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Experimental Study on Strength Properties of Concrete using Brick Aggregates

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Abstract: *Concrete has captured almost entire construction industry and its ingredients such as cement, manufacture of cement and bricks consume large quantities of natural resources and fuel with $C0_2$ to the green house gases resulting in global warming. Therefore, under such critical scenario of shrinkage of natural aggregates resource and ever increasing pressure to reduce construction costs and further construction & dismantling of old structure producing heavy debris needing disposal has made it necessary to invert, discover & think of other alternatives for replacement of coarse aggregate.*

The present paper aims with the study of strength properties of concrete using brick aggregates. To use over-burnt bricks, normal burnt brick as replacement to conventional normal aggregate in different proportions. Brick aggregates can fully or partly replace the conventional coarse aggregate to produce M_{20} concrete. M_{20} grade concrete mix with different proportions i.e. [1:1.5:1, 1:1.5:2, 1:1.5:3] are carried out using over-burnt, normal burnt brick aggregates. Physical proportions of cement, fine aggregate & normal aggregate, normal burnt brick aggregates, over-burnt brick aggregates are carried out. Cube compressive strength test & split tensile test are carried out for 7 & 28 days. An attempt has been made using brick aggregate concrete to replace normal aggregate concrete.

Keywords: *Aggregates, Bricks, Concrete, Compressive test, conventional*

I. INTRODUCTION

Concrete is a versatile and composite construction material. Composed of cement (commonly ordinary Portland cement) and cementitious material such as fly ash, silica fume and slag cement, aggregate (generally coarse aggregate of gravels or crushed rocks such as limestone or granite plus a fine aggregate such as sand), water and chemical admixtures.

The word concrete comes from the Latin word “concretus”(means compact or condensed) the perfect passive participate of“concrescre”from ‘con –(together)and “crescer”(to grow). Concrete seems to be simple but it is a complex product. It involves physio-chemical reactions and has so many unmanageable benevolent features. For the last 150 years, no cost effective substitute material is found, as such concrete stands unchallenged and unbeatable product. Concrete is eco friendly and no natural energy is consumed. By-products of toxic nature are not librated. Further concrete itself can be recycled various waste products such as fly ash, silica fume, blast furnace slag, rice husk ash, metakaolin etc may be incorporated and number of different types of light weight aggregates such as lytag granule, polite, liapor, shale, slate and brick bats. Till today strength driven concrete design rather than durability and performance based concrete for durable concrete, micro cracks in concrete must be minimized by adding of pozzolanic materials and mineral admixtures like fly ash, silica fume.

Concrete has technologically very much advanced and has under gone so many changes from normal to high strength concrete, high performance to ultra high performance concrete, fiber reinforced concrete, prestressed concrete, reinforced cement concrete, self compacting concrete, high volume fly ash concrete, lunar concrete, light weight concrete, ready mixed concrete etc. The waste brick bats such as over burnt bricks, normal burnt bricks are thrown away from the brick manufacturing units. These brick bats are obtained and used. Also recycled bricks obtained from the dismantled structures can be used in the concrete as an alternative replacement to coarse aggregate.

II. OBJECTIVES OF PRESENT STUDY

1) To Study the Compressive strength of cubes and split tensile strength of cylinders for over burnt brick aggregate, normal burnt brick aggregate, normal aggregate for various proportions (1:1.5:1, 1:1.5:2, 1:1.5:3) with different water-cement ratio’s.

2) To Study the water absorption capacity of brick aggregate concrete in comparison with the conventional aggregate concrete.

3) To Study bulk density of over burnt brick aggregate, normal burnt brick aggregate and normal aggregate.

III. BRICK AGGREGATE CONCRETE

Aggregate are generally cheaper than cement and impart great volume stability strength density and durability to concrete. Coarser and finer particles are so graded that voids are packed to minimum and cement-sand mortar matrix fills the gaps and interspaces and binds the entire matrix to form rock like solid substance called concrete. Natural aggregate are derived from any one of rocks belonging to igneous, sedimentary or metamorphic origin. But artificial aggregate mainly consists of broken bricks and also air cooled blast furnace slag, cinder expanded slag and shale etc.

Bricks may be natural mud (laterite) blocks cut to sizes or artificial manufactured in clamps and kilns. Artificial bricks shall be well-burnt so that their crushing strength is not less than 30N/mm². Under burnt bricks shall not be used to make brick aggregate. However normal or over burnt bricks make good aggregate. Bricks aggregate possess all properties of other well recognized light aggregate since ancient days. Therefore brick aggregate can very well be considered as light weight aggregate with due protection against corrosion given and with increased cover given to steel reinforcement brick aggregate can be adopted to R.C.C works also.

Bricks are manufactured in clamps, local kilns and energy efficient large kilns to produce hand moulded burnt clay bricks and are called artificial bricks. In the ancient days natural mud blocks cut to size were used for housing units to monuments and also for minor culverts, bridges and drains. In India present demand for bricks is over 100 billion bricks per year which stands second in demand of the construction materials after the cement. The fuel used for burning of air dried bricks itself cost around 30 to 40% of production cost of bricks. The conventional practice of firing clay bricks in traditional clamps and kilns consumers large quantity of coal, wood and biomass fuel. Next to china, India is second largest producer of bricks in the world and consumer coal wood and fossil fuels more than 24 million tons per annum. Construction industry as a whole contributes 17% of CO2 in our country out of which cement contributes about 17% and bricks industry contributes about 3%. Government of India has already restricted burning of fuel in cement industry and brick industry in urban areas.

IV. TESTS ON MATERIALS

CEMENT Brand name: OPC ACC cement (43 grade)

SL NO	Physical Properties	Sample-1	Sample-2	Requirement as per is-8112 1989
1	Specific Gravity	3.15	3.15	
2	Normal consistency	30	34	
3	Initial setting time	55	66	minimum: 30 min
4	Final setting time	320	400	maximum:600 min
5	Fineness of cement	4.0mm	5.1mm	maximum:10%

Table no-1: Cement test results

AGGREGATES

Sl no	Aggregates	Fineness modulus	Water absorption (%)	Bulk density (Kg/m^3)
1	Overburnt Brick aggregate	8.23	5.33	1112.96
2	Normal Burnt Brick Aggregate	8.44	6.16	1010.89
3	Normal Aggregate	8.206	1.66	1671.18
4	Fine aggregate	2.72 Confirming to IS-383-1970 fine aggregate falls under zone II	-	-

Table no-2: Aggregates test results

SPECIFIC GRAVITY TEST

Sl.no	Aggregates	Sample-1	Sample-2
1	Over burnt brick aggregate	2.23	2.50
2	Normal burnt brick aggregate	2.48	2.62
3	Normal aggregate	2.96	3.0
4	Fine aggregate	2.64	2.62

Table no- 3: Specific gravity test results

V. TESTING OF BRICK AGGREGATE CONCRETE

- Mechanical (strength) properties of brick aggregate concrete

Mechanical properties of concrete related to strength and density comprise of the following which are carried out in our investigation.

1) Cube (150mm×150mm×150mm) and cylinder (150mm diameter and 300mm height), compressive strength for 7, 28 days curing period.
2) Split tensile strength of concrete (150mm diameter and 300mm height) samples.

The present study mainly concentrates on normal burnt brick aggregates and over burnt bricks aggregate concrete whose mechanical or strength properties are compared with conventional or normal aggregate concrete of mix design of grade M20

- Strength of concrete

The compressive strength is one of the most important and valuable properties of concrete. It gives an overall picture of the quality of the concrete. Compressive is also used as a qualitative measure for other properties of hardened concrete. Strength of concrete is nothing but its resistance to rupture. It may be measured as strength in compression and tension etc. All these indicate strength with reference to a particular method of testing.

- Types of tests on hardened concrete

The tests carried out on hardened concrete are

1) Compressive strength
2) Split tensile test

- Compressive strength

Compression test is an easy test to perform and most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. For compression testing of concrete 150mm×150mm×150mm cubes and 150mm diameter and 300mm height cylinders are cast and tested. In our project work, the cubes of 150mm×150mm×150mm size and cylinder of 150mm diameter and 300mm height size were cast and tested in saturated surface dried (SSD) condition. For each mix, minimum of three cubes/cylinders were tested on compression on testing machine of 3000KN capacity.

Crushing strength fc= (ultimate or breaking load/ area of loading)

- Failure of compression specimen

1) Cubical specimens are tested after 7 and 28 days after casting and curing in water.
2) Cubical specimens are dried in air after 7 or 28 days and tested in a compression testing machine.
3) Compression on test develops a more complex system of stresses.
4) Cube/cylinder undergoes lateral expansion due to compression load.
5) The elements within the specimen are subjected to a shearing stress and compression.
6) Failure depends on the shape of the specimen.

- Tensile strength

Plain concrete (without steel reinforcement) is quite weak in tensile strength which may vary from $1/8^{th}$ to $1/20^{th}$ of the ultimate compressive strength. Testing of cube or beam or cylinder specimen for tensile strength means holding the specimen properly in grip and applying uniform uniaxial tensile load without giving room for stress concentration and eccentricity of loading which in turn may give rise to bending stresses due to which true value of tensile strength may not be assessed. This is direct method involving lot of difficulties and ultimately values obtained are apparent. Therefore indirect methods are employed namely determination of split tensile test.

- Split tensile strength test

The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and applying compressive load until failure of the specimen along the vertical diameter. When load is applied along the generatix, an element on vertical diameter of the cylinder is subjected to horizontal stress of.

Split tensile $ft=[(2P)/(\pi Ld)]$

Where;
'P' is the compressive load on the cylinder in KN
'L, d' is the length and diameter of the cylinder specimen in mm
In our study specimen cylinder were tested for 7and 28 days strength

VI. COMPRESSIVE STRENGTH TEST RESULTS OVER BURNT BRICK AGGREGATES

Concrete grade M_{20} of proportion [1:1.5:1, 1:1.5:2, 1:1.5:3] with water-cement ratio 0.5, 0.55 and 0.55 using over burnt brick aggregate, normal burnt brick aggregate and normal aggregate were casted and tested. The results of normal burnt brick aggregate and over burnt brick aggregate are compared with normal aggregate (conventional concrete).

Sl no	Ratio's	Bulk weight in Kg	Failure load in KN	Cross sectional area in (mm^2)	Compressive strength in N/mm^2	Average compressive strength in N/mm^2
1	1:1.5:1	8.05	1008	22.5×10^3	44.80	40.91
		7.79	976.7	22.5×10^3	43.40	
		7.86	777.5	22.5×10^3	34.55	
2	1:1.5:2	8.02	887.1	22.5×10^3	39.42	36.2
		7.78	788.4	22.5×10^3	35.04	
		7.85	768.3	22.5×10^3	34.14	
3	1:1.5:3	7.97	928.6	22.5×10^3	41.27	43.50
		8.15	1002.0	22.5×10^3	44.53	
		7.93	1006	22.5×10^3	44.71	

Table no-4 :7 days compressive strength of over burnt brick aggregate for cubes

Sl no	Ratio's	Bulk weight in Kg	Failure load in KN	Cross sectional area in mm²	compressive strength in N/mm²	Average compressive strength in N/mm²
1	1:1.5:1	7.92	919.5	22.5×10³	40.86	43.54
		8.03	908.9	22.5×10³	40.39	
		8.09	1111.0	22.5×10³	49.37	
2	1:1.5:2	7.88	967.2	22.5×10³	42.98	47.54
		8.04	1090.0	22.5×10³	48.44	
		7.85	1152.0	22.5×10³	51.20	
3	1:1.5:3	7.94	1086.0	22.5×10³	48.26	46.25
		8.40	995.3	22.5×10³	44.23	
		8.01	1041	22.5×10³	46.26	

Table no- 5: 28 days compressive strength of over burnt brick aggregate for cubes

NORMAL BURNT BRICK AGGREGATE

Sl No	Ratio's	Bulk Weight in Kg	Failure Load in KN	Cross Sectional Area in (mm²)	Compressive Strength in N/mm²	Average Compressive Strength in N/mm²
1	1:1.5:1	7.55	465.5	22.5×10³	20.68	20.83
		7.48	435.6	22.5×10³	19.36	
		7.56	505.3	22.5×10³	22.45	
2	1:1.5:2	7.78	588.6	22.5×10³	26.16	25.28
		7.67	565.8	22.5×10³	25.14	
		7.74	552.2	22.5×10³	24.54	
3	1:1.5:3	7.65	333.2	22.5×10³	14.80	15.70
		7.67	389.3	22.5×10³	17.30	
		7.42	337.7	22.5×10³	15.0	

Table no-6: 7 days compressive strength of normal burnt brick aggregate for cubes.

Sl No	Ratio's	Bulk Weight in Kg	Failure Load in KN	Cross Sectional Area in (mm^2)	Compressive Strength in N/mm^2	Average Compressive Strength in N/mm^2
1	1:1.5:1	7.81	607.9	22.5×10^3	27.01	25.61
		7.83	590.2	22.5×10^3	26.23	
		7.79	530.9	22.5×10^3	23.59	
2	1:1.5:2	7.79	783.7	22.5×10^3	34.83	27.89
		7.76	601.3	22.5×10^3	26.72	
		7.90	498.2	22.5×10^3	22.14	
3	1:1.5:3	7.69	527.1	22.5×10^3	23.42	20.79
		7.68	467.6	22.5×10^3	20.78	
		7.81	409.1	22.5×10^3	18.18	

Table no-7: 28 days compressive strength of normal burnt brick aggregate for cubes.

NORMAL AGGREGATE

Sl No	Ratio's	Bulk Weight in KN	Failure Load in KN	Cross Sectional Area in (mm^2)	Compressive Strength in N/mm^2	Average Compressive Strength in N/mm^2
1	1:1.5:1	8.01	546.6	22.5×10^3	24.29	26.94
		8.17	578.8	22.5×10^3	25.72	
		8.26	693.3	22.5×10^3	30.81	
2	1:1.5:2	8.21	693.6	22.5×10^3	30.82	33.86
		8.44	758.1	22.5×10^3	33.69	
		8.54	834.1	22.5×10^3	37.07	
3	1:1.5:3	8.68	594.2	22.5×10^3	26.40	25.40
		8.71`	578.2	22.5×10^3	25.69	
		8.67	542.9	22.5×10^3	24.12	

Table no-8: 7 days compressive strength of normal aggregate for cubes

Sl No	Ratio's	Bulk Weight in Kg	Failure Load in KN	Cross Sectional Area in (mm^2)	Compressive Strength in N/mm^2	Average Compressive Strength in N/mm^2
1	1:1.5:1	8.18	770.5	22.5×10^3	34.24	38.79
		8.08	940.0	22.5×10^3	41.77	
		8.22	908.5	22.5×10^3	40.37	
2	1:1.5:2	8.37	895.6	22.5×10^3	39.80	39.05
		8.47	701.6	22.5×10^3	31.18	
		8.44	1039.0	22.5×10^3	46.17	
3	1:1.5:3	8.56	678.0	22.5×10^3	30.13	31.55
		8.61	734.6	22.5×10^3	32.64	
		8.83	717.4	22.5×10^3	31.88	

Table no-9: 28 days compressive strength of normal aggregate for cubes

AVERAGE COMPRESSIVE STRENGTH OF CUBES FOR 28 DAYS

Sl no	W/C Ratio	Ratio's	Over burnt brick aggregates in N/mm^2	Normal burnt brick aggregates in N/mm^2	Normal aggregates in N/mm^2
1	0.5	1:1.5:1	43.54	25.61	38.79
2	0.55	1:1.5:2	47.54	27.89	39.05
3	0.55	1:1.5:3	46.25	20.79	31.55

Table no-10: 28 days average compressive strength of cubes

AVERAGE SPLIT TENSILE STRENGTH OF CYLINDERS FOR 28 DAYS

Sl no	W/C Ratio	Ratio's	Over burnt brick aggregates in N/mm^2	Normal burnt brick aggregates in N/mm^2	Normal aggregates in N/mm^2
1	0.5	1:1.5:1	3.65	1.31	2.19
2	0.55	1:1.5:2	2.85	1.48	2.52
3	0.55	1:1.5:3	3.27	1.81	2.06

Table no-11: 28 days average split tensile strength of cylinders

BULK DENSITY OF CUBES FOR 28 DAYS

Sl no	W/C Ratio	Ratio's	Over burnt brick aggregates in kg/m³	Normal burnt brick aggregates in kg/m³	Normal aggregates in kg/m³
1	0.5	1:1.5:1	2373.33	2314.07	2417.77
2	0.55	1:1.5:2	2346.66	2314.07	2494.81
3	0.55	1:1.5:3	2402.96	2287.40	2565.92

Table no-12: 28 days bulk density of cubes

BULK DENSITY OF CYLINDERS FOR 28 DAYS

Sl no	W/C Ratio	Ratio's	Over burnt brick aggregates in kg/m³	Normal burnt brick aggregates in kg/m³	Normal aggregates in kg/m³
1	0.5	1:1.5:1	2328.30	2252.83	2412.24
2	0.55	1:1.5:2	2341.50	2269.81	2503.71
3	0.55	1:1.5:3	2339.62	2267.92	2528.30

Table no: 13: 28 days bulk density of cylinders

COMPACTION FACTOR TEST RESULTS [WORKABILITY TEST]

Sl no	W/C Ratio	Ratio's	Over burnt brick aggregates	Normal burnt brick aggregates	Normal aggregates
1	0.5	1:1.5:1	0.80	0.83	0.82
2	0.55	1:1.5:2	0.84	0.85	0.86
3	0.55	1:1.5:3	0.82	0.80	0.84

Table no-14: Compaction factor test results

TESTS RESULTS AND DISCUSSIONS

A detailed study of physical and mechanical properties is carried out for the following ingredients of concrete

a) Over burnt brick aggregates of 20 mm d/s.
b) Normal burnt brick aggregates of 20mm d/s.
c) Normal aggregates of 20mm d/s.

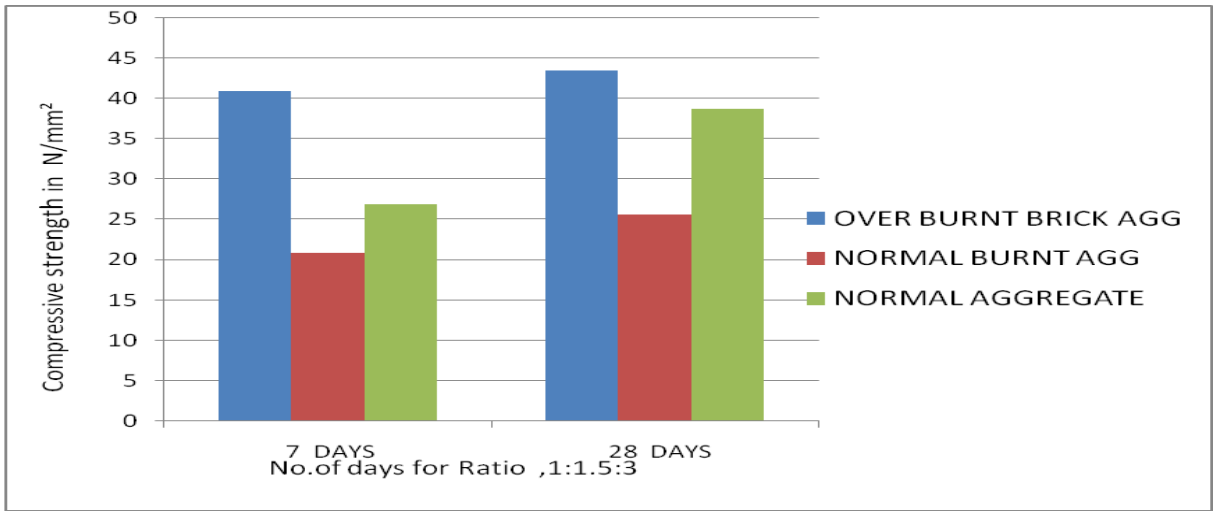
The tests carried out to know the strength or mechanical properties are as under

1. Cube compressive strength for 7, 28 days.
2. Split tensile strength of cylinders for 28 days.
3. Bulk density of concrete at different age of 7, 28 days.
4. Specific gravity and water absorption.

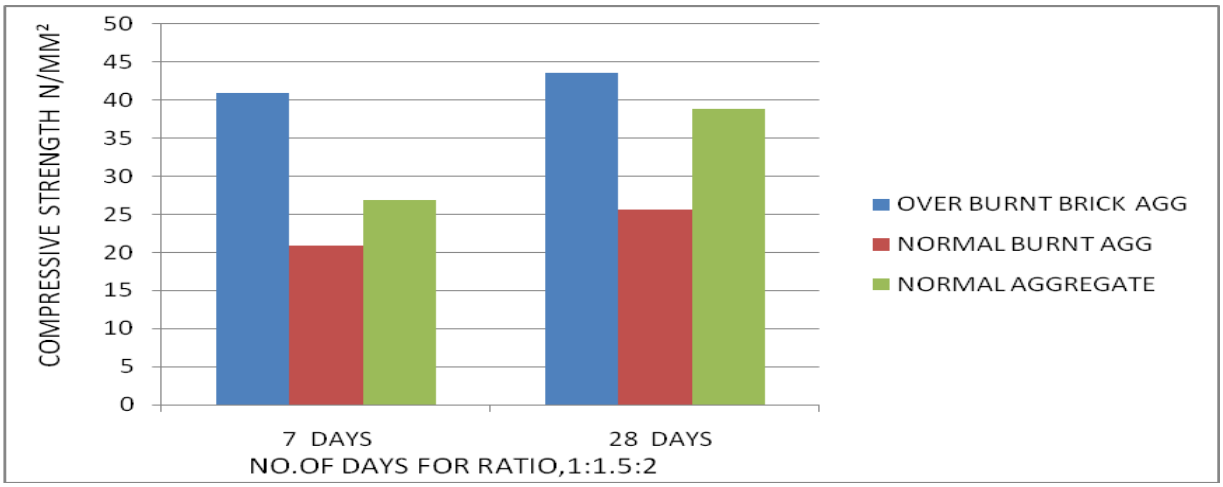
The following tables (Refer table 4 to 14) gives the comparative results of compressive test, split test, & densities for normal aggregate, normal burnt brick aggregate & over burnt brick aggregate concrete.

VII. GRAPHS

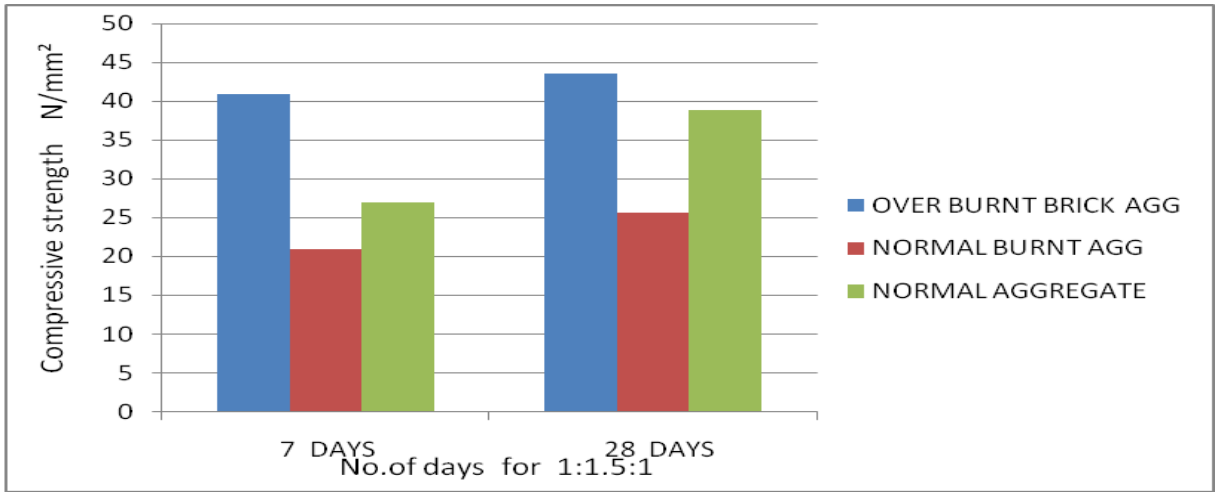
Comparison of Compressive strength for Over burnt brick aggregate [OB], Normal burnt brick aggregate [NB] & Normal Aggregate [NA]



Graph -1: Comparison of compressive strength for OB, NB and NA for ratio 1:1.5:3

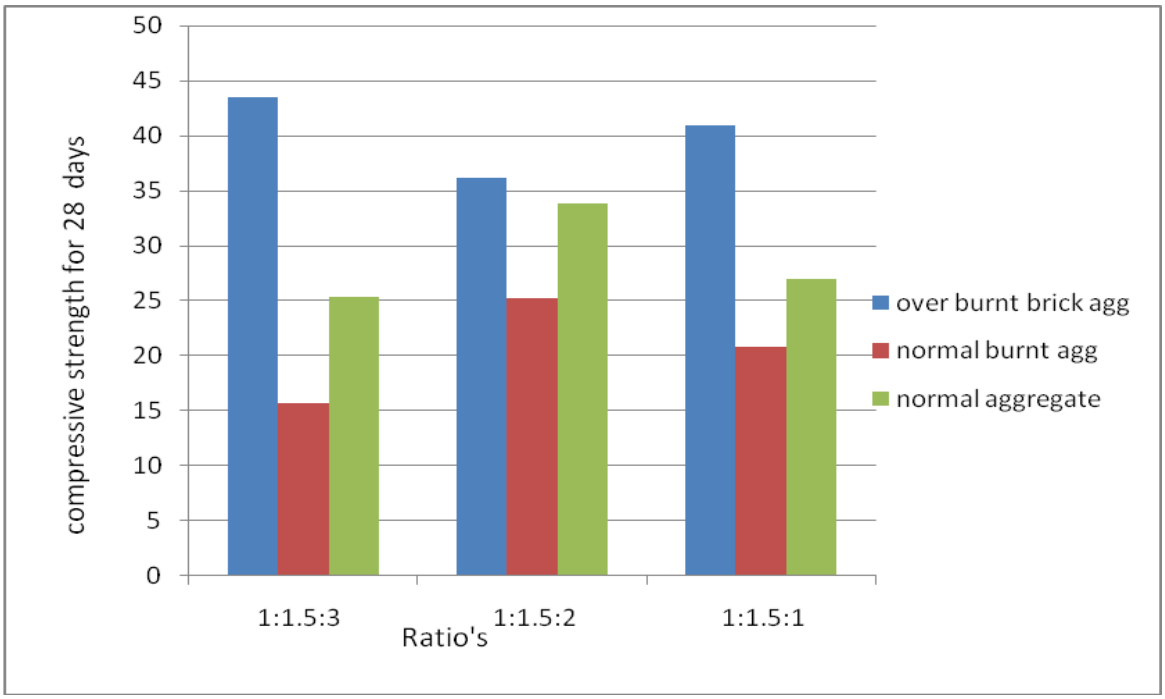


Graph-2: Comparison of compressive strength for OB, NB and NA for ratio 1:1.5:2



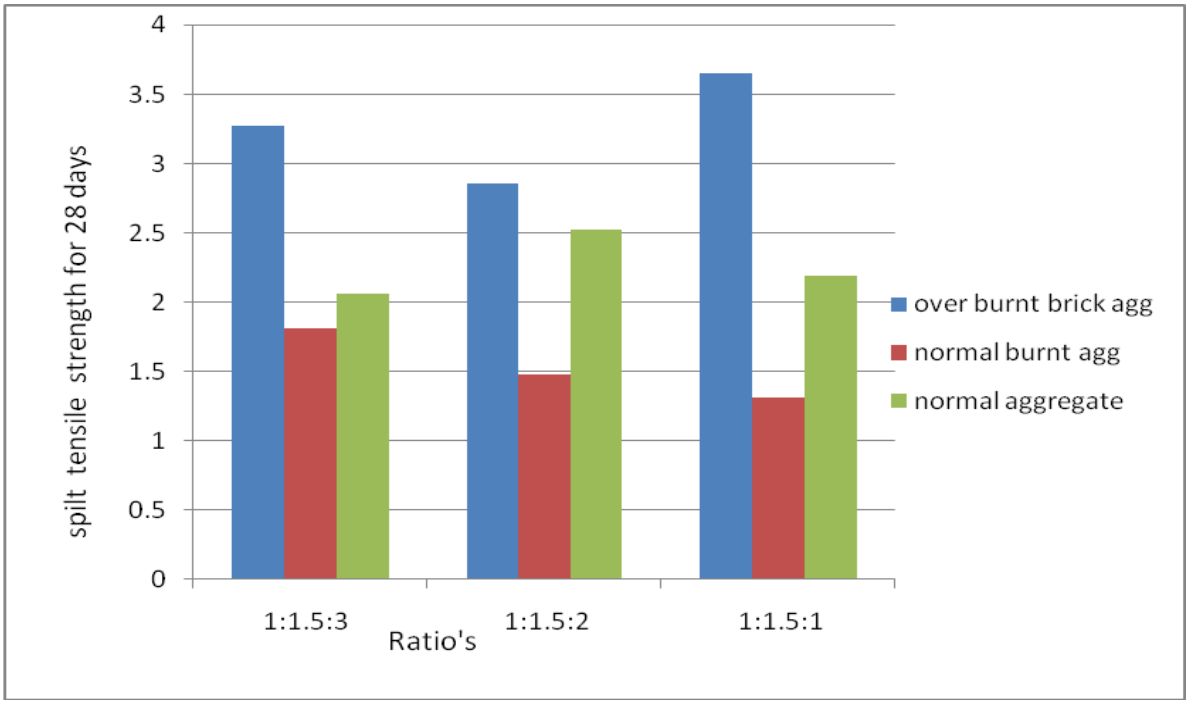
Graph-:3 Comparison of compressive strength for OB, NB and NA for ratio 1:1.5:1

COMPARISON OF COMPRESSIVE STRENGTH B/W RATIO'S



Graph-4: Comparison of compressive strength between ratio's [1:1.5:3, 1:1.5:2, 1:1.5:1] for 28 days

COMPARISON OF SPILT TENSILE STRENGTH FOR OB, NB& NA



Graph-5: Comparison of split tensile strength for OB, NB and NA between ratio's for 28 days.

VIII. SUMMARY & CONCLSIONS

1) Compressive Strength for over burnt brick aggregate concrete found comparatively higher than the normal aggregate concrete (As shown in table no-10 and graph no 1, 2, 3).
2) Compressive strength for normal burnt brick aggregate concrete found nearly equal to normal aggregate concrete (As shown in table no-10 and graph no 1, .2, and 3). i.e. normal burnt brick aggregate concrete can also replace normal aggregate concrete.
3) Split tensile strength for over burnt brick aggregate concrete found to be higher than normal aggregate concrete.
4) Out of over burnt brick aggregates and normal burnt brick aggregates, over burnt brick aggregates can very well replace normal aggregates due to their hardness, low water absorption and higher cube strength. When used in concrete.
5) Bulk density of brick aggregate (over burnt brick aggregate + normal burnt brick aggregate) is in the range of 1000kg/m³ to 1200kg/m³. Hence brick aggregate can be considered as light weight aggregates.
6) Normal burnt brick aggregate can be broken to sizes of 40, 20, 10mm and down size aggregate by hand breaking, but over burnt bricks need crusher for breaking down sizes of aggregate. Thus it may be very well concluded that hard over burnt bricks may be taken as 'artificial stone' or 'metamorphic stone'.

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