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Research Article

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Properties of Concrete Reinforced With Steel Crown Cap Waste as Fiber Material

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Abstract Conventional cement concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Attempts have been made to improve the tensile properties of concrete not only as composite action in it tension zone only, but uniformly distributed across its entire mass to behave as composite materials with properties significantly different from conventional concrete. Fiber reinforcement (FR) is often added into concrete as a small fraction of short fibers during mixing. Steel fiber is one of the most commonly used fiber. A study was carried out to investigate the use of Steel Crown Cap Waste (SCCW) as reinforcement in concrete. SCCW are wastes obtained from cover of soft drink bottles, the materials which were dumped and scattered within the environment, therefore causing pollution. The SCCW was collected and assessed in terms of its physical properties. Concrete M25 was produced using a mix ratio of 1:2.08:3.12. It was added at 0, 1, 2, 3 and 4% by weight to serve as reinforcement. The workability of the fresh concrete was determined and observed to decrease as the quantity of SCCW increased. The concrete samples were cured at 3, 7 and 28 days, for each curing period. The compressive strengths and flexural strengths were also determined at each curing period. The result showed that the compressive and flexural strength increases as the quantity of SCCW increased. The compressive strength was maximum at 4% addition of SCCW which increased by 19.47%. Similarly, the flexural strength was maximum at 1% addition of SCCW which increased by 27.95% when compared with conventional concrete cured at 28 days curing period.

Keywords Concrete, Fiber, Reinforcement, Strength, Steel Crown Cap Waste

Introduction

All content should be written in English and should be in Single column. Concrete is well known to be weak in tensile strength and this strength is about a tenth of the compressive strength which is an index to other properties of concrete [1]. Due to its lack of tensile strength, it is often reinforced with steel reinforcing bars in structural application. However, internal micro cracks are inherently presents in the concrete and its poor tensile strength is due to the propagation of such cracks [2]. Deterioration and failures in concrete structures are now of wide-spread concern, because despite the re-bars, some cracks developed in the concrete caused reinforced concrete structure to decay as result of steel re-bars corrosion which is due to ingression of fluid into the steel region. Therefore, cement based matrix of normal concrete is being modified, so as to improve some properties that are suitable for particular purpose. In order to improve the mechanical properties of concrete it is good to mix cement with fiber which have good tensile strength and this reduces the requirement amount of re-bars or mesh, and also adds to the improvement of durability by delaying the crack propagation [3]. In corporation of composite materials (steel and polypropylene fibers) in concrete significantly improves its plastic settlement, strains and stress concentrations imposed by external restraints, bleeding, thermal and shrinkage [4]. Although, various waste such as nylon, plastic, tyre, coir and sugarcane bagasse have been used as fibers in concrete [5], but steel fiber is one of the most commonly used fibers [2]. The weak matrix in concrete, when reinforced with steel fibers, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete.

Fiber reinforced concrete (FRC) is often made by adding a small fraction of short fibers to the concrete mix during mixing. In FRC, a number of researches have been conducted to improve the properties of conventional concrete. Murali *et al.*, [6] added mild steel lathe waste, empty beverage tin, soft drink bottle caps and waste steel powder at a dosage of 1% of the total weight of concrete as fiber in concrete of M25 mix. The first three wastes were deformed into rectangular strips of 3mm width and 10mm length. The results showed that the steel powder fiber increased compressive strength by 41.25% and tensile strength by 40.81%, while the soft drink bottle caps exhibited an increased in flexural strength of by 25.88%.

Devaki and Seenuvasan [7] reported that incorporating soft drink bottle caps in concrete gave better split tensile and flexural strength when compared to conventional concrete. Shrivastava and Joshi [8] investigated the reuse of lathe waste steel scrap in concrete pavements. The steel scrap fiber reinforced concrete (SSFRC) was prepared with 0.5 -2% scrap content and was found to increase the mechanical properties of concrete. Compressive strength had up to 3% increment, while the tensile strength up to 20% and up to 40% for flexural strength. Vasudev and Vishnuram [9] studied the tensile and compressive behavior of composite concrete with varying percentage of scraps from lathe shops ranging from 0, 0.25, 0.5, 0.75 & 1% for sustainable development by reducing waste from environment. The splitting tensile strength of the plain concrete improved by 20% for M20 concrete and 22% for M30 concrete by addition of the turn steel fibers, while the variation of the direct compressive strength for concrete cubes was found to be inconsistent with the increase in percentage of fibers. In a nut shell, inclusion of steel fiber improve the mechanical properties of conventional cement concrete [5], [10].

The purpose of this research is to expand the body of knowledge on the application of steel fiber in concrete production, because the property and constituents of these steel fibers differ all over the world. Therefore, the incorporation of steel fiber from a particular part of the world needs to be explored. As such this research work aimed at investigating on the effect of using steel crown cap waste as reinforcement in concrete.

Materials and Methods

A. Materials

i. Cement

Ordinary Portland cement, Grade 32.5 (Ashaka Cement) which complied with BS EN 197-1[11] was used for casting the entire sample and has a specific gravity of 3.15. It has a consistency of 30%, setting time (Initial (75 min) and Final (250 min) and soundness of 1.5 mm in accordance with BS EN 196-3 [12].

ii. Fine Aggregate

Natural river sand complying with BS EN 12620 [13] was used for the study. It has specific gravity of 2.64 and fineness modulus of 2.32 (with effective size of 0.2 mm) conforming to zone II of BS882 [14].

iii. Coarse Aggregate

The type of coarse aggregate (CA) used in the study is machine crushed granite rock complying with BS EN 12620 [13]. The Physical properties of the aggregates are given in table 1.

Table 1: Physical Property of Coarse Aggregate

S/No	Property	Result
1	Effective Particle size	16mm
2	Aggregate impact value (AIV)	12.8%
3	Aggregate crushing value (ACV)	21.43%
4	Specific gravity	2.71

iv. Steel Crown Cap Waste (SCCW)

The steel crown cap wastes were those of Nigerian Bottling Company, Nigerian Breweries, Guinness Nigeria, Jos International Breweries, 7UP Company and those of other breweries collected from bars and restaurants within Bauchi metropolis. The shapes of the waste were deformed into approximately rectangular dimension of 4 mm width and 40 mm length. The Physical properties of the aggregates are given in table 2.

Table 2: Physical Property of SCCW

S/No	Property	Result
1	Effective Particle size	37mm
2	Aggregate impact value (AIV)	0.04%
3	Aggregate crushing value (ACV)	0.09%
4	Specific gravity	7.82

v. Water

Water fit for drinking is suitable for mixing concrete, therefore water available in the college campus conforming to the requirements of water for concreting and curing [15].

B. Methods

i. Mix Design

In this work, a mix proportion of 1: 2.08: 3.12: 0.60 was design in accordance to BS EN 206-2 [16] for M25 grade concrete. The steel crown caps were added into the concrete with 1%, 2%, 3% and 4% by weight of the concrete. Concrete produced with 0% weight of SCCW served as control for comparison.

ii. Mixing of concrete

Hand mixing was adopted throughout the experimental work. The sand was laid in a layer approximately 10 cm thick. Then cement was added to the sand and mixed thoroughly to get a uniform colour. The coarse aggregate was then spread on the cement –sand mix, followed by the SCCW on the CA. the water was measured and added, and mixed thoroughly to obtain a uniform colour and consistency.

iii. Workability

The workability of the fresh concrete was determined using slump test, which was carried out in accordance with BS EN 12350-2 [17].

iv. Casting of Cubes

For casting the cubes and beams specimens, standard cast iron metal mould of size of 150 mm×150 mm×150 mm cubes and 100 mm x 100 mm x 500 mm beams conforming to BS EN 12390-1 [18] were used to produce the test samples in accordance with BS EN 12390-2(2000). A total number of 45 beams and 90 cubes were produced with 0%, 1%, 2%, 3% and 4% SCCW.

v. Curing of Cubes

After 24 hours the moulds were de-molded and the sample were completely immersed in water for curing age of 3days, 7days and 28days in accordance with BS EN 12390-2 [19].

vi. Compressive Strength Test

The test specimens (cubes) were removed from water after specified curing time and excess water was wiped out from the surface. The dimension of the specimen was taken to the nearest 0.2 m. The bearing surface of the testing machine was cleaned. The loading was carried out in accordance with BS EN 12390-3 [20].

vii. Flexural Strength Test

The test specimens (beams) were removed from water after specified curing time and excess water was wiped out from the surface. The dimension of the specimen was taken to the nearest 0.2 m. Two points loading was adopted and was carried out in accordance with BS EN 12390-5 [21].

Results & Discussion

1. Workability

The slump results conducted on the fresh concrete mix sample of designed proportion of the SCCW is given in table 3 below. It appeared that the addition of the waste up to 4% showed a decrease in slump of 25 mm at 0% to 7 mm at 4%, therefore, the effect of the SCCW on the workability can be well understood as shown in Fig 1. The result indicates that increase in percentage of the waste decrease the workability of FRC. Moreover, the result shows a true slump, as it was designed for medium workability of 30-50 mm.

Table 3: Slump Test Result

Percentage of waste added	Slump value(mm)
0%	25
1%	21
2%	17
3%	12
4%	7

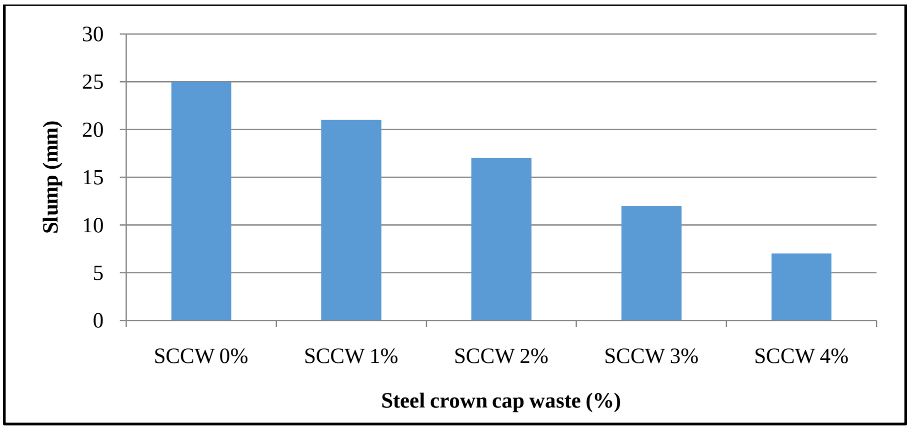

Figure 1: Slump chart

2. Compressive Strength

Figure 2 shows the compressive strength of all 5 mixes determined at ages of 3, 7 and 28 days and with respect to percentage of SCCW respectively. It showed that there is an improvement in the compressive strength, which increased as the percentage of SCCW and curing period increased but the peak value was obtained at 4% addition of SCCW at 28 days of curing. Table 4 showed the compressive strength comparison with control concrete. The highest and lowest 3-day compressive strength (11.89 N/mm^2 and 10.46 N/mm^2) were recorded at 4% and 0% addition of SCCW respectively. While that of 7-day compressive strength (20.38 N/mm^2 and 17.11 N/mm^2) were recorded at 4% and 0% addition of SCCW respectively. Also at 28-day compressive strength (31.89 N/mm^2 and 26.20 N/mm^2) were recorded at 4% and 0% addition of SCCW respectively. It can be seen that incorporating SCCW into concrete is advantageous as the compressive strength is seen to have increased greatly. However, it is to be noted that the slump value addition of SCCW beyond 4% will decrease the workability and compaction thereby reducing the strength of the concrete.

Table 4: Compressive Strength Comparison with Control Concrete

Conventional Concrete (N/mm^2)	SFRC (N/mm^2)	Increase in Strength, %
0%: 10.46 @ 3days	1%: 11.20	7.07
	2%: 11.44	9.37
	3%: 11.83	13.10
	4%: 11.88	13.58
0%: 17.11 @ 7days	1%: 19.19	12.16
	2%: 19.60	14.55
	3%: 20.23	18.23
	4%: 20.38	19.11
0%: 26.20 @ 28days	1%: 29.70	13.36
	2%: 30.11	14.92
	3%: 31.12	18.78
	4%: 31.30	19.47

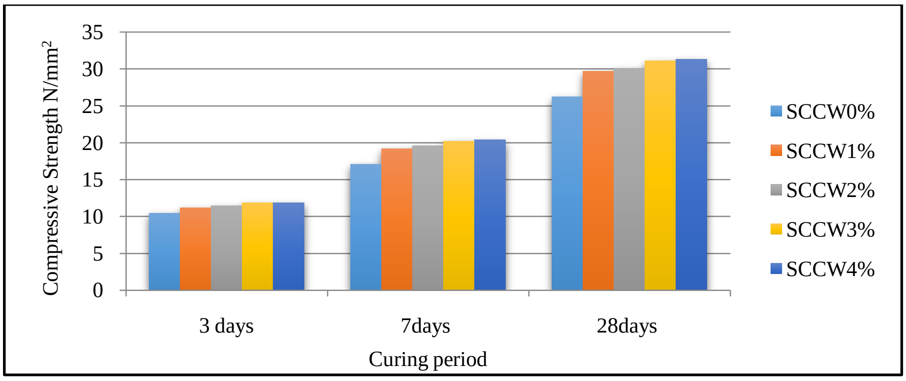

Figure 2: Compressive Strength of Cubes

3. *Flexural Strength*

Figure 3 shows the Flexural strength of all 5 mixes determined at ages of 3, 7 and 28 days and with respect to percentage of SCCW respectively. It showed that there is an improvement in the flexural strength, which increased as the percentage of SCCW and curing period increased but the peak value was obtained at 4% addition of SCCW at 28 days of curing. Table 5.0 showed the flexural strength comparison with control concrete. The highest and lowest 3-day flexural strength (0.78 N/mm^2 and 0.69 N/mm^2) were recorded at 4% and 0% addition of SCCW respectively. While that of 7-day flexural strength (3.55 N/mm^2 and 2.97 N/mm2) were recorded at 4% and 0% addition of SCCW respectively. Also at 28-day flexural strength (7.37 N/mm^2 and 5.76 N/mm^2) were recorded at 4% and 0% addition of SCCW respectively. It can be seen that incorporating SCCW into concrete is advantageous as the flexural strength is seen to have increased greatly. SCCW improves the flexural strength of concrete with a maximum value of 1% addition. Thus, it provides better resistance to ending stresses in comparison with the rest of the percentages.

Table 5: Flexural Strength Comparison with Control Concrete

Conventional Concrete (N/mm^2)	SFRC (N/mm^2)	Increase in Strength, %
0%: 0.69 @ 3days	1%: 0.78	13.04
	2%: 0.74	7.25
	3%: 0.74	7.25
	4%: 0.71	2.90
0%: 2.97 @ 7days	1%: 3.55	19.53
	2%: 3.24	9.09
	3%: 3.27	10.10
	4%: 3.49	17.51
0%: 5.76 @ 28days	1%: 7.37	27.95
	2%: 7.00	21.53
	3%: 7.09	23.09
	4%: 7.13	23.78

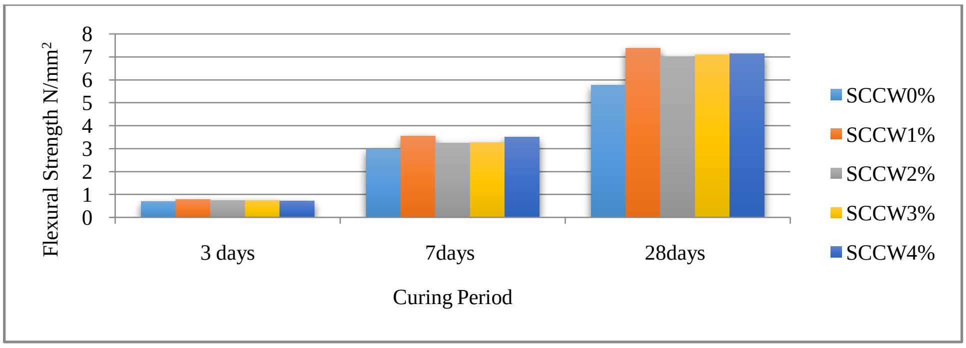

Figure 3: Flexural strength of Beams

Conclusion

1. The workability of concrete had a maximum slump value of 25 mm and a minimum slump value of 7 mm, decreasing with increase in SCCW.
2. The compressive strength of concrete increased with increase in the SCCW content with a maximum value of 31.30 N/mm^2 at 4% SCCW and a minimum value of 26.20 N/mm^2 at 0% SCCW addition.
3. The compressive strength of concrete at 4% addition of SCCW after 28days of curing increased by 19.47% when compared to conventional concrete.
4. The flexural strength of concrete increased with increase in the SCCW content with a maximum value of 7.37 N/mm^2 at 1% SCCW and a minimum value of 5.76 N/mm^2 at 0% SCCW addition.
5. The flexural strength of concrete at 1% addition of SCCW after 28days of curing increased by 27.95% when compared to conventional concrete.

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