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Research Paper

Fresh and Mechanical Properties of Lightweight Aggregate Concrete with Scrap Steel Fiber Reinforcement and Bagasse Ash

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ABSTRACT

A sustainable concrete solution was developed by partially replacing aggregates and cement with lightweight plastic aggregates (LWPA) and bagasse ash, respectively. Three types of mixes were studied: (i) concrete with 10-30% cement replaced by bagasse ash (BA), (ii) Bagasse ash concrete mix with scrap steel fiber, and (iii) Bagasse ash concrete with scrap fiber and 10-50% lightweight aggregate. The addition of bagasse ash positively influenced the fresh properties of concrete. However, workability decreased by 56% with the incorporation of scrap fibers and lightweight aggregate compared to the control mix. Slump values reduced in concrete mixes containing plastic aggregate (PA) due to mortar accumulation in voids within the hollow aggregate, significantly diminishing workability. The density of concrete decreased with bagasse ash and lightweight aggregate inclusion, aiding in reducing structural dead weight. However, the strength decreased notably with 30% replacement using hollow lightweight plastic aggregate. Voids in concrete specimens increased with LWPA percentage. Observations from fresh and hardened concrete tests suggest that plastic aggregate, bagasse ash, and scrap fiber can effectively replace up to 20% of gravel aggregate.

1 Introduction

Urbanization accelerates the depletion of natural resources and intensifies energy consumption. Concrete, a pivotal construction material, heavily relies on cement, sand, and gravel, with developed countries averaging 1.5 to 3 tons of concrete per person annually, straining future resource availability [1]. To foster sustainability and curb rapid resource depletion, there's a shift towards substituting key concrete components such as cement and aggregate, with eco-friendly alternatives. These alternatives, sourced from industrial or agricultural waste/by-products, curtail CO₂ emissions, mitigate

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open land waste dumping, and reduce environmental pollution while maintaining concrete strength and integrity [2]. Compared to high-density industrial waste like slags, agricultural waste presents a viable alternative with lower density, superior sound insulation, enhanced thermal resistance, cost-effectiveness, and renewability [3]. Efforts to replace coarse aggregate, which constitutes 70-80% of total resource consumption in concrete, have led to a focused exploration of alternative materials such as copper slag, steel slags, sintered fly ash aggregate, plastic aggregate, and agricultural waste like palm shell, coconut shell, and kernel shell. These by-products and waste materials offer promising solutions for sustainable construction practices. In comparison to fly ash, renowned for its exceptional pozzolanic properties but derived as a combustion residue of coal (a non-renewable resource), biomass ash emerges as a preferred option in the construction sector [4]. Utilizing such agricultural waste as replacements for cement and aggregate in concrete not only reduces construction costs but also mitigates environmental pollution caused by the disposal of these wastes in open land [5]. Beyond cement and natural coarse aggregate replacements, extensive research conducted over the past two decades has focused on examining the mechanical behavior and durability characteristics of fiber-reinforced concrete. Various synthetic and plant fibers, including polyolefin, glass, carbon, polypropylene, banana fiber, sisal fiber, caryota fiber [6], roselle fiber, jute fiber, and coconut fibers, are now utilized as reinforcements in concrete to enhance the mechanical strength and ductility of both normal and lightweight aggregate concrete [7-12]. Despite synthetic fibers offering superior thermal resistance, mechanical strength, and durability compared to natural fibers, plant fibers are increasingly favored due to their low cost and high renewability [13-15]. Incorporating steel fibers of different aspect ratios and origins has been shown to enhance the mechanical properties of concrete. Recent research efforts have explored the use of steel fibers as reinforcement in both normal and lightweight concrete to reduce brittleness and improve tensile properties [16-18]. Building upon this knowledge, this research paper will primarily focus on utilizing lightweight plastic aggregate (LWPA) as a partial replacement for natural gravel aggregate, with bagasse ash (BA) serving as a partial replacement for cement, and lathe industry scrap steel fibers (SrF) as fiber reinforcement.

2 Recent studies on light weight aggregate concrete

A novel artificial aggregate comprised entirely of plastic waste, with 80% polyolefins and 20% other plastics, has been developed, paving the way for the creation of concrete mixes capable of achieving a compressive strength of 20 MPa. By incorporating plastic aggregates into non-structural concrete applications, sustainability is greatly improved through the minimization of plastic waste. Moreover, the lightweight properties of the concrete make it ideal for precast elements such as sound barriers, facades, and ancillary structures, further enhancing its utility and environmental benefits [19]. Experiment was conducted to measure the permeability and porosity of light-weight concrete with various amount of plastic waste aggregate (PWA) in different confining pressure and pore pressure. The research outcomes indicate, the corrected permeability and porosity of PWA cement mortar rises with the increase of PWA content [20]. Experiments were conducted using light weight aggregates, polyethylene alcohol and polyvinyl alcohol both in combine and individually. From the experimental results it was found that only 0.6% compressive strength increased after 28 days with 20% replacement of aggregates by light weight aggregates in addition to 1% polyethylene [21]. A study was conducted to examine the impact of incorporating Light Weight Aggregates (LWA) in Self Compacting Concrete (SCC). As part of the investigation into potential alternatives, diatomite aggregate was explored by partially substituting natural coarse aggregate at varying replacement levels of 5%, 10%, 15%, and 20%. The results indicated a reduction in compressive strength of 22%, 24%, 26%, and 28% respectively, corresponding to the replacement percentages of 5%, 10%, 15%, and 20% [22]. Lightweight and normal weight aggregate reinforced-concrete beams were subjected to ambient and elevated temperatures. Lightweight aggregate beams demonstrated better seismic performance at high temperatures. The dissipated energy varied by the concrete type and the heat exposure level [23]. aims to fill the research gaps in the literature review by comprehensively examining the synergistic environmental effects of using novel sustainable recycled plastic aggregates instead of traditional aggregate in concrete. A two-story residential building case study in Saudi Arabia was chosen to examine and compare normal aggregate concrete mix with six mixes containing different percentages of recycled plastic aggregates [24]. A study focuses on the economic aspects of using Polyethylene based fine aggregates and Polyethylene Terephthalate based coarse aggregates as partial replacement (10%, 20%, 30% and 40%) of natural fine and coarse aggregates separately and simultaneously, with special emphasis given on environmental and social cost. The result shows that the total cost of concrete decreases with increase of replacement percentage and cost reduction varies between 0.65% and 7.58% compare to conventional concrete depending on the percentage and type of replacement without compromising strength [25]. For the present study, nine concrete mixtures of M30 grade concrete containing recycled plastic waste polyethylene (RPE) and plastic waste polyethylene-terephthalate (WPET) were prepared as a fractional volumetric

replacement for both natural coarse aggregates (NCA) and fine aggregates (NFA). The replacement levels were 0%, 5 %, 10%, 15%, 20%, 25%, 30%, 35% and 40% keeping constant the water-cement ratio (0.37). The usage of waste plastic aggregates for preparation of concrete were assessed through different fresh and hardened properties like slump, dry density, compressive strength (CS), flexural strength (FS), split tensile strength (STS) and ultrasonic pulse velocity [26]. Green concrete was produced using manufactured recycled plastic aggregate (MA). Influence of replacement levels of MA on concrete properties were examined. Slight reduction of mechanical properties of green concrete were observed. Improvement in the Poisson's ratio and abrasion of green concrete were obtained. Analytical correlations between mechanical properties were developed [27]. A paper addresses the utilization of granulated ABS as an aggregate replacement material in concrete. The compressive strength and abrasion resistance of granulated ABS derived from electronic waste in concrete were evaluated in different replacement intervals (0 %, 5 %, 10 %, 25 %, 50 %, 75 %, and 100 %). It was found that increasing the replacements of granulated ABS for the natural aggregate reduced concrete's workability, strength, and abrasion resistance [28]. Thus, various research has been carried out to know the possible application of plastic aggregate in concrete. therefore, in this present study a new type of plastic aggregate is to investigated and it fresh and mechanical properties are to be studied.

3 Experimental methodology

3.1 Material for concrete specimen

The materials used for the preparation of concrete mix includes cement, gravel aggregate, plastic aggregate, M – Sand, Bagasse Ash (BA), water reducing admixture and portable water. The sugarcane bagasse ash was received from sugarcane mill located at virudhachalam district, Tamilnadu, India. To obtain the BA, sugarcane fiber was heated in a muffle furnace at 10°C /min. The burnt ash was subjected to a high temperature of 900°C for 2 hours and then the ash trays were allowed to cooled in the open air. After proper cooling each sample were ground in a ball mill at 66 rpm, until the fineness of the BA sample is within the range of cement (2750 cm²/g). The pictures of cement, sieved bagasse ash, scrap steel fiber and plastic aggregate is shown in Figure 1(a-d).

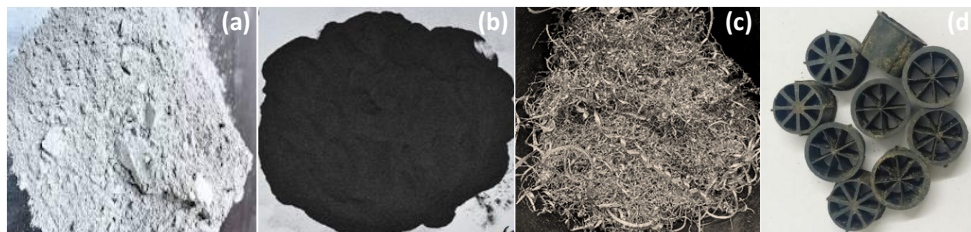


Fig. 1 – (a) Cement, (b) Sugarcane bagasse ash, (c) Scrap Steel Fibre and (d) Plastic Aggregate

3.2 Mix proportions and specimen ID

Prior to preparing the concrete mix, the plastic aggregates underwent thorough washing to ensure cleanliness, with special attention given to clearing any dirt or waste particles from the hollow spaces within the aggregates. The concrete ingredients for the control mix, including cement, sand, coarse aggregate, water, and Plasticizer, were combined in the ratio of 1:1.64:1.72:0.32:0.01. A total of ten mixes were prepared, with the first mix serving as the control mix, comprising 100% cement (CM) without any mineral admixtures. In the second set of mixes, bagasse ash was introduced as a replacement for cement at varying proportions of 10%, 20%, and 30%, designated as CM-10BA, CM-20BA, and CM-30BA, respectively. After evaluating the second set, the optimal replacement percentage of bagasse ash was determined to be 10%. This percentage was maintained in the third set of mixes, comprising a total of six variations. The first mix in this set, CM-BA-SrF, included 10% bagasse ash replacement, 3% scrap steel fiber, and 100% gravel aggregate. In the subsequent mixes of the third set, coarse aggregate replacements ranged from 5% to 20% with plastic aggregate, while maintaining 10% bagasse ash, 3% steel fiber. The mixes were labeled accordingly, such as LWC-5%-BA-SrF for 5% plastic aggregate replacement, 10% bagasse ash, and 3% scrap fiber. These adjustments were applied consistently across all variations. The specific mix proportions are detailed in Table 1.

Table 1 – Mix proportions

Specimen ID	Cement (kg/m ³)	Bagasse Ash (kg/m ³)	Sand (kg/m ³)	Coarse Aggregate (Kg/m ³)	Plastic Aggregate (Kg/m ³)	Scrap steel fiber (Kg/m ³)	Water content (Kg/m ³)	Super plasticizer (Kg/m ³)
CM	500	-	820	860	-	-	160	5
CM -10 BA	450	50	820	860	-	-	160	5
CM -20 BA	400	100	820	860	-	-	160	5
CM -30 BA	350	150	820	860	-	-	160	5
CM-BA-SrF	450	50	820	860	-	15	160	5
LWC-5-BA- SrF	450	50	820	774	27	15	160	5
LWC-10-BA- SrF	450	50	820	688	64	15	160	5
LWC-15-BA- SrF	450	50	820	602	86	15	160	5
LWC-20-BA- SrF	450	50	820	516	110	15	160	5
LWC-25-BA- SrF	450	50	820	430	165	15	160	5

3.3 Testing of specimen

To evaluate the workability of both control and plastic aggregate concrete mixes, slump cone tests were conducted, with the slump values recorded for each mix. Only one trial was conducted for each slump cone test. The fresh density and hardened density of each mix were determined by measuring the weight of specimens in their fresh and hardened states, as well as after oven drying. Strength properties of the concrete specimens were assessed through various tests. These included compressive strength tests on 150 mm-sized cubes, splitting tensile strength tests on cylinder specimens measuring 150 mm × 300 mm, flexural strength tests on beams with dimensions of 100 mm × 100 mm × 500 mm, and modulus of elasticity tests on cylinders sized at 150 mm × 300 mm. The testing procedures for these strength properties are depicted in Figure 2 (a-e). For the hardened concrete tests, three readings were taken for each specimen, and the average values were calculated to determine the strength properties.

**Fig. 2 – Fresh and hardened concrete test setup**

4 Results and Discussion

Experimental study was done to understand the fresh and hardened property of plastic aggregate scrap steel fiber reinforced concrete. The fresh density, hardened density and slump values were measure for all the mixes and tabulated. Similarly, the hardened concrete test such as compressive, split, modulus of elasticity and flexural properties were measured and tabulated.

4.1 Material Characterization

The elemental composition of cement and bagasse ash, showed silica content of 23.86% and 56.37% respectively. The calcium oxide of cement binder is about 50.76%, while the Loss on Ignition (LOI) for cement and bagasse ash is around 6–10%. The elemental composition of bagasse ash is within the limit specified by ASTM standards for pozzolana. The detailed chemical composition of cement and BA is listed in Table 2. The XRD analysis of cement showed the presence of calcium oxide, calcium silicate, calcium carbonate and gypsum. Similarly, the XRD of BA ash showed a high range of cristobalite at angle $2\theta = 23^\circ$ and reactive silicas and oxides in other range. The XRD pattern for cement and BA is shown in Figure 3. The plastic aggregate used in this work was obtained from the desalination plant which was used as the sedimentation bed and stored as waste. The waste plastic was then collected from the plant and cleaned thoroughly to remove the waste particles sticking to the plastic aggregate and used as replacement for coarse aggregate. To improve the strength of plastic aggregate lightweight concrete, scrap steel fiber stored as waste in the manufacturing laboratory were collected and used as fiber reinforcement. The length of fibers was cut to 20–40 mm and the diameter of the scrap steel fibers varies from 0.5–0.7 mm. The physical properties of plastic aggregate and scrap steel fiber are listed in Table 3. The Scanning Electron Microscope (SEM) image showing the uniform crystalline structure of cement particles and image of bagasse ash with spherical, cuboidal and polygonal particles is shown in Figure 4 (a & b).

Table 2 – Chemical properties of cement and bagasse ash

Material	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	P ₂ O ₅	Na ₂ O	K ₂ O	MgO	LOI
Cement	23.86	5.77	2.19	50.76	0.12	0.91	0.92	1.36	6.97
Bagasse Ash (BA)	56.37	14.61	5.04	2.36	0.85	1.57	3.29	1.43	10.53

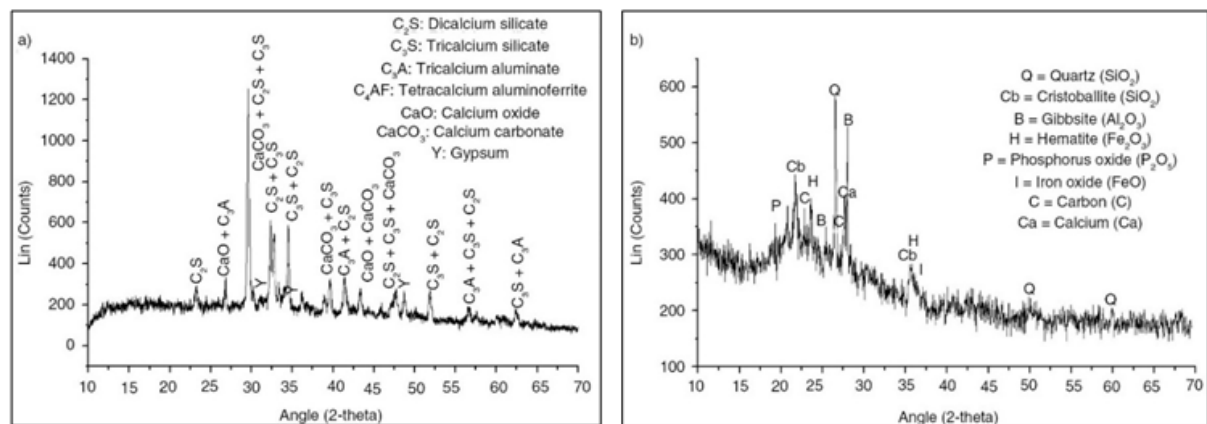


Fig. 3 – XRD pattern of (a) cement and (b) bagasse ash

Table 3 – Physical property of plastic aggregate and scrap steel fiber

Physical Properties of Plastic aggregate		Physical Properties of scrap steel fiber	
Specific Gravity	1.2	Cross-section	Deformed and straight
Crushing Value(%)	2.38	Diameter (mm)	0.3 – 0.75
Impact Value(%)	7.15	Length (mm)	5 – 20
Water Absorption(%)	-	Unit Weight (kg/m ³)	7850
Fineness Modulus	-	Elasticity modulus (N/mm ²)	2×10 ⁵
Bulk Density (kg/m ³)	450	Tensile strength (N/mm ²)	500 – 3000
Abrasion value (%)	1.6	Aspect ratio (%)	45 – 100
Crushing value (%)	2.47	Elongation (%)	5 – 35

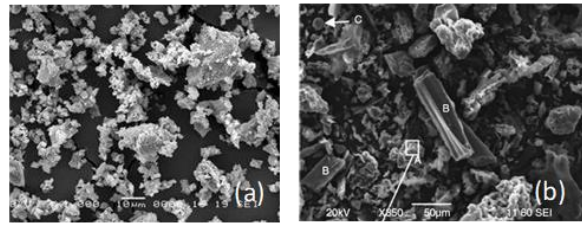


Fig. 4 – SEM image of (a) cement; (b) bagasse Ash with polygonal, cuboidal and spherical shaped particles;

4.2 Density of scrap steel fiber reinforced plastic aggregate concrete

For each mix, the fresh weight of the concrete specimen, weight of the demolded specimen, weight of the specimen following 24 hours of air drying, and final weight of the specimen following 24 hours of oven drying at 120°C were measured. The fresh density, air dried density and oven dried density was determined and summarized in Table 4.

Table 4 – Density and workability properties of control and plastic aggregate concrete

Specimen ID	Wet density (kg/m ³)	Demolded density (kg/m ³)	Air dried density (kg/m ³)	Oven dried density (Kg/m ³)	Slump
CM	2708	2631	2625	2560	85
CM -10 BA	2645	2504	2489	2433	78
CM -20 BA	2610	2480	2425	2390	76
CM -30 BA	2590	2455	2394	2350	75
CM-BA-SrF	2693	2593	2581	2530	73
LWC-5-BA- SrF	2463	2223	2211	2155	63
LWC-10-BA- SrF	2237	2199	2210	2128	60
LWC-15-BA- SrF	2140	2046	2122	2060	55
LWC-20-BA- SrF	2069	2069	2140	2000	50
LWC-25-BA- SrF	2001	2007	2017	1875	40

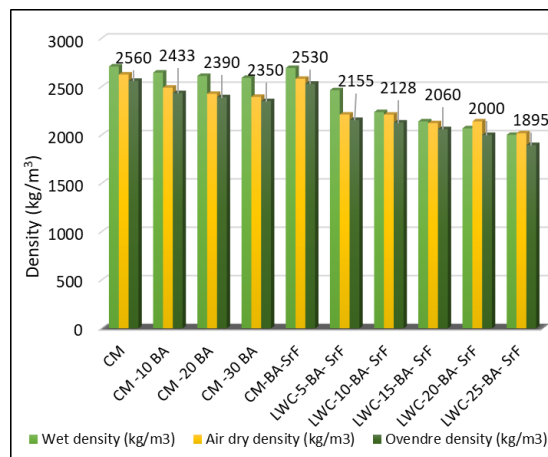


Fig. 5 – Wet density, air dried density and oven dried density of lightweight plastic aggregate-SrF reinforced concrete

Normally the density of light weight aggregate concrete varies between the range of 1600-2000Kg/m³, but in the present study the gravel aggregate were partially replaced with PA, and therefore the oven dry density of plastic aggregate concrete varied from 2155-1895 Kg/m³, in which, the LWC-25-BA-SrF mix with 25% replacement of PA falls under the category of light weight concrete. For the control mix (CM) the density of concrete was around 2560 Kg/m³, as the cement content was partially replaced with 10-30% BA, the dry density decreased from 2433 Kg/m³ to 2350 Kg/m³, this is because, specific gravity of BA ranges is lesser when compared to cement. Therefore when cement is replaced with BA, a higher volume of concrete will result with lesser density [29]. For 10%, 20% and 30% replacement of cement with BA, the density

reduction is approximately around 5%, 7% and 8% respectively. The addition of SrF to BA replaced concrete (CM-BA-SrF) slightly increase the density from 2433 Kg/m³ to 2530 Kg/m³, due to the addition of steel fiber. For the third set of mixes namely the plastic aggregate concrete, the density decreases with the increased percentage of PA. For 5% replacement of PA the wet density and dry density was around 2463 Kg/m³ and 2155 Kg/m³ respectively. As the replacement percentage increase to 25%, the wet density and dry density decrease to 2001 Kg/m³ and 1875 Kg/m³. The variation of density for control mix (CM) and BA concrete mix with BA (CM-BA) and plastic aggregate BA concrete with scrap steel fiber (LWC-BA-SrF)) is shown in Figure 5. The linear regression plot to correlate density with the compressive strength is shown in Figure 9 and the developed equation with a high regression value ($R^2 = 0.89$).

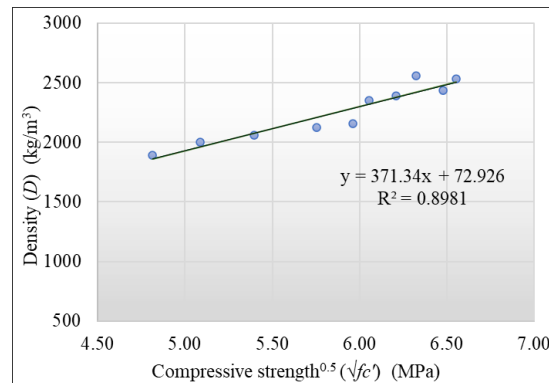


Fig. 6 – Correlation of density with compressive strength^{0.5}

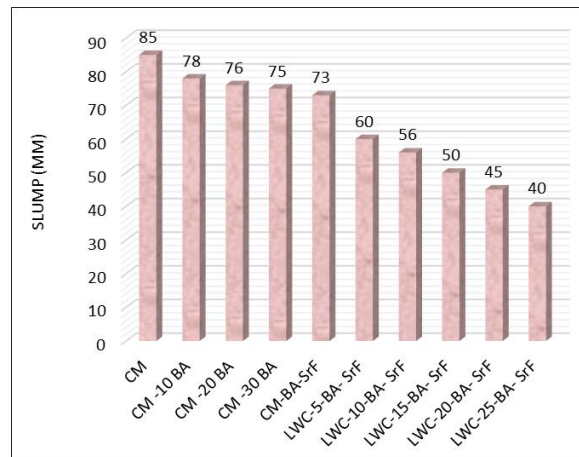


Fig. 7 – Variation of slump for control and plastic aggregate concrete

4.3 Workability of scrap steel fiber reinforced PA concrete

The slump test is widely utilized to gauge the flowability of concrete, crucial in determining how easily concrete can be poured and placed into molds. In this study, slump values were recorded and are presented in Table 4. Previous research indicates that conventional concrete typically exhibits slumps ranging from 100 to 125 mm, while lightweight aggregate concrete tends to have slumps between 50 and 75 mm [30]. In the current investigation, the slump values for plastic aggregate concrete ranged from 65 mm to 45 mm. Specifically, the slump value for the control mix was 85 mm, which increased with the incorporation of bagasse ash (BA) in concrete. With 10%, 20%, and 30% BA additions, the slump values rose to 89 mm, 90 mm, and 92 mm respectively. This increase in workability can be attributed to the lower bulk density of BA compared to cement. BA fills small pores within the cement matrix, occupying more volume in the concrete mix, thereby enhancing flowability and reducing permeability. Consequently, the addition of mineral admixtures up to 5–20% results in increased concrete workability [29]. However, the inclusion of steel fibers impedes aggregate movement, leading to reduced fresh concrete workability. For instance, the workability of lightweight concrete with BA and scrap steel fiber decreases from 89 mm to 73 mm with a 3% scrap steel fiber addition. Furthermore, for plastic aggregate scrap steel fiber reinforced concrete, workability diminishes to 60 mm, 56 mm, 50 mm, 45 mm, and 40 mm with 5%, 10%, 15%, 20%,

and 25% replacement of coarse aggregate respectively. The presence of hollow spaces in the aggregate tends to decrease concrete workability. The variations in workability for plastic aggregate concrete are illustrated in Figure 7, while the correlation between slump and plastic aggregate percentage for all concrete mixes is depicted in Figure 8.

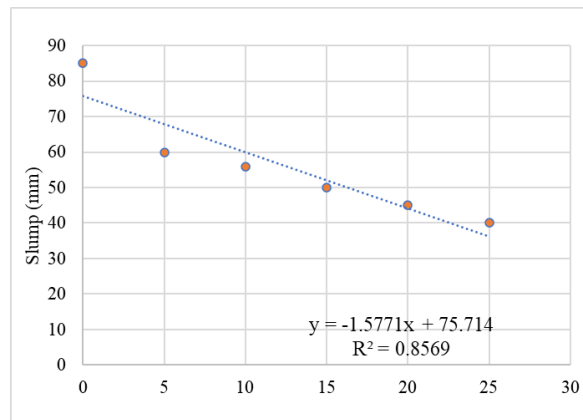


Fig. 8 – Correlation relation of slump with the percentage replacement of PA

4.3 Compressive Strength

The hardened concrete test was done after 28 days of water curing and the values are listed in Table 5. The variation of compressive strength of concrete for control mix, bagasse ash concrete mix and fiber reinforced plastic aggregate lightweight concrete mix is shown in Figure 9. In the present work, for 10% replacements of cement with BA the compressive strength increases from 40.01 MPa to 41.94 MPa which is about 4% higher than the control mix. Previous research on bagasse ash concrete, proved that the strength of concrete, increases for up to 5-10% substitution of cement with BA. Beyond 10% the strength is slightly affected [29].

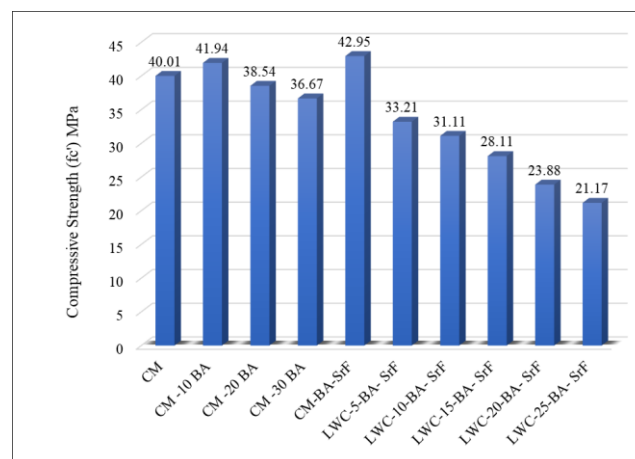


Fig. 9 – Compressive strength of control, BA concrete and Plastic aggregate scrap steel fiber concrete

From the previous research, it was observed that there is an obvious increase in the water demand, attributed to the increased surface area of the blended cements. Bagasse ash, as seen from the morphological studies, has irregularly shaped particles and leads to the friction between particles during the mixing process. In addition, the porous structure of BA reduces the free water available in the blended cement mixture, resulting in a drop in workability and leading to a stiff mixture. Bagasse ash has lesser specific gravity compared to that of cement, which increases the powder volume in the binary mixture when weight-based replacement is adopted. Increase in the strength properties is due to the high silica content of BA which is obtained during the burning process of sugarcane fiber at 800°C in control chamber. The silica content in BA has excellent pozzolanic property which helps to improve the strength of concrete [31]. Also the lower bulk density of BA occupies small pores in concrete mix which reduces the permeability and also increase the compressive strength [4]. From the tabulated values it can be concluded that, out of three types of cement replaced bagasse ash concrete

mix, the concrete mix with 10% BA showed increase in compressive strength. Our present result matches well with the previous research finding on BA replaced concrete. Therefore, 10% of replacement of cement with BA was adopted as standard for other mixes with plastic aggregate and scrap steel fibers. In the fiber reinforced BA concrete mix, the fiber holds the aggregates and cement matrix and effectively distributes the crack, which delays the development of major crack plane and increases the load carrying capacity. The compressive strength of fiber reinforced BA concrete (CM-BA-SrF) showed up to 2% increase in strength compared to unreinforced mix (CM-10BA). It was proved from the authors previous research work that, up to 3% of fiber addition will help to improve the strength of fiber reinforced concrete [9]. Therefore 3% of steel fibers added was maintained for the remaining concrete mixes with PA. The Scanning Electron Microscope (SEM) image of 5% and 25% PA lightweight concrete along with the failed specimen is shown in Figure 10 (a-d).

Table 5 Strength properties of control and plastic aggregate steel fiber reinforced concrete

Specimen ID	Compressive Strength (N/mm ²)	Splitting Tensile Strength (N/mm ²)	Flexural Strength (N/mm ²)	Modulus of Elasticity (GPa)
CM	40.01	3.76	4.43	27.39
CM -10 BA	41.94	3.89	4.62	28.04
CM -20 BA	38.54	3.65	4.35	26.88
CM -30 BA	36.67	3.54	4.29	26.22
CM-BA-SrF	42.95	3.98	4.78	29.23
LWC-5-BA- SrF	33.21	3.36	4.17	25.10
LWC-10-BA- SrF	31.11	3.11	4.03	23.40
LWC-15-BA- SrF	28.11	3.01	3.67	22.23
LWC-20-BA- SrF	23.88	2.77	3.21	21.11
LWC-25-BA- SrF	21.17	2.57	3.01	20.20

For the plastic aggregate fiber reinforced concrete, the compressive strength decreases with the increases in percentage of PA. The strength decreases from 42.95 MPa to 33.21 MPa, 31.11 MPa, 28.11 MPa, 23.88 MPa and 21.17 MPa for 5%, 10%, 15%, 20% and 25 % replacement of coarse aggregate with PA. The compressive strength values of all the LWC-BA-SrF reinforced concrete satisfied the minimum requirement of structural lightweight concrete (20MPa) for all percentage of replacement of PA.

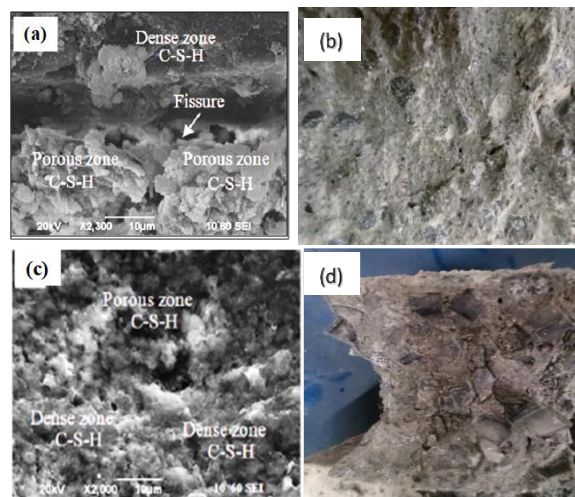


Fig. 10 – (a &c) SEM image of PA concrete showing the dense and porous Calcium-Silicat-Hydrate (C-S-H) region; (b &d) tested PA cube specimen.

4.4 Split tensile strength

The splitting tensile strength values of all the concrete mixes are listed in Table 5. The variation of splitting tensile strength for all the mixes is shown in Figure 11. The splitting tensile strength of control mix was 3.76 Mpa, which increased by 3.5% with the addition of 10% BA. Similar to compressive strength, the tensile strength also showed increase

in the splitting tensile strength for 10% of BA, beyond which the splitting tensile strength decreases. For the fiber reinforced mix, the addition of 3% scrap steel fiber increases the tensile strength from 3.89 to 3.98 MPa. As the steel fibers has higher tensile strength, the fiber binds the aggregate and the cement matrix together, prevents the propagation of cracks and help to improve the tensile strength. For fiber reinforced plastic aggregate concrete, the tensile strength decreases with the increase in the percentage of plastic aggregate. Reduction in the strength properties is due to the hollow shape of aggregate, orientation of the aggregate, bond between the aggregate and cement matrix [31]. The failure of specimen occurred through the failure of plastic aggregate. the cement matrix got filled in the hollow space in the plastic aggregate and results in the formation of lot of honey combs in the specimen, which reduces the strength of concrete. The tested specimen showing the irregular orientation of PA aggregate, honey combing and crushed aggregate after loading can be visualized in Figure 12(a-e). For 5%, 10%, 15%, 20% and 25% PA aggregate scrap steel fiber reinforced concrete the splitting strength was 3.36 MPa, 3.11 MPa, 3.01 MPa, 2.77 MPa and 2.57 MPa. Even though the strength reduces with the increase in the percentage of replacement of PA, the splitting tensile strength recorded for all the plastic aggregate scrap fiber mixes was well within the minimum splitting tensile strength requirement (2MPa) for structural light weight concrete.

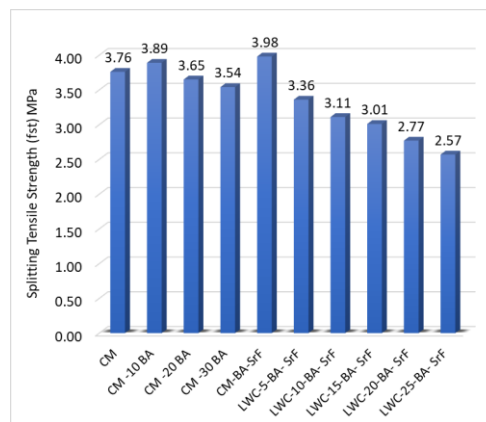


Fig. 11 – Splitting tensile strength of control, BA concrete and fiber reinforced plastic aggregate concrete

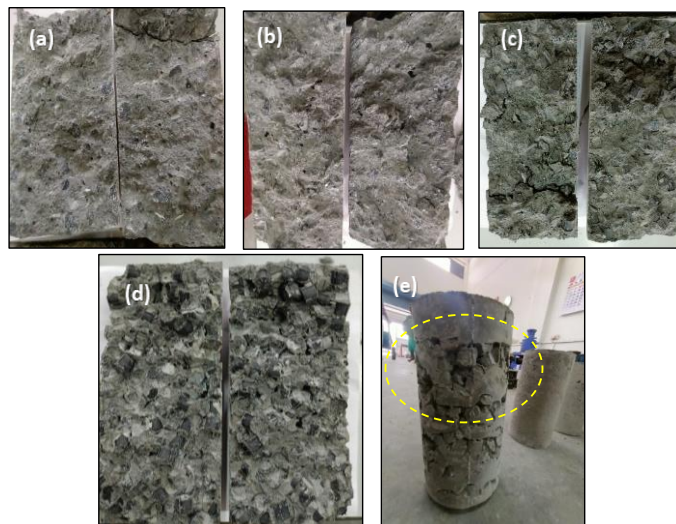


Fig. 12 – (a-e) Failed specimen of 5%,10%,15%,20% plastic aggregate concrete; (f) increase in voids with increase in PA%

4.5 Flexural Strength

The flexural strength of normal and plastic aggregate fiber reinforced concrete is given in Table 5. The flexural strength of control specimen was 4.9 MPa which increased by 8.5% for 10% replacement of cement with BA. Like compression and splitting tensile strength, the flexural strength also increases with the addition of 10% of BA, beyond

which the strength reduces. For the fiber reinforced mix the strength increased by 16 % with the addition of 3% scrap steel fiber when compared to control mix (CM). The post-peak toughness of the beam under flexural load is increase by the addition of fiber. All the fibers embedded in the concrete matrix involves in the stress transfer, till the failure of specimen, which occurs after the ultimate capacity of fibers are reached. The failure pattern of beam is shown in Figure 13. For the PA fiber reinforced mix, the flexural strength values vary from 4.17 MPa, 4.03 MPa, 3.67 MPa, 3.21 MPa and 3.01 MPa for 5%, 10%, 15%, 20% and 25% PA fiber reinforced concrete respectively. The variation of flexural strength is shown in Figure 14. The present flexural strength values agree well with the previous research findings. The linear regression plot to develop a correlation between the compressive strength and flexural strength with high regression value ($R^2 = 0.91$) is shown in Figure 15.



Fig. 13 – Flexural failure of beam with plastic aggregate

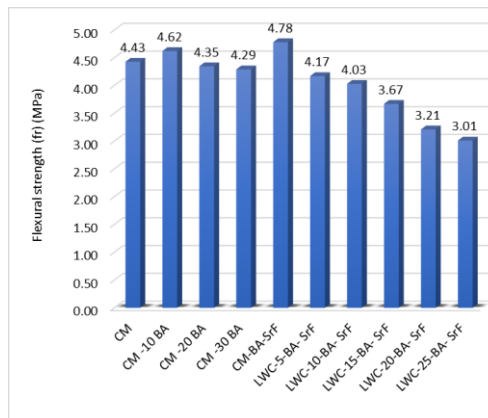


Fig. 14 – Flexural strength of control, BA concrete and plastic aggregate scrap steel fiber concrete

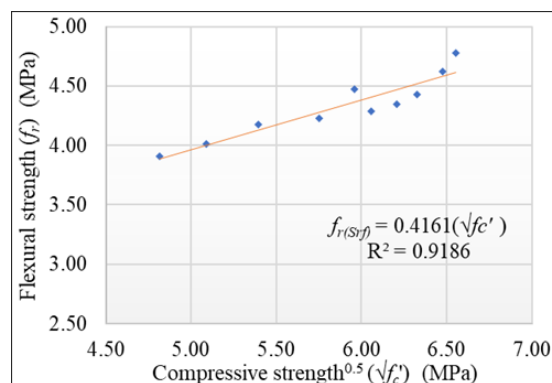


Fig. 15 – Regression plot of flexural strength Vs compressive strength

5 Conclusion

From the experimental investigation carried out to study the fresh and mechanical properties of lightweight plastic aggregate bagasse ash scrap steel fiber reinforced concrete, the following conclusions can be derived. Bagasse ash concrete

mix helps to reduce the self-weight of structural concrete. replacement of coarse aggregate with 25% of plastic aggregate results in the density which is within the limit for lightweight concrete. The slump value of the concrete decreases with the replacement of cement with bagasse ash as the mobility of the concrete mix is reduced by bagasse ash. Addition of plastic aggregate greatly reduces the workability of concrete as the mortar mix are accumulated inside the plastic aggregate. the compressive strength, splitting tensile strength and flexural strength of concrete reduces with the replacement of gravel with plastic aggregate. addition of fibers to the concrete help to increase the tensile property of lightweight plastic aggregate concrete. hence it is concluded that plastic aggregate can be used up to certain limit to produce sustainable lightweight fiber reinforced concrete.

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