Experimental Investigations on Strength Performance of the Brick Produced by Blending Demolished Waste with Pozzolanic Materials

Manish S. Dharek, Prashant Sunagar, K. S. Sreekeshava, B. Nagashree, Poornachandra Thejaswi, Pramod Kilabanur, K. Nruthya, and C. Satish Chandra

1 Introduction

Bricks are one of the most important components in construction industry [1]. Rapid urbanization has led to tremendous problems in construction and demolished waste disposal. Generally, when compared to the construction waste, brick waste is not to the larger extent, but it greatly contributes in the activities as demolished waste. These waste materials, if the materials are directly landfilled, cause serious environmental issues [2, 3]. Incorporating the sustainable materials in the brick manufacturing can limitedly tackle this issue [4]. Henceforth, utilization of waste materials could become the major solution to overcome this issue due to their occurrence and object of recycling. In order to decrease the effect of demolished brick waste on the ecosystem, effective reuse of the waste materials is adopted in the construction industry. Utilization of the waste materials for greener construction is a dominating way to improve the productivity with cost effectiveness [2, 3]. Pozzolonas [5], which

P. Sunagar · B. Nagashree · K. Nruthya
Department of Civil Engineering, Ramaiah Institute of Technology, Bengaluru, India

K. S. Sreekeshava
Department of Civil Engineering, Jyothy Institute of Technology, Bengaluru, India

P. Thejaswi
Department of Civil Engineering, Bangalore Institute of Technology, Bengaluru, India

P. Kilabanur
Department of Civil Engineering, JSPM's RSCOE, Pune, India

C. Satish Chandra
Consulting Civil Engineer, Bengaluru, India

M. S. Dharek (✉)
Department of Civil Engineering, BMS College of Engineering, Bengaluru, India
e-mail: manish.shashikant@gmail.com

S. Biswas et al. (eds.), *Advances in Sustainable Construction Materials*, Lecture Notes in Civil Engineering 124, https://doi.org/10.1007/978-981-33-4590-4_54

are the generally the waste by products, possess the functions to improve the properties of the raw materials in a positive sense. In the present study, brick waste obtained from the demolition waste is reused by mixing it with pozzolanic material and casted to normal standard brick size. Tests such as compressive strength, flexural strength, and brick density have been conducted in order to determine the performance in comparison with normal burnt clay brick. Due to rapid urbanization, many old buildings are demolished and the waste generated out of these is dumped at landfills. However, it can be seen that demolition waste can be recycled which can lead to improved sustainability and conservation of natural resources, etc. In the present study, brick waste obtained from the demolition waste is reused by mixing it with pozzolonic material and casted to normal standard brick size. Tests such as compressive strength, flexural strength, and brick density have been conducted in order to know whether it meets the standards of normal burnt clay brick

2 Review of Literature

Yacoob et al. [6] carried out studies on bricks produced by blending them with recycled fine aggregate by varying them in different percentages (25, 50, 75, 100%) by weight of natural sand. Mechanical properties such as water absorptions characteristics, compressive strength and flexural strength, drying shrinkage, and density were studied which showed good characteristics similar to conventional bricks when the replacement percentage was in the range of 50–75% of natural fine aggregate. Ismail et al. [7] carried out studies on utilization of paper sludge and palm oil fuel ash as an active ingredient along with cement toward production of bricks by blending these ingredients in varied proportions. Studies conclude that paper sludge–palm oil fuel ash (POFA) bricks made with 60% cement, 20% paper sludge, and 20% POFA satisfied the various engineering properties for bricks as per BS 6073 part 2:2008. Sumalatha et al. [8] studied the properties of concrete blocks prepared by blending crummed rubber, cement, fly ash, and lime as its active ingredients. The results showed a reduction of about 25% in its unit weight when compared with conventional concrete blocks due to inclusion of crummed rubber in it. The strength properties were slightly lower when compared with minimum strength of conventional concrete blocks.

3 Material Properties

In order to evaluate the performance of the produced brick from the demolished waste, it has to be compared with that of the normal bricks. Various mix proportions are carried out for manufacturing the bricks by using the raw materials, viz. cement, fine aggregates, fly ash, lime, and blast furnace slag. The properties of the various materials are shown in Table 2.

Table 1 Particle size distribution of fine aggregates

Particle size	Cumulative % finer
4.75 mm	99.42
2.36 mm	96.6
1.18 mm	79.7
600 μm	45.2
300 μm	12.3
150 μm	6.33

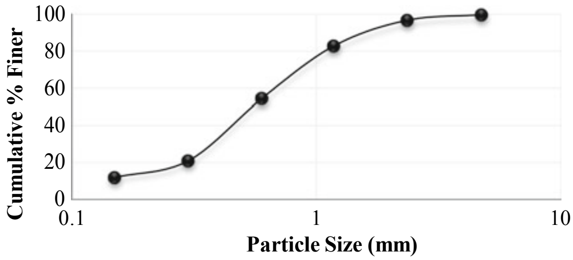

Fig. 1 Cumulative percentage versus particle size of the sand

3.1 Cement

Ordinary portland cement of 43 grade confirming to IS:8112-1989 [9] is used in the present study. The properties of the OPC are shown in Table 2.

3.2 Fine Aggregates (FA)

Fine aggregates confirming to zone 2 of IS:383-1970, with specific gravity of 2.8, is used for the present work. Particle size distribution of FA is shown in Table 1.

With reference to Fig. 1, i.e., particle size distribution of FA, it can be seen that the percentage of the finer content is more, which may be resulting in better mechanical properties.

3.3 Lime

The raw lime used for the present study was hydrated into pulverized form and was brought down to room temperature by cooling. This was later transferred into a airtight bag to ensure that the lime does not react with moisture in air in order to prevent the carbonation. Since lime has comparably a higher specific surface area, it

Table 2 Properties of the raw materials used in manufacturing of bricks [10]

Raw material	Specific surface area (m^2/kg)	Specific gravity	Density (gm/cc)
C	343	3.13	2.9
L	591	2.1	1.98
FA	452	2.2	2.13
BS	352	2.5	2.6

has a capability to bind the other particles with it and reduce the water content when blended with clay brick powder.

3.4 Fly Ash

Fly ash was procured from Raichur thermal power station, Karnataka, and has been used in the present work. As per IS: 1727-1967 [10], the reactivity of fly ash with lime was carried out and the result obtained was 4.0 N/mm^2 which was confirmed to IS 3812-1981.

3.5 Ground-Granulated Blast Furnace Slag (GGBS)

GGBS was procured from a local vendor in Bellary, Karnataka, and was used in experiments and also used for casting of bricks (Table 2).

4 Experimental Program

Bricks required for the experimental program were obtained from a dumping site from Northern region of Bengaluru where demolished building waste was dumped on regular basis. The mortar layer from the waste bricks was removed by using hammer blows and these bricks were further soaked in water for 24 h. After removing the mortar from bricks, the bricks were powdered by using heavy roller such that it is crushed for finer powder. The crushed bricks were sieved using 1 mm sieve and the powdered bricks passing 1 mm sieve were stored in air tight bag. A total of about 400 kg of brick powder was prepared for this experimental process. To enhance the property of brick, the lime and other pozzolanic materials were used. The following mix proportions were adopted for mixing with brick powder (Table 3).

For the above mix proportion, a total of 20 bricks was casted for each mix. A brick of size adopted was 230 mm × 110 mm × 75 mm. For each mix compression and flexural strength was to be found out. The bricks were casted by using trowel;

Table 3 Mix proportion adopted for casting of bricks

S. No.	Mix proportion	Material used						
		Lime	Brick waste powder		Sand	Fly ash	Cement	GGBS
1	M-1	1	4		2	–	–	–
2	M-2	1	6		2	1	–	–
3	M-3	1	6		2	–	1	–
4	M-4	1	6		2	–	–	2

first the brick waste powder was spread then lime and sand were mixed with the powder with keeping water percentage of about 9% of total mix. The mix was laid on brick mold and compacted in three layers and finished top layer with trowel and left for 24 h drying. After 24 h, the bricks were de-molded from mold and kept for air drying. Likewise for others, proportions were casted using cement, fly ash, and GGBS, and a total of 20 bricks was casted for each mix and kept for normal curing for 28 days by sprinkling water on them (Figs. 2, 3, 4 and 5).

After 28 days of curing, the brick was burnt with light gas flame so as to fuse the pozzolonic material with clay such that it gains strength by fusion of material. The compressive and flexural strength test was conducted as per codal provisions of Indian standards [11, 12].

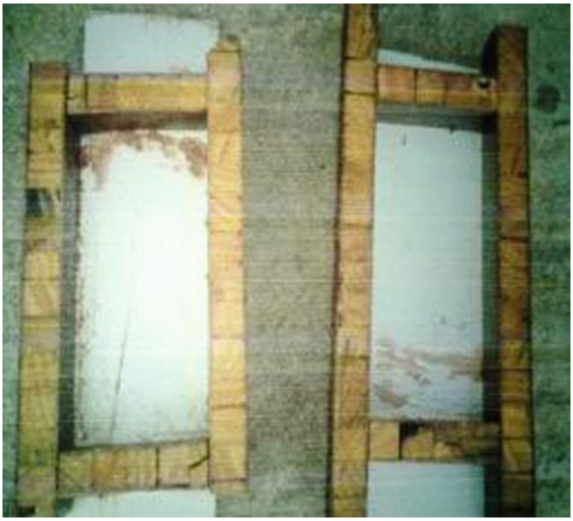

Fig. 2 Mold preparation for brick casting

Fig. 3 Compressive strength testing of bricks

Fig. 4 Sample brick casted in laboratory conditions

Fig. 5 Water absorption test on brick

5 Results and Discussions

The bricks of different mix proportion casted were tested for water absorption, compressive strength, and flexural strength, and the results are tabulated in Table 4, 5, 6, 7 and 8 and (Fig. 6).

Mix *M*-1 has got the least compressive strength whereas mix M-4 has got maximum strength and mixes M-2 and M-3 more or less same. Compressive strength in mix M-1 is less due to insufficient pozzolonic reaction. The pozzolonic materials present in the mix are only in form of brick powder. The brick powder used in the present study is 1 mm down size which is far greater in particle size for complete

Table 4 Water absorption for recasted demolished bricks

Mix No.	Proportion	Water absorption %
M-1	1:4:2 (lime: brick powder: sand)	10.00
M-2	1:6:2:1 (lime: brick powder: sand: fly ash)	18.50
M-3	1:6:2:1 (lime: brick powder: sand: cement)	19.00
M-4	1:6:2:2 (lime: brick powder: sand: GGBS)	13.20

Table 5 Compressive strength for recasted demolished bricks

Mix No.	Proportion	Compressive strength (MPa)
M-1	1:4:2 (lime: brick powder: sand)	3.76
M-2	1:6:2:1 (lime: brick powder: sand: fly ash)	5.56
M-3	1:6:2:1 (lime: brick powder: sand: cement)	5.87
M-4	1:6:2:2 (lime: brick powder: sand: GGBS)	8.68

Table 6 Flexural strength for recasted demolished bricks

Mix No.	Proportion	Flexural strength (MPa)
M-1	1:4:2 (lime: brick powder: sand)	4.91
M-2	1:6:2:1 (lime: brick powder: sand: fly ash)	2.10
M-3	1:6:2:1 (lime: brick powder: sand: cement)	3.96
M-4	1:6:2:2 (lime: brick powder: sand: GGBS)	5.93

Table 7 Brick density for recasted demolished bricks

Mix No.	Proportion	Brick density (kg/m^3)
M-1	1:4:2 (lime: brick powder: sand)	1599.50
M-2	1:6:2:1 (lime: brick powder: sand: fly ash)	1562.10
M-3	1:6:2:1 (lime: brick powder: sand: cement)	1623.20
M-4	1:6:2:2 (lime: brick powder: sand: GGBS)	1777.10

pozzolanic reaction, whereas for the mix M-4 compressive is maximum among all the four mixes. This could be attributed to the fact that more pozzolanic material is present in the mix in the form of ground-granulated blast furnace slag (GGBS). Thereby more C-S-H compounds are formed from the pozzolonic reaction between lime and GGBS apart from the C-S-H from the reaction between lime and brick powder. Even though the mix proportions of mix M-2 and M-3 are identical except for the one part of fly ash in mix M-2 and one part of cement in mix M-3. The compressive strength of mix M-2 is less than that of mix M-3. This difference in the compressive strength between these two mixes is very marginal. A trend can be observed, mix without any pozzolonic material compressive strength is less whereas mix with more pozzolonic material compressive strength is more. However, with cement in the mix strength is comparable with that of mix with fly ash by same quantity. Result present in Table 5 is of 28 days strength of bricks. However, the long-term strength may improve beyond 28 days. The compressive strength vs water absorption variation is shown in Fig. 7. However, water absorption value for the mixes M-4, M-3, and M-2 is on the higher side, whereas water absorption for mix M-1 is least. It is known fact that with lesser void in the brick structure water absorption would be less. The other fact could be filled up of the pores with finer particles. For instance, in mix M-2, one part is fly ash. Fly ash being very finer particle it may fill the pores there by reducing the pores present in the brick structure. The brick density of M-4 was on the higher side whereas brick density for M-2 was least. The reason attributed to the presence of GGBS whose fineness is higher compared to fly ash which also has led to higher flexural strength of brick samples blended with GGBS which is shown in Fig. 8. The variation of brick density is shown in Fig. 9.

6 Conclusion

From the above results, it is concluded that the water absorption and strength obtained for mix M-1, M-2, M-3, and M- 4 are within limits, but the compressive strength obtained for each mix it seen that there is variation from the brick casted with lime, sand, and brick powder showing less strength to that of lime, sand, and brick powder

Table 8 Comparison between normal brick and recycled bricks

S. No.	Characteristics	Normal brick	Recycled brick			
			M-1	M-2	M-3	M-4
1	Compressive strength	3.5–6 MPa	3.76	5.56	5.87	8.66
2	Water absorption	10–14	10.00	18.50	19.00	13.20
3	Flexural strength	<6 MPa	4.91	2.10	3.96	5.93
4	Brick density	>1600 kg/m^3	1599.50	1562.10	1623.20	1777.10
5	Efflorescence	Nil	Nil	Nil	Nil	Nil
6	Soundness	Ringing sound	Ringing sound	Ringing sound	Ringing sound	Ringing sound
7	Hardness	No impression	No impression	No impression	No impression	No impression
8	Structure	Homogenous	Slightly non-homogenous	Slightly non-homogenous	Slightly non-homogenous	Slightly non-homogenous
9	Shape	Rectangular sharp edges	Rectangular but no sharp edges	Rectangular but no sharp edges	Rectangular but no sharp edges	Rectangular but no sharp edges

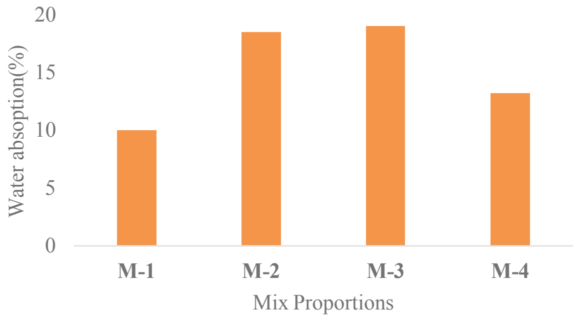

Fig. 6 Water absorption vs mix proportions

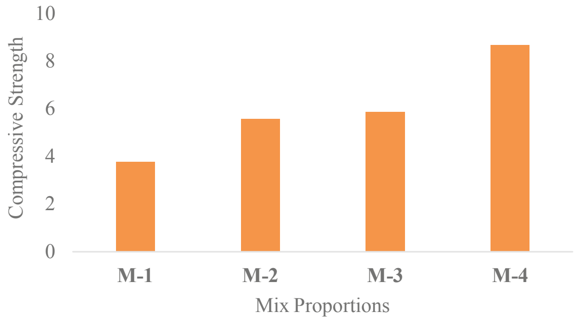

Fig. 7 Compressive strength vs mix proportions

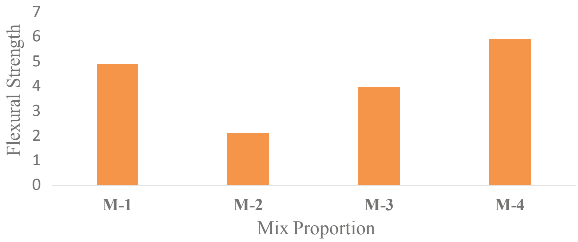

Fig. 8 Flexural strength vs mix proportions

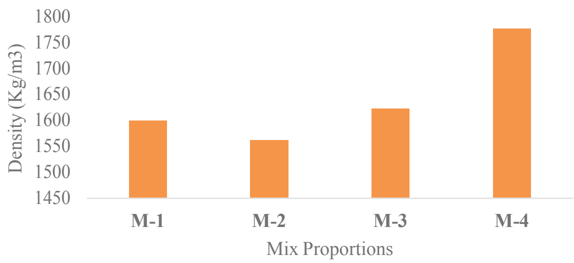

Fig. 9 Flexural strength vs mix proportion

with other pozzolonic material which is showing higher strength. However, the flexural strength obtained for all four mixes is comparable with standard values. But still depending on the compressive strength the bricks can be reused for lighter structures.

References

1. Punmia BC, Jain AK (2005) Building materials. Laxmi Publications 2005 Edition
2. Dharek MS, Sunagar P, Bhanu Tej KV, Naveen SU (2019) Fresh and hardened properties of self-consolidating concrete incorporating alumina silicates. In: Das B, Neithalath N (eds) Sustainable construction and building materials. Lecture Notes in Civil Engineering, vol 25. Springer, Singapore. https://doi.org/10.1007/978-981-13-3317-0_62
3. Dharek MS, Sunagar P, Harish K, Sreekeshava KS, Naveen SU, Bhanutej (2020) Performance of self-flowing concrete incorporated with alumina silicates subjected to elevated temperature. In: Subramaniam K, Khan M (eds) Advances in structural engineering. Lecture Notes in Civil Engineering, vol 74. Springer, Singapore. https://doi.org/10.1007/978-981-15-4079-0_10
4. Jagadish KS, Venkataramareddy V, Nanjunda Rao KS (2012) Alternative building materials and technologies. New Age International Publications, Edition
5. Neville AM (2012) Properties of concrete. Pearson Education, Fifth Edition
6. Ismail S, Yaacob Z (2010) Properties of bricks produced with recycled fine aggregate. World Acad Sci Eng Tech 43: 670–674 2010-07-22
7. Mohammad Ismail MA, Ismail SK, Lau BM, Zaiton M (2010) Fabrication of bricks from paper sludge and palm oil fuel ash. Concr Res Lett 1(2):60–66
8. Sumalatha J, Dharek Manish S, Niranjan GH, Prashant S, Chaurasiya AK (2020) Development of sustainable building blocks with tyre waste, flyash and lime. Int J Civil Eng Tech (IJCIET). 11(5):93–104
9. IS: 8112-1989 43 Ordinary portland cement specification. Bureau of Indian Standards, New Delhi
10. IS: 1727-1967 Methods of test for pozzolonic materials. Bureau of Indian Standards, New Delhi
11. IS: 3495 (Part 1 to 4)—1992. Methods of test of burnt clay building bricks. Bureau of Indian Standards, New Delhi
12. IS: 12894-2002 Pulverized fuel ash-lime Bricks—specification, Bureau of Indian Standards, New Delhi