereupon of conventional concrete. Four basic mixes were chosen for crushed granite to appreciate concrete with grades from 30 to 60 MPa. The opposite number brick-aggregate concrete for each mix was achieved by interchanging granite with an alike capacity of crushed bricks, the whole thing else keep on the undistinguishable. Test results indicate that brick aggregate concrete can attain the identical compressive strength, gives a higher tensile strength (in general 12%) in comparison with conventional concrete. However, it exhibits a substantially smaller elastic modulus (approximately 30%). Also, the peak stress is reached at same way higher strain.

From the above review of literature, we see that they didn't consider the strength of brick over their research and they failed to establish any relationship between the properties of brick aggregate concrete and also,the strength of brick.

III. METHODOLOGY

The properties of materials are utilized in this study are described within the following.

BRICKS

First class These bricks are well burnt to owna smooth and even surface with an ideal rectangular shape and uniform reddish color. These brick mustn't absorb water over 20% of its own dry weight after 24 hours' immersion in water.

Second class These bricks are slightly over burnt to possess a rough surface and not perfectly rectangular in shape. These brick mustn't absorb water over 22% of its own dry weight after 24 hours' immersion in water.

Picked These bricks are over burnt with an irregular shape. These bricks are dark bluish in color.

Table 1 Properties of bricks

Type of bricks	Unit weight (Kg/m³)	Absorption Capacity (%)	Compressive strength	
			MPa	psi
Picked	1952	10.30	35.84	5197
1st Class	1856	14.30	29.77	4317
2nd Class	1832	15.30	23.36	3387

AGGREGATES

Coarse Aggregate Materials which will be retained on 4 No. Sieve i.e. a sieve with four opening per linear inch is termed as coarse aggregate (Nilson 1979). Coarse aggregate greatly influences the strength of the hardened concrete, as they comprise the largest segment of the constituent. The coarse aggregate to be used in making concrete should be clean, well graded, strong and durable and should be free from impurities and deleterious materials such as salts, coal readies etc.

Fine Aggregates It is the aggregate most of which is passes through 4.75 mm IS sieve and contain only that much coarser material as is permitted by the specifications. Sand is generally considered to have lower size limit of about 0.07m.

Table 2 Properties of coarse aggregate

Types of brick aggregate	Unit weight (dry rodded condition) kg/m³	Bulk Specific gravity	Absorption Capacity (%)	F.M	
		Oven dry	SSD		
Picked	930	1.97	2.20	11.42	6.57
1st Class	1000	1.90	2.16	13.92	6.39
2nd Class	983	1.84	2.14	16.50	6.10

Table 3 Properties of fine aggregate

Types of sand	Fineness Modulus (F.M)	Bulk Specific Gravity		Absorption Capacity (%)	Combined F.M.
		Dry	SSD		
Local	1.16	2.5	2.56	3.09	1.88
Sylhet	2.61	3.81	3.85	1.01	

CEMENT

A reinforcing material is unique which has the bonding agent and fragmented properties essential to connection inactive aggregates into a solid mass of sufficient strength, durability. For creating structural concrete, so called hydraulic cements are used exclusively. Water is required for the natural action (hydration) within which the cement powder sets as hardens into solid mass. Various hydraulic cements are developed, Portland cements, this was first patented in England in 1824, is by far and away the foremost common (Nilson-1979). In hydraulic cements that solidifies by relating with water and forms water repelling compound when it obtains it concluding sets. It's highly durable and compressive strength in mortar and concrete. Its specific gravity ranges from 3.12 to 3.16 and weight 1208 kg/m3 (945lb/ft3). Its measured fineness by particle size ranges from 10 microns to 50 microns (Nawy 2001). The HOLCIM CEMENT is manufactured by HEIDELBERG CENENT GROUP was employed in this study.

Table 4 Properties of cement

Properties	3 days MPa (psi)	7 days MPa (psi)
Compressive strength	16.12 (2337)	22.85 (3313)
Tensile strength	0.39 (56)	0.52 75)

IV. EXPERIMENTAL PROGRAMMES

Compressive strength of concrete

The most common of all test on harden concrete is the compressive strength test. The compressive strength of concrete is one of its most important and useful properties and can be made easily. There are two types of compression test specimens are used: cube and cylinder. The study only on the basis of the cylinder test not cube test. Under this test, 4 specimens of cylinder made with picked aggregate, 4 specimens of cylinder made with 1st class brick aggregate, 4 specimens of cylinder made with 2nd class aggregate at the mixing proportion ratio 1:1.25:2.5 and same number of specimens at the ratio 1:1.5:3 are tested.

Cylinder test

The compressive strength of concrete is usually determined by loading 6 inch (152mm) diameter by 12 inch (305mm) high cylinders to failure in uniaxial compression. Cylinders are tested after they had hardened for 28 days. During the 28 days before testing, the cylinders are stored under water or placed in constant temperature room maintained at 100% humidity. The 28 days' maximum compressive strength, which occurs between a strain of approximately 0.002 to 0.003.

Figure 1: Photo view of cylinder test in the study

Tensile strength of concrete

Experimental studies show that the tensile strength of concrete is very variable and ranges from 8 to 15% of compressive strength (f'c). Although concrete isn't normally designed to resist direct tension, the knowledge of tensile strength is useful in estimating the load under which cracking will develop. Cracking complications happen when transverse rigidity rising from shearing stresses grows, but the foremost numerous event of cracking is thanks to controlled shrinkage and temperature gradients. There are substantial experimental problems in defining the right tensile strength of concrete. Because it is difficult to work out the tensile strength of concrete by conducting an immediate tension test, it's computed by the flexure test.

Flexure strength test

In this test, a comprehensible concrete beam is subjected to flexure employing a third point or center point loading. The test specimen is 150mm*150mm*450mm. The study was supported on the middle point loading and tension properties are measured in terms of modulus of rupture. The modulus of rupture (fr) is computed on the premise of the ordinary elastic theory and is adequate $3PL/(2BD^2)$. Under this test, 3 specimens of a prism made with picked aggregate, 3 specimens of a prism made with 1st class brick aggregate, 3 specimens of prism made with 2nd class aggregate at the mixing ratio 1:1.25:2.5 and the same number of specimens at the ratio 1:1.5:3 are tested.

Figure 2: Photo view of prism after flexure strength test in the study

Split cylinder test

The another method to determine the tensile strength of concrete is split cylinder test because of the difficulties involved in conducting the direct tension test. The test contains of spread over compressive line load alongside contrary generator of a concrete cylinder placed with its axis horizontal among the platens. Owing to the applied line loading a justly unchanging tensile stress is prompted over nearly two third of the loaded diameter as achieved from an elastic investigation. The magnitude of split cylinder strength is given by $f_{sp} = 2p/(\pi dl)$. Under this test, 2 specimens of cylinder made with picked aggregate, 2 specimens of cylinder made with 1st class brick aggregate, 2 specimens of cylinder made with 2nd class brick aggregate at the ratio 1.1.25:2.5 and same number of specimens at the ratio 1:1.5:3.5 are tested.

Figure 3: Photo view of cylinder after split test in the study

Modulus of elasticity of concrete

Since stress strain curve of concrete is nonlinear, its modulus of elasticity is given by the slope of the stress strain curve. The modulus of elasticity (Ec) increases with increases of compressive strength of concrete. The modulus of elasticity (Ec) of concrete depends on the following factor:

- Age of concrete
- Properties of aggregate and cement
- Rate of loading
- Type of size of specimen

According to ASTM standard Ec is computed on the basis of 40% of compressive strength. Modulus of elasticity of concrete equals to [(40% of ultimate strength of concrete)/corresponding strain]. Under this test, 3 specimens of cylinder made with picked aggregate, 3 specimens of cylinder made with 1st class brick aggregate, 3 specimens of cylinder made with 2nd class aggregate at the ratio 1:1.25:2.5 and the same number of specimens at the ratio 1:1.5:3 are tested.

Figure 4: Photo view of cylinder after modulus of elasticity test in the study

V. RESULTS AND DISCUSSION

In total 48 cylinders and 18 prisms were tested in this study. Among these 18 cylinders for compressive strength, 18 cylinders for modulus of elasticity, 12cylinders for split cylinder strength and 18 prisms were tested for tensile strength. All specimens were tested after 28 days' normal water curing.

Table 5 Properties of concrete from the experimental investigation

Type of Bricks	Casting ratio (by volume)	Compressive strength of concrete f'c	Modulus of rupture fr	Split cylinder strength fsp	Modulus of Elasticity Ec
		MPa	MPa	MPa	MPa x10³
Picked	1:1.25:2.5	31.82	7.10	3.64	17.54
	1:1.5:3	27.20	5.40	3.23	15.70
First Class	1:1.25:2.5	30.71	5.69	2.91	12.69
	1:1.5:3	24.86	5.60	2.79	11.29
Second Class	1:1.25:2.5	19.35	4.88	2.65	8.30
	1:1.5:3	16.96	4.52	2.45	7.61

From the above table it has been clear that, the strength properties of concrete increases with the increase of strength of brick.

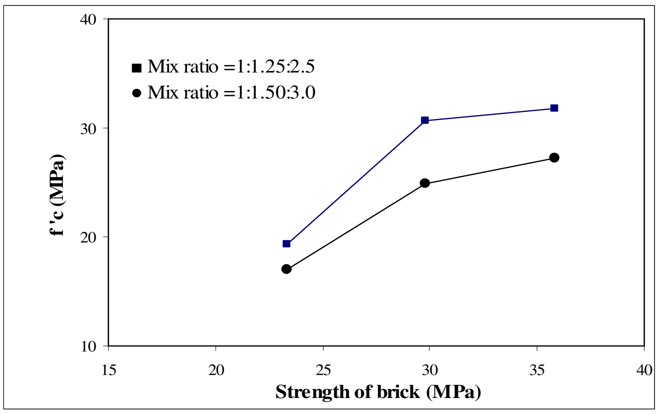

Figure 5: Concrete compressive strength versus brick strength

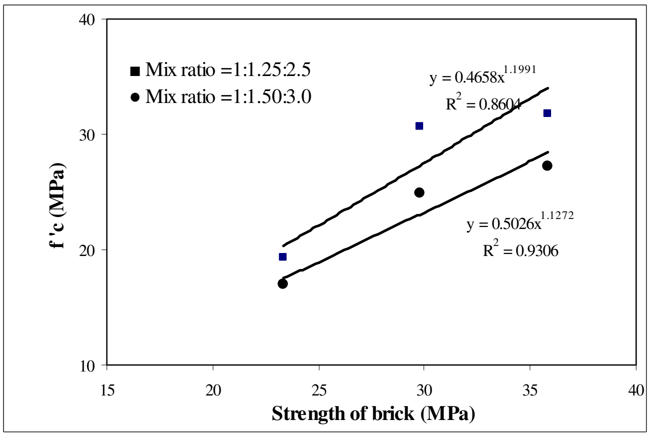

Figure 6: Variation of concrete compressive strength versus brick strength

From the above figure 5-6, it has been seen that the compressive strength of concrete initially increases at a higher rate with the increase of strength of brick and then the rate decreases with the increase of strength of brick.

The following equation is suggested to relationship between compressive strength of concrete and brick strength by observation above two curves:

For mix ratio 1:1.25:2.5,

$f_c' = 0.4658 f_b^{1.1991}$ … … … (5.1)

For mix ratio 1:1.50:3.0,

$f_c' = 0.5026 f_b^{1.1272}$ … … … (5.2)

f_b = Strength of brick

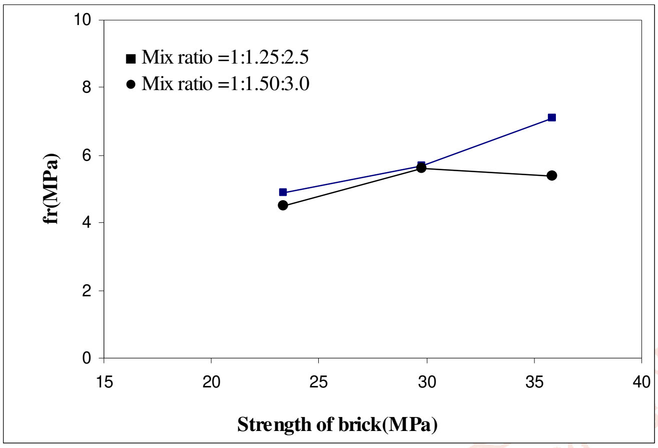

Figure 7: Modulus of rupture versus brick strength

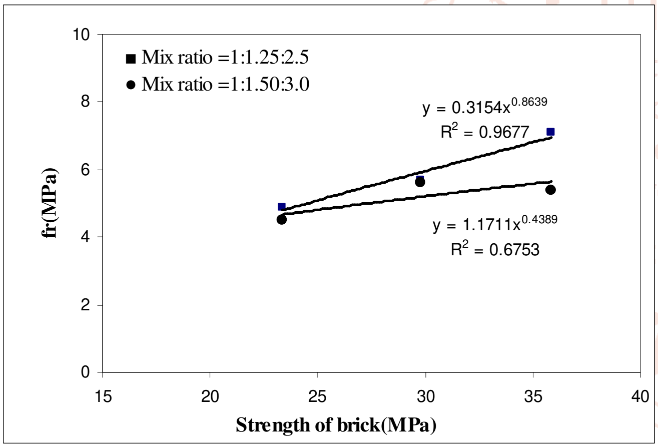

Figure 8: Variation of modulus of rupture versus brick strength

From the above figure 7-8, it has been seen that the modulus of rupture of concrete initially increases with the increase of strength of brick and then it shows scattered properties with the increase of strength of brick.

The following equation is suggested to relationship between modulus of rupture of concrete and brick strength by observation above two curves:

For mix ratio 1:1.25:2.5,

$f_r = 0.3154 f_b^{0.8639}$ … … … (5.3)

For mix ratio 1:1.50:3.0,

$f_r = 1.1711 f_b^{0.4389}$ … … … (5.4)

f_b = Strength of brick

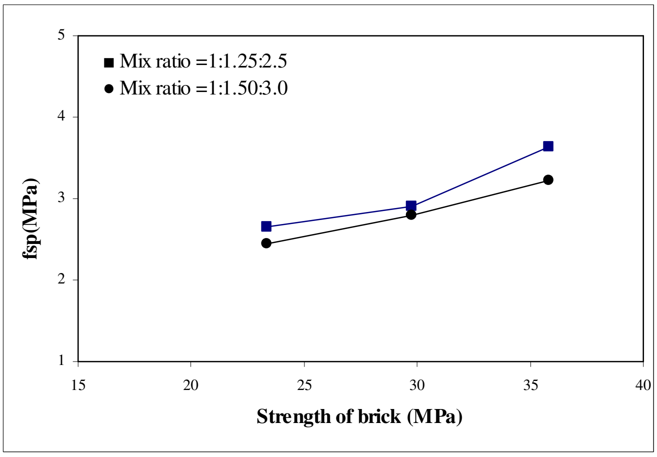

Figure 9: Split cylinder strength versus brick strength

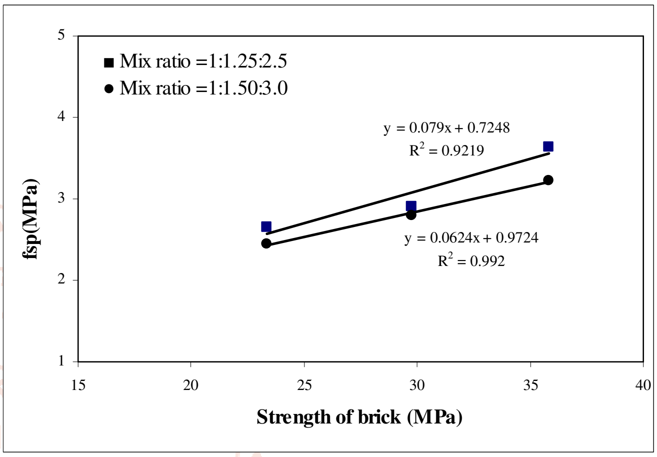

Figure 10: Variation of split cylinder strength versus brick strength

From the above figure it has been seen that split cylinder strength of concrete increasing linearly with the increase of strength of brick.

The following equation is suggested to relationship between split cylinder strength of concrete and brick strength by observation above two curves:

For mix ratio 1:1.25:2.5,

$f_{sp} = 0.079 f_b + 0.7248$ … … … (5.5)

For mix ratio 1:1.50:3.0,

$f_{sp} = 0.0624 f_b + 0.9724$ … … … (5.6)

f_b = Strength of brick

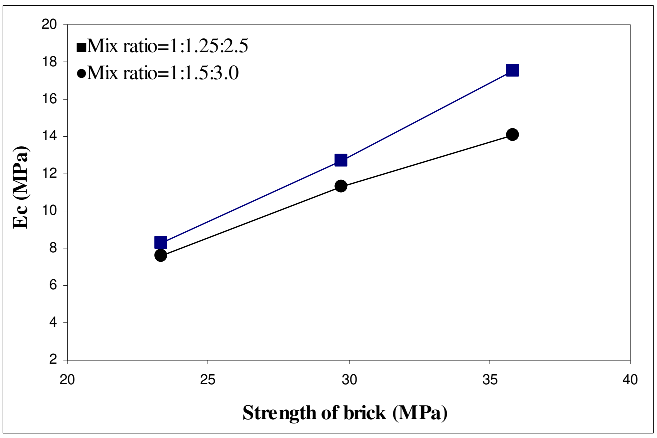

Figure 11: Modulus of elasticity versus brick strength

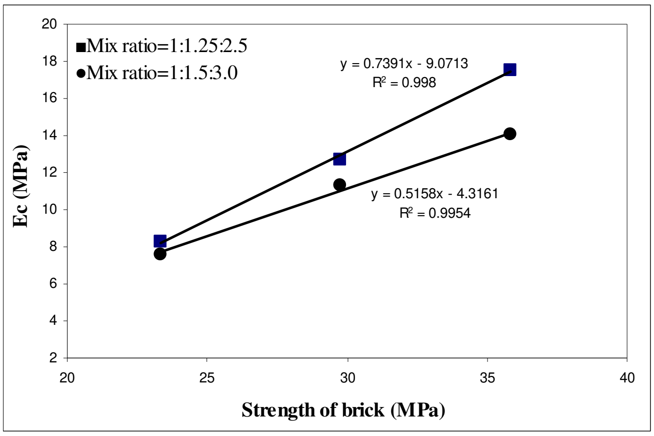

Figure 12: Variation of modulus of elasticity versus brick strength

From the above figure it has been seen that modulus of elasticity of concrete increasing linearly with the increase of strength of bricks.

The following equation is suggested to relationship between modulus of elasticity of concrete and brick strength by observation above two curves:

For mix ratio 1:1.25:2.5,

$E_c = 0.739f_b - 9.0713 \dots\dots\dots (5.7)$

For mix ratio 1:1.50:3.0,

$E_c = 0.5158f_b - 4.3161 \dots\dots\dots (5.8)$

$f_b =$ Strength of brick

VI. CONCLUSION

The following conclusion can be drawn from the experimental results:

- The compressive strength of picked aggregate concrete is about 3.62% and 64.4% higher than first class and second class brick aggregate concrete respectively for mix ratio of 1:1.25:2.5 and 9.41% and 60.4% higher than first class and second class brick aggregate concrete respectively for mix ratio of 1:1.5:3.0.
- The compressive strength of first class brick aggregate concrete is about 58.70% higher than second class brick aggregate concrete for a mix ratio of 1:1.25:2.5 and 46.60% higher than second class brick aggregate concrete for a mix ratio of 1:1.5:3.0.
- The modulus of rupture of picked aggregate concrete is about 24.80% and 45.50% higher than first class and second class brick aggregate concrete respectively for mix ratio of 1:1.25:2.5 and 6.4% lower and 19.50% higher than first class and second class brick aggregate concrete respectively for mix ratio of 1:1.5:3.0.
- The modulus of rupture of first class brick aggregate concrete is about 16.60% higher than second class brick aggregate concrete for a mix ratio of 1:1.25:2.5 and 23.90% higher than second class brick aggregate concrete for a mix ratio of 1:1.5:3.0.
- The split tensile strength of picked aggregate concrete is about 25% and 37.40% higher than first class and second class brick aggregate concrete respectively for mix ratio of 1:1.25:2.5 and 15.80% and 31.80% higher than first class and second class brick aggregate concrete respectively for mix ratio of 1:1.5:3.0.
- The split tensile strength of first class brick aggregate concrete is about 9.80% higher than second class brick aggregate concrete for a mix ratio of 1:1.25:2.5 and 13.90% higher than second class brick aggregate concrete for mix ratio of 1:1.5:3.0.
- The modulus of elasticity of picked aggregate concrete is about 40.3% and 24.40% higher than first class and second class brick aggregate concrete respectively for a mix ratioof1:1.25:2.5 and 111.70% and 78.90% higher than first class and second class brick aggregate concrete respectively for mix ratio of 1:1.5:3.0.
- The modulus of elasticity of first class brick aggregate concrete is about 50.80% higher than second class brick aggregate concrete for mix ratioof1:1.25:2.5 and 43.90% higher than second class brick aggregate concrete for mix ratio of 1:1.5:3.0.
- The equations 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7 and 5.8 are suggested in determining the compressive strength, f'_c; modulus of rupture, f_r; split tensile strength, f_{sp} and modulus of elasticity, E_c from the strength of bricks.

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