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SUSTAINABLE UTILIZATION OF DISCARDED FOUNDRY SAND AND CRUSHED BRICK MASONRY AGGREGATE IN THE PRODUCTION OF LIGHTWEIGHT CONCRETE

Gireesh MAILAR[a], Sujay Raghavendra N.[b], Parameshwar HIREMATH[c],
Sreedhara B. M.[d], Manu D. S.[e]

[a]*Department of Civil Engineering, Karavali Institute of Technology, Neermarga,*
Mangalore 575029, India
[b, d]*Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka,*
Surathkal, Mangalore 575025, India
[c, e]*Department of Civil Engineering, National Institute of Technology Karnataka,*
Surathkal, Mangalore 575025, India

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Abstract. Nowadays, there is a considerable shortage in the availability of river sand and natural stone aggregate for the construction activities all around the globe and the way out is being worked out by the use of discarded foundry sand and crushed brick masonry aggregate for construction purposes. In the present study, river sand was partly replaced by the discarded foundry sand procured from steel moulding industries and the crushed brick masonry aggregate was used as coarse aggregate for the production of lightweight concrete. The experimental program involved casting of six distinct mixes with 0%, 20%, 40%, 60%, 80% & 100% replacement of fine aggregate by discarded foundry sand. The mechanical and durability properties of the lightweight concrete were assessed for each of the six diverse blends. Even though the 80% and 100% replacement mixes were found to be less dense than the rest of the mix, the blend of 40% replacement acquired desirable mechanical and durability properties when compared to that of all other mixes. The optimum replacement level of the discarded foundry sand by mass to the river sand was 40%. The lightweight concrete produced by utilizing crushed brick masonry aggregate and discarded foundry sand (40% substitution level) can be employed in all major structural lightweight construction aspects and is ideally suited for sloped roof slabs and making architectural or decorative concrete blocks.

Keywords: lightweight concrete, discarded foundry sand, crushed brick masonry aggregate, sorptivity, architectural concrete.

Introduction

In the recent decade, the automobile industry is booming in India. The essential parts of the automobiles are moulded in steel moulding industries and the sand used in the process of manufacturing them are disposed of as salvage in bulk quantities. Presently there is a huge shortage in availability of river sand for the construction activities and the way out of this crisis can be worked out by the utilization of recycled fine aggregate. Concrete plays a significant role in fashioning a reliable built environment. The use of naturally available resources as part of the concrete will not be cost effective and already there is a shortage in the supply of river sand for constructional activities in many metro cities of the country. The excess demand for river sand has resulted in the discovery of alterna-

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Corresponding author:
G. Mailar E-mail: *gireeshmailar@zoho.com*

tive materials to meet the present-day requirements. The discarded sand from steel moulding industries is said to cause several environmental problems and hence the usage of this discarded sand in producing concrete can be an eco-friendly measure of waste disposal (Yuan, Liyin 2011; Rao *et al.* 2007). Globally the major construction firms have taken a responsible step to ensure that natural resources are not over-exploited.

The advantages of using recycled aggregates of construction and demolition (C&D) debris include reduction in the amount of C&D debris entering the landfill sites, contributes to environmental protection by serving as an additional source of construction material and finally, if the C&D debris is used in-situ, the haulage costs can also be avoided (Tabsh, Akmal 2009). The recycled aggregates can be used for diverse applications in the construction industry, such as in concrete production, foundation filling, pavement construction and general earthwork filling. They can also be used for ground improvement purposes such as vibrated columns and slope stabilization. Production of Recycled aggregate from the existing hardened concrete or masonry is a relatively simple process. It involves breaking, removing, and crushing of existing concrete or brick masonry into a material of required size, shape and quality. The quality of recycled aggregate is very much dependent on the quality of recycled material used (Malešev *et al.* 2010).

The concrete is said to be a Lightweight Concrete (LWC) generally if it has a density of less than 1840 kg/m^3 and compressive strength of more than 17 N/mm^2 (ASTM C330 / C330M-14: 2014). The challenge of producing LWC is in decreasing the density while maintaining the strength along with the economy. LWC can either be foamed concrete, lightweight aggregate concrete or autoclaved aerated concrete. Incorporating different varieties of lightweight aggregates into the concrete matrix is one of the methods to lower the concrete's density. The crushed stone and sand are the elements that are usually replaced with lightweight aggregates (LWA) to produce LWC. Due to its lower density and superior thermal insulation properties, LWC has gained popularity nowadays (Gunasekaran *et al.* 2011; Haque *et al.* 2004). It also offers design flexibility and substantial cost savings by providing less dead load, improved seismic structural response and lower foundation costs etc. The applications range from lightweight partition walls to secondary structural components. The volcanic rocks such as pumice and scoria having a density ranging from 500 to 900 kg/m^3 are the naturally occurring LWA and some of the artificially manufactured LWA also exist, such as expanded clay, expanded shale, foamed slag, blast furnace slag, pulverized fuel ash and perlite (Hossain 2004). The main characteristic of LWA is its high porosity, which results in a low specific gravity. Even though there is sufficient availability of natural and commercially produced LWA, if waste materials are used as an aggregate in the production of LWC, more environmental and economic benefits may be derived.

India is the second largest metal casting producer on the globe after USA as per the latest World Census of Casting and the India based metal casting foundries dispose about 6 million tons of spent sand into landfills every year. The spent foundry sand can put forth significant environmental implications if not properly managed (Mitterpach *et al.* 2016). There is a growing interest in recent times to use discarded foundry sand as fine aggregate in producing concrete, which is a viable alternative for natural resource conservation. In the present study, natural sand is partially replaced by the discarded foundry sand from steel moulding industries and the crushed brick masonry aggregate is used as coarse aggregate for the production of lightweight concrete. The experimental program involved casting of six distinct mixes with 0%, 20%, 40%, 60%, 80% & 100% replacement of fine aggregates by discarded foundry sand. The mechanical and durability properties of the lightweight concrete are assessed for each of the six diverse blends.

1. Materials and methodology

1.1. Cement

Ordinary Portland Cement (OPC) of 53 grade was used in the experimental investigation. The physical properties of the cement confirm to the specifications of IS: 12269 – 1987 (1999). The properties such as fineness, soundness, compressive strength, chemical composition, initial and final setting times of cement are provided in Table 1.

1.2. Aggregates

Locally available river sand (RS) and discarded foundry sand (DFS) were used as fine aggregate in varying proportions in each of the six distinct mixes. The river sand and discarded foundry sand used in this study were conforming to grading zone II and zone IV of IS: 383-1970 (1997) respectively. The results of fineness modulus, specific gravity (Pycnometer determined), saturated surface dry (SSD) density and water absorption of river sand and discarded foundry sand are presented in Table 2 along with its chemical composition. Minute quantities of carbon silicate, residue metals (Fe, Zn) were also found to be present in the discarded foundry sand. Crushed Brick Masonry (CBM) aggregate of maximum size 20 mm (fractions passing through a 20 mm sieve, but retained on 16 mm IS sieve) produced by crushing large blocks of demolished brick masonry were used as coarse aggregate. Some impurities like small mortar chunks adhered to the brick pieces coexisted with CBM aggregate. Moderately rough surface and blunter intersecting angles were witnessed in the laboratory crushed brick masonry aggregate. The present study involves only one size of coarse aggregate (i.e., fractions passing through a 20 mm sieve, and retained on 16 mm IS sieve) which allows for all the fine aggregate particles to pass through the voids between the compacted coarse aggregate. Such a manner of grading of coarse aggregate is typically employed in architectural concrete production to obtain uniform textures in exposed-aggregate finishes (Litvin, Donald 1965). Furthermore, the aggregate packing density gets affected paving way for less dense concrete. If smaller size aggregates are incorporated, habitually, more cement and water will be required due to increase in the total aggregate surface area. The results of specific gravity (Pycnometer determined), saturated surface dry (SSD) density and water absorption of CBM aggregate are presented in Table 2 along with its chemical composition.

Table 1. Properties of cement

Composition of Cement	
Lime Saturation Factor	0.90
Alumina Iron Ratio	1.05
Magnesium oxide (MgO)	1.4%
Sulphuric Anhydride	2.0%
Chlorides	0.01%
Alkali	0.52%
Insoluble residue	1.0%
Loss of ignition	1.3%
Fineness	
Specific Surface	290–315 (m^2/kg)
Soundness	
Lechatelier Method	1.0 mm
Auto clave	0.03%
Setting Time	
Initial	30 minutes
Final	600 minutes
Compressive Strength	
3 days	34 MPa
7 days	45 MPa
28 days	59 MPa

Table 2. Physical properties and chemical composition of aggregates

Physical Properties				
Aggregate	Fineness Modulus	Specific Gravity	SSD Density (kg/m^3)	Water Absorption (%)
River Sand	2.4	2.65	2720	0.60
Discarded Foundry Sand	1.5	2.40	2490	0.70
Crushed Brick Masonry Aggregate	–	2.0	2050	5.0

Chemical Composition					
River Sand		Discarded Foundry Sand		Crushed Brick Masonry Aggregate	
Component	Percentage	Component	Percentage	Component	Percentage
Silica (SiO_2)	97.05	Silica	88.23	Silica	52.56
Alumina (Al_2O_3)	1.28	Alumina	3.25	Alumina	23.67
Fe_2O_3	0.33	Fe_2O_3	2.45	Magnesia (MgO)	4.67
Organics	0.50	MgO	1.83	Calcium oxide	10.35
LOI	0.84	P_2O_5	1.45	Fe_2O_3	4.55
		Mn_2O_3	1.13	CuO	3.32
		SO_3	0.89	Alkali and organic matter	0.75
		LOI	0.77	LOI	0.13

1.3. Concrete proportioning

Proportions for lightweight concrete were organized following the Weight method, in accordance with ACI 211.2 (1998). The equations developed by Abdullahi *et al.* (2009) were adopted for the mix design and proportioning of batch compositions of lightweight concrete. An 80 mm slump of concrete was considered in the mix design to achieve workable concrete. The 28-day compressive strength of over 35 MPa was targeted while the cement content was based upon the water/cement (w/c) ratio of 0.40. A concrete mix composition is usually expressed as the weight ratio of cement, fine aggregate and coarse aggregate with the indication of water-to-cement ratio; the quantity of cement being taken as unity. Therefore, in its general form the designed composition of the lightweight concrete mix was 1: 1.30: 1.60 with w/c = 0.40. A total of 6 trial mixes was formulated by varying the percentage of discarded foundry within the sphere of fine aggregate and were designated as M1 (0% DFS), M2 (20% DFS), M3 (40% DFS), M4 (60% DFS), M5 (80% DFS) and M6 (100% DFS). The actual weigh batch compositions are presented in Table 3.

A slightly different approach of mixing of concrete ingredients was followed in this study. Initially, dry mixing of coarse and fine aggregate was done for two minutes in the revolving single axis type drum mixer and the mixing was continued for another two minutes after the addition of 50% of the total quantity of water. As soon as achieving surface saturated aggregate mix, cement was introduced into the mix, allowing the cement for adsorption onto the surface of the saturated aggregates. Mixing was continued for another four minutes with the intention to allow the cement to fill in the micro voids of the coarse aggregate (CBM aggregate) surface. Finally, remaining 50% of the total quantity of water was added and mixed for another 2–4 minutes so that uniform consistency was achieved. On the whole, the mixing was done for about 10–12 minutes. Lightweight aggregates tend to absorb water in the mixer unless they are fully saturated with water and results in undesirable loss of workability before the concrete is poured into its position. Therefore, it was essential to pre-wet the aggregates till they become saturated. The saturated surface dry aggregates were employed during the mixing process. Apparently, handling and placing of lightweight concrete were similar to that of conventional concrete. The high porosity of lightweight aggregate and the continuous absorption of water by coarse aggregate within the concrete mix resulted in a quiet stiff mix. Hand operated grid tamper was used to consolidate the lightweight concrete matrix placed into the moulds in three layers of equal thickness.

Table 3. Mix proportion of trial mixes

Mix	Cement (kg/m^3)	FA (kg/m^3)		CA (kg/m^3)	Water (litres)
		DFS (Replacement %)	RS		
M1	350	0 (0%)	455	560	140
M2	350	91 (20%)	364	560	140
M3	350	182 (40%)	273	560	140
M4	350	273 (60%)	182	560	140
M5	350	364 (80%)	91	560	140
M6	350	455 (100%)	0	560	140

2. Testing procedure

The Slump test as per IS: 1199-1959 (1995) was carried out to assess the workability of the lightweight concrete mixtures. The density of lightweight concrete was measured at the fresh and oven-dry state as per the stipulations of ASTM C138 (2016) and ASTM C567 (2014) respectively. The compressive and flexural strength tests on lightweight concrete specimens were done according to IS: 516-1959 (2004). All the test specimens were water cured until the day of testing up to 28 days. The compression test was carried out on the water cured specimens for 7, 14, and 28 days whilst the flexure test was performed on the samples which were cured for 28 days. Concrete cubes of size 150 mm and rectangular prism shaped beams of size 100×100×500 mm as per the specifications of IS: 10086-1982 (1995) were employed for determining the compressive and flexural strengths of the designed concrete respectively. Split tensile strength tests on lightweight concrete specimens were carried out at the age of 28 days conforming to the specifications of IS: 5816-1999 (1995). Cylindrical concrete specimens measuring 150 mm diameter and 300 mm height were used for determining the tensile strength of the concrete. Sorptivity test on lightweight concrete specimens were conducted as per the specifications of ASTM C. 1585-13 (2013). The concrete specimens used were circular discs of diameter 100 mm and height 50 mm and the test was conducted at 28 days on specimens of all mix. Saturated Water Absorption of the lightweight concrete cubes of size 100 mm were determined as per BS 1881-122 (2011) after 28 days of water curing.

3. Results and discussion

3.1. Fresh concrete properties

Consistency and workability of fresh concrete affects the placing of fresh concrete on site and to obtain sufficient compactness and an appropriate surface finish of hardened concrete, a certain amount of work needs to be applied to the corresponding fresh mix. The incorporation of uniform size coarse aggregate may not be beneficial in cases of shrinkage and creep behavior. The slump values obtained for the lightweight concrete mixes are tabulated in Table 4 and Figure 1 provides a high-low-close chart of slump values. The "close" point represents the recurrent slump value for a particular mix.

Table 4. Workability and Density of the Lightweight Concrete

Mix	Workability		Density (kg/m^3)	
	Slump (mm)	Standard Deviation	Fresh State	Oven Dry State
M1	69	±2.08	1750	1685
M2	77	±3.51	1715	1646
M3	79	±2.51	1660	1583
M4	85	±3.06	1628	1548
M5	88	±3.61	1595	1512
M6	89	±3.00	1583	1487

By visual and experimental evaluation, it was noticed that with the increase in the substitution of discarded foundry sand content there was an additional increase in the degree of workability. The effect of water content on the workability of the concrete can be expressed by Lyse's rule (Lyse 1932) which says that for a given type of aggregate, workability of the mix depends on the water content of the concrete, irrespective of the water-to-cement ratio. It is to be remembered that, the greater the aggregate surface greater is the amount of water and cement paste necessary to cover the aggregate. Thus, in general, the finer the aggregate, the lesser the workability of the concrete. However, it has been verified experimentally that the aggregate fraction of less than 0.6 mm fineness, and also the cement, does not negatively affect the workability as one might expect from the high surface area to be covered by water. Indeed, a certain fraction of this fine material, excluding very fine aggregates, is necessary in obtaining a workable fresh concrete since it acts as a lubricant for the coarse aggregates. For concrete with a high cement content, in particular, those with aggregate-cement ratios equal to or less than 2, the effect of the type of the aggregate on workability, with regard to both angularity and specific surface area, becomes virtually negligible. The spherical shape, fineness (mostly smooth) and water resistant property of the discarded foundry sand particles indeed imparted a plasticizing effect to the fresh lightweight concrete mix.

The density of the lightweight concrete mixtures decreased as the percentage of discarded foundry sand (DFS) replacement increased. The fresh state density of the mix M1, which had 0% DFS was 1750 kg/m^3; whilst the density of mix M6 involving 100% DFS was about 1583 kg/m^3 representing a decrease of about 9.54% (Table 4 and Fig. 2). There was about 3–6% decrease in the density of specimens of each mix after oven drying the fresh state specimens cured for 28 days. The oven dry density of the specimens ranged between 1685 kg/m^3 and 1487 kg/m^3, classifying them as lightweight concrete.

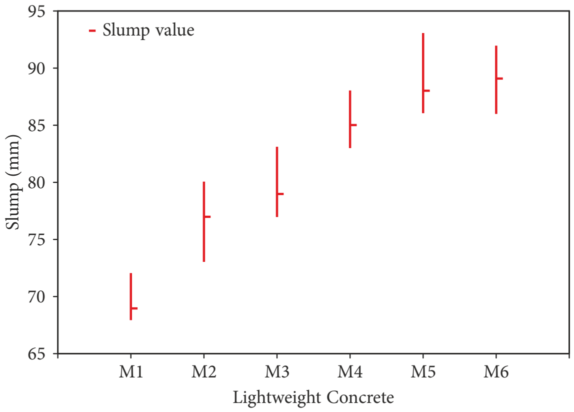

Fig. 1. Workability of Lightweight Concrete Mixes in terms of Slump value

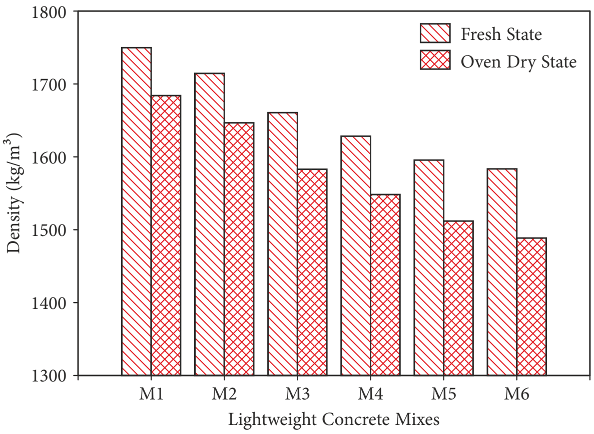

Fig. 2. Fresh and Oven Dry Density of Lightweight Concrete Mixes

3.2. Strength properties of lightweight concrete

The strength properties of hardened concrete are directly affected by the characteristics of the various existing pore systems in the cement paste. The strength depends principally on the total volume of the pores, and the resistance to chemical attack, through permeability, in relation to the pore sizes and their degree of continuity, besides volume and shrinkage. The strength characteristics of "Lightweight Concrete" with respect to compression, tension and flexure was carried out via testing the cubes, cylinders and beams correspondingly.

3.2.1. Compressive strength of lightweight concrete

The results of the cube compressive strength at 7, 14 and 28 days of curing are represented graphically in Figure 3. The compressive strength decreases with increasing quantity of discarded foundry sand substitution up to 60% and the decreasing trend turn out to be marginal at 80% and 100% substitution. From Figure 3, it can be seen that all the specimens have attained a compressive strength which is higher than the target compressive strength at the end of 28 days. With the addition of different proportions of discarded foundry sand, cubes of lightweight concrete produced with maximum substitution levels have shown quite lesser strengths than the cubes of 0% substitution. This behaviour may be attributed to the bulk proportion of less dense aggregates; and the pores present in the hardened paste. Additional pores other than the cement hydration products (gel pores) associated within the structure of the concrete formed due to air entrapped during the mixing and casting of the specimens were also responsible for the compressive strength reduction in the high volume DFS lightweight concrete. The results of compressive strength variation with curing age for different mixes are also presented in Figure 3.

Figure 4 demonstrates a strong correlation and polynomial relationship between the 28-day compressive strength and density of lightweight concrete. The relatively high correlation existed at the higher range of concrete density. As the density of the lightweight concrete specimens increases, there exists a polynomial tendency for build-up in the compressive strength. The compressive strength of the mix M6 (100% DFS) having a density of 1487 kg/m^3 was slightly low and the conduct may be attributed to the stress concentrations in the composite matrix brought about by the shape and texture of the discarded foundry sand; the micro and macro roughness at the interfaces. The lightweight concrete mix with 100% discarded foundry sand (DFS) gave the lowest compressive strength of 36.15 MPa which was almost 18.5% lower than the strength of 0% DFS concrete mix.

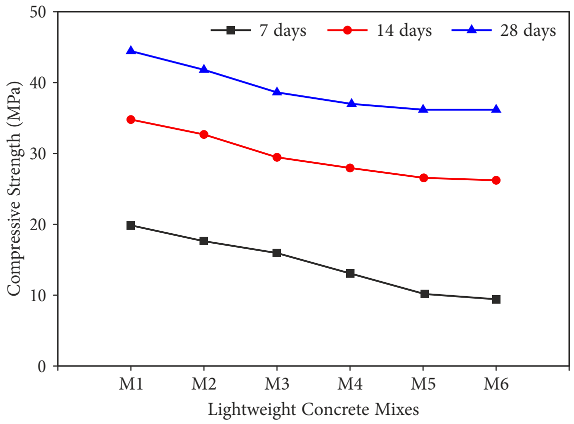

Fig. 3. Cube compressive strength results of Lightweight Concrete

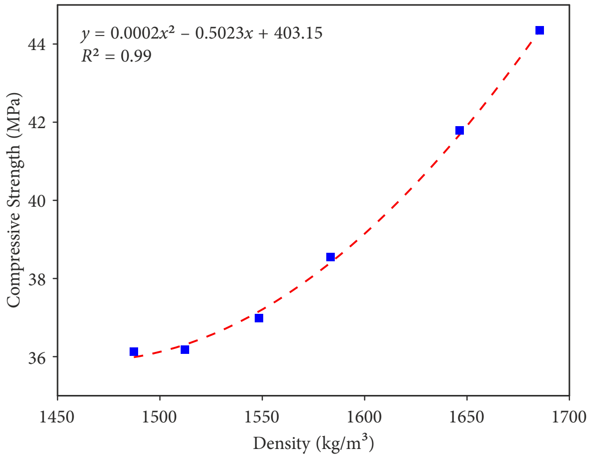

Fig. 4. Relation between Compressive Strength and Dry Density of Lightweight Concrete

3.2.2. Tensile and flexural strength of lightweight concrete

The tensile and flexural strengths of lightweight concrete mixes are represented graphically in Figure 5. The tensile strength at 28 days varies from 2.9 to 4.8 MPa and the flexural strength at 28 days varies from 4.15 to 6.3 MPa. It can be seen that the tensile and flexural strengths of the mix without DFS recorded higher strength values than the other mixes. The M5 (80% DFS) and M6 (100% DFS) mixes exhibited quite lesser tensile and flexural strengths as compared to

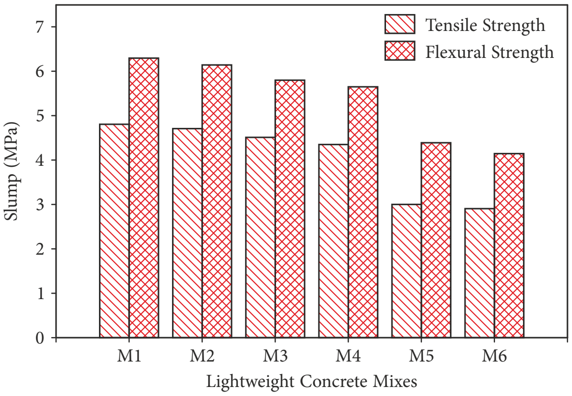

Fig. 5. Tensile and Flexural Strengths of Lightweight Concrete Mixes at the age of 28 days

that of other mixes. The variation of tensile strength of M1 (0% DFS), M2 (20% DFS), M3 (40% DFS), M4 (60% DFS) mixes are not too much fluctuating with reference to each other. All the tensile strength test specimens (cylinders) presented a linear-elastic behaviour until cracking. The flexural strength of lightweight concrete is generally sensitive to interior structure characteristics (for e.g., porosity and micro cracks). The porosity of the crushed brick aggregate and discarded foundry sand are higher than that of the conventional aggregates, this may be the reason for the tensile and flexural strength reduction.

The defects in concrete microstructure directly influences its mechanical strength properties. Microstructural observations using Scanning Electron Microscope (SEM) of a fractured surface of lightweight concrete (M6 – 100% DFS) reveal a porous morphology. From Figure 6, it can be seen that, the voids entrapped within the lightweight concrete are quite bulky, frequent and discontinuous. The presence of voids in the concrete matrix reduces the extent of hydration products required to bond the aggregates thereby minimizing the mechanical strength of concrete. From Figure 7, it is very clear that, T-shaped cracks are developed along the interfaces between the cement paste and DFS aggregates. The smoother surface of DFS particles offers weaker bond and persuade cracks in the transition zone. Extensive branching of microcracks growth can also be seen either at the interface or within the cement paste in the LWC matrix (Fig. 8). Due to the water absorption potential of CBM aggregates, the development of oriented calcium hydroxide crystals and other hydration products were hindered at the aggregate paste interface instigating micro-voids in the paste and making the concrete permeable.

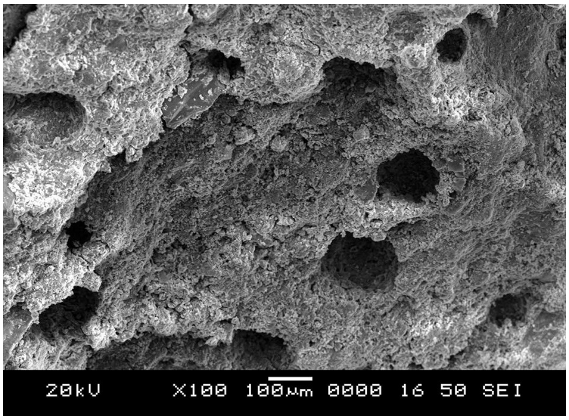

Fig. 6. SEM micrograph (secondary electron image) showing voids entrapped within the lightweight concrete

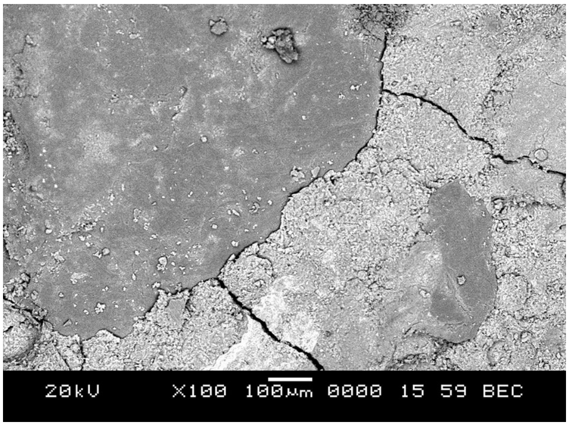

Fig. 7. SEM micrograph (backscattered electron image) showing T-shaped cracks

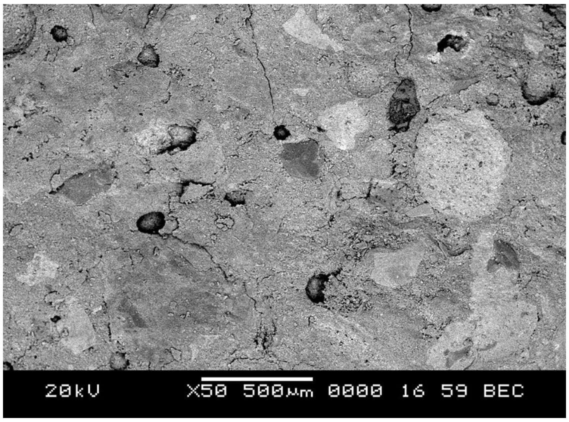

Fig. 8. SEM micrograph (backscattered electron image) showing microcracks growth

3.3. Durability properties of lightweight concrete

3.3.1. Sorptivity test

Sorptivity measures the water absorptivity of concrete through capillary suction. The results of Sorptivity of lightweight concrete specimens are as tabulated in Table 5. The highest sorptivity value (secondary rate) was spotted in the specimens of the M6 mix (100% DFS) which was about 5.65×10^{-4} mm/√s, whereas the sorptivity of the concrete specimens of M1 mix (0% DFS mix) was about 49% lesser than the M6 mix specimens. The initial rate of water absorption values signifies the initial 6-hour absorption measurements while the secondary rate of water absorption represents the absorption measurements from the first day to 7th day. The relationship between the 28 days compressive strength and sorptivity of the lightweight concrete specimens are shown in Figure 9. As the water sorptivity of lightweight concrete specimen increased from 2.89×10^{-4} mm/√s (M1 – 0% DFS) to 5.65×10^{-4} mm/√s (M6 – 100% DFS), the compressive strength reduced from 44.35 MPa (M1) to 36.15 MPa (M6). Previous investigations on cement concrete have shown that specimens with higher sorptivity recorded lesser durability (Singh, Siddique 2015; Kubissa, Jaskulski 2013). Figure 10 illustrates the relationship between the sorptivity and density of lightweight concrete specimens. Sorptivity has been observed to increase as the density of the lightweight concrete decreases (Fig. 10).

Table 5. Sorptivity of lightweight concrete mixes

Mix	Sorptivity (mm/√s)	
	Initial rate of water absorption	Secondary rate of water absorption
M1	4.87×10^{-4}	2.89×10^{-4}
M2	5.21×10^{-4}	3.45×10^{-4}
M3	5.88×10^{-4}	3.97×10^{-4}
M4	6.45×10^{-4}	4.56×10^{-4}
M5	6.9×10^{-4}	5.18×10^{-4}
M6	7.3×10^{-4}	5.65×10^{-4}

3.3.2. Saturated water absorption test

Saturated Water Absorption test of concrete is performed in order to assess the properties like intrinsic porosity and permeability of concrete. Water can penetrate into the pores of the concrete during complete immersion and in turn adversely affect the strength and durability properties of the concrete. The quantity or volume of moisture, which passes through the concrete depends on the concrete permeability and interconnectivity between pores. The water absorption of lightweight concrete specimens after immersion for 28 days are presented in Table 6.

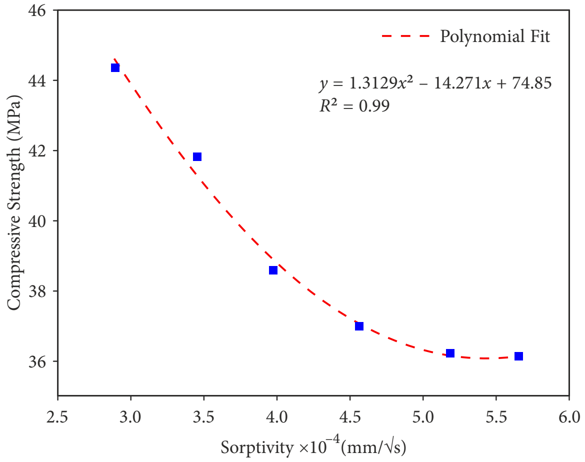

Fig. 9. Relation between compressive strength and sorptivity of the lightweight concrete

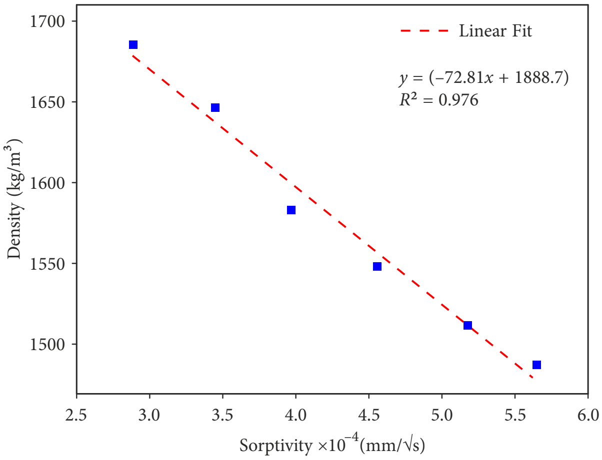

Fig. 10. Relation between density and sorptivity of the lightweight concrete

Table 6. Saturated water absorption of lightweight concrete mixes

Mix	Saturated Water Absorption (%)	Standard Deviation
M1	6.3	± 0.4
M2	6.9	± 0.3
M3	7.3	± 0.3
M4	7.7	± 0.4
M5	8.1	± 0.3
M6	8.6	± 0.4

The grains of discarded foundry sand were round with medium to high sphericity giving good flowability and permeability to concrete at low or medium binder additions. The less angular and high sphericity property of foundry sand is the reason for higher porosity and permeability of the lightweight weight concrete specimens crafting them to absorb more quantity of water. Rounded grains usually have a low surface area-to-volume ratio and therefore the water in the mix occupies the space in concrete mass and as it vaporizes, it leaves more voids. The possible inter-connection of voids in the concrete leads to minor cracks inside the matrix, thus increasing the water absorption value.

Conclusions

In the view of achieving both low density and significant strength, the mix (M3) with a blend of 40% discarded foundry sand and 60% natural sand was found to have virtuous strength and durability properties. Due to the presence of large amounts of fines (discarded foundry sand) in 60, 80 and 100% mixes, there was no improvement in the strength development. The lightweight concrete produced by utilizing crushed brick masonry aggregate and discarded foundry sand (40% substitution level) can be employed in all major structural lightweight construction aspects and is ideally suited for sloped roof slabs and making architectural or decorative concrete blocks.

Blending of discarded foundry sand with natural sand reduces the amount of macro pores, which improves the workability of concrete, but however the strength and durability properties of the lightweight concrete are not substantially improved due to the reason that the sphere-shaped and smooth particles of DFS cause micro voids and microcracks within the hardened matrix. From the microstructural observations; due to the water absorption potential of CBM aggregates, the development of oriented calcium hydroxide crystals and other hydration products were hindered at the aggregate paste interface instigating micro-voids in the paste and making the concrete permeable. Lubricating effect of the cement-paste which in turn is solely governed by the degree of dilution, affects the workability of a lightweight concrete mix.

A very good correlation was observed between the compressive strength and sorptivity values i.e., as the sorptivity increased due to extensive micro pores in the structure of LWC specimens, the compressive strength reduced considerably indicating a less dense microstructure.

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APPENDIX

Practical aspects of using lightweight aggregate concrete

Lightweight aggregate such as crushed brick continues to absorb water for over a long period. Consequently, in the concrete mixer, unless the aggregate is fully saturated with water, it continues to absorb water from the concrete mix and may result in undesirable loss of workability before it is placed into its position. It is therefore very essential to pre-wet the aggregate or allow longer mixing time. Efforts of pre-wetting a stock pile have not been successful. The most favoured technique is to spray water on the aggregate just prior to its delivery to the batching plant. The concrete proportioning procedure is also influenced. Variation in moisture absorbed by lightweight aggregates is wide; consequently, the change in bulk density of aggregate is likely to introduce unacceptable errors in proportioning of concrete mixes, if weigh batching is adopted. The volume batching of lightweight aggregate concrete ingredients is safe and simple. Apparently handling and placing of lightweight concrete is similar to that of conventional concrete. The high porosity of lightweight aggregate and the comparative lightness of coarse aggregates (which causes floating of coarse aggregate on the mortar, on prolonged vibration) however, necessitate some departures from normal practice.

Gireesh MAILAR is an Assistant Professor and Head of the Civil Engineering Department at Karavali Institute of Technology, Neermarga, Mangalore-575029, India. He holds a Master's Degree in *Computer Aided Design of Structures* from Visvesvaraya Technological University, Belgaum, India. His research interests focus on production of eco-friendly concrete, resilient engineering materials, intelligent infrastructure systems etc. He is a resource person in the area of concrete technology and has authored a few articles in the above said themes, besides teaching.

Sujay Raghavendra N. is a *Research Scholar* working for Doctoral degree in the Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka, Surathkal, Mangalore-575025, India. He graduated with a B.E. in *Civil Engineering*, and specialized in *Water Resources Engineering and Management*. His principal research interest includes estimation of streambed hydraulic properties, stream-aquifer interaction modeling, statistical and geostatistical analysis etc. Other interests include advanced concrete technology, built environment, restoration and sustainable design of architectural concrete. He is a member of professional bodies like Soft Computing Research Society, IWRA, IAHS etc. He has authored several research articles in various international journals and conferences. In addition to this, he has served as reviewer for many indexed journals.

Parameshwar HIREMATH. is currently a PhD student in the Department of Civil Engineering, National Institute of Technology Karnataka, Surathkal, Mangalore-575025, India. Earlier, he worked as Assistant Professor at Veerappa Nisty Engineering College, Shorapur (India). He received Civil Engineering degree from PDA Engineering College, Gulbarga and M.Tech. degree in *Structural Engineering* from Basaveshwar Engineering College, Bagalkot in the year 2013. His research interest includes production of reactive powder concrete, eco-friendly concrete etc.

Sreedhara B. M. is a PhD student in the Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka, Surathkal, Mangalore-575025, India. His educational background includes an undergraduate degree in *Civil Engineering* and M. Tech. degree in *Computer Aided Design of Structures* from Visvesvaraya Technological University, Belgaum, India. His current research interests include numerical modeling of bridge scour, green concrete, structural engineering, finite element analysis etc. He has to his credit several peer-reviewed published articles in international journals and conferences.

Manu D. S. is a Doctoral student in the Department of Civil Engineering, National Institute of Technology Karnataka, Surathkal, Mangalore-575025, India. He holds M.Tech. degree in *Environmental Engineering* from Visvesvaraya Technological University, Belgaum, India. His field of research is related to wastewater treatment, utilization of various industrial wastes and by-products in the concrete etc. He has authored several research articles in various international journals and conferences.