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Properties of Concrete Produced with Waste Bottle Caps (WBC) as a Partial Replacement of Coarse Aggregate and Orange Leaves Powder as Plasticizer

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Abstract
Green building is an increasingly important global concern and a critical way to conserve natural resources and reduce the amount of materials going to our landfills. Large quantities of metal waste are generated from empty metal cans and bottle caps of juices and soft drinks. This is an environmental issue as metal waste is difficult to biodegrade and involves processes either to recycle or reuse. Today the construction industry is in need of finding effective materials for increasing the strength of concrete structures with low cost, and with less environmental damage. This research is aimed at addressing such issues by investigating the possibility of using waste bottle caps (WBC) to partially substitute for coarse aggregate and using orange leaves powder as plasticizer in concrete production. The slump, demoulded density, split tensile strength, compressive strength, flexural strength properties at different percentages replacement of coarse aggregate with waste bottle caps were investigated in the laboratory. The work shows that compressive strengths of 83.88%, 76.25% and 63.17% of the control (0%) can be achieved at the 28-day by replacing coarse aggregate with 5%, 10% and 15% of the waste bottle caps respectively. The research also indicates that optimum result in terms of compressive strength is between 5% and 15% of gravel replacement given a value of 35.85N/mm^2 and 27N/mm^2 respectively.
Keywords: Landfills, Green building, Compressive strength, Flexural strength, Waste Bottle Caps, Construction industry and Biodegrade

INTRODUCTION
Concrete is the most widely used construction material worldwide, this is due to its versatility, strength, durability and ease to place into forms and shapes (Dadu etal, 2012). Chandrakaran, Mohammed and Nambiar (1996), confirmed that rapid increase in the construction activities lead to acute shortage on conventional building materials. According to Mamman and Abdulsalam (2011), concreting in the construction industry is today consuming about 11.5 billion tones of concrete every year and it's expected that this may reach 18 billion tones in the year 2050. Saffuidin, etal (2010), stated that the traditional conventional materials such as concrete, hollow blocks, solid blocks and tiles are all being produced from the existing natural resource. This is damaging the environment due to continuous exploration and depletion of natural resources. One solution to this crisis lies in recycling waste into useful and sustainable products (Sukesh etal 2012).

Among different waste fractions, metallic and plastic waste products deserve special attention on account of non-biodegradable property which is creating a lot of problems in the environment. In India approximately 40 million tones of solid waste is produced annually (Ramadevi1 and Manju, 2012). This is increasing at a rate of 1.5 to 2% every year. Metals and Plastics constitute 12.3% of total waste produced most of which is from discarded water bottles. Today the construction industry is in need of finding effective materials for increasing the strength of concrete structures with low cost, and with less environmental damages.

Murali et.al (2012) observed that soft drink bottle caps reinforced blocks exhibited an increase in flexural strength of concrete by 25.88%. Venu and Neelakanteswara (2011) investigated the impact of cement bags waste (High Density Polyethylene (HDPE)) on concrete, and found that when the percentage of fiber in concrete was 3.5% it's compressive and tensile strength increased considerably. Kandasamy and Murugesan (2011) added 0.5% by volume of polythene (domestic waste polythene bags) fiber to concrete the cube compressive strength increased by 5.12%, 3.84% and 1.63% respectively.

An attempt has been made in the present investigation to study the influence of addition of waste materials of metal bottle caps of drinks as fibers and as coarse aggregate in concrete production using Orange leaves powder as a plasticizer.

Aim and objectives of study
The aim of this study is to evaluate the properties of concrete produced with Waste Bottle Caps (WBC) as partial replacement of coarse aggregate and Orange leaves powder as plasticizer.

The specific objectives of the study are:

- **i.** To determine the physical properties of waste bottle caps as a partial replacement of coarse aggregate.
- **ii.** To assess the fresh properties of concrete when coarse aggregates are partially replaced with Waste Bottle Caps (WBC) using orange leaves powder as plasticizer.

MATERIALS AND METHODS

Dangote brand of Ordinary Portland cement (OPC) of grade 42.5R produced from the cement factory at Gboko, Benue state, was used as the binding material. . The fine aggregate used for this research was river dredged natural sharp sand with a specific gravity of 2.65 compacted bulk density of 1346kg/m^3 and 16-43% passing 300µm size which falls within the grading limit of zone 2 specified by BS 882, 1975. The coarse aggregate used was crushed gravel with apparent specific gravity of 2.43, water absorption of 1.2%, compacted bulk density of 1568kg/m^3 and having a maximum size of 9mm. Powdered orange leaves was used as plasticizer and added by weight of the cement. Oladiran etal, (2012) investigated the use of orange leaves powder as reducing/retarding admixtures on the properties of concrete, and compared its properties with concrete of equal constituents but without the admixture. The results showed that the workability of the mix improved while the water cement ratio reduced gradually as the admixture content was increased.

The waste bottle caps were collected from eateries, event places and bars from various locations in Jos, Plateau state, Nigeria. The bottle caps were identified as having steel properties by using a magnet over the bottle caps, and all caps attracted was considered to be steel. The steel bottle caps were then crushed, by using a hammer to flatten them to an average size of 4mmx100mm so they could be used in concrete to avoid any trapping of voids.

A concrete mix of ratio 1:2:4 was used and a constant water content of 0.5 was adopted using 0.2% orange leaves powder as plasticizer to achieve good workability of the matrix as a result of addition of waste bottle caps. The materials were place on a clean metal surface and were thoroughly mixed in the dry state before water was added slowly to obtain a uniform paste. Borehole water supplied by the University of Jos was used as mixing water for the experiment. Similar water was used for curing.

The workability of each mix was assessed using both slump and compacting factor tests. A total of thirty (36) cubes and twenty four (24) beams were produced. Some of the cubes were produced using 0% by weight of steel waste bottle caps to serve as control samples.

The determination of compressive strength of concrete was done to satisfy the requirement as recommended by BS 1881: Part 116: 1983. This is to achieve early and progressive strength of concrete. Nine concrete cubes of sizes 150×150×150mm were cast for each percentage replacement (5%, 10% and 15%) and cured in water for periods of 7, 21 and 28 days . Three specimens were crushed at the end of each curing regime and the average recorded as strength achieved. The compressive strength was determined using equation 1:

$$\text{Compressive strength} = \frac{\text{Failure load}}{\text{Surface Area}} \quad \text{.................(1)}$$

Concrete beams of size 100×100×500mm were cast with varying percentages of waste bottle caps (5%, 10% and 15%) respectively by weight of gravel for flexural strength (ASTMC 78-02), and 150mm diameter x 300mm size cylinders for splitting tensile (ASTM C 496) tests were employed. The flexural and splitting strengths were determined using equations (2) and (3)

$$\text{Flexural Strength, } R = \frac{1000PL}{bd^2} \text{.................(2)}$$

Where: R = flexural strength in N/mm^2
P = maximum applied load in N
b = width of specimen in mm
d = depth of specimen in mm

The measured splitting tensile strength (f_t) of the specimen was calculated to the nearest 0.05 N/mm^2 .

$F_t = 2P/\pi LD$...........................(3)

Where: F_t = splitting tensile strength in N/mm^2
P = maximum load applied to the specimen in kN
L = length of the specimen in (mm)
D = diameter of specimen in (mm)

PRESENTATION OF RESULTS, ANALYSIS AND DISCUSSION

Physical properties of waste bottle caps

The steel waste bottle caps used for this study were flatten to an average size of 4mm x 10mm. The waste bottle caps have an apparent specific gravity of 2.67, compacted bulk density of 583kg/m^3 and the un-compacted bulk density of 456kg/m^3

Slump and Compacting Factor Values

Table 1 shows the water/cement ratio, slump and compacting factor values. The result of the slump is as prescribed by BS 1881: Part 102, 1983 and BS 1881: part 103:1983 which is measured to the nearest 5mm. The slumps is in the range of 9.5mm – 10mm indicating a workable concrete. Also, the result of the compacting factor test ranges from 0.75 – 0.82 which indicates its workability as prescribed in BS 1881: part 103:1983.

Table 1: **Workability of concrete with waste bottle caps**

Design Strength (N/mm^2)	Content (%) Gravel	WBC	Water/ Cement Ratio	Cement (Kg)	Orange Leave Powder (%)	Slump (mm)	Compacting factor
42.74	100	0	0.5	17.55	0.2	9.5	0.82
35.85	95	5	0.5	17.55	0.2	10	0.75
32.59	90	10	0.5	17.55	0.2	10	0.81
27.00	85	15	0.5	17.55	0.2	10	0.78

Compressive strength and demouded density

(Tables 2 to 5) show the results of the compressive strengths of concrete cubes with WBC (waste bottle caps) and control cubes. The result shows the strength at percentages of 0% (control), 5%, 10%, and at 15% WBC gravel replacement. It is observed that as the age of curing increases, the difference in strength between 0% waste bottle caps (control) and the various percentage replacements tend to decrease. From Tables 2-5, the percentage strength gained at 28 days for 5%, 10% and 15% to the control are 83.93%, 76.23% and 63.22% respectively.. The implication of this is that, at higher quantities above 15% there will be a reduction in strength of the concrete member. 15% WBC content gives an optimum strength of 27.02 N/mm^2 at 28 days, given by IS 456-2000 concrete mix grade M15 which correspond approximately to a mix proportion of 1:2:4. Tables 2 to 5 also shows that the demoulded densities of the concrete cubes ranged from 2291 Kg/m^3 to 2583 Kg/m^3. This values lies within the range of 2200 to 2600 Kg/m^3 specified for the density of normal weight concrete (Neville, 2000).

Table 2: Compressive strength values for concrete with 100% Gravel and 0% wbc, w/c = 0.5

Cube No.	Hydration Period(days)	Weight (Kg)	Density (Kg/m^3)	Crushing Load(kN)	Average Strenght (N/mm^2)
` A1	7	8.72	2583	635	28.22
A2	14	8.65	2563	795	35.33
A3	28	8.68	2573	962	42.74

Table 3: Compressive strength values for concrete with 95% Gravel and 5% wbc, w/c = 0.5

Cube No.	Hydration Period(days)	Weight (Kg)	Density (Kg/m^3)	Crushing Load(kN)	Average Strength (N/mm^2)
A1	7	7.73	2291	635	28.22
A2	14	8.35	2474	732	32.53
A3	28	8.40	2489	807	35.87

Table 4: Compressive strength values for concrete with 90% Gravel and 10% wbc, w/c = 0.5

Cube No.	Hydration Period(days)	Weight (Kg)	Density (Kg/m^3)	Crushing Load(kN)	Average Strength (N/mm^2)
A1	7	8.03	2380	633	28.13
A2	14	8.17	2420	765	34.00
A3	28	8.40	2489	733	32.58

Table 5: Compressive strength values for concrete with 85% Gravel and 15% wbc, w/c = 0.5

Cube No.	Hydration Period(days)	Weight (Kg)	Density (Kg/m^3)	Crushing Load(kN)	Average Strength (N/mm^2)
A1	7	8.70	2578	560	24.89
A2	14	8.68	2573	708	31.47
A3	28	8.62	2553	608	27.02

Flexural strength

Table 6 shows the flexural strength values for the various sample beams cured at 28 days. The 28-day flexural strength of WBC concrete ranges from 15.8% to 19.81% of its compressive strength with varying percentages of waste bottle caps . This also indicates an optimum strength of 6.50 N/mm^2 as compared to an optimum strength of 6.14 N/mm^2 achieved by Devaki and Seenuvasan (2014).

Table 6: Flexural Strength of beams with waste bottle caps at 28 Days.

Mould No.	Percentage Replacement (%)	Hydration Period (Days)	Weight (Kg)	Density (Kg/m^3)	Crushing Load(KN)	Average Strenght (N/mm^2)
A1	0% WBC	28	12.31	2463	10.50	5. 25
A2	5% WBC	28	12.32	2463	11.33	5.65
A3	10% WBC	28	12.75	2550	13.00	6.50
A4	15% WBC	28	12.80	2560	10.70	5.35

(1)

Splitting tensile strength

The splitting tensile strength for the various sample cylinders cured at 28 days is shown (Table 7) The split tensile strength at 28 days declines from 5% to 10% WBC content compared to control; it increased at 15% replacement. The 28-day splitting tensile strength of WBC concrete ranges from 5.24% to 11.40% of its compressive strength, with an average of 7.62%. The result also indicates an optimum percentage replacement of WBC in concrete to be 15%, which gave a strength of 3.08 N/mm^2 higher as compared to that of Devaki and Seenuvasan (2014) of 2.67 N/mm^2.

Table 7: Splitting tensile strength for concrete with waste bottle caps at 28 Days.

Mould No.	Percentage Replacement (%)	Hydration Period (days)	Weight (Kg)	Density (Kg/m^3)	Crushing Load (KN)	Average Strength (N/mm^2)
A1	0% WBC	28	4.43	1847	120.00	2.55
A2	5% WBC	28	4.23	1764	88.00	1.88
A3	10% WBC	28	4.40	1833	95.00	2.02
A4	15% WBC	28	4.35	1812	145.00	3.08

SUMMARY OF RESEARCH FINDINGS

1. The distorted bottle caps were in sizes of 4mm wide and 10mm long which conforms to ASTM D 4791 recommendation for flat and elongated aggregate.
3. The compressive strength of the WBC concrete at the end of 28th day, at 5%, 10% and 15% WBC replacement of gravel were 35.87 N/mm^2, 32.58 N/mm^2, and 27.02 N/mm^2 respectively.
4. The 28-day flexural strength of WBC concrete is between 5.35N/mm^2 and 6.50N/mm^2 averaging 16.3%, 17.92% and 21.6% of its compressive strength at 5%, 10% and 15% WBC replacements respectively. It was further observed that the flexural strengths of concrete with WBC replacements were higher than the conventional samples (control) at 28 days.
5. The 28-day splitting tensile strength for WBC concrete lies between 1.88N/mm^2 and 3.08N/mm^{2,} which is approximately 5.24%, 6.2% and 11.40% of its compressive strength at the 5%, 10% and 15% WBC replacements respectively..
6. The result for the specific gravity test and bulk density test conducted on the samples of the waste bottle caps showed that the specific gravity of the WBC was 2.67 while the bulk density was 456 Kg/m^3 and 583 Kg/m^3 for un-compacted and compacted respectively.
7. The densities of the concrete cubes ranged from 2291 Kg/m^3 to 2583 Kg/m^3. This lies within the range of 2200 to 2600 Kg/m^3 specified as the density of normal weight concrete (Neville, 2000).
8. The result from the slump test showed that the addition of 0.2% orange leaves powdered with w/c of 0.5 improves the workability of the mix.

CONCLUSION AND RECOMMENDATION

The possibilities of using waste bottle caps (WBC) as partial replacement of gravel have been explored. The waste bottle caps has a specific gravity of 2.67 with a bulk density of 456 Kg/m^3 and 583 Kg/m^3 for un-compacted and compacted respectively. The compressive strengths of the WBC concrete gained at the end of 28 days at 5%, 10% and 15% replacement of gravel were 83.93%, 76.23% and 63.22% of the control (0%) respectively. The results obtained from this study indicates that the compressive strength of waste bottle caps (WBC) with concrete gives optimum behaviour between 5% and 15% (35.85N/mm^2 and 27.02N/mm^2). This shows an encouraging behaviour for the material to be used for concrete works.

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