OPEN ACCESS

Saudi Journal of Civil Engineering
Abbreviated Key Title: Saudi J Civ Eng
ISSN 2523-2657 (Print) | ISSN 2523-2231 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com/journal/sjce/home

Original Research Article

Assessment of the Performance of Crushed Cow Bones as a Partial Replacement for Coarse Aggregate for Concrete

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DOI: 10.36348/sjce.2024.v08i03.001 | **Received:** 13.02.2024 | **Accepted:** 25.03.2024 | **Published:** 30.03.2024

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Abstract

Researches have been geared at not only ameliorating the rising cost of providing affordable housing units to the ever increasing populace but also tackling global challenges such as climate change, environmental degradation, pollution, biodiversity and others concerns and animal bones which have posed challenges through its disposing, treating and processing is the focus of this research by investigating the possibility of its use as coarse aggregate in concrete. Animal bones were crushed in sizes ranging from 10-20mm, these crushed cow bone (CCB) aggregate, were used in concrete specimens as a partial replacement for conventional aggregates in percentages 0%, 5%, 10%, 20%, 25%, and 30%. The particle size distribution of fine aggregates, granite, and cow bone aggregate will be determined in line with BS EN 933-2:2020. Slump test was executed in line with the provisions of BS EN 12350 Part 2: (BSI, 2019). The compressive strength test was carried out using concrete cube (150 mm) specimens in line with the provisions of British Standard codes for concrete (BS EN 12390-3 (BSI, 2019) and cured by immersion for 7, 14, and 28 days. The results of the compressive strength of the concrete made with different percentages of CCB showed very promising strengths between 5- 15% but with optimal strength values at 15% replacement. This implies that CCB can be used to ease the cost of construction in the use of coarse aggregates provided its use is limited to 15% replacements.

Keywords: Cow bones, concrete, compressive strength, sieve analysis.

INTRODUCTION

Concrete is an essential part in the construction industry and with surge in the usage in modern structures. The constituents of concrete are cement and aggregate with addition of water; the aggregate can be divided into fine and coarse aggregate. There has been drastic soar in the prices of construction materials that have made researchers to concentrate widely on the use of eco-friendly materials that can suitably replace some of these expensive construction materials. Steel reinforcement, an important part of reinforced concrete has now been replaced fibers (Soyemi & Abbas, 2021), bamboo has also been used for reinforcing concrete (Ghavami, 2005), seashells as substitutes for coarse aggregate (Bamigboye, *et al.*, 2020), Polyethylene terephthalate was also used in concrete as a coarse aggregate (Rahman. *et al.*, 2020). Some of the materials that have been used to replace fine aggregates are copper slag (Frigione, 2010), plastic fines (Ullah, *et al.*, 2022), Volcanic ash (Karolina, *et al.*, 2015). Some materials that have been used for cement includes rice husk ash (Soyemi & Adegbesan, 2020), Guava leaf ash (Adegbesan, *et al.*, 2020). All these researches are geared at ameliorating the rising cost of providing affordable housing units to the ever increasing populace.

Concrete is made of materials such as cement, aggregates (fine and coarse) with distinctive individual characteristics whose combination will give a material with characteristics that differs from its constituents. The reason, concrete is classified as composite material where the aggregates are bond with cement paste after thorough mixing and then hardens with time. Structural elements in a building made of concrete can be of different shapes and sizes. Concrete in its hardened state is resistant to water with less production cost. Concrete construction can be made to be plain, but this type of concrete can only take care of compressive stresses and reinforced when the bending stresses are to be considered. Aggregates, are size biased, with some being fine 0.06 mm-2.0 mm and some having larger sizes 4 mm – 64 mm. Those having larger sizes are classified as coarse and are the main matrix while those having fine sizes are known as fine aggregate whose major function are to form filler matrix. Aggregates occupy approximately between 70 -80% of the volume of the concrete with the coarse aggregates being classified as according to shape as rounded, irregular, flaky, elongated and combination of flaky and elongated.

The need to tackle global challenges such as climate change, depletion of natural resources, pollution, biodiversity, environmental degradation, and others concerns have necessitated conversion of abattoir wastes to wealth by leveraging on the challenges posed by the disposing, treating and processing of wastes especially the bones by using them as suitable substitute for coarse aggregates in concrete. The investigation is aimed at determining the viability of using crushed cow bones in place of coarse aggregate in concrete, either partially or completely. This will be in accordance with BS EN 933-2:2020, BS EN 12350-2:2019 and BS EN 12390-3:2019 for particle size distribution, workability and compressive strength respectively.

Many experiments have been conducted that by adding new materials, which could be organic, recycled, or synthetic, to concrete can enhance its properties. The additional (new) material may serve as an additive, a replacement for cement or aggregate or, or both; however, a lot of these supplementary materials are deployed as aggregate in the formation of lightweight concrete. Diatomite, volcanic cinders, pumice, scoria, and tuff are the main natural lightweight aggregates (LWAs) (Aka, *et al*., 2008). According to Polat *et al*., (2010), using LWA is the most prevalent way to create light weight concrete (LWC).

A significant amount of researches has been undertaken on lightweight concrete structural performance, however, most of this research has been limited to naturally formed, manufactured and industrial byproducts aggregates. Numerous accomplishments have been completed in this section, and the topic is gaining popularity due to the functional benefits of reusability of waste and sustainable development. The ability to produce light-weight structures and reduce construction costs are additional benefits.

Many research conducted in recent years (Mannan and Ganapathy, 2004; Olaoye, *et al.,* 2011; Traore, *et al.,* 2018; Adesina, *et al*., 2020) on the usage of palm kernel shells (PKS) as lightweight aggregate (LWA) to create lightweight concrete (LWC). Crushed clinker bricks were also used as coarse aggregate in concrete by Khaloo (1994). When compared to natural aggregate concrete, he found that concrete's compressive strength only decreased by 7%. In addition to the decrease in strength, the crushed brick concrete unit weight decreased by 9.5%. Semi-lightweight concretes made with volcanic slag as coarse aggregate were also studied, and it was discovered that making semi-lightweight concrete with volcanic slag is safe (Topcu, 1997). Concrete's cost is decreased when lightweight aggregate made of a mixture of grained palm kernel shell (GPKS) and coconut shell was used (Tukiman and Sabarudin, 2009). Fly ash, blast furnace slag, expanded slate, expanded shale, scoria, pumice, and crushed animal bones are a few examples of lightweight aggregates. To achieve the desired light weight concrete, coarse aggregate was partially replaced by crushed bones in the current study.

Since using naturally formed aggregates leads to environmentally degradation and depletion of natural resources, a diversity of recycled waste constituents and explored as aggregates in concrete (Medina, *et al.,* 2014), saw dust (Oyedepo, *et al*., 2014), fly ash (Kou, and Poon, 2013); Clay (Farzadnia, *et al.,* 2013); waste glass (Castro, and Brito, 2013); Plastic waste (Saikia, and De Brito, 2012; Sule, *et al.,* 2017)) and animal bones (Akinyele, *et al.,* 2020). Several studies conducted to explore the impact of the use of glass waste as a replacement for concrete constituents on the behaviour of the concrete, and it has been discovered that the inclusion of glass waste affects the strength and the workability of the concrete (Park, *et al.,* 2004; Petrounias, *et al*., 2019).

Chen, *et al*., (2018), Tamanna, and Tuladhar (2020) conducted research on using waste glass cullet (WGC) in concretes, looking at how the different amounts of WGC affect the concrete properties by partly replacing natural aggregates. Furthermore, the use of recycled ceramic tile waste as aggregate in concrete helps to alleviate industrial waste disposal issues while also preserving natural aggregate resources (Adeala, and Omisande, 2021; Medina, *et al*., 2014). Several researchers have tried replacing fine and coarse natural aggregates partially or entirely. (Pacheco-Torgal, and Jalali, 2011; Akinboboye, *et al*., 2015), examining the properties of the concrete that was produced and, in particular, making use of the unique qualities of tile waste particles. In addition to being a typical by-product of asphalt road rehabilitation, crushed asphalt has been utilised to partially replace natural aggregates in concrete, lowering waste storage, which has improved significantly lately (Copola, *et al*., 2016).

Animal bones are considered as waste and can be considered for use in concrete as a replacement for either fine or coarse aggregates. Goats, sheep, and cows are among the animals utilized to make meat-based foods in the modern era. Large numbers of these waste bones are just carelessly dumped in pits and trash cans, harming the environment and polluting both land and water. It is required to investigate the possibility for animal bones to be used constructively in the production of concrete, nonetheless more importantly, to study its application in the provision of excellent structural elements for constructions purposes. As a result, these (crushed) bones have been used to try and find out how animal bones affect concrete. Bhat *et al*., (2012) worked on using mechanically crushed animal bones to replace some of the coarse aggregates in lightweight concrete. Fapohunda, *et al.*, (2016) carried out an study into the viability of using crushed cow bone (CCB) as a substitute for some of the fine aggregates used to make concrete, with the results revealing a decrease in the flow of concrete with a rise in the proportion of CCB replacing sand. The use of crushed cow bones (CCB) likewise produced harsh mixes with slump of low workability. The concrete specimens' density decreased as the percentage of sand replaced by CCB increased. Depending on the density achieved, using CCB in place of some of the sand can produce various types of concrete.

Housing is one of the most basic necessities of life, ranking second only to food in importance to man (Falade and Ikponmwosa, 2006). Governments at various levels have made efforts to carry out a policy of direct intervention in the provision of shelter by constructing low-cost housing units. Significant progress in these schemes appeared to be impossible due to challenges posed by the continued rise in the cost of conventional structural materials as well as geometrical population growth, particularly in urban areas. This has prompted a search for alternative, less expensive materials. Affordable building materials are required to provide adequate housing for the world's growing population. The cost of conventional materials for construction continues to rise as the majority of the population stays impoverished. As a result, there is a need to look for indigenous resources as substitutes for building but cost effective. The cost of granite or gravel, an essential component of concrete, is becoming unsettling, and many investigations have been carried out on finding alternatives that can wholly or partially replace the granite/gravel in concrete while still performing satisfactorily. One such example is the use of crushed cow bone.

Table 1: Aggregates' physical characteristics

Properties	crushed animal bone (CAB) Aggregate	Normal Aggregate
Max. aggregate size, mm	20	20
Bulk density, Kg/m3	822	1510
Sp. gravity (SSD)	1.61	2.65
Fineness modulus (FM)	6.66	6.59
1-day water absorption (%)	4.00	0.20
Aggregate crushing value (%)	22.0	16.8

MATERIALS AND METHODS

Animal bones were machine crushed in sizes ranging from 10-20mm and for the purposes of the current work to produce aggregates known as crushed cow bone (CCB) aggregate. These CCB aggregates were used in concrete specimens as a partial replacement for traditional aggregates. The replacement percentages will be 0%, 20%, 40%, 60%, 80%, and 100% where 0% serves as control specimen. Fine aggregate (river sand) and coarse aggregates (crushed granite aggregates, 10-20mm in size) were used in the concrete specimen for the investigation.

Preliminary tests were accompanied in order to determine some properties of the concrete constituents and they include the following: sieve analysis of fine aggregates, granite, and cow bone aggregate will be determined in compliance with BS EN 933-2:2020. This was accomplished by passing each material through the sieve set manually shaken thoroughly. The aggregate's properties will be determined by plotting the cumulative percentage passing on semi-logarithmic graph paper.

The concrete mix C20 (1: 1.5: 3; cement: sand: granite or CCB), was used with water/cement ratio of 0.45. Nominal mixtures are regular mixtures of stable cement, fine aggregate (sand), and aggregate proportions that guarantee adequate strength. Standard blends make things simple and, under normal circumstances, have a stronger strength margin than required.

Figure 1: Workability test

The evaluation of the workability and freshness properties of concrete with CCB as a partial replacement of coarse aggregates was carried out through the slump test in line with the requirements of BS EN 12350 Part 2: (BSI, 2019). The test will be used to detect changes in workability as the percentage of CCB in the concrete increases. It was performed using a 300mm high cone in which fresh concrete will be poured into the cone (which will be placed on a flat impervious platform) and carefully compacted in three layers using a tamping rod (with 25 blows each) before the cone is removed. The difference in height between the concrete after the cone is removed and the cone will indicate the type of slump.

Nine cubes [150mm] were used for each mix of specimens. The concrete was cast into various mixes at 0%, 5%, 10%, 15%, 20%, 25%, and 30% replacement. After 24 hours, the specimen was demoulded, labeled, and placed in a room-temperature water mixture to cure. The compressive strength of the cubical mould was tested on the 7th, 14th, and 28th days using the universal testing machine [UTM].

The compressive strength test was undertaken on concrete cube specimens. After 7, 14, and 28 days of moist curing, the cube specimens were tested. After being removed from the curing tank, the specimens were allowed to dry for about two hours. Each cube's compressive strength characteristics is then determined. Three (3) specimens for each curing age will be crushed to failure and the failure load will be documented. The average failure load of the three specimens was calculated and recorded.

Figure 2: Cast cubes of crushed cow bones

Figure 3: Compressive strength machine

RESULTS AND DISCUSSION

The results and discussion of both the preliminary and the actual concrete test carried out in order to make necessary contributions towards the possibility of CCB being used as a replacement for coarse aggregate in concrete.

The results of preliminary test which includes the sieve analysis, and slump test are presented Tables 2-4 and Figures 4 & 5.

Table 2: Sieve Analysis of fine Aggregate [Sand]

Sieve size	Weight retained (g)	Weight passing (g)	Percentage passing (g)
5mm	2.03	197.97	98.99
4.76mm	1.15	196.82	98.41
2.36mm	9.65	187.17	93.59
2mm	7.88	179.29	89.65
1.18mm	24.98	154.31	77.16
600µm	59.47	94.84	47.42
425µm	47.16	47.68	23.84
300µm	25.19	22.49	11.25
212µm	13.22	9.27	4.64
150µm	5.89	3.38	1.70
63µm	2.96	0.42	0.21
Residue	0.42	0.00	0.00

Coefficient of uniformity (Cu) = D60/D10
=0.8/0.3
=2.67

Coefficient of curvature (Cz) = $D^230/(D60.D10)$
$= 0.47^2/(0.8\times0.3)$
= 0.92

The coefficient of uniformity and curvature of 2.67 and 0.92 respectively falls below the value for well graded sample of 4 - 6 and 1 – 3 for Cu and Cc respectively which indicate a not well graded fine aggregate.

200g of river sand was poured into the sieve set for sieve analysis test. The sieve analysis provide an insight into the particle distribution of the fine aggregate, by size, within the given sample. From the result obtained, a dense gradation (that is, a roughly equal quantities of various sizes of aggregate), by this, most of the air voids amongst the material are filled with particles.

Table 3: Sieve Analysis of Coarse Aggregate [Granite]

Sieve size	Weight retained (g)	Weight passing (g)	Percentage passing (g)
25mm	110.19	4889.81	97.80
19mm	1522.10	3367.71	67.35
14mm	1901.6	1466.11	29.32
10mm	468.45	997.66	19.95
5mm	436.62	561.04	11.22
2.36	212.23	348.81	6.98
residue	348.81	0.00	0.00

Coefficient of uniformity (Cu) = D60/D10
=19/4.1
=4.63

Coefficient of curvature (Cc) = $D^230/ (D60.D10)$
$= 14.5^2/ (19\times4.1)$
= 2.69

The coefficient of uniformity is 4.63 which translate to a sample specimen with value of Cu between 4 and 6 means the sample is well graded. While with a Cc of 2.69, the sample to be well graded, having the value of Cc between 1 and 3.

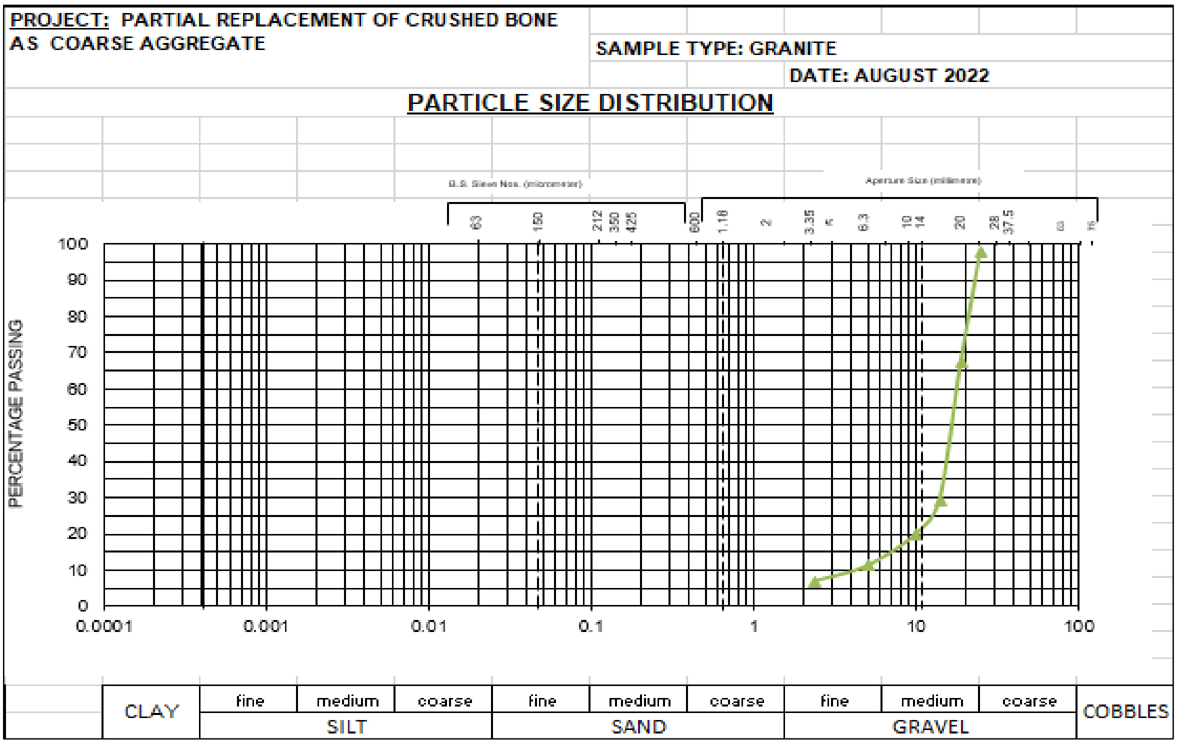

Figure 4: Sieve Analysis Graph of Coarse Aggregate

400g of the coarse aggregate was placed in the sieve set to determine the particle gradation by size, and for comparison with the sieve analysis of CCB. The result was an open and narrow gradations which means the aggregate sample has very little fine aggregate particles. This clearly shows the presence of numerous air voids, because there are no small particles to fill them. On the graph, it appears as a curve that both steep and nearly horizontal in the size range.

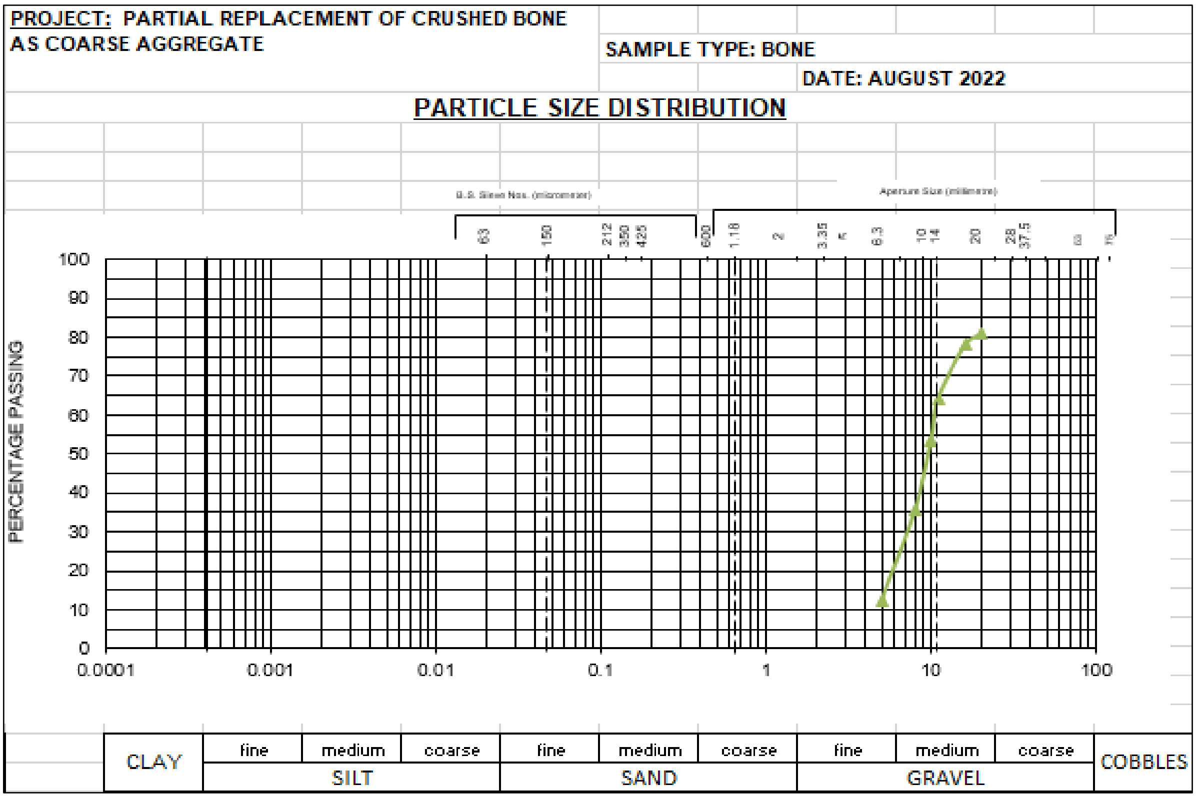

Figure 5: Sieve Analysis Graph of CCB

400g of the CCB was also placed in the sieve set to determine the particle gradation by size, in order to determine conformity with control specimen. The result shows a uniform narrow gradation, which indicate that the sample has aggregate of roughly the similar sizes. The curve on the gradation graph is very steep, and occupies a small range of the aggregate

Workability was within the range of 3.0mm – 5.0mm for the replacement coarse aggregate and 22mm for the control specimen. The result was got from the difference between the cone height and the height of the fresh concrete mix after compaction and removal of the cone. The workability of concrete made with crushed bones as a partial replacement for coarse aggregate is poor. This also implies that the water-cement ratio is low.

Table 4: Slump values

S/N	Percentage Replacement	Slump Height
1	0%	
2	5%	5mm
3	10%	5mm
4	15%	4mm
5	20%	3mm
6	25%	3.5mm
7	30%	3.5mm

The workability of the control specimen shows a true collapse, indicating a flowing and workable fresh concrete. This also indicates that the water-cement ratio is sufficient for a workable mix.

Table 5: Compressive Strength of CCB Concrete

Percentage replacement	Compressive strength at different ages MPa		
	7 Days	14 Days	28 Days
0	8.446	13.453	19.322
5	4.106	5.111	8.772
10	5.380	6.017	10.653
15	6.052	6.603	13.254
20	2.491	2.991	3.171
25	1.773	2.041	2.743
30	1.075	1.176	1.834

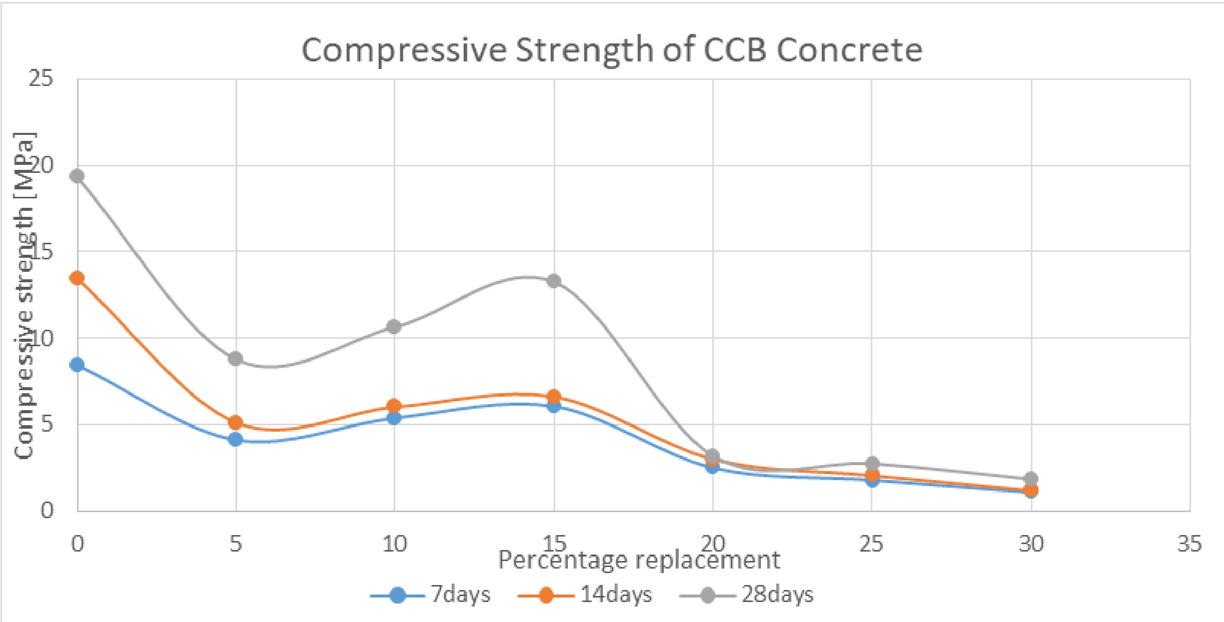

Figure 6: Compressive Strength of CCB Concrete

Table 5 and Figure 6 give the compressive strength of concrete made with CCB. As the percentage of replacement increased, the compressive strength of concrete made with crushed bones as a partial replacement for coarse aggregates decreased at the first instance and then rises up until 15% replacement with optimal value in strength and then a decline as the percentage replacement increases. Up to 15% of the coarse aggregate should be replaced by crushed bone for light concrete. At optimum strength of the replacement, it gives 68.6% of the control result. Using crushed bone in concrete production will reduce agro-waste and improved the environment.

CONCLUSION

Concrete made with granite replaced with 15% CCB can be deployed for areas where low strength of concrete is required, such as, residential ground floor, small stores and other like structures that are not required to carry heavy loads (lintel etc.)

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