PROPERTIES OF LIGHT WEIGHT CONCRETE BEAM EMBEDDED WITH EMPTY CYLINDRICAL TIN WASTES

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ABSTRACT

The search for new construction materials is on the increase due to the overwhelming environment wastes generated and dumped in the surroundings. This research is focused on environment littered with Empty Cylindrical Tin Wastes(ECTW) which poses environmental problems (pollution)and the cost of reducing such waste is alarming.This research tests the viability of these wastes as construction materials. Modulus of rupture (MoR), density, absorption and deflection tests were carried out on the samples of beams embedded with ECTW below the neutral axis. The results from the tests carried out showed a promising strength, reduced deflection and better physical properties as compared with the conventional beam samples for the curing periods of7, 14, 21, and 28days. **The results also revealed that the use of ECTW as embedded materials in the concrete beam samples will yield an economy of 29.33%.** ***It was concluded that ECTW can serve as a new construction material for light weight structures thereby reducing environmental wastes, pollution and cost of disposal of such waste.***

Keywords: Beams, Compressive strength, Concrete, Cylindrical Tin wastes, Density, Strength.

1.0 INTRODUCTION

Industrialization, urbanization and the rapid increase in population density in the world todayhas led to infrastructural development leading to problems like shortage of conventional construction materials(e.g concrete materials) and increased productivity of wastes which has caused environmental issues due to inadequate recycling/disposal facilities in most developing countries. Reinforced concrete(RC) is a composite material made up of two different, but complimentary materials: concrete and steel.Samreen et al. (2019).

In reinforced concrete(RC), concrete which hasrelatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength and/or ductility,Raju and Mohsin(2015).Reinforced Concrete are most commonly used material in the construction and building industries all over the world.Concrete is a composite material of cement (as binder), fine aggregate(sand), coarse aggregate(granite or gravel) and water in a well-defined proportion;Ajagbe *et al*(2018). Admixtures are substanceswhich are of different types and purposes and are sometimes added to concrete mixes in order to improve or modify the properties of either fresh or hardened concretes or both, Wasiu and Baba(2020).Chana(2011) and Nadimalla*et al*(2019) reported that approximately 25billion tonnes of concrete are manufactured every year worldwide. Beam as a reinforced concrete member, like columns are commonly encountered in structures and they are usually acted upon by a system of external loads acting transversely to the axis,Sohail*et al*(2017).

It was stated byYanuar*et al*(2017) that light weight concrete is a concrete with density: 200 - 2000kg/m^3, while structural lightweight concrete is a concrete with lightweight aggregate or a mixture of light weight, coarse aggregate and sand with its density not greater than 1850kg/m^3.Structurallight weight concrete which has been used in the construction of buildingsfor many years due to reduction of dead load it provides, with other advantages, and has density which varied from 1440 – 1840kg/m^{3}compared to 2240 – 2400kg/m^3 for normal weight concrete, Huda (2019). Oyenuga (2011)reported that light weight concrete has density range of 160 - 1920kg/m^3, normal weight concrete has density equal to 2400kg/m^3 while the compressive strength of concrete for structural purpose has been stipulated to be in excess of 17.25MPa according to ACI 311-05:2000.

The future need for construction materials which are light, durable, economic and more environmentally sustainable has been of great concerns.It is a known fact that 3R's program (Reduce, Reuse and Recycle) of waste materials helps to reduce pollution of the environment, Indradi*et al*., (2019).Hence many researchers have carried out many studies on the reuse of waste materialssuch as plastic cover, PET fibers, PET bottles on concrete with a view to understanding their effects on concrete mechanical properties and other characteristics.

1.1 Literature Review

Cans are usually used as packaging medium for beverages(evaporated and condensed milks), drinks(soft drink and beers), food(tin tomatoes) and other materials like shoes polish, body spray, etc. They are usually made of different metals and alloy like tin, iron, magnesium, aluminum, steel etc.Coating assists in the making of electrolytic tinplate(ETP) and tin – free steel(TFS) cans, Peter et al. (2017).

Marsh and Bugusu(2007) reported that Aluminum and steel are the two most commonly used metals for packaging while Umezuruike and Asanda(2013)stated that Aluminum is the predominantlyused metal in making of cans, foil and laminated paper. Bev et al,(2011)stated that both Aluminum and steel are used for packaging material due to their relative low cost, non- toxic nature and strength. Due to the environmental pollution problems cause by these metal packaging cans it therefore essential to find an innovative method of using these waste tin can materials which will help to reduce environmental pollution and dependence on the conventional concrete materials.Many researchers have studied the use and effects of different waste materials in different forms on the properties of fresh and hardened concretes.

Yanuar*et al*., (2017) investigated the mechanical properties of lightweight aggregate concrete reinforced with soda can waste fiber with volume fraction varying between 0, 0.3, 0.6, and 0.9 respectively. They added 2% by cement weight of superplasticizer in order to facilitate the casting process.They found out that the fibrous concrete they produced had a density less than 2000kg/m^3 which categorized them as lightweight concrete and they also observed improvement on the mechanical property of the concrete. They then concluded that 0.3% be taken as optimum replacement due to its better strength performance

Hikmatullah and Vipasha(2020)reviewed the properties of concrete using soft drink aluminum Cans fiber at 0.5%, 1%, 1.5%, and 2% replacement by weight of cement respectively. They concluded that the addition of soft drink Can fiber improved the concrete compressive strength, and split tensile strength while it reduced the concrete workability with1% addition of soft drink Can-fiber.

Kampa(2016) worked on the strength characteristics of Coca – Cola Tin waste as fibers in concrete. The Coca – Cola Tin fiber was added at 0%, 0.5%, 1.0%, and 1.5% by volume of concrete. He used the design mix of 1:1.5:3, as nominal concrete mix for 100mm x100mm x 100mm cubes.He determined the mechanical properties of the concrete made with the Coca – Cola Tin fiber at the different percentage addition.The research concluded that Coca – Cola Tin waste can be used as filler material in concretesince the fiber addition to the concrete at different dosage didnot cause any significant effect at the 28 days compressive strength and split tensile strength respectively.

Arul *et al*., (2017) carried out a study on the mechanical properties of concrete with partial replacement of coarse aggregate by waste bottle caps (at 1.5%, 2%, 2.5% and 5%) and fine aggregate replaced with quarry dust at 50%. They revealed from their study that split tensile strength of the concrete was higher at 0% replacement, the flexural strength was higher at 2.5% waste bottle caps, and 50% quarry dust and the compressive strength increased with increase in percentage of replacement of coarse aggregate with waste bottle caps.

Suji*et al* (2017)investigated the influence of soft drink bottle cap on M25 concrete. They used soft drink caps at different percentages (0.25, 0.5, 1, 1.5, 2) of total weight of concrete. The bottles were cut into strips of 3mm (width) and 10mm(length) respectively. Their findings showed that the compressive, split tensile and flexural strengthsimproved positively with increase in the bottle fiber addition.

Nadimalla*et al*., (2019)worked on PET bottles waste as partial substitution forfine aggregate in concrete. The found out that the shape of the PET bottle aggregate reduced the concrete workability and the compressive strength improved significantly at 5% replacement while the flexural and split strengths also improved up to 10% addition respectively.

Literatures have shown several researches on the use of different waste materials in different forms for the production of concrete. Butthe use of empty cylindrical waste as embedded materials in reinforced concrete production has not been explored.Thus,this study is aimed at bridging the gaps in literature by investigating the effects of empty cylindrical tin waste (ECTW) as embedded material in the production of light weight reinforced concrete beams which help to prevent the environmental strains caused by the empty cylindrical tin waste (ECTW), and also limit the dependence and consumption of high amounts of natural resources used in concrete production.

2.0 MATERIALS AND METHODS

The empty cylindrical tin waste(ECTW) which are locally available environmental wastes were collected within Ado – Ekiti, Ekiti State as see in Figure 1.The cement used in this research work is the Ordinary Portland Cement (OPC) of grade 42.5R (Dangote brand) obtained from Ado-Ekiti Metropolis. It is the most common type of cement in use in the Nigerian construction industry (Wasiu *et al*, 2019) and it conformed to the requirements stipulated in BS 197 – 1:2000.The fineand coarse

2.1 Materials

aggregatesused for the work were collected from Ado-Ekiti metropolis with their physical properties shown in Table 2 and Table 3 respectively.The water used in mixing the concrete was potable water collected from tap while the steel reinforcement, of 10mm diameter used in making the reinforced concrete beam samples that were used for the flexural tests were also obtained from Ado - Ekiti metropolis.

Fig 1:PackedEmpty Cylindrical Tin Waste(ECTW)

2.2 Methods

The methods employed in this research includes: Determination of the physical and mechanical properties of materials used and the test specimen.

2.2.1 Physical properties of materials

Experimental investigations were carried out on the materials used in this researchin accordance with specification. The laboratory investigation of the physical properties of cement, fine and coarse aggregates are presented in Tables 1,2 and 3 respectively. The particle size distribution curves for the fine and coarse aggregates are represented in Figure 2. Coefficient of curvature (Cc) and coefficient of uniformity (Cu) were estimated from equations 1 and 2.

$$C_c = \frac{(D_{30})^2}{D_{60}.D_{10}} \quad (1)$$

$$C_u = \frac{D_{60}}{D_{10}} \quad (2)$$

Table 1: Properties of grade 42.5 Ordinary Portland Cement(OPC)

S/N	Physical test	Experimental Values	BS EN:2000 Specification
1	Fineness (retained on 90µm sieve) (%)	6.90	≤ 10
2	Specific gravity	3.15	-
3	Density (Kg/m^3)	1450	-
4	Vicat Setting time (minutes)	Initial setting time = 90 Final setting time = 256	≥ 45 ≤ 375

Table 2: Physical properties of fine aggregate(River sand)

S/N	Physical test	Experimental Values	BS EN:2000 Specification
1	Fineness modulus	2.85	2.3 – 3.0
2	Specific gravity	2.65	2.63 – 2.67
3	Apparent specific gravity	2.68	-
4	Water absorption (%)	0.55	-
5	Coefficient of uniformity (Cu)	2.18	≤ 4
6	Coefficient of curvature (Cc)	1.14	1 – 4

Table 3: Physical properties of coarse aggregate

S/N	Physical test	Experimental Values	BS EN :2000 Specification
1	Aggregate impact value (AIV) (%)	14.3%	≤ 25%
2	Specific gravity	2.65	2.6 – 2.7
3	Apparent specific gravity	2.69	-
4	Water absorption (%)	0.61	-
5	Coefficient of uniformity (Cu)	1.57	≤ 4
6	Coefficient of curvature (Cc)	1.05	1– 4

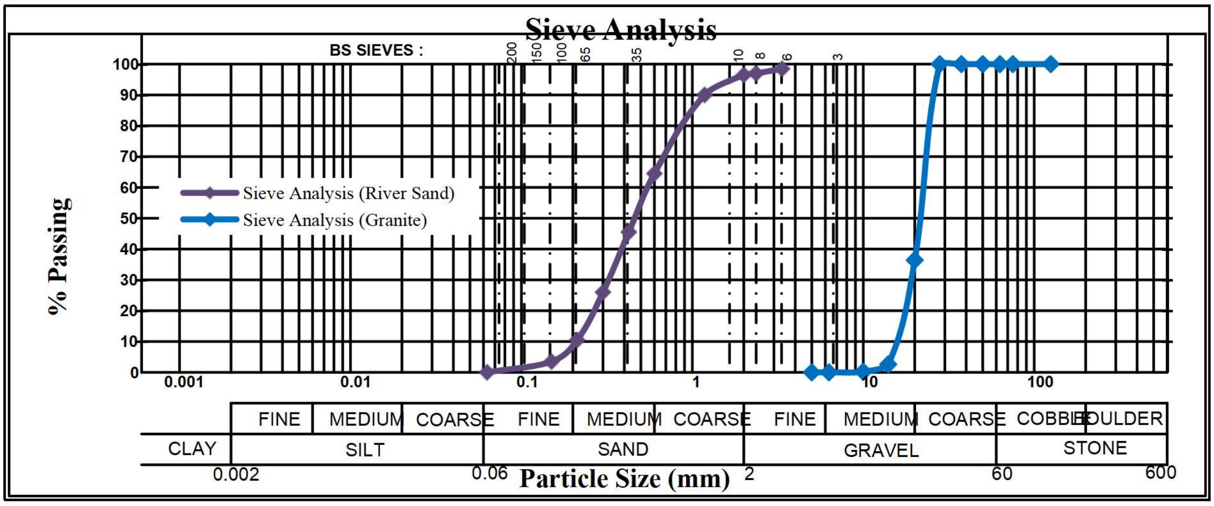

Fig 2:The particle size distribution curves for the fine and coarse aggregates

2.2.2 Mechanical Properties

The mechanical properties investigated is Flexural Strength test. This test was carried out in accordance with required specifications.

2.2.3 Concrete Mix Proportion/Beam Casting

The concrete mix used for the study was designed using Department of Environment (DOE) method (DOE, 2019). Design mix of **1:1.84:3.42 with w/c of 0.55** forC25/M30 concrete grade was obtained using the DOE method. The mix ratio showed the various constituent materials: cement, fine and coarse aggregates used in making the concrete cubes and reinforced concrete beam samples with and without the embedded empty cylindrical tin waste (ECTW). The following were done for casting the conventional and embedded empty cylindrical tin reinforced concrete beams: four (4) reinforcement of 10mm diameter with span of 900mm were tied with the links rod using a spacing of 250mm for each beam. Four (4) beams were cast for each curing periods of 7days, 14days, 21days and 28days for both conventional and embedded empty cylindrical tin reinforced concrete beams with a total of thirty-two (32) beams. The beam molds were filled with concrete in three layers with each layer tamped to a desired degree after putting the steel bar in place for the conventional beam samples while ECTW were fitted into the reinforcement for beams containing embedded empty cylindrical tin wastes as shown in Fig. 3, while Fig. 4 shows the beam after casting.

Fig 3:ECTWwith Reinforcement arrangement before casting

2.2.4 Density Test
The densities of the concrete cube samples were obtained by algebraic calculations. The density test was conducted for concrete cubes with and without empty cylindrical tin waste (ECTW) for different curing periods (7, 14, 21 and 28 days), respectively. The density was obtained using a cube volume of 150 x 150 x 150 mm and the density estimated using equation 3.

$$\text{Density} = \frac{\text{Mass(M)}}{\text{Volume(V)}} \quad (3)$$

Fig 4: Cross section of beams after demolding operation

2.2.5Water Absorption Test
The water absorption (WA) test is used to ascertain the level at which a sample takes in or retains water. The test was conducted in accordance with BS 1881-122:2011 for concrete cubes made with and without empty cylindrical tin waste (ECTW) at different periods of 7, 14, 21 and 28 days respectively. The average water absorption was then computed for each sample from equation 4.

$$\text{Water Absorption(WA)} = \left(\frac{W_1 - W_o}{W_o} \text{ x } 100\right) \quad (4)$$

Where,
W_o is the weight of the hardened samples after demolding,
W_1 the weight of the hardened sample at the curing periods of 7, 14, 21 and 28day.

2.2.6Flexural Strength Test
The flexural strength test was performed in accordance with the ASTM C293 / C293 - 16:2016 with the reinforced concrete beam with 48 number of samples (100 x 1000 x 1000 mm) – with and without empty cylindrical tin waste (ECTW) for different curing periods (7, 14, 21 and 28days), respectively. The flexural strength test was used to determinethe flexural modulus, crack pattern, bending moment, deflection and ultimate load of concrete beams subjected to a center point loading

system keeping the beams at constant support distance of 800 mm.The test was performed using a digital 100 kN Universal Testing Machine (UTM) located at the ABUAD Structural Engineering laboratory.

3.0 RESULTS AND DISCUSSION

3.1Density

Table 4 shows the computed densities for concrete cubes made without and with empty cylindrical tin waste(ECTW) for different curing periods(7, 14, 21 and 28days) respectively. There is an increase in density for the conventional beams without ECTWand values ranges from 2430-2490 kg/m^3 at curing age of 7-28 days. These range the specification for dense concrete while the density of the concrete with ECTW showed a range value from 1754-1900 kg/m^3.The decrease in the density was as result of the volume occupied by ECTW.It was observed that the concrete beam made with embedded ECTW met the density(160 – 1920kg/m^3) requirements for light weight concreteas reported inOyenuga(2011).

3.2Water Absorption

The results for the water absorption of the different samples and at the specified curing periods is presented in Table 5. The concrete beams without ECTW have water absorption values ranging from 2.6-3.10% while concrete beams with ECTW have water absorption values ranging from 1.7-2.6% as shown in Fig. 5. The concrete society (2021) specified a range value of 6-7% for lightweight concrete mix. Both samples fall within these range.

Table 4: Density results with and without ECTW for different curing periods

Types of concrete	Density (kg/mm^3) of concrete samples at different curing Periods(days)			
	7days	14days	21days	28days
Concrete without embedded ECTW	2430	2440	2470	2490
Concrete with embedded ECTW	1754	1800	1885	1900

Table 5: Water absorption results with and without ECTW for different curing periods

Types of concrete	Water absorption (%) of concrete samples at different curing Periods(days)			
	7days	14days	21days	28days
Concrete without embedded ECTW	2.60	2.81	2.92	3.10
Concrete with embedded ECTW	1.70	2.10	2.30	2.60

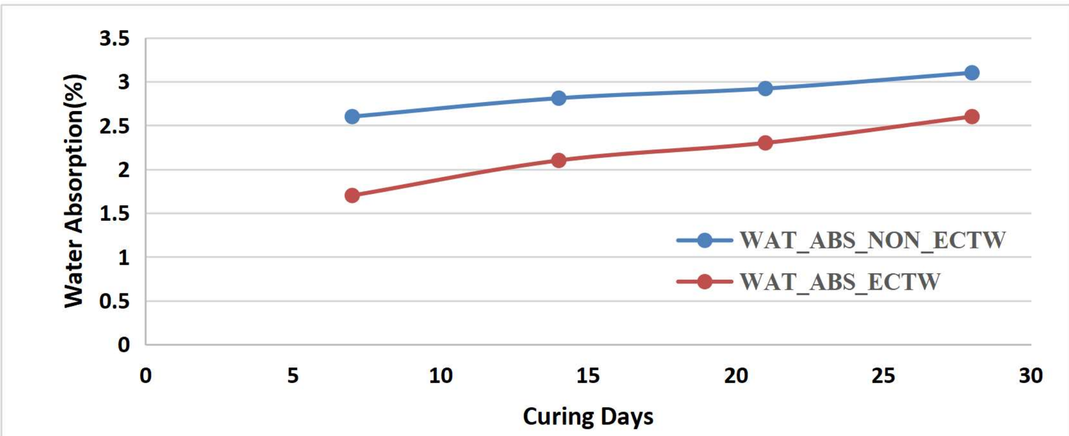

Fig. 5: Plot water absorption against curing days for both specimens

3.3 Flexural Strength

The summary results for deflection and modulus of rupture(MoR) for the different curing periods(7, 14, 21 and 28 days) respectively are presented in Table 6. The deflection of the concrete beams with and without embedded ECTW decreased with increase in curing period.The beam with ECTW recorded a lower deflection (0.08 mm) at 28 days curing period as compared with beams without ECTW which recorded a deflection of 11.30 mm at 28 days curing. The reduction in deflection is due to the presence of ECTW in the beams which increased its resistance to deflection compared to beams without ECTW.

The MoR recorded for beams with ECTW at 28days curing periods is higher (21.5 N/mm^2) than beams without ECTW. The beams with embedded ECTW gave better performance in terms of deflection and MoR respectively.

Table 6: Deflection and Modulus of rupture with and without ECTWfor different curing periods

Age of curing	Beam deflection (mm)		Modulus of Rupture(MoR)(N/mm^2)	
	concrete without ECTW	concrete with ECTW	concrete without ECTW	concrete with ECTW
7	17.94	1.23	11.40	16.50
14	17.94	0.60	12.50	17.50
21	12.27	0.08	14.20	18.40
28	11.30	0.08	14.60	21.50

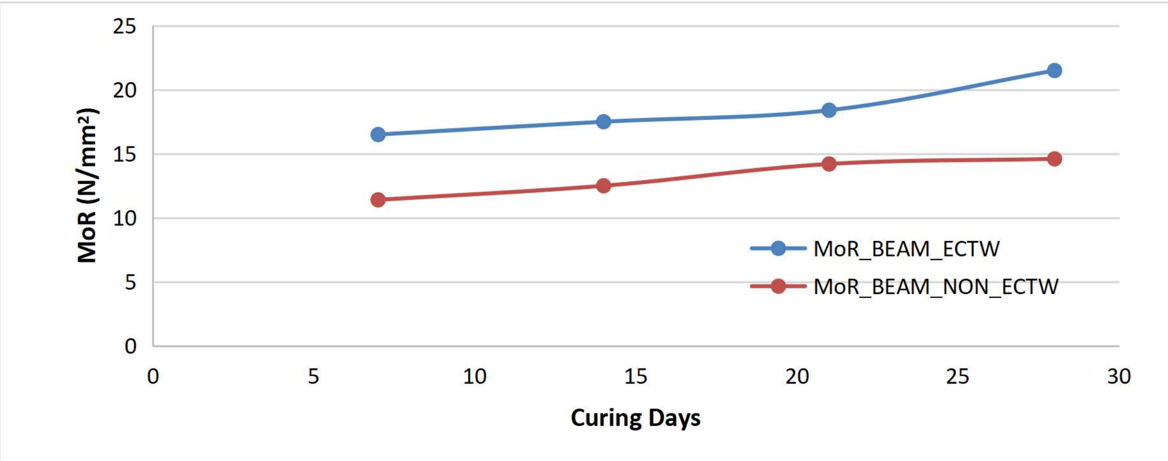

Fig. 6: MoR against curing days for beam specimen with and without ECTW

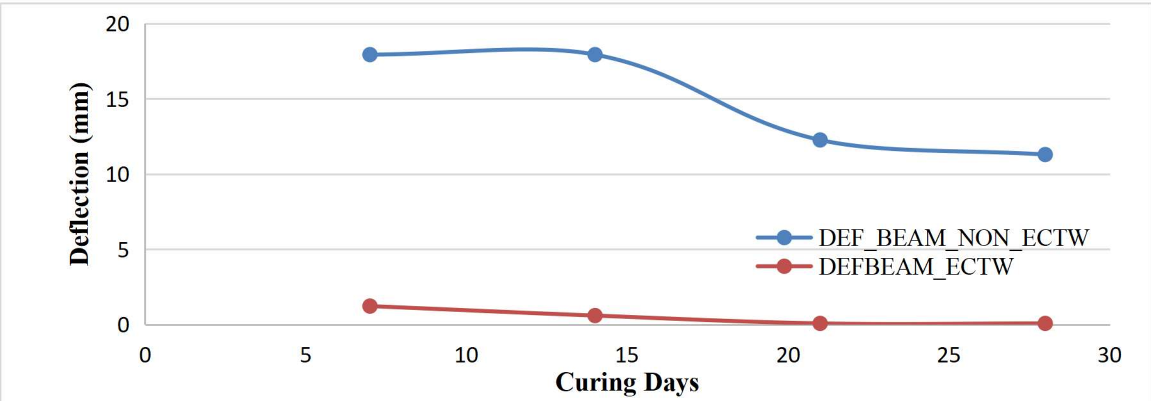

Fig.7: Deflection against curing days for beam specimen with and without ECTW

4.0 CONCLUSIONS

The following conclusions are drawn from this research work:

1. The density of the reinforced concrete beams with embedded ECTW at 28 days curing falls within the acceptable range for lightweight concrete (160-1920 kg/mm^3). This can be adopted for high rise buildings where weight reduction is required;

2. The reinforced concrete beams with embedded ECTW showed a promising physical and mechanical properties such as modulus of rupture, deflection, density and water absorption;

3. The used of ECTW as embedded material in reinforced concrete beams will save about 29.33% (i.esubtracting volume of Cans from the volume of beam) volume of concrete. This will provide an economic design while maintaining safety.

4. The use of ECTW as embedded material in reinforced concrete beams has considerably reduce the amount of tin waste generated into our environment, cost of waste disposal which is a major problem in today's world due to limited landfill space and provision of economic and viable design of beams elements in reinforced concrete structures such as lightweight structures, lintel and roof beams.

5.0 RECOMMENDATION

It is recommended that ECTW be applied to lightweight reinforced concrete elements only. The effect of corrosion, chemical polymer and mineral additives on reinforced concrete with ECTW and their consequential effects on concrete strength can be investigated further.

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