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# Effect of Crushed Coconut Shell and Over Burnt Brick on the Mechanical Behaviour of Green Concrete as a Partial Replacement of Coarse Aggregate

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ABSTRACT

*Coarse aggregate (CA) is a major ingredient of the concrete, constituting around 60-75% of total concrete volume in a conventional mix design. The demand for CA is drastically growing, resulting in the diminishing of natural resources, and its extraction demands heavy machinery input, which triggers additional environmental issues. This research investigates the mechanical behavior of green concrete by partially substituting CA with wasted coconut shells (CS) and over-burnt bricks (OB). CS replaces at 5%, 10%, and 15% during the mix design, whereas OB substitutes at 20%, 25%, and 30%. Total 216 specimens were cast in the form of cubes, cylinders, and beams. It was observed that the workability and density of concrete decrease with increasing CS and OB. The compressive strength, split tensile strength, and flexural strength of the specimen decreased in both substitutes with the increasing amount of substituting materials when used individually. However, an increment is found in the mechanical behavior of green concrete when CS and OB were both used at 5% and 20% replacement, respectively. The study has multiple implications for casting eco-friendly or green concrete, such as the reuse of waste materials, reducing the carbon emissions obtained from the extraction of CA, and preserving the natural resources.*

*Keywords: Coarse Aggregates; coconut shell; over burnt brick; mechanical behaviour; concrete; environment*

## INTRODUCTION

Construction is one of the major sectors of industrial growth in any country, which creates several environmental issues, especially in the form of carbon emissions from concrete production. As a result, environmental degradation has been seen as a real occurrence globally due to large-scale construction growth. The construction industry involved a substantial percentage of concrete in almost every project where Coarse Aggregates (CA) form a significant portion of the blend. CAs are extracted from mountains via heavy utilization of machinery. The redevelopment of naturally extracted aggregates requires quite a significant duration which in result causes scarcity of material. Furthermore, the quarrying process causes a negative effect on the environment because of machinery smoke, fuel, noise, and air pollution. The quarrying process strips the land and depletes natural resources as well. In contrast, the construction industry has recently promoted numerous innovative methods to counteract the carbon footprint, such as utilizing natural and industrial waste (Fapohunda et al. 2017; Kang et al. 2019). Nonetheless, most methods do not produce effective outcomes and offer lesser energy-efficient concrete (Sandanayake et al. 2020; Tavakoli et al. 2018). In this regard, various studies suggest the utilization of agricultural and industrial wastes to minimize carbon footprints (Chindaprasirt et al. 2019; Ikponmwosa et al. 2021).

Various agricultural and industrial wastes are prevalent in developing nations like Pakistan, which poses threats to the environment. The safe utilization of such waste is a blessing for the environment. In the past, numerous studies have utilized agricultural and industrial wastages to minimize the carbon footprint. Such research studies include corn cob ash (Binici et al. 2008, 2009), wheat straw ash (Aksoğan et al. 2016; El-Sayed & Shaheen, 2020; Luhar et al. 2019; Prabakar et al. 2004), coconut shell ash (Oyedepo et al. 2015; Pennarasi et al. 2019; Ramesh Kumar & Kesavan, 2020), sugarcane bagasse ash (de A. Mello et al. 2020; Khan et al. 2021), rice husk ash (Adesina & Awoyera, 2019; Lo et al. 2021; Rattanachu et al. 2020), and milet husk ash (Jimoh et al. 2013) as partial replacement of cement, whereas, biomass aggregate (Akhund et al. 2017), coconut shell (Abdulfatah Abubakar 2011; Kanojia & Jain 2017; Olanipekun et al. 2006; Yerramala Ramachandrudu, 2012), palm kernel shell (Olanipekun et al. 2006), jhama class bricks (Patil & Autade 2015), over burnt brick bat waste (Kanchidurai et al. 2017), recycled aggregates (Bheel et al. 2018), etc., for substituting the CA.

Looking at the studies above that utilized agricultural and industrial waste, the utilization of CS as agricultural waste, and OB as industrial waste can be a positive direction for the Pakistan construction sector. The coconut is widely growing in lower Sindh in Pakistan, with 10,168 tonnes per annum. Aggregates formed by breaking CS into desired pieces can be efficiently utilized in concrete by partially alternating gravels up to a limited quantity (Gunasekaran et al. 2015). Using CS as a CA would reduce unit weight and offer a solution for recycling CS waste. Furthermore, this non-biodegradable material can be used in concrete production, which would reduce environmental pollution if utilized rather than wasting it. Apart from CS, the bricks' production contributes to the country's gross domestic products (GDP). It adds around 1.5% in GDP, making it the 3rd largest brick-producing country in South Asia with a yearly production of 45 billion bricks (Bheel et al. 2020). The OB is mostly wasted; however, such bricks can have high strength because of more densely compacted mass because they are burnt at higher temperatures than normal first-class bricks (Apebo et al. 2013).

In the past, several investigations are conducted in an attempt to produce green concrete. (Olanipekun et al. 2006) designed a concrete by mixing the squashed CS and palm shell as a CA substitute. The study observed that a higher percentage of replacing shells reduces the compressive strength; however, CS mix quality offers a higher strength than palm shells. Besides, (Abdulfatah Abubakar, 2011) completely substitutes CA with the CS. The study examined that mechanical properties of mix design reduced to small proportions. In contrast, Gunasekaran (2008) utilized CS as CA in the mix to produce lightweight concrete. Laboratory experiments found that CS displays more resistance against smashing effect in contrast to ordinary crushed stone. Yerramala Ramachandrudu (2012) analyzed the properties of concrete after partially replacing the cement with fly ash and aggregates with the CS. The investigations unveiled that CA with the identical load of fly slag has no impact when contrasted with the properties of relating CS added to concrete. Rajeevan and Shamjith (2015) worked out an optimal percentage of CS aggregates as partial replacement of CA. It was noted that concrete achieved an equal strength to the normal mix at a 15% CS ratio. Kanojia and Jain (2017) added solid particles of CS and found that it reduces the mechanical properties of concrete up to 20% at 28 days of strength. The outcomes affirmed that besides the reduction of strength, the mix could have significant perks in terms of cost efficiency and eco-friendly production of concrete.

Apart from the CS, several studies added burned bricks as a partial replacement of aggregates. Patil and Autade (2015) examined the impact of the fractional substitution of CA by jhama class block in cement concrete. The study invested that there was a small reduction in compressive strength of concrete (i.e., from 6 to 12%) which further improves as the age of concrete increases from 3 to 28 days. Furthermore, the tensile and flexural strength increased by a small proportion from 2.74% to 9%, but it reduced when the amount of substitute agent increased. (Kumar et al. 2017) replaced the normal CA with over burnet bricks and tested compressive strength, elasticity, and flexural performance on various grades of concrete such as M25, M30, and M35. The study found that the properties of concrete were reduced while replacing the CAs with burnt bricks. In contrast, Kanchidurai et al. (2017) found that replacing 25-50% of CA with OB did not lower the quality of concrete.

Overviewing the aforementioned researches witnessed that there are contradictions in the previous findings. Past studies could not truly reflect the appropriate directions of utilizing CS or OB. Furthermore, the combined effect of CS and OB at various percentage replacement of CA is a novel investigation. Moreover, the abundant availability of CS and OB in Pakistan unrest authors to investigate their effects on concrete. Therefore, this study aims to examine the combined effect of locally available CS and OB to investigate various mechanical properties of concrete. Furthermore, this study would fill the large gap in the literature; to the best of our knowledge, none of the similar studies has been carried out to investigate the combined effect of CS and OB.

## SIGNIFICANCE OF THE STUDY

Concrete has evolved into the primary building material of choice for virtually all aspects of construction tasks. Nevertheless, concrete consumes a colossal amount of natural raw materials and generates a considerable carbon dioxide. Different materials are being used to reduce Carbon dioxide emissions and avoid rapid depletion of natural raw materials. Rapid agricultural development has resulted in a massive amount of waste by-products. Owing to the unavailability of proper disposal of these agricultural wastes, agricultural residues have developed into a major environmental concern. This is due to the fact that the majority of industrial wastes are disposed of in open-air dumping sites, which results in land scarcity and pollution of the surrounding environment as the human population grows. Currently, the majority of agriculture and industrial waste products are converted into biomass fuel, and the resulting ash is discarded in landfills. Moreover, waste from agricultural waste, such as coconut shell, can be used to substitute for a variety of concrete ingredients (Bheel et al. 2022). Using agricultural waste as a cementitious, aggregate, and/or filler material can assistance reduce greenhouse gas emissions associated with concrete production, reduced project material costs, alleviate waste disposal pressure, conserve natural resources, and prevent soil and air pollution (Bheel et al. 2022). While the source of stone aggregate remains constant, the resources are excavated daily, resulting in the depletion of stone aggregate. When natural stone deposits become scarce after a few decades, burnt clay bricks will serve as a viable source of coarse aggregate. It is quite frequent to use crushed brick concrete to establish rigid road surface, small - medium to medium-span bridges and culverts, and structures up to six stories high. Nevertheless, bricks can be manufactured in large quantities and are made from readily accessible and reliable materials such as crushed stone aggregate. Brick aggregate concrete has been observed to be significantly lighter than stone aggregate concrete owing to its low unit weight. By substituting brick aggregate for stone aggregate in various components of a building structure, dead load on columns and foundations can be significantly reduced. Thus, substituting brick aggregate for stone aggregate (in part or entirely) may result in a more cost-effective concrete structure.

## MATERIALS AND METHOD

### MATERIALS

Coconut Shell (CS) is utilized as a replacement for coarse aggregates (CA) up to 15%, and Over-burnt brick (OB) is used from 20%-30% as CA replacement in concrete. CS is collected from Hyderabad, Sindh, and OB is obtained from the local kiln of Tando Hyder near Hyderabad, Sindh, Pakistan. Both materials were brought to Department of Civil Engineering MUET Jamshoro and then were crushed with a hammer, separated from a 20 mm sieve, washed, and soaked for 24 hours before mixing in the concrete mix. CS and OB utilized in this experimental study are shown in Figure 1 and Figure 2, respectively. Besides, the locally available Portland Cement (PC) was used as a binding material in the matrix, and the composition of the oxide of PC is represented in Table 1. Moreover, the natural sand were used as fine aggregates (FA), which were passed from the #4 sieve, and crushed stone was utilized as CA, having 20 mm size. These aggregates were collected from Jamshoro, Sindh, Pakistan, and various tests were performed on aggregates before using them, as demonstrated in Table 2. The sieve analysis curve for FA is indicated in Figure 3, while the CA, CS, and OB are illustrated in Figure 4. In addition, the drinking water was utilized for curing and mixing concrete.

Over-burnt brick has water absorption of 4.4%, which is lesser than the allowable range of 8% (Nordin, 2014). The obtained value of aggregate shape tests is within the allowable limit of 45% (Gunasekaran et al. 2015; Patil and Autade, 2015). CS being an agricultural product has a very high absorption value because of its porous structure (Yerramala Ramachandrudu, 2012).

FIGURE 1. Crushed coconut shell

FIGURE 2. Crushed over-burnt brick

TABLE 1. Oxides composition of PC

| Oxides (%) | | | | | |
|---|---|---|---|---|---|
| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | $Na_2O$ | $SO_3$ |
| 20.78 | 5.11 | 3.17 | 60.22 | 0.18 | 2.86 |

TABLE 2. Laboratory tests conducted on FA, CA, OB, and CS

| Material | Fineness Modulus ASTM C136 | Water Absorption ASTM C128 | Specific Gravity ASTM C128 | Flakiness Index ASTM C1252 | Elongation Index ASTM C1252 |
|---|---|---|---|---|---|
| Fine Aggregate | 2.9 | 0.55% | 2.59 | - | - |
| Coarse Aggregate | 7.6 | 1.27% | 2.61 | 40% | 38.5% |
| Over-burnt Brick | 7.7 | 4.4% | 2.15 | 43% | 41% |
| Coconut Shell | 7.9 | 17.75% | 1.3 | 38% | 36% |

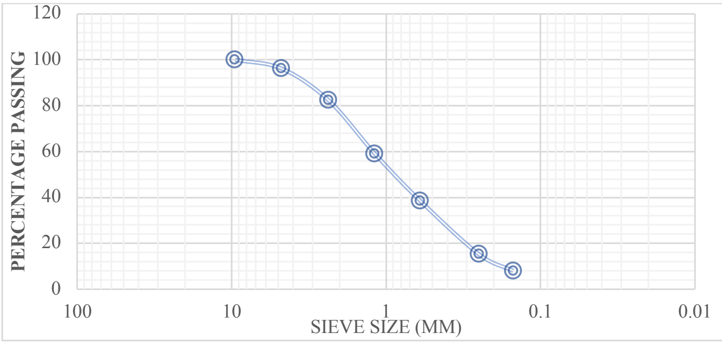


FIGURE 3. Sieve Analysis for FA

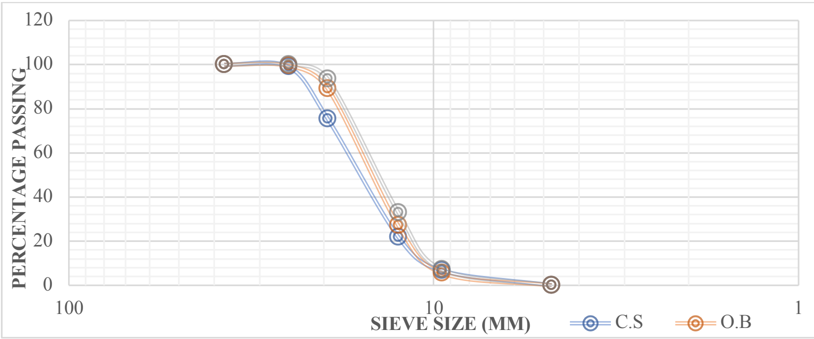


FIGURE 4. Sieve analysis for CA, CS, and OB

## RESEARCH METHODOLOGY

This research work was performed on all mixtures of concrete incorporating with 5%-15% of coconut shell (CS), 20%-30% of over burnt brick (OB), and 5% of CS along with 20% of OB as a replacement for CA in concrete for determining the fresh, physical, and mechanical properties of concrete. However, a total of 216 concrete specimens were equipped to achieve the targeted strength of 25MPa at a 0.55 water-cement ratio. For this experimental setup, cubes were cast to investigate compressive strength, cylinders were tested for split tensile strength, and beams were cast to analyze the flexural strength of concrete after 7, 14, and 28 days of curing, respectively. Moreover, the concrete specimens were prepared for checking the density and water absorption of concrete at 28 days in the age of curing correspondingly. The detail of specimens is illustrated in Table 3, where samples were tested for control mix (CM), CS replacement at 5% (CS5), 10% (CS10), and 15% (CS15). Similarly, the samples were examined with replacement of OB at 20% (OB20), 25% (OB25), and 30% (OB30). In last, after testing optimum percentages of CS and OB are combined used with 5% replacement by CS and 20% replacement by OB (OB20CS5).

TABLE 3. Mix proportion of concrete

| Specimen ID | Coarse Aggregates Content (%) | | | Amount of Material Required to Produce 1 m$^3$ Concrete (Kg) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | CA | CS | OB | PC | CA | CS | OB | FA | Water |
| CM | 100 | 0 | 0 | 372.73 | 1062.72 | 0 | 0 | 769.55 | 205 |
| CS5 | 95 | 5 | 0 | 372.73 | 1009.58 | 53.14 | 0 | 769.55 | 205 |
| CS10 | 90 | 10 | 0 | 372.73 | 956.45 | 106.27 | 0 | 769.55 | 205 |
| CS15 | 85 | 15 | 0 | 372.73 | 903.31 | 159.41 | 0 | 769.55 | 205 |
| OB20 | 80 | 0 | 20 | 372.73 | 850.18 | 0 | 212.54 | 769.55 | 205 |
| OB25 | 75 | 0 | 25 | 372.73 | 797.04 | 0 | 265.68 | 769.55 | 205 |
| OB30 | 70 | 0 | 30 | 372.73 | 743.90 | 0 | 318.82 | 769.55 | 205 |
| OB20CS5 | 75 | 5 | 20 | 372.73 | 797.04 | 53.14 | 212.54 | 769.55 | 205 |

## PROCEDURES FOR TESTING

### SLUMP TEST

A slump test was conducted on all mixtures of fresh concrete, including several replacement levels of CA with CS and OB separate and combine in the concrete by conforming to BS EN 12350-2 (British Standards Institution, 1983) code.

### MECHANICAL PROPERTIES OF CONCRETE

The water absorption and density of hardened concrete were performed on concrete, including 5%-15% of CA replaced with CS; 20%-30% of CA replaced with OB, and 20% of OB along with 5% of CS as CA replacement in concrete by following BS 1881 (British Standards Institution, 2000) and BS EN 12390–7 (BSI, 2009a) procedures, respectively.

However, the cubical samples (100mm x 100mm x 100mm) were prepared for determining the compressive strength, and cylindrical specimens (200 mm x 100 mm) were made for exploring the splitting tensile strength of concrete with the addition of CS and OB as CA separate and together in concrete by following the BS EN 12390-3 (BS, 2009) and BS EN 12390-6 (BSI, 2009b) code practice correspondingly. Similarly, flexural strength was performed on beams (100 mm x 100 mm x 500 mm) samples of concrete prepared with CS and OB as a replacement for CA individually and combined in mixture by obeying BS EN 12390-5 (BSI, 2009b) code practice. These all-concrete samples were cured and tested at 7, 14 and 28 days. The experimental setup of concrete testing is shown Figure 5.

(a) Slump test

(b) Compressive strength test

(c) Split tensile strength test

(d) Flexural strength test

FIGURE 5. Experimental setup of concrete testing

## RESULTS AND DISCUSSIONS

### SLUMP TEST

The slump test measures the consistency of concrete that changes the concrete ingredients into the uniform mix. The workability of the concrete mix made of 5%-15% of CA replaced with CS; 20%-30% of CA as replaced with OB, and 5% of CS and 20% of OB as a replacement for CA in concrete as indicated in Figure 6.

The slump is noted as 10.20%, 15.9% and 18.8% at 5%, 10% and 15% of CA replaced with CS. Furthermore, 23.18%, 27.54%, and 31.88% at 20%, 25%, and 30% of CA replaced with OB and 34.78% at 5% of CS along with 20% of OB as a replacement for CA are lower than that of control mix concrete, respectively. The results unveil that the replacement of CA with CS and OB separate and combined increases in the mixture, resulting in dropping the workability of fresh concrete. There is a reduction in a slump because OB and CS used as aggregates absorb more water than natural CA. This opinion is explored by Mhatre et al. (2019) that the slump of green concrete is dropped as the CS content as CA rises in concrete. Bolouri Bazaz and Khayati (2012) stated that the quantity of recycled aggregates is increased in concrete, resulting in a decrease in mixture workability. Bheel et al. (2020) examined that the slump is dropped as the replacement of CA with brick waste (BW) rises in concrete.  Moreover, the desirable workability of concrete incorporating OB and CS as a replacement for CA is required in the construction industry by using water-reducing admixture in the mixture to improve the flow of green concrete.

### COMPRESSIVE STRENGTH

Figure 7 indicates the compressive strength of concrete at 5%-15% of CA replaced with CS; 20%-30% of CA as replaced with OB and 5% of CS along with 20% of OB as a replacement for CA in concrete at 7, 14, and 28 days, respectively. The optimum compressive strength is recorded as 25 N/mm², 28.17 N/mm², and 31.28 N/mm² for the control mix concrete, and the lowest compressive strength is measured as 15.80 N/mm², 17.83 N/mm², and 21.74 N/mm² at 15% of CA replaced with CS after 7, 14, and 28 days, respectively. The experimental outcome witnessed that the compressive strength of green concrete mix is reduced as CA replacement with CS increases in concrete. Verma et al. (2019), George et al. (2016), and Kanojia and Jain (2017) described that the compressive strength falls as the replacement of CA with CS increases in concrete. Similarly, the highest compressive strength is estimated as 21.65 N/mm², 26.21 N/mm², and 28.67 N/mm² at 20% of OB as a replacement for CA, and minimum strength is noted as 19.50 N/mm², 23 N/mm², and 24.35 N/mm² which are lower than that of the control mixture after 7, 14 and 28 days, respectively. The obtained results show that the compressive strength of green mix is decreased with replacing in the content of CA with OB increases in concrete. Moreover, the compressive strength of green mix is noted as 16.32 N/mm², 22.70 N/mm² and 25 N/mm² at 5% of CS along with 20% of OB as replacement for CA in concrete which is lesser as compared to concrete without replacement of CA at 7, 14 and 28 days, respectively.

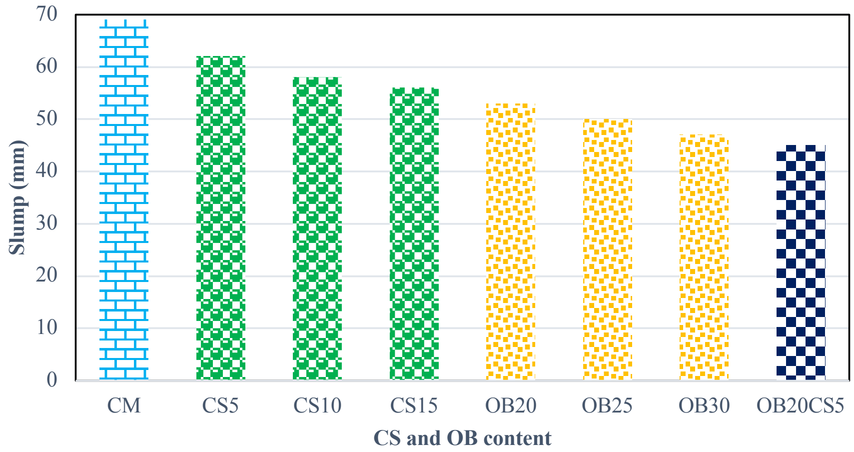


FIGURE 6. Workability of concrete

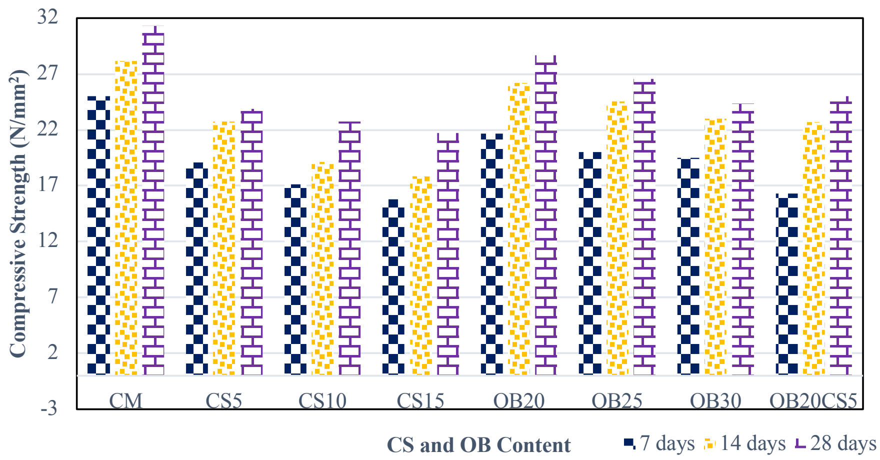


FIGURE 7. Compressive strength of concrete

There is a reduction in compressive strength owing to the improper interlocking of the aggregate particles in concrete. On the contrary, the reduction in compressive strength may be attributed to the lower compressive strength of OB and CS. Furthermore, the reduction in strength may be associated with the porosity of CS and OB, which absorb a high amount of water comparing to CA in concrete. Nevertheless, the compressive strength of all mixtures calculated is more than 17 N/mm²; henceforth, appropriate for structural applications (Neville & Brooks, 2010). These interpretations associate with comparable findings wherever construction and demolition wastes were utilized as CA (Adesina and Awoyera, 2019; Corinaldesi, 2011). Bheel et al. (2018) stated that the compressive strength is reduced as the replacement of CA with BW increases in concrete at 28 days.

### SPLITTING TENSILE STRENGTH

Figure 8 indicates the split tensile strength of concrete at 5%-15% of CA replaced with CS; 20%-30% of CA as replaced with OB, and 5% of CS along with 20% of OB as a replacement for CA in concrete at 7, 14, and 28 days, respectively. The optimum split tensile strength is recorded as 2.0 N/mm$^2$, 2.20 N/mm$^2$, and 2.30 N/mm$^2$ at control mix concrete, and the lowest strength is measured at 1.47 N/mm$^2$, 1.58 N/mm$^2$, and 1.88 N/mm$^2$ at 15% of CA replaced with CS after 7, 14, and 28 days, individually. The examination of results finds the split tensile strength of green concrete mix is lowered as the replacement of CA with CS increases in concrete. George et al. (2016) stated that the compressive strength falls as the replacement of CA with CS increases in concrete. Similarly, the highest split tensile strength of green mix is achieved as 1.97 N/mm$^2$, 2.1 N/mm$^2$, and 2.20 N/mm$^2$ at 20% of OB as a replacement for CA, and minimum strength is noted as 1.47 N/mm$^2$, 1.80 N/mm$^2$, and 2.05 N/mm$^2$, which are lower than the control mixture after 7, 14 and 28 days, respectively. The investigation portrays that compressive strength of green mix decreases with replacing in the content of CA with OB increases in the concrete mix.

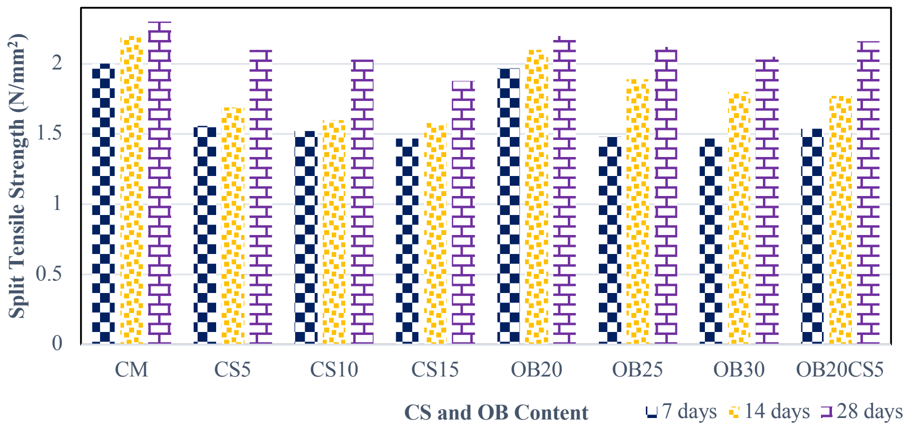


FIGURE 8. Splitting tensile strength of concrete

### FLEXURAL STRENGTH

Figure 9 indicates the results of beam testing with incorporating 5%-15% of CA replaced with CS; 20%-30% of CA as replaced with OB, and 5% of CS along with 20% of OB as a replacement for CA for measuring the flexural strength at 7, 14 and 28 days, respectively. The highest flexural strength of the green mix is recorded as 3.15 N/mm$^2$, 3.75 N/mm$^2$, and 4.52 N/mm$^2$ for the control mix concrete, and the lowest flexural strength is measured as 2.46 N/mm$^2$, 2.69 N/mm$^2$, and 3.33 N/mm$^2$ at 15% of CA replaced with CS after 7, 14, and 28 days, respectively.

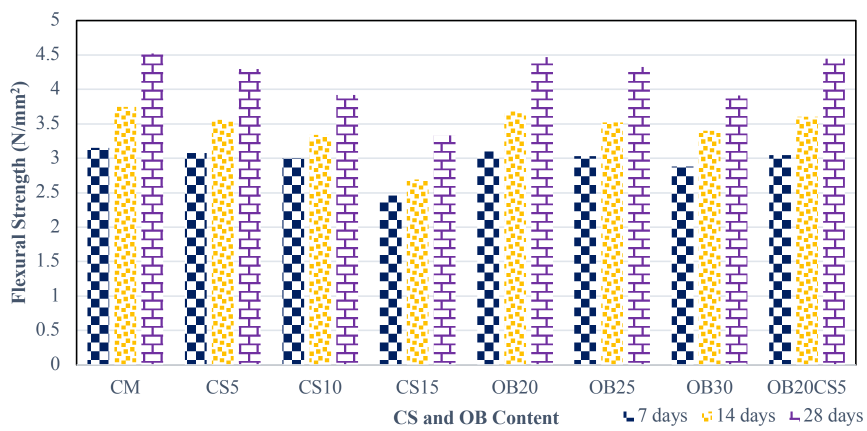


FIGURE 9. Flexural strength of concrete

The result witnessed that the flexural strength of green concrete reduces as the replacement of CA with CS increases. George et al. (2016) reported that the flexural strength drops as the replacement of CA with CS increases in concrete. Similarly, the highest flexural strength is measured as 3.10 N/mm$^2$, 3.68 N/mm$^2$, and 4.47 N/mm$^2$ at 20% of OB as a replacement for CA, and minimum strength is noted as 2.88 N/mm$^2$, 3.40 N/mm$^2$, and 3.91 N/mm$^2$ at 30% of OB, which are lower than the control mixture after 7, 14, and 28 days, respectively. The results indicate that flexural strength decreases while replacing the content of CA with OB increases in concrete. Moreover, the flexural strength is noted as 3.05 N/mm$^2$, 3.60 N/mm$^2$, and 4.45 N/mm$^2$ at 5% of CS and 20% of OB as a replacement for CA in concrete, which is lesser than concrete without replacement of CA at 7, 14, and 28 days, respectively. There is a decrease in flexural strength due to the improper interlocking of the aggregate particles in concrete. On the other hand, the decrement in the flexural strength of concrete blended with CS and OB as aggregates replacement increases in concrete is due to lower crushing strength of CS and OB as compared to the natural coarse aggregates. From the literature, it has been observed that the use of CS and OB as aggregates in concrete which produces the improper interlocking among the ingredients of concrete. Moreover, the water absorption of CS and OB is more than that of CA therefore it make fresh concrete mix hard that results in improper interlocking among the concrete ingredients. In addition, the reduction in compressive strength may be attributed to the lower compressive strength of OB and CS. Related findings of experimental work were performed by replacing CA with recycled aggregates in concrete (Choi and Yun, 2013; Gurdián et al. 2014)and natural coarse aggregate substitution by recycled aggregate. The aim is to evaluate the behavior of concretes with a reduced impact on the environment by replacing a 50% of cement by industrial by-products (15% of spent fluid catalytic cracking catalyst and 35% of fly ash. Also, Bheel et al. (2018) stated that the flexural strength is reduced as the replacement of CA with BW increases in concrete at 28 days.

## WATER ABSORPTION

The concrete samples are made at 5%-15% of CA replaced with CS; 20%-30% of CA replaced with OB and 5% of CS along with 20% of OB as a replacement for CA in concrete for measuring the water absorption of concrete at 28 days as indicated in Figure 10. The water absorption of green concrete mix is noted as 2.98%, 3.42%, and 3.82%, at 5%, 10%, and 15% of CA replaced with CS in a mixture which is higher as compared to concrete without replacement of CA at 7, 14, and 28 days, respectively. Similarly, the water absorption is recorded as 2.29%, 2.48%, and 2.75% at 20%, 25%, and 30% of CA replaced with OB in concrete which is higher than the control mixture after 7, 14, and 28 days, respectively. Moreover, the water absorption of green concrete found as 2.42% at 5% of CS along with 20% of OB as a replacement for CA is greater than the control mix concrete at 28 days. The findings suggest that the replacement of CA with CS and OB separate and combined increases in the mixture that results in improving the water absorption of green concrete. This increment in water absorption is associated with the high porosity of CS and OB materials as compared to CA. As a result, these materials absorb a high amount of water with an increase in the content of CS and OB in concrete. This opinion is explored by Mhatre et al. (2019) that the water absorption of concrete is increased as the CS content as CA increases in concrete. This opinion is also investigated by Azunna and Ogar (2021) that the quantity of OB aggregates is increased in the mixture that results in an increase in water absorption of concrete.

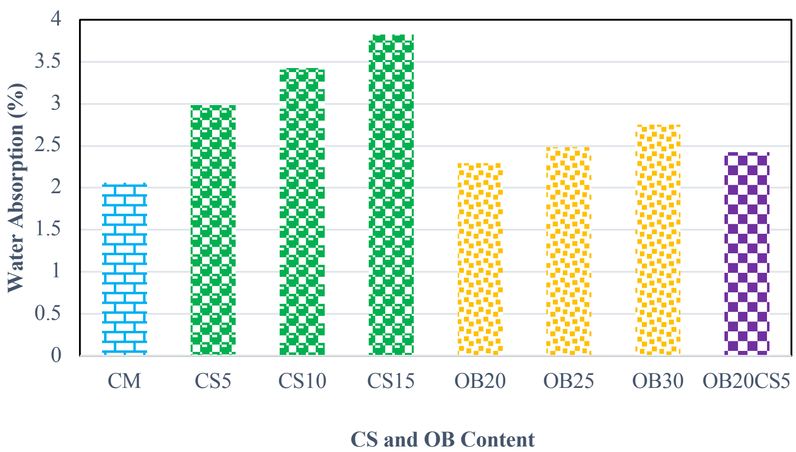


FIGURE 10. Water absorption of concrete

DENSITY OF CONCRETE

Figure 11 illustrates the density of concrete incorporating 5%-15% of CA replaced with CS; 20%-30% of CA replaced with OB, and 5% of CS along with 20% of OB as a replacement for CA in concrete at 28 days. The density of green mix concrete is noted as 2320 kg/m$^3$, 2270 kg/m$^{3,}$ and 2238 kg/m$^3$ at 5%, 10%, and 15%, respectively of CA replaced with CS in the mixture, which is lower as compared to concrete without replacement of CA at 28 days, correspondingly. Kanojia and Jain (2017) stated that the density of concrete drops as the content of CS comparing to CA increases in concrete. Similarly, the water absorption is estimated as 2318 kg/m$^3$, 2293 kg/m$^{3,}$ and 2273 kg/m$^3$ at 20%, 25%, and 30%, respectively of CA replaced with OB in concrete which is lesser than the control mixture after 28 days. Moreover, the water absorption is recorded as 2220 kg/m$^3$ at 5% of CS along with 20% of OB as a replacement for CA, which is lesser than the control mix concrete at 28 days. The obtained results demonstrated that the density of concrete reduces as the percentages of CA replaced with CS and OB increases in green concrete. This reduction in density due to the less specific gravity of CS and OB than that of natural CAs. Moreover, less weight of OB and CS particles may cause a decline in density.

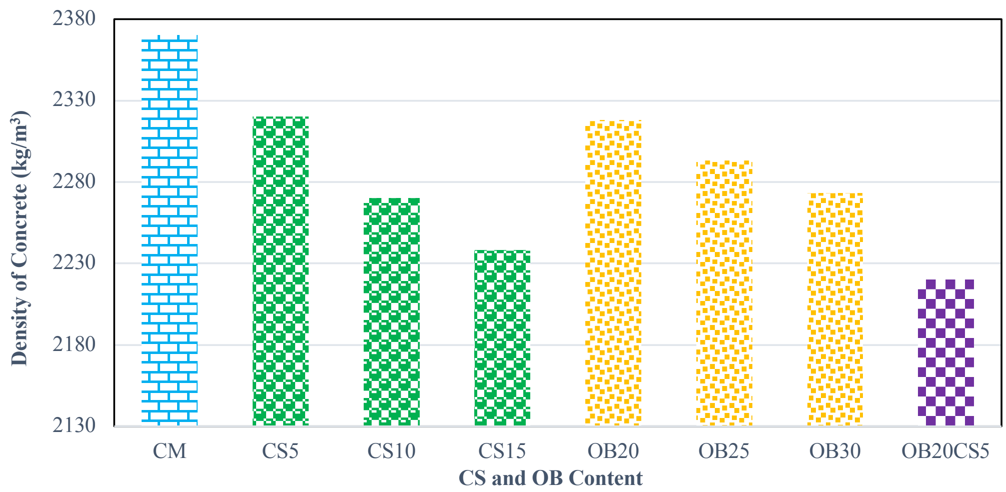


FIGURE 11. Density of concrete

Therefore, the usage of CS and OB as CA in concrete could be utilized to have concrete with a lower weight. This aspect is related to that of Bheel et al. (2018) that the density of concrete is decreased as the replacement of CA with BW increases in concrete at 28 days. Azunna and Ogar (2021) stated that the quantity of OB aggregates is increased in the mixture, resulting in a decrease in the density of concrete.

CONCLUSIONS

This experimental work is performed by incorporating CS and OB as a replacement for CA individually and combined to investigate the fresh, physical, and hardened properties of concrete. The following conclusions can be made from the experimental investigations:

- The workability of green concrete is reduced while the replacement level of CA with CS and OB content separate and combine rises in concrete. This reduction is due to the porosity of CS and OB materials that absorb more quantity of water which led to a decline in the limited supply of water for the flow of concrete.
- The compressive strength, split tensile strength, and flexural strength of concrete is decreased with incorporating CS and OB as a replacement for CA separate and together with increases in concrete at 7, 14, and 28 days, respectively. There is a decrease in strength due to the improper interlocking of the aggregate particles in concrete. On the contrary, the reduction in strength may be attributed to the lower strength of OB and CS. Furthermore, the reduction in strength may be associated with CS and OB porosity, which absorb a high amount of water than that of CA in concrete.
- The replacement of CA with CS and OB separate and combine increases in the mixture that results in improving the water absorption of concrete. This increment in water absorption is associated with the high porosity of CS and OB materials compared to CA; therefore, these materials absorb a high amount of water with an increase in CS and OB content in concrete.
- The density of concrete is dropped as the replacement of CA with CS and OB content individually and combined in concrete. This reduction in density is due to the less specific gravity of CS and OB than the natural CAs. Moreover, the lesser weight of OB and CS particles may cause a drop in density. Therefore, the usage of CS and OB as CA in concrete could be utilized to have concrete with a lower weight.
- Based on the conducted research work, it is concluded that the use of 5% CS along with 20% of OB as a replacement for CA in concrete could provide satisfactory outcomes for structural application.

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DECLARATION OF COMPETING INTEREST

None

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