Case Studies in Construction Materials 13 (2020) e00355

Contents lists available at ScienceDirect

Case Studies in Construction Materials

journal homepage: www.elsevier.com/locate/cscm

Potential use of coconut stem as reinforcement in concrete slab

Olatokunbo Ofuyatan[a,*], Adeoye Olowofoyeku[b], Gbenga Adaramaja[a], John Oluwafemi[a], Sunday Edeki[c]

[a] Department of Civil Engineering, College of Engineering, Covenantm University, Ota, Ogun State, Nigeria
[b] Department of Civil Engineering, Yaba College of Technology, Yaba, Lagos, Nigeria
[c] Department of Mathematics, College of Science, Covenant University, Ota, Ogun State, Nigeria

ARTICLE INFO

Article history:
Received 2 October 2019
Received in revised form 29 March 2020
Accepted 30 March 2020

Keywords:
Coconut stem
Compressive strength
Impact load
Concrete slab

ABSTRACT

The utilization of an economical, eco-friendly, renewable building material has gained the attention of researchers lately. The construction sector is responsible for depleting large quantities of non-renewable resources. This activity not only generates millions of tons of mineral waste but millions of tons of carbon dioxide gas emissions as well. Research is thus needed on building materials based on renewable resources such as vegetable fibres. Investigated was on the possible use of coconut stem strips as reinforcement in concrete paste. The coconut stem was cut into various lengths, diameter, treated and coated with gloss paint and coal tar. Various tests in accordance to standard were conducted to determine the performance of the coconut stem strips. Compressive strength test and impact load tests were carried out on the concrete slab specimens to satisfy the desire of incorporating coconut stem as reinforcement in concrete slab. The compressive strength was performed on a large number of concrete cubes; 3 cubes each for day 7, 14, 21 and 28. As regards the impact loads test, 13 slabs were cast, 3 slabs each containing steel, dried coconut stem strips, gloss painted coconut stem strips, coal tar coated coconut stem strips with varying dimensions of 16 × 15 mm, 20 × 15 mm and 25 × 15 mm and plain slab without reinforcement serving as control. As expected, the slab reinforced with steel showed better strength in the cured state; however, the 2% of the coconut stripes reinforcement treated with coal tar would serve as good as the conventional steel reinforcement for normal concrete. The coal tar can be used for low-bearing load structures such as lintel and pavement.

1. Introduction

Due to the growth in the rural and urban environment, effort is been made to recognise and see the importance of sustainable and renewable eco-friendly materials that could improve infrastructure in developing countries [1].

Highly sort after construction materials are in high demand; steel, a reinforcing material used globally is considered to be expensive, has a high production cost, high noise during construction, its raw materials expensive. The unaffordability of steel results in scarcity, and often times unavailable in rural communities. However, researchers have discovered materials

* Corresponding author.
E-mail address: olatokunbo.ofuyatan@covenantuniversity.edu.ng (O. Ofuyatan).

https://doi.org/10.1016/j.cscm.2020.e00355

that share similar characteristics with steel but advantageous in terms of cost, availability, sustainability and renewability useful for low cost housing [1,2]. On of such materials readily available in abundance, non-polluting, less stress in production, cost efficient and ease of use in the rural areas is coconut stem fibre [3,4].

Some natural fibres commonly used as household commodities such as ropes, raw sacks, weaving materials possess adequate potential to be used as reinforcement in composite matrix such as soil blocks in an environment that is friendly and low-cost dwelling units [5]. The incorporation of fibre in concrete was to be found to reduce weight, friendly, noticeable strength gain and they are safe during construction handling process. Natural fibers are cheap in many countries and are available locally. Compared to the total cost of the composites, their use as a building material to improve the properties of the composites costs very little [6].

Coconut fibre stem is considered to be cheap, readily available in local sub-hubs of the western and southern Nigeria. They are presently used as roofing materials, pavements and support structures in building [7,8]. Ofuyatan et al. [9], Reported that the use of oil palm stem as reinforcement in concrete beam developed strength equivalent to half the values of steel reinforced concrete beams at the ultimate values and its use should be restricted to light load bearing structures. Ghavami [10] Investigated that the possible use of Bamboo as reinforcement material in concrete structures have good engineering properties and perfect for low-cost housing. It can be used primarily as structural reinforcement. In line with the investigation of [9,11] also carried out an experiment on a 40-year old coconut palm tree's stem both in different lateral positions and in different height positions. The results gave the compressive strength parallel to the grain for air dry condition to be equal to 12.41 N/mm^2 while the compressive strength for oven dry condition was 12.85 N/mm^2. Also, the compressive strength parallel to the grain for air dry condition was 9.28 N/mm2 while the compressive strength for oven dry condition was 9.64 N/mm^2. Hence there are diverse possibilities for the usage of coconut stem in many structural purposes. Bonding behavior of bamboo reinforced composite without coating was reported by [12]. There was adequate bonding with the concrete matrix and the sprinkling of sand on the epoxy based coating could provide extra protection without loss of bond strength. The possible use, properties in terms of fibre length, diameter, strength of three natural fibres, coconut husk fibre, oil palm-fruit fibre and sugarcane bagasse fibre were looked into by [13] though they behaved differently, yet all the fibres had characteristics properties that are acceptable as natural fibres to be used as reinforcement in soil blocks. Laroque [14] derided from his study that bamboo could be used as a sway suspended bridge. The widely used reinforcing material is carbon steel and concrete provides a covering to reduce corrosion observed by [15] in high ph environment. Some authors [16–18] found that the use of 50 % replacement of steel with fibre, crushed sand, had a similar performance with strength and flexure with concrete beams replaced with steel with 14 % less in strength, had minimal cracks patterns but could be use as reinforcement in beams. Further investigation by [19] in the use of cassava peel ash indicate that the, compressive strength of concrete specimens decreased as the percentage of cassava peel ash increases. Also, compressive strength increases as the age of curing increases for each of the percentage replacement.

One of the reasons for deterioration in infrastructure is corrosion of steel bar. Several tons of steel are used in the construction of bridges and buildings that are affected by corrosion problems and billions of naira are used in the repair. From personal view, a cubic meter of concrete will require 300 kg of steel bar in casting a beam or slab; therefore vegetable fibres is a viable step to the possible replacement of reinforced steel bar to attain a more provable construction. The aim of this paper is to evaluate the impact load and possible use of integrating coconut stem as an appropriate material in the development of concrete slab, which is locally available and is ideal for lightweight structural members in rural communities.

2. Experimental work

2.1. Material selection

The cement used was ordinary Portland cement complied with EN197-1. Natural river sand and granite with maximum size of 12 mm was used, coconut stem strips. The quality of water used for concrete work was potable and free from impurities and deleterious chemical substances like acids, alkalis and impurities.

2.2. Coconut stem strips

The stem was fell with the aid of a machine saw. It was then transported to a nearby sawmill for sawing of the logs to various split sizes and shapes. Five different samples were tested. Plain concrete-PC (without any strip/bar), Reinforced steel bar-RC, Dried coconut strip reinforced concrete-DCSC, Gloss coconut strip –GCSC and Coal tar coconut strip-CCSC. The height and the length of the coconut stem strips were of constant parameters 15 mm by 400 mm respectively. However, the width diameter of the coconut stem strips varied (16 mm, 20 mm and 25 mm) as shown in Figs. 1, 2 and 3. The sawn coconut stem was later transported to the Civil Engineering Department in Covenant University, Ota for air seasoning with a moisture value of 13 %. This experimental study subjected the coconut stem strips to various conditions in order to know the behaviour of the coconut strips in concrete. The water/cement ratio adopted for the mix was 0.4. A matured coconut palm stem was gotten from Badagry, Lagos, (6°25′N and 2°53′E), Nigeria.

Fig. 1. (1-a) Coconut stem strips of size16 mm x 15 mm. (1-b) Coconut strips of size 20 mm x 15 mm. (1-c) Coconut strips of size 25 mm x 15 mm.

Fig. 2. Coconut palm stem strip reinforcement.

Fig. 3. Casting of concrete cubes.

2.3. Casting and curing of concrete

Concrete moulds of 150 × 150 × 150 mm were used and cast as shown in Fig. 2. The mixed concrete was placed into the moulds in three layers. After each layer, the concrete was tamped with tampering rods 25 times. A total of 72 cubes were cast and cured for 7, 14, 21 and 28 days to determine the compressive strength; Three (3) slabs containing no reinforcements served as (control), 3 slabs containing steel reinforcements (16 mm, 20 mm and 25 mm diameter), 3 slabs containing 8 dried coconut stem strips (16 mm by 15 mm, 20 mm by 15 mm and 25 mm by 15 mm), 3 slabs containing 8 gloss painted coconut stem strips (16 mm by 15 mm, 20 mm by 15 mm and 25 mm by 15 mm), Lastly, 3 slabs containing 8 coal tar coconut stem strips (16 mm by 15 mm, 20 mm by 15 mm and 25 mm by 15 mm) were cast. A mix ratio of 1:2:4 was adopted and the

Table 1
Compressive strength.

Days control	Sample 1 (N/mm^2)	Sample 2 (N/mm^2)	Sample 3 (N/mm^2)	Average (N/mm^2)
7	18.7	17.5	17.4	17.9
14	24.6	24.0	25.8	24.8
21	26.3	26.0	26.5	26.3
28	27.3	27.4	27.5	27.4

Table 2
Result of the ultimate failure load.

concrete slab	Reinforcement	No of blows at first crack	No of blows at ultimate failure	Drop Mass (Kg)	Drop Height (m)	G (m/s^2)	Ultimate Failure load(KN)
PC	*None*	1	4	7.5	0.3	9.81	79.5
RC 1	16*mm dia steel*	2	15	7.5	0.3	9.81	298.0
RC 2	20*mm dia steel*	3	22	7.5	0.3	9.81	437.0
RC 3	25*mm dia steel*	3	30	7.5	0.3	9.81	595.9
DCSC 1	16*mm by* 15*mm*	1	7	7.5	0.3	9.81	139.0
DCSC 2	20*mm by* 15*mm*	2	9	7.5	0.3	9.81	178.8
DCSC 3	25*mm by* 15*mm*	2	11	7.5	0.3	9.81	218.5
GCSC 1	16*mm by* 15*mm*	2	6	7.5	0.3	9.81	119.2
GCSC 2	20*mm by* 15*mm*	2	10	7.5	0.3	9.81	198.7
GCSC 3	25*mm by* 15*mm*	1	11	7.5	0.3	9.81	218.5
CCSC1	16*mm by* 15*mm*	1	8	7.5	0.3	9.81	158.7
CCSC2	20*mm by* 15*mm*	2	10	7.5	0.3	9.81	198.7
CCSC3	25*mm by* 15*mm*	2	13	7.5	0.3	9.81	258.3

Note: PC- Plain concrete, RC- Reinforced Concrete, DCSC- Dried Coconut strip concrete, GCSC- Glossed coconut strip concrete, CCSC- Coal tar coconut strip concrete.

arrangement of the reinforcement is shown in Fig. 3. The strength obtained from the concrete was based on the 7, 14, 21 and 28 days of curing. Compressive strength test and Impact load was carried out in this study.

3. Results and discussions

The results obtained from the experiments conducted on the concrete slab reinforced with coconut stem strips of varying diameters are shown in Table 1.

3.1. Compressive strength test

.

3.2. Impact load test

The ultimate failure load results for the various types of reinforced slab are shown in Table 2 and the charts shown Figs. 4 and 5.

The compressive strength test results for the respective days portrayed corresponding values to idealized values from different codes of practice. The concrete mix procedure employs a mix ratio of 1:2:4, a common mix ratio used in construction of numerous reinforced concrete buildings. The mix shows a compressive strength percentile of 10 % at 7days, 25 % at 14 days, 65 % at 21 days and 90 % at 28 days. The results of the at 7days test had a concrete strength of 17.9 N/mm^2, 24.8 N/mm^2 at 14 days, 26.3 N/mm^2 at 21days and 27.4 N/mm^2 at 28days as shown in Fig. 4. This result confirms a concrete grade in accordance to BS 8110: 1997. Also, from the Table 1 and Fig. 4, it is observed that the magnitude of load required to crush the concrete cube samples was increasing with number of curing days.

The results gotten from the impact test in Fig. 6 shows the trend of impact resistance for different reinforcing condition. The impact test analysis gives the ultimate load or impact to cause a failure mechanism in a concrete structure. The failure loads for plain concrete (i.e. no reinforcement), steel reinforced concrete, concrete reinforced with dried coconut stem, concrete reinforced with glossed coconut stem and finally concrete reinforced with coal tar coated coconut stem was noted.

The results shows that plain concrete had the weakest impact load resistance requiring just 4 numbers of blows to failure and an impact load resistance value of 79.5 kN. This was followed by gloss and dried coconut stem concrete requiring 6 and 7 number of blows respectively for failure or collapse with an impact load resistance of 119.2 kN and 139.1 kN respectively for 16 mm by 15 mm dimension. Also, significant notice on the number of blows for dried and gloss strips were 9 and 10 for 20 mm by 15 mm with impact resistance values of 198.8 kN and 178.8 kN respectively. This value might be due to part of the mix

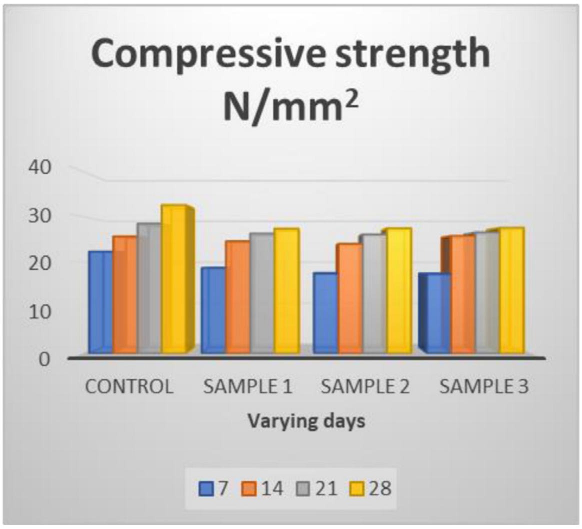

Fig. 4. Compressive strength.

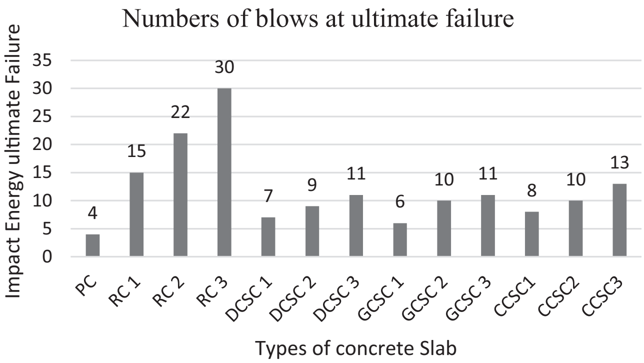

Fig. 5. Bar Chart showing the number of blows at ultimate failure on the various types of concrete slab.

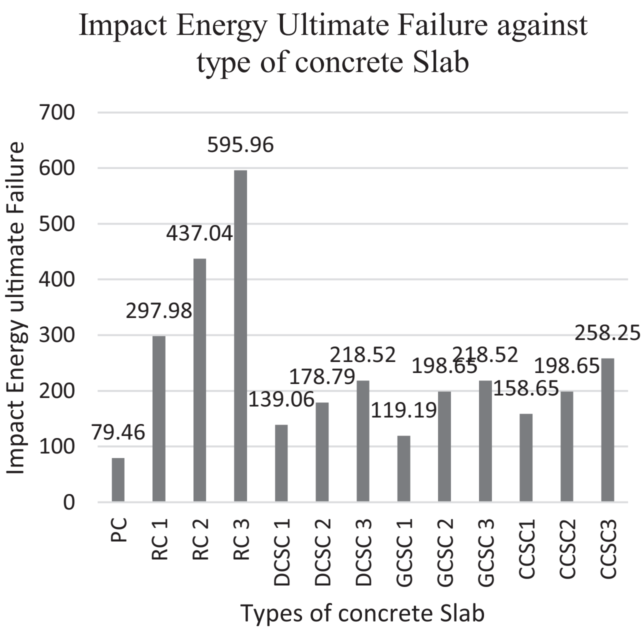

Fig. 6. The Impact energy ultimate failure on the various types of concrete slab.

or unforeseen honeycombs in cast product. The 25 mm by 15 mm dimension strips for both glossed and dried coconut showed equal resistance of 218.5 kN and number of blows being 11 each. Hence if an average value is taken on all diameters for each sample, we will notice that the deviations from each other may be negligible. Similar pattern were shown by the glossed and dried strips.

Impact test on slab reinforced with coal tar coated coconut strip performed favourably because on the contrast the coat acts as a protective or impervious film not allowing proper bonding of the concrete with the stem. The bond however, showed better impact resistance than plain concrete, dried coconut strip and glossed coconut strip concrete. It required a number of 8, 10 and 13 for dimensions 16 mm by 15 mm, 20 mm by 15 mm and 25 mm and 15 mm respectively and the impact load being 158.7 kN, 198.7 kN and 258.3 kN respectively.

However, concrete reinforced with steel bars performed better though it may contain demerits, this test proves the usefulness and importance of steel reinforcement in reinforced concrete structure. The reinforced concrete needed blow numbers of 15, 22 and 30 for failure and had enormous impact resistances of 298.0 kN, 437.0 kN and 596.0 kN for diameters 16 mm, 20 mm and 25 mm. This shows steel reinforcement as best qualifying material to be used in industrialized and populated cities, towns and societies in general as it ensures durable structures which will suffice its intended use in event of unforeseen impact occurrence. All the slabs tested failed in shear, there was an increase in crack as the size of strips also increased. The coconut strip coated with coal tar performed the best amongst the other natural fibre used with an ultimate load failure of 258.3 kN at 13blows.

4. Conclusion

From the results, it can be deduced that the ultimate load carrying capacity of the coal tar coconut stem had 55 % strength of the steel reinforced slab, which had a ratio 1:2 gain in strength somehow similar in behaviour as the control slab. As expected, the slab reinforced with steel showed better strength in the cured state; however, the 2% of the coconut stripes reinforcement treated with coal tar would serve as good as the conventional steel reinforcement for normal concrete. It can serve as a sustainable material in construction of low-load carrying structures.

Also, from the results, if lots of attention is given to the use of coconut stem as reinforcements, it will increase the importance of coconut tree in the economy and reduce the disadvantages of steel as reinforcements. The incorporation of coconut palm stem can be adopted for lightweight concrete structures.

Disclosure statement

No potential conflict of interest was reported by the authors.

Declaration of Competing Interest

There is no conflict of interest amongst the authors. The experimental work was carried out by the authors and each had its own role.

Acknowledgments

The authors appreciate Covenant University for their support and the laboratory assistants.

References

[1] M.A. Aziz, P. Paramasivam, S.L. Lee, Prospects for natural fibre reinforced concretes in construction, Int. J. Cement Compos. Lightweight Concrete 3 (2) (1981) 123–132.
[2] P. Ragavendra, Reddy, A. Dongre, Fibre Reinforced concrete- a case study, Conf. Pap. Natl. Conv. Archit. Eng. Natl. Semin, Inst. Eng. India Assoc. with Indian Assoc., 2017 Architectural Eng. Asp. Sustain. Build. Envel. ArchEn-BuildEn-2017.
[3] Noor Sadiqu, Habibur Rahman Sob, Shiblee Sa, Saiful Isl, The use of coconut fibre in the production of structural lightweight concrete, J. Appl. Sci. 12 (9) (2012) 831–839.
[4] Jerlin, A Study on the Behaviour of Coconut Shell in Lightweight, Anna Univ., Chennai, 2015, pp. 1–15.
[5] G.J. Alberti, M.G. Enfedaque A, Fibre reinforced concrete with a combination of polyolefin and steel-hooked fibres, Compos. Struct. 171 (2017) 317–325.
[6] D. S. S., D.S.S. Kumara. Incorporating Natural Fibres for Precast Slab Panels. International conference on sustainable built environment, 2017.
[7] E. Uwubanmwen, Okere Nwawe, Dada, Harnessing the potentials of the coconut palm in the nigerian economy, World J. Agric. Sci. (2011) 684–691.
[8] Idise, Emmanuel Okiemute, Studies on wine production from coconut (Cocos nucifera), J. Brew. Distill. 2 (5) (2011) 69–74.
[9] Olatokunbo Ofuyatan, Olutoge Festus "Flexural Characteristics and Potentials of Oil Palm Stem as Reinforcement in Concrete Beams", J. Emerg. Trends Eng. Appl. Sci. 4 (2013) 642–647.
[10] Ghavami, Bamboo as reinforcement in structural concrete elements, Cem. Concr. Compos. 27 (6) (2005) 637–649.
[11] M.N. Rana, A.K. Das, M. Ashaduzzaman, Physical and mechanical properties of coconut palm (Cocos nucifera) stem, Bangladesh J. Sci. Ind. Res. Vol. 50 (1) (2015) 39–46.
[12] Alireza Javadian, Mateusz Wielopolski, Ian F.C. Smith, Dirk E. Hebel, Bond-behavior study of newly developed bamboo-composite reinforcement in concrete, Constr. Build. Mater. 122 (2016) 110–117.
[13] Humphrey Danso, Properties of coconut, oil Palm and bagasse fibres: As potential building materials, 3rd International Conference on Natural Fibers: Advanced Materials for a Greener World, ICNF 2017, Braga, Portugal, 2017 21-23 June.
[14] P. Laroque, Design of a Low-cost Bamboo Footbridge, Massachusetts Institute of Technology, 2007.
[15] Johan Karlsson, Alternative Reinforcement Approaches, Chalmers University of Technology, Göteborg, Sweden, 2014.

[16] P.O. Awoyera, S. Karthik, P.R.M. Rao, R. Gobinath, Experimental and numerical analysis of large-scale Bamboo-reinforced concrete beams containing crushed sand, Innov. Infrastruct. Solut. 4 (1) (2019) 41.
[17] S. Anandaraj, J. Rooby, P.O. Awoyera, R. Gobinath, Structural distress in glass fibre-reinforced concrete under loading and exposure to aggressive environments, Constr. Build. Mater. 197 (2019) 862–870.
[18] K. Gunasekaran, Annadurai, Plastic shrinkage and deflection characteristics of coconut shell concrete slab, Constr. Build. Mater. (2013) 203–207.
[19] O.M. Ofuyatan, A. Ede, R. Olofinnade, S. Oyebisi, T. Alayande, J. Oluwafemi, Assessment Of Strength Properties Of Cassava Peel Ash-Concrete, Int. J. Civil Eng. Technol. 9 (January (1)) (2018) 965–974.