Strength and durability studies on concrete with partial replacement over burnt brick bat waste

S Kanchidurai*, G Bharani and K Saravana Raja Mohan

School of Civil Engineering, SASTRA University, Thanjavur, Tamil Nadu, India.

*Email: kanchidurai@civil.sastra.edu

Abstract. This paper presents the partial and complete replacement of over burnt brick bat (OBB) 20-30mm as coarse aggregate in the concrete. OBB are formed at extreme heating to a temperature not less than 1600 degree Celsius. The burnt bricks change from red to blue-black ceramics color. The series of tests are conducted to study the effect of 0%, 25%, 50%, 75% and 100% replacement of coarse aggregate with over burnt bricks. Totally 36numbers of 150mm concrete cube with 5 different percentage replacement mix are cast and tested and three numbers of the flexural beam. In durability aspects, water absorption and sorptivity were tested. Experimental results found 25-50% of overburnt brick bat wastes can be replaced with the normal and mass concrete without quality compromisation.
Keywords: Brick bats, Compressive strength, Flexural strength and sorptivity

1. Introduction

Concrete is the base material for construction industries. It is strong in compression and weak in tension, the main constituent of the concrete in cement, sand, coarse aggregate and water, replacing some of these material makes significant changes in cost as well as performance. Coarse aggregate filled almost 70% of volume in concrete [1], the cost of coarse aggregate rapidly increasing also the availability of the aggregate is getting reduced. The major cost of the concrete is belonged to the aggregate [2]. The over burnt brick bat (OBB) wastes 20-30mm size having available in the brick manufacturing industries. In recent research, the OBB wastes were replaced with concrete. This OBB maintains strength and performance to the concrete also reduce the weight of the concrete [3[4[5]. Strongly OBB replaced with concrete can be performed in the mass concrete filling area [6]. In environmental aspects replacement of OBB in concrete is reduce the conservation in the natural resources [7].Raw material utilization can be diminished which at last spare time and vitality. These will diminish the measure of ozone-harming substance era [8]. The blocks which are close to the fire in the oven subjected to high warmth more than 1000 degree centigrade it will shrink and changes in shape, the shading ends up noticeably ruddy and its appearance like rosy to blackish inclination stone[9][10]. This over consumed block fills in as waste in the development business and needs to amass some place during the time spent reusing.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

The primary objective of this research is to study the influence of partial and complete replacement of coarse aggregate with brick bats, and to compare it with the compressive and flexural strength of ordinary M20 concrete. Also trying to find the percentage of brick bats replaced in concrete that makes the strength of the concrete maximum. Brick bats are usually considered as waste material. So, by replacing coarse aggregate with brick bats, proposing a method that can be of great use in reducing pollution to a great extent.

2. Properties of Material

Ordinary Portland Cement (OPC) 53 grade cement conforming to IS 10262 – 2009 [11] was used. The physical properties of the used cement, sand, coarse aggregate and brick bat aretested provision given by Indian standard Table 1 shows the physical properties of raw materials.

3. Mix design

Mix proportion of the available raw material is derived as per IS456:2007 [12] as specified in Table2. Mix Ratio1:1.57:2.75.

Table 1. Physical properties

No	Material	Description	Value
1	Ordinary Portland Cement	Specific gravity	3.145
2	Ordinary Portland Cement	Standard consistency (%)	28%
3	Ordinary Portland Cement	Initial setting time	32 min
4	Ordinary Portland Cement	Compressive strength	54.25 MPa
5	River sand (FA)	Specific Gravity	2.60
6	Coarse Aggregate	Specific Gravity	2.71
7	Coarse Aggregate	Water absorption	0.50
8	Over burnt bricks	Specific Gravity	2.17
9	Over burnt bricks	Water absorption	4.4

Table 2. Mix proportion for M20 grade concrete

Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (l/m^3)	Water cement ratio
399.2	642.8	1097.2	191.6	0.48

4. Experimental investigation

4.1 Compressive strength

Totally 36 numbers of cubes and 3 number of beams were casted, out of which 9 cubes were conventional and other 27 cubes were replaced with 25%, 50%, 75% and 100% for coarse aggregate by OBB, this was formed five sets of concrete cube compressive strength tests. Figure 1 shows the concrete mould 150 x150 x150mm placed M20 grade different replaced concrete [14].

4.2 Flexural strength

OBB replaced 25 and 50% of coarse aggregate, conventional beam casted for comparison. The specimen size was maintained 100 x 150 x 100 as specified in Indian standard [13][14]. The beams are designed as the singly reinforced beam with 2 numbers of 10mm diameter bar in tension zone and two numbers of 10mm diameter bar at compression zone. For shear reinforcement, 8mm diameter bars were used at 100mm spacing. The beams are identified as (CB) conventional beam and for beams with brick bats as

(BBB) Brick bat beam. The specimens are tested using two point loading by 100T loading frame. Figure 2 shows the flexural beam mould placed by different percentage

4.3 Water absorption
As per guidelineof ASTM C642 [15] water absorption of partially mixed OBB concrete was tested. Table 5 shows the percentage of water absorption of OBB mixed concrete. Initially, the sample dry weight was measured in cool temperature, after 110 degree Celsius and 24hours kept in the oven specimen.Similarly, different masswas taken and compared natural temperature as per ASTM procedure.

4.4 Sorptivity
This strategy is planned to decide the helplessness of an unsaturated cement to the entrance of water. At 50'C for 3 days the 100mm diameter and 50mm height test specimen were placed hot oven, after oven curing, specimen placed normal temperature in for 15 days.The complete circumference of the specimen was sealed and top and bottom portion kept open.Mass of dried specimen was noted and the procedure as per ASTM C1585 [16].The absorption I (mm) = $\Delta m/ (a \times d)$ (a-exposed area, Δm- change in mass in g and d-density of water in g/cu.m).

An experimental test was performed in the compressive testing machine (CTM) which is having 3000 kN capacity. The flexural strength of beams istested by universal loading machine (UTM). The ultimate load carrying capacity of beam was found by subjecting the beam to two-point loading using 1000kN loading frame. The deflection and flexural strength of beam is measured by placing LVDT at the mid-span and quarter of span of the beam. In this two point loading method, the load is divided into two parts as, P = P/2+P/2, here 'P' is the total load given on the beam through the loading frame and is divided into two separate loads by placing two I-sectioned rollers below the beam and the load is transferred to beam. The load at first crack is noted when the cracking was developed in the concrete and the maximum load is indicated by LVDT. From this test it is found out there is no much difference in load carrying capacity between the conventional beam and beam with replaced brick bat.

Figure 1. Concrete specimens for compressive strength and durability test

Figure 2. Flexural member concrete placement for 25% OBB

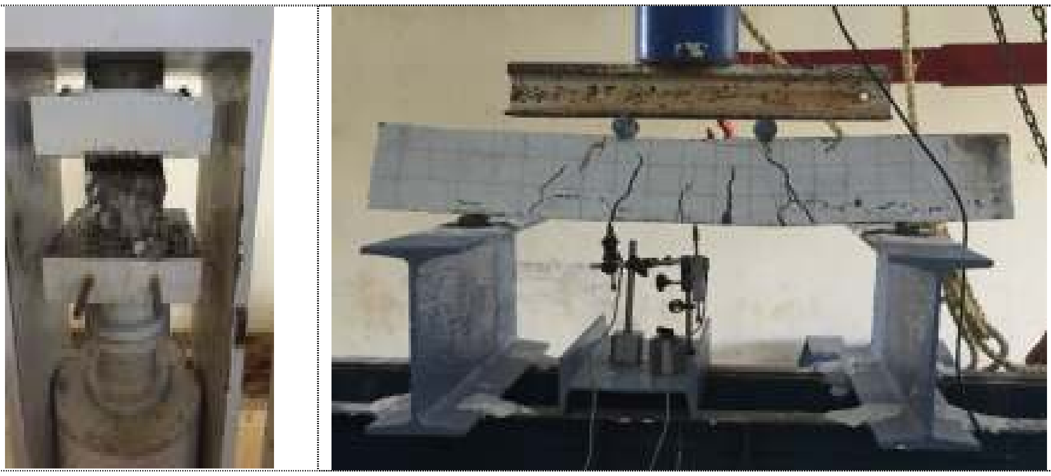

Figure 3. Experimental set-up (a) compressive strength (b) flexural strength

5. Results

Table 3. Compressive strength of cubes

Replacement / Curing	7 Days	14 Days	28 Days
Conventional	21.06 MPa	29.15 MPa	30.18 MPa
25% Replacement	14.57 MPa	17.3 MPa	24.6 MPa
50% Replacement	8.46 MPa	12.08 MPa	16.4 MPa
75% Replacement	6.31 MPa	11.40 MPa	12.06 MPa
100% Replacement	1.92 MPa	3.99 MPa	4.98 MPa

Table 4. Flexural Strength of beam

Description	Conventional	25% Replacement	50% Replacement
Peak Load(kN)	63.1	58	46.9
First Crack Load(kN)	30.1	24.2	21.5
Flexural Strength(MPa)	19.63	18.04	14.59
Maximum Deflection(mm)	9.86	9.45	9.28
Deflection under loading(mm)	7.25	6.24	6.56

Table 5. Sorptivity test values

Replacement	I = Δm/(a x d)											
	5min	10min	15min	30min	1hr	2hr	3hr	4hr	5hr	6hr	24hr	48hr
0%	0.25	0.51	0.71	1.02	1.02	1.53	1.78	2.03	2.29	2.55	2.55	2.55
25%	0.25	1.02	0.53	1.78	2.29	2.55	2.55	2.29	2.55	2.80	2.80	2.80
50%	0.25	0.71	0.27	1.78	2.80	4.07	4.83	5.09	5.34	5.53	7.09	7.09
75%	0.51	0.51	1.02	1.53	2.29	3.31	4.07	4.33	4.84	5.34	9.31	9.31
100%	0.25	0.51	0.51	1.27	12.22	12.73	3.31	3.56	4.33	5.09	11.14	11.14

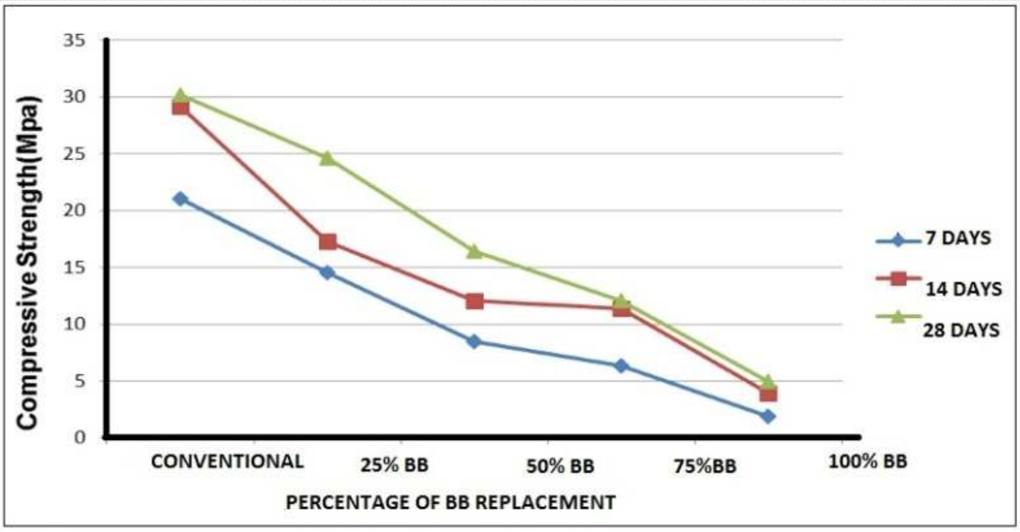

Figure 4. Graphical representation of compressive strength of cubes

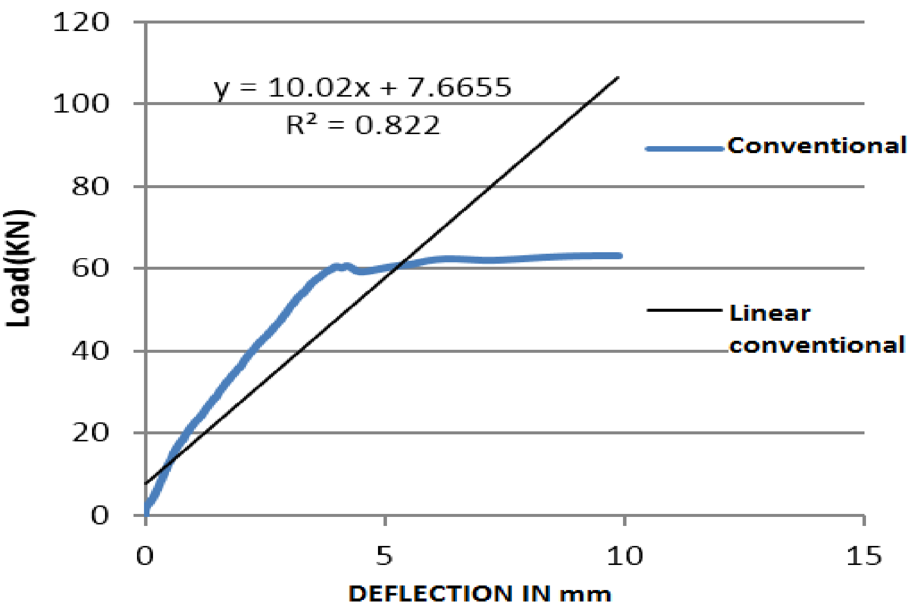

Figure 5. Graphical representation of flexural strength of conventional beam

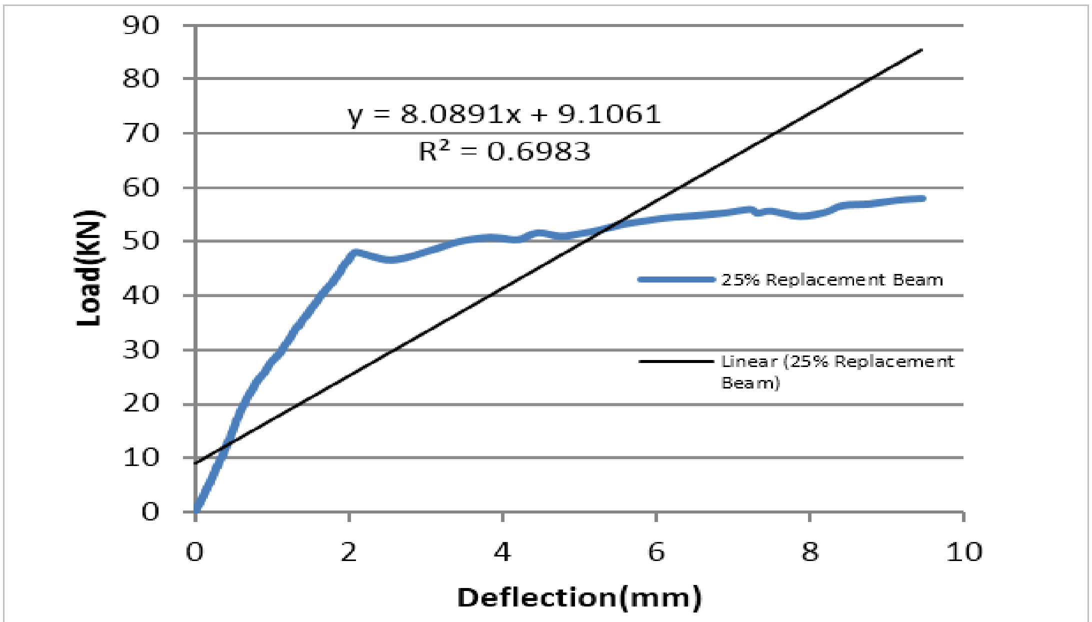

Figure 6. Graphical representation of flexural strength of 25% replaced beam

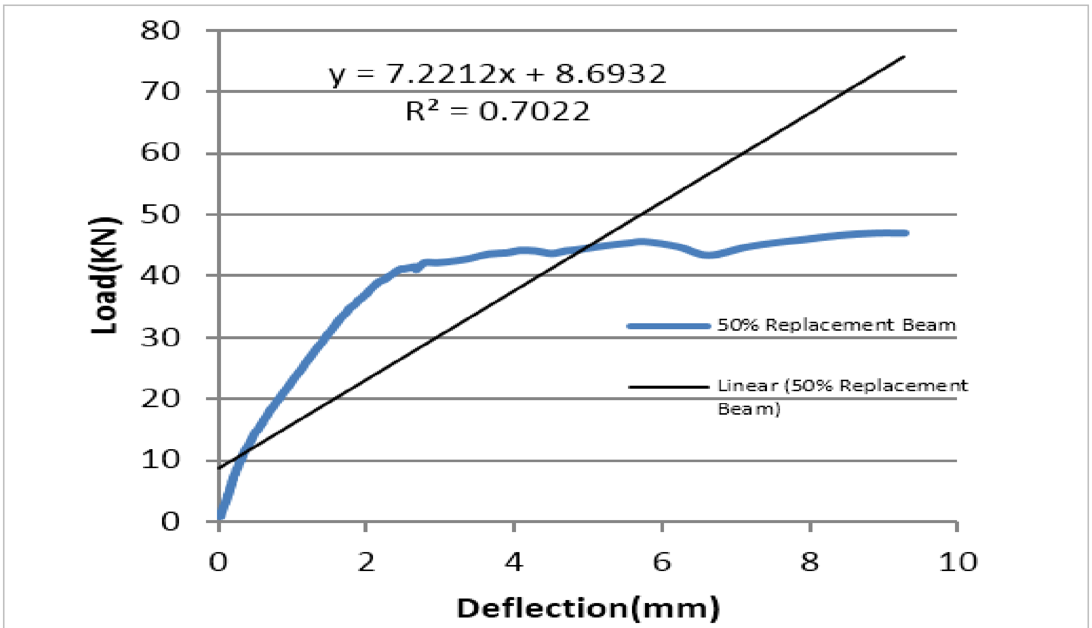

Figure 7. Graphical representation of flexural strength of 50% replaced beam

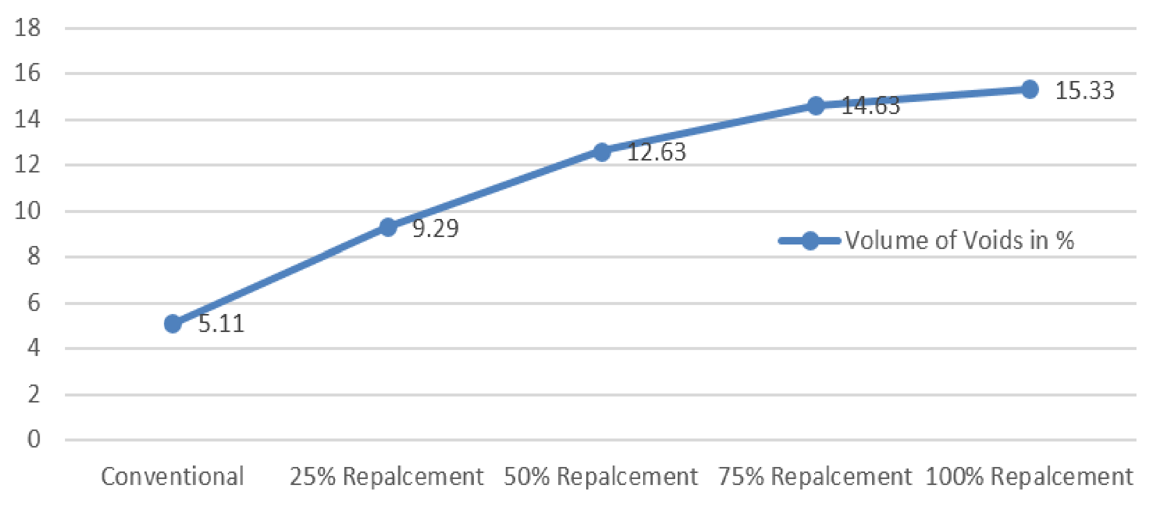

Figure 8. durability - volume of voids in %

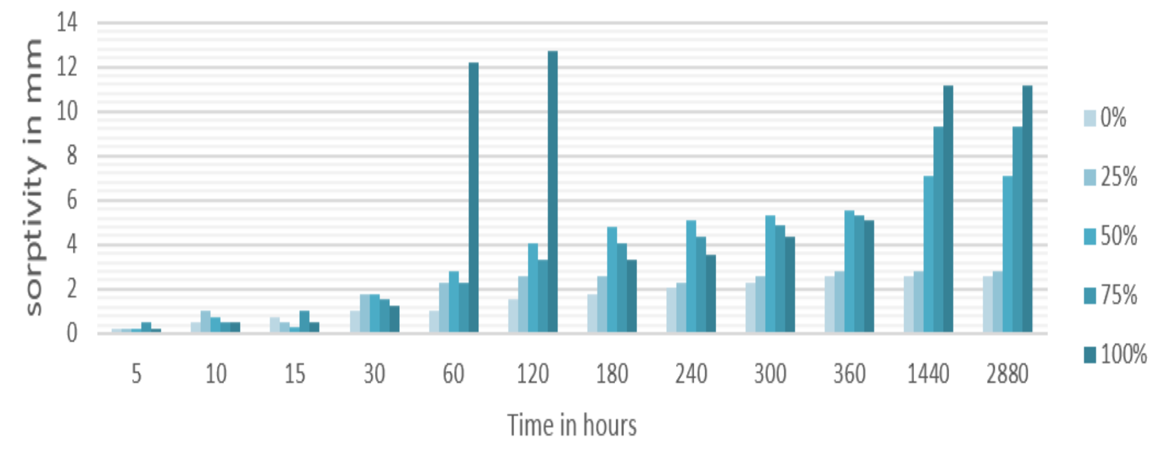

Figure 9. durability - Sorptivity I value

Table 6. Water absorption test values [17]

Description	**Formula**	**Replacement %**				
		0%	**25%**	**50%**	**75%**	**100%**
Mass of oven dry sample in air (g)	A	926	882	810	826	810
Mass of Surface-dry sample in air after immersion (g)	B	962	942	876	900	882
Mass of surface-dry sample in air after immersion and boiling(g)	C	956	930	866	882	868
Apparent mass of sample in water after immersion and boiling(g)	D	400	400	500	500	400
Absorption after immersion (%)	$[(B-A)/A]\times100$	3.89	6.80	8.15	8.98	8.89
Absorption after immersion and boiling (%)	$[(C-A)/A]\times100$	3.24	5.44	6.91	6.78	7.16
Bulk density, dry (g/cc)	$[A/(C-D)]\times\rho = g_1$	1.67	1.66	2.21	2.16	1.73
Bulk density after immersion (g/cc)	$[B/(C-D)]\times\rho$	1.05	1.58	2.39	2.36	1.89
Bulk Density after immersion and boiling (g/cc)	$[C/(C-D)]\times\rho$	1.72	1.05	2.37	2.31	1.86
Apparent density (g/cc)	$[A/(A-D)]\times\rho = g_2$	1.76	1.83	2.61	2.53	1.98
Volume of voids (%)	$[(g_2-g_1)/g_2]\times100$	5.11	9.29	12.63	14.63	15.33

6. Discussion and Conclusion

Table 3 shows the decrement in the compressive due to replacing OBB but at the same time the replacement for 25% satisfies the strength for M20 grade, also the OBB replacement reduces the concrete weight slightly. Figure 4 shows the continuous decrement in compressive strength. In Table 4 shown the flexural performance, the flexural strength of 25% and 50% OBB replaced concrete attains nearly conventional flexural resistance -8% to -30% reduced flexural strength noticed, Figure 5,6 and 7 shows curves for load Vs deflection. Table 6 and figure 8 shows the durability – water absorption test results in the percentage of a volume of voids, 25% of OBB replacement in the concrete gives the nearest value of voids content. Table 5 and Figure 9 shows the results for durability in sorptivity aspect, results gives ‘I’ (in mm) almost near to the 25% OBB replacement in concrete.

- From the present study, it is found that brick batcan be used as a replacement of coarse aggregate by various percentages.
- The strength of the replaced concrete is less than conventional concrete and the workability is little poor than conventional concrete. This can be easily overcome by adding water reducing admixtures.
- From the compressive strength of cubes, it is found that the optimum replacement level of brick bats is 25% volume of coarse aggregate.
- Flexural strength of concrete was studied for 3 beams (Conventional, 25% Replacement and 50% Replacement). Some durability parameters such as sorptivity and water absorption were studied for all various percentages. From the results 25% and 50% replacement of brick bats are found to be suitable for concrete.
- Durability aspects water absorption and sorptivity results hold good for 25% OBB replacement.

Acknowledgement
Authors express heartfelt gratitude to Vice-Chancellor, SASTRA University for given me the permission to carry out works at SASTRA.

References
[1] Adamso M, Razmjoo A and Poursaee A 2015 Durability of concrete incorporating crushed brick as coarse aggregate. *Constr. Build. Mater.* **94** 426-32.
[2] Apebo N S, Iorwua M B and Agunwamba J C 2013 Comparative analysis of the compressive Strength of concrete with gravel and crushed over burnt bricks as coarse aggregate. *Nigerian J. Technol.* **32**(1) 7 - 12.
[3] Attaullah Shah, Irfan U Jan, Raza U Khan and Ehsan U Qazi 2013 Experimental investigation on the use of recycled aggregate in producing concrete. *Struct. Eng. Mech. An Int. J.* **47**.
[4] Ezeokonkwo J C, Apebo N S and Agunwamba J C 2014 The Suitability of crushed over burnt bricks as coarse aggregates for concrete. *Int. J. Eng. Sci. Innov. Technol.* **3**(1) 315-21.
[5] Saravanakumar P and Dhinakaran G 2013 Durability characteristics of recycled aggregate concrete. *Struct. Eng. Mech.* **47**(5).
[6] Paulo B Cachim 2009 Mechanical properties of brick aggregate concrete. *Constr. Build. Mater.* **23** 1392-7.
[7] Subhash C, Yaragal, Dumpati C Teja and Mohammed Shaffi 2016 Performance studies on Concrete with recycled coarse aggregate. *Adv. Concr. Constru.* **4**(4).
[8] Subramani T and Kumaran S 2015 Experimental investigation of using concrete waste and brickwaste as a coarse aggregate. *Int. J. Appl. Innov. Eng. Manage.* **4**(5) 294-303.
[9] Tanvir Hossain, Md. Abdus Salam and Mohiuddin Abdul Kader 2012 Pervious concrete using brick chips as coarse aggregate: An experimental study. *J. Civ. Eng. (IEB)* **40**(2) 125-37.
[10] Zhi Ge, Hongya Yue and Renjuan Sun 2015 Properties of mortar produced with recycled claybrick aggregate and PET. *Constr. Build. Mater.* **93** 851-6.
[11] IS 10262: 2009, Indian Standard Recommended Guidelines for Concrete Mix Design. *Bureau of Indian Standards.*
[12] IS 456: 2000, Indian Standard Code of Practice for Plain and Reinforced Concrete. *Bureau of Indian Standards.*
[13] SP16: 1980, Design Aids for Reinforced Concrete.
[14] IS 516: 1959, Method of Tests for Strength of concrete. *Bureau of Indian Standards.*
[15] ASTM C642 -2006, Standard Test Method for Density, Absorption and Voids in Hardened Concrete.
[16] ASTM C1585- 2004, Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic Cement Concrete.
[17] Sharmila P and Dhinakaran G 2016 Compressive strength, porosity and sorptivity of ultra-fine slag based high strength concrete. *Constr. Build. Mater.* **120** 48-53.