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MINNA, NIGER STATE, NIGERIA

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SETIC 2020 INTERNATIONAL CONFERENCE

BOOK OF PROCEEDINGS

MAIN THEME:

Sustainable Housing And Land Management

3RD -5TH MAY, 2021

SCHOOL OF ENVIRONMENTAL TECHNOLOGY COMPLEX, FUT, MINNA, NIGER STATE, NIGERIA

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Dean, School of Environmental Technology

Federal University of Technology Minna, Nigeria

School of Environmental Technology International Conference (SETIC 2020)

3RD – 5TH MAY, 2021

Federal University of Technology Minna, Niger State, Nigeria

CONFERENCE PROCEEDINGS

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PREFACE

The School of Environmental Technology International Conference (SETIC 2020) is organised by School of Environmental Technology, Federal University of Technology Minna, Nigeria. In collaboration with Massey University New Zealand, Department of Civil Engineering Faculty of Civil Engineering and Built Environment Universiti Tun Hussein Onn Malaysia, Malaysia Centre For Professional Development and Industrial Project Development School of Professional and Continuing Education (SPACE) UTM-KL Malaysia, Global Academia, Department of Architecture, Faculty of Engineering and Architecture, Istanbul Gelisim University Istanbul Turkey, Sustainable Environmental and Technology (SET) Research Group, Department of Architecture, Universiti Sains Islam.

The main theme for this year conference is “SUSTAINABLE HOUSING AND LAND MANAGEMENT”. This promotes and encourage innovative and novelty for policy issues for inclusive and sustainable housing; access to finance for housing and land development; sustainable building materials; building cost management; sustainable and resilient cities; geoinformatics for land management; rapid urbanization; sustainable land use and spatial planning and gender issues in access to land.

The responses from participants for this conference are overwhelming, well attended, and successful. The operation mode was virtual for all participants who choose the oral presentation mode and physical for all poster medium presenters. Our participants are from various Universities and other sector across the globe, from countries like United State of America (USA), Turkey, Malaysia, China, Saudi Arabia, Kenya, New Zealand and South Africa just to mention a few. Hence, this conference provides a good platform for professionals, academicians and researchers to widen their knowledge and approach on latest advances in research and innovation. Papers presented in this conference cover a wide spectrum of science, engineering and social sciences.

Finally, a note of thanks must go to SETIC 2020 Local Organizing Committee (LOC) for their remarkable dedication in making this conference a success. We hope the event will prove to be an inspiring experience to all committee members and participants.

ACKNOWLEDGEMENTS

The effort put together in achieving the success of SETIC 2020 is predicated on the feat of the first and second edition of School of Environmental Technology International Conference held in 2016 and 2018, respectively. The support and goodwill from Vice-Chancellor of Federal University of Technology, Dean School of Environmental Technology, Dr Dodo Y. A., Dr Moveh S. and many other highly motivated people are highly appreciated.
It is also my privilege and honour to welcome you all, on behalf of the Local Organizing Committee (LOC) to the 3rd edition of the Biennial School of Environmental International Conference (SETIC 2020). This Conference which was earlier schedule for 7th to 11 April, 2020 is holding now (3rd to 5th May, 2021) due to the challenges of COVID-19 Pandemic and the ASUU-FGN crisis which made our public Universities in Nigeria to be closed for about one year. We thank God for keeping us alive to witness the great SETIC2020 event, in an improved form exploiting the new-normal situation posed by the Pandemic for a hybrid (i.e. both physical and virtual) form of Conference participation.

The conference provides an international forum for researchers and professionals in the built environment and allied professions to address fundamental problems, challenges and prospects Sustainable Housing and Land Management. The conference is a platform where recognized best practices, theories and concepts are shared and discussed amongst academics, practitioners and researchers. This 2020 edition of SETIC has listed in the program a Round Table Talk on Housing Affordability beyond COVID-19 with selected Speakers from across the globe available to do justice on the topic of discussion.

Distinguished Conference participants, permit me to warmly welcome our Keynote and Guest Speakers:

- Prof. Ts. Dr. Mohd Hamdan Bin Ahmad, *Deputy Vice Chancellor (Development) Universiti Technology Malaysia (UTM)*;
- Assoc. Prof. Dr. James O.B. Rotimi, *Academic Dean Construction, School of Built Environment, College of Sciences, Massey University of New Zealand*;
- Assoc. Prof. Sr. Dr. Sarajul Fikri Mohammed, *General Manager, Centre for Professional Development and Industrial Project Development School of Professional and Continuing Education (SPACE), UTM-KL.*
- Prof. Ts. Dr. Zanail Abidin Akasah, *Visiting Professor on Sustainable Solar Integrated Design Building Design, International Micro Emission University (IMEU)/HIMIN Ltd. China & Senior Research Fellow, The Architects Resourcery, Jos, Nigeria*;
- Ar. Dr. Elina Mohd Husini, *Department of Architecture, Faculty of Engineering & Built Environment, Universiti Sains Islam*;
- Asst. Prof. Dr. Yakubu Aminu Dodo, *Department of Architecture, Faculty of Engineering and Architecture Istanbul Gelisim University, Istanbul Turkey*

and the five Speakers for our Round Table Talk on "Housing Affordability beyond COVID-19"

- Dr. Muhammad Mustapha Gambo, *Manager, Policy, Research and Partnerships, Shelter Afrique, Nairobi, Kenya*;

- Prof. Dr. Soumia Mounir, *Department of Architecture Ecole Nationale d'Architecture d'Agadir [The National School of Architecture of Agadir], Morocco*
- Dr. Said Alkali Kori, *General Manager, Projects and Portfolio management, Family Homes Fund, Federal Ministry of Finance, Abuja*;
- Ts. Dr. Sasitharan Nagapan, *Department of Civil Engineering, Faculty of Engineering and Built Environment, Universiti Turn Hussein Onn Malaysia, Malaysia*;
- Dr. Mercy Nguavese Shenge, *AIA Assoc. Historic District Commissioner, City of Rockville, MD, USA*.

for accepting to share from their knowledge, wealth of experience and be available to interact with participants on varied issues on "**Sustaining Housing and Land Management**".
As reflected on the Conference program, the Conference activities will be Virtual for power point presenters to run in four parallel sessions on the Zoon platform while the participants for Poster presentations (mostly Postgraduate students) are expected to have their Posters displayed in the Environmental Complex Building of the Federal University of Technology, Minna. With a total of One Hundred and One (101) articles captured in the Conference Proceedings covering the seven subthemes of the Conference, I have no doubt that we are all in for an impactful experience at SETIC2020 as we brainstorm, exchange ideas, share knowledge and participate in evolving more approach to sustainable housing and land management drives.

I implore us all to enjoy every moment of the deliberations and ensure we maximize the great opportunity offered by the Conference to network for better research and career development as we also make new friends.

I also on behalf of myself and the LOC express our appreciation to the Dean, School of Environmental Technology and the entire Staff of the School for giving us the opportunity to steer the ship for SETIC2020. To the Reviewers and various Committees that served with us, I say thank you for helping us through despite the pressure of work.

Thanks, and God bless you all.

Olawuyi, B.J. (PhD)
Chairman, LOC
SETIC2020

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Characteristics and Properties of Rice Husk Ash Based Fibrous Concrete Manufactured with Waste Metallized Plastic Film Fibre

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Abstract
The promotion of the use of eco-friendly substitutes to cement by several stakeholders in the construction industry are on the increase. This is due to the record portraying the cement and concrete industry as one of the largest producers of greenhouse gas globally. In order to reduce the waste generated globally, industrial and agricultural waste have been reported to enormous potential for reducing global cement reliance. One exciting material that has attained this feasibility is rice husk. The advancement in concrete technology in most recent times tends to deduce the potential means available for the optimum recycling of waste materials in construction practices for the purpose of sustainability in construction. In this article, effect of Waste Metallized Plastic Film (WMPF) fibre on the compressive and tensile properties of Rice Husk Ash (RHA) based Fibrous Concrete (FC). Mixes containing varying percentage of WMPF fibre (0%, 0.5% and 1.0%) were made with and without RHA to produce FC. The laboratory test revealed that the combination of WMPF fibre and RHA decreased the slump values and increased the VeBe time of fresh concrete. Similarly, the inclusion of WMPF fibre, either into CEM 1 cement or RHA concrete, did not improve the compressive strength. However, the positive interaction amongst the WMPF fibre and RHA lead to higher splitting tensile strength. It was revealed from the tensile test failure mode that WMPF fibre act as bridges across the cracks, which improved the load-transfer capacity of the matrix. The study showed that the utilization of WMPF fibre and RHA in the production of concrete is achievable from both technical and environmental viewpoints.

Keywords: *compressive strength, fibrous concrete, rice husk ash, tensile strength, waste metallized plastic film fibre*

1. INTRODUCTION

Waste management is a vital process towards enhancing the well-being of a nation. The world in general has been in extreme clamor to see in vivid terms an effective strategy formulated to enable the control of wastes and avert its effects on the general public. The exploitation of waste materials is one of the fundamental matters of waste management strategies in many parts of the world. The benefits of recycling comprise reducing environmental pollution, plummeting landfilling and discarding of wastes and conserving natural resources (Awal et al., 2015; Hossein and Mahmood, 2018). Mechanization and technological inventions produce huge amounts of waste materials from pre- and post-consumers products every year. In the construction industry, the knowledge of sustainability emboldens the use of waste products to substitute raw materials, such as fine and coarse aggregates, cement and fibrous materials. This leads to sustainable, green and environmentally friendly construction by decreasing the price of the constituents likened to disposing of the materials. Concrete is the utmost imperative construction material and its consumption is growing all around the globe. In addition to the normal applications, higher tensile strenth, ductility and energy absorption capacity are time and again required in different bids like runway, industrial floors, highway paving and bridge decks.

Cements are usually classified as calcium silicate and calcium aluminate cement. Calcium silicate cement is further classified into Portland and Slag, while calcium aluminate is classified into High alumina and Pozzolona cement (Jackson and Dhir, 1991). Rice Husk Ash (RHA) has been recognized as pozzolan. A pozzolan is a siliceous/aluminous material which in itself has little or no cementitious value, but which will in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide liberated during the hydration of Portland Cement (PC) to produce stable, insoluble cementitious compound which contributes to its strength and impermeability (Sima, 1974). Addition of RHA to PC does not only improve the early strength of concrete, but also forms a Calcium Silicate Hydrate (CSH) gel around the cement particles which is highly dense and less porous, and may increase the strength of concrete against cracking (Saraswathy and Ha-Won, 2007). The chemical analysis of the RHA revealed high amount of silica, alumina and oxides such as calcium oxide and iron oxide responsible for strength, soundness and setting of the concrete. It also contained some amount of magnesia which is responsible for the unsoundness (Saraswathy and Ha-Won, 2007).

The study of Nagrale *et al.* (2012) reported that addition of 15% RHA influences the density of concrete by reducing the weight concrete to about 72-75%. Thus, RHA concrete can be effectively used in the production of light weight concrete for the construction of structures where the weight of structure is of supreme importance. Nagrale *et al.* (2012) study further explained that the Compressive Strength of concrete will increase with the addition of RHA and noted that the inclusion of RHA in concrete considerably reduces the water absorption of concrete. Thus, concrete containing RHA can be effectively used in places where the concrete can come in contact with water or moisture. RHA has the potential to act as an admixture, which increases the strength, workability & pozzolanic properties of concrete.

Hossein and Mahmood (2018) reported that Plain unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. Due to the lack of tensile strength in concrete, it is reinforced with bars in structures. But this kind of reinforcement is crude and ineffective for crack control. Also this reinforcement gets decayed and corroded when exposed to the environments. The roles of randomly distributed discontinuous fibres is to bridge across the cracks and provide some post-cracking ductility. If the fibres are sufficiently strong and efficiently bonded to the material then it will permit the concrete to carry significant stresses over a relatively large strain capacity in the post-cracking stage (Saraswathy and Ha-Won, 2007).

Hossein and Mahmood (2018) stated that concrete mixtures of Waste Chopped Metallic Film (WCMF) fibre with 20% POFA produce a decreased compressive strength of 13.5% at 7 days and 10.2% at 28 days curing when compared to that of the PC-based concrete mix. However, at the curing period of 91 days, POFA based fibrous concrete mixtures attained compressive strength values higher than that of OPC-based mixtures.

Besides the workability properties, the aspects of strength properties are measured in the valuation of performance and possible application of any new waste material in concrete composites. Hitherto and to the authors' knowledge, there is no literature on the strength properties of WMPF fibre concrete composites containing RHA. Considering the pozzolanic behavior of RHA as well as the availability of WMPF fibres, studies on the application of the supposed materials in concrete were carried out in the Department of Building, Federal University of Technology Minna (FUTMINNA), Niger State, Nigeria. In view of that, the drive of this study was to utilize RHA as a supplementary cementing material in WMPF fibre concrete composite. Beside the fresh concrete properties, the strength properties such as compressive and tensile properties were tested and related with that of PC fibreless concrete. This attempt on using WMPF fibres and RHA in concrete composites could be cost-effective and environmental friendly as it limits the exploitation of virgin and natural resources that leads to the depletion of the earth surface. Also, the utilization of WMPF fibres and RHA in concrete production as the potential of decreasing landfilling problems in our environment in order to achieve a cleaner environment and inclusive cleaner production in the construction industry.

2. EXPERIMENTAL PROGRAM

This study focuses on the workability, compressive and splitting tensile strength of WMPF fibre reinforce concrete containing RHA. Mix designs of the fibre reinforced concrete with the different percentage of WMPF fibre and 15% RHA were developed. Slump test and vebe test was conducted to measure the workability of the mix designs. Upon preparation of the RHA base WMPF fibre reinforced concrete samples, they were cured in water for different ages of 7, 28 and 56 days. Compressive strength test and tensile strength test was conducted to measure the strength properties of the RHA base WMPF fibre reinforced concrete.

2.1 Materials

The materials used was placed in dry environment and air dry naturally. The detailed description of each material that was used in this study is discussed below:

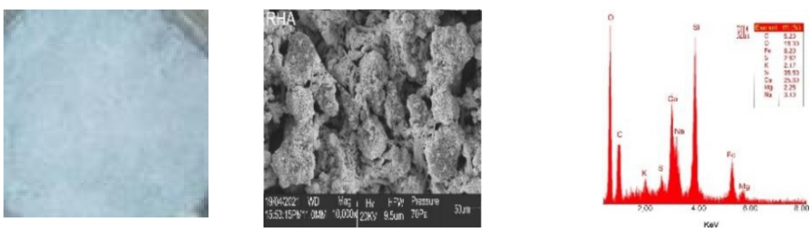
The rice husk were collected from Grain mill in Dama, Bosso Local Government of Niger State. The husk was dried and burnt in open air to get the ash which act as the pozzolan in the concrete material. The cascinated RHA was sieved to remove impurities after which it was grinded to a finer form and finally sieved using a 75µm sieve (Figure 1a). The specific gravity of the RHA is 2.51. RHA was used to replace the portland cement at a constant percentage of 15%. Figure illustrate a sieved RHA material. The obtained RHA is in consonance with the provisions of BS 3892: Part 1 (1997). According to ASTM C618 (2015), RHA can be characterised as class C and F. However, based on the type, source and comparatively low CaO (1.25%) content, this ash was classified as low calcium content ash. The chemical compositions of RHA are given in Table 1.

Table 1: Physical properties and chemical compositions of RHA

Chemical composition (%)										
Binder	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**P_2O_5**	**MgO**	**K_2O**	**TiO_2**	**Mn_2O**	**LOI**
PC										
RHA	83.79	0.54	1.38	1.26	6.29	1.55	1.56	0.20	0.29	2.93

The Scanning Electron Micrograph (SEM) of RHA is presented in Figure 1(b). The SEM micrograph of the RHA showed marginal pores at the magnification of ×10,000. The pore opening sizes could affect the workability of fresh concrete since it would mean a propensity to engross water. It could also affect the number of voids and capillaries, thus plummeting the density of the packed structure. Figure 1(b) showed that the RHA comprises spherical particles with a smooth surface.

The EDS analysis (Figure 1c) showed that the predominant elements in the tested RHA sample were; Si, Ca, and O in various compounds, although lower amounts of the elements Mg, S, K, Na, C and Fe were also observed.



(a) (b) (c)

Figure 1: (a) Calcined RHA photo (b) SEM image (c) EDS image (d) XRD pattern of the RHA sample used in the study

The fibres used for this work is the Metallic Plastic Film (MPF) used for packaging of beverage such as Peak Milk (Figure 2a). The WMPF were sought out for around the environment of the study area, since it's a readily available plastic waste common in student residence environment. The WMPFF were chopped into smaller piece of 20 mm length by 2 mm width as illustrated in Figure 2(b&c). Table 2 shows the Engineering properties of WMPF fibre.

Table 2: *Engineering properties of WMPF fibre.*

Property	Values
Resin category	Polypropylene
Plastic type	LDPE
Thickness (mm)	0.07
Size (W*L) (mm)	2 x 20
Density range (kg/m3)	0.915–0.945
Tensile strength (MPa)	400
Elongation (%)	8–10
Reaction with water	Hydrophobic

Source: Hossein & Mahmood (2018).

(a) Post-consumer waste metalized plastic films (b) fabricated metalized plastic fibres (c) WMP fibres used in this study.

Figure 2: Waste metalized plastics fibres

The cement used was a Nigerian based brand of Portland cement (PC) with 28 days strength of 52.5 MPa. The specific gravity of the Portland cement is 3.15. ASTM Type 1, with brand name Dangote Portland cement, Portland cement is a hydraulic material, when mixed with water; it results in formation of exothermic bonds. The fine aggregate used for the production of the concrete is collected from a local river sand and it has a maximum sieve size of 4.75 mm with a specific gravity of 2.64 was used as the fine aggregate. Coarse aggregate used was crushed granite with a maximum sieve size of 10 mm and a relative specific gravity of 2.7. The water used for preparing and curing concrete was collected from a Bore hole supply in the School of Environment Technology, Department of Building laboratory. Superplasticiser (SP) of trade name CONPLAST SP 430 conforming to ASTM C494 (2018) requirement was used as a water reducing admixture to enhance the workability of the fresh concrete. Owing to the high viscosity, the super plasticiser was added to the mixing water. CONPLAST SP 430 is a high range water-reducing concrete admixture. It is a highly effective dual action liquid super plasticiser for the production of free-flowing concrete or as a substantial water reducing agent for promoting high early and ultimate strength. It is chloride free and is compatible with all types of Portland Cement.

2.2 Mix Proportion and Sample Preparation

The concrete mix proportions were designed in accordance to the appropriate provisions of the Department of Environmental (DOE) methods of concrete mix design manual. To show the authentication of the determined mix design carried out, trial mixes tests were carried out to obtain the suitability of the mix and to ensure that concrete is produced with respect to the desired fresh concrete characteristics. RHA based fibre reinforced concrete suitable mix design and appropriation mixing procedure were developed after several trial mixes had been done. Table 3 shows the values obtained from the mix design prepared. Different mix proportions of PC-based concrete and RHA-based concrete composites are given in Table 3.

Several mixes with different fibre volume fractions were prepared, of which one batch was made of PC type cement without any fibre content, and also RHA based concrete of 15% replacement without fibre which was assumed as the control mix. There were four batches which includes mixes containing fibre contents of PC based concrete with WMPF fibres content of 0, 0.25, 0.50, 0.75, and 1.0%. The other four mixes, which are referred as group of RHA, were prepared by replacing PC cement with 15% RHA with the addition of the corresponding WMPF fibre contents as stated above.

Table 3: *Mix proportion details of concrete constituent*

Mix Type	Mix ID	Cement (Kg/m^3)	RHA (%)	RHA (Kg/m^3)	Water (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	V_f (%)
Group A	PC	521	0	0	250	784.5	784.5	0
	PF1	521	0	0	250	784.5	784.5	0.5
	PF2	521	0	0	250	784.5	784.5	1.0
Group B	R1	442.5	15	78.2	250	784.5	784.5	0
	RF1	442.5	15	78.2	250	784.5	784.5	0.5
	RF2	442.5	15	78.2	250	784.5	784.5	1.0

Note: PC=Plain concrete, R1=RHA based concrete with 15% replacement of cement, PF1=Cement + Aggregate+ WMFF of 20mm length at 0.5% addition, PF2=Cement + Aggregate + WMPF fibre of 20mm length at 1.0% addition, RF1= RHA based concrete at 15% of cement replacement + WMPF fibre of 20mm length at 0.5% addition and RF2= RHA based concrete at 15% of cement replacement + WMFF of 20mm length at 1.0% addition.

2.3 Test Methods

The workability investigation carried out on the fresh concrete mixture are slump test (BS EN 12350-2, 2009) and vebe time test (BS EN 12350-3, 2009). 100 mm x 100 mm x 100 mm cube specimen were used to determine the compressive strength of the concretein conformity to BS EN 12390-3 (2009). Cylinderical specimen of 100 mm diameter and 200 mm height was used to carryout splitting tensile strength which conforms to ASTM C 496 (2011) at the curing periods of 7, 28 and 56 days.

3. RESULTS AND DISCUSSION

3.1 Workability

The influence of RHA and WMPF fibres on the consistency of concrete composites was investigated using the slump and VeBe time tests and the results are presented in Figure 3&4. It was observed that the workability of fresh mixtures is significantly influenced by WMPF fibres and RHA. It was found that the addition of WMPF fibre in the concrete mixtures caused decrease of slump values and an increase of VeBe times. The inclusion of WMPF fibres affects the viscosity of the matrix. The addition of fibres at higher volume fraction also interjects the consistency of the mixture, which was directed to the balling effect of concrete components and WMPF fibres. As demonstrated in Figure 3, the slump value of the control mixture (0% RHA/%Fibre content), was recorded as 180 mm. By the addition of WMPF fibre at volume fraction of 0.25%, 0.5%, 0.75% and 1%, the slump values reduced to 125, 85, 60, and 50 mm, respectively. Furthermore, the addition of RHA into the mixtures would make the matrix denser by filling up the micro-pores in the mixture, as stated by Mohammadhosseini *et al*. (2017), and Sata et al. (2007). Consequently, it caused a stiffer mixture with a corresponding decrease in the flowability of the matrix. From the experimental findings, it was evident that the addition of 15% RHA added into the mixture, made the slump values reduced to 165 mm and VeBe time increased to 17 seconds compared to that of 180 mm and 16 seconds for Portland Cement control mixture (0% RHA/0% Fibre) (Figure 4). Increased fibre volume fractions in RHA-based mixtures also contributed to the reduction in workability of concrete composites. For example, the slump values of 110, 60, 45, and 40 mm were recorded for the similar fibre content, respectively. For a given fibre volume fractions, the addition of a constant amount of RHA lead to higher VeBe times as well. The reduction in the workability of the RHA-based mixtures could be attributed to the high surface area, high porosity of RHA particles in addition to the high water absorption physiognomies of RHA as likened to other pozzolanic materials such as fly ash. On the other hands, as RHA is an agriculture waste and contains carbon and unburned particles, these particles absorb superplasticizer and water, and therefore, decrease the workability of concrete, as reported by Khankhaje et al. (2016) and Sata et al. (2007).

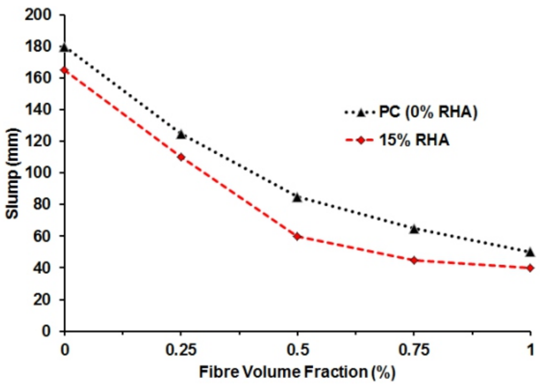


Figure 3: Effects of WMPF fibres on slump values of concrete containing 0% RHA and 15% RHA.

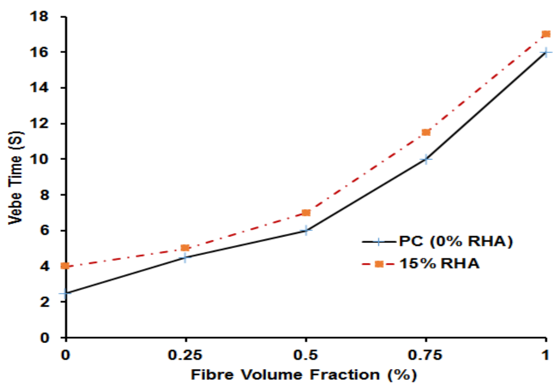


Figure 4: Effects of WMPF fibres on VeBe times values of concrete containing 0% RHA and 15% RHA.

3.2. Compressive Strength

The result of cube compressive strength of all the concrete mixtures gotten from the laboratory test shows a trend of reduction as the fibre volume fraction is increased. Figure 5&6 reveals the experimental results for the compressive strength of Portland Cement (PC) (0% RHA) and RHA-based concrete mixes (15% RHA) incorporating WMPF fibres at different curing periods. Relating the 28 days compressive strength values of the plain concrete mixture (0% RHA/% fibre), the inclusion of WMPF fibres at volume fraction of 0.25%, 0.5%, 0.75%, and 1% reduced the cube compressive strength by 5.75%, 9.43%, 12.25% and 18.65%, respectively. In concrete mixtures with 15% RHA, further reductions in compressive strength of 35.45% at 7 days and 11.68% at 28 days hydration were observed related to that of the PC based concrete mixture.

The acquired results of this study agree with those findings by Hossein *et al* (2018), who reported the decrease in compressive strength values by the adding of metalized plastic waste fibres. Air voids noticed in the matrix which consequently increased as fibres were further added to concrete, and lead to the reduction in the compressive strength of the concrete. Hence, effects of air voids in reduction of strength was more real, compared to arresting the further crack openings. Beyond 28 days, the compressive strengths of RHA-based concretes tended to increase with the curing age for all fibre volume fractions and gave higher compressive strength than that of Portland Cement (PC) concrete at 56 days. This can be described by the fact that the higher fineness of RHA develops pozzolanic properties and particle packing density. These characteristics tend to develop concrete strength as well as its density (Chandara, *et al.*, 2010; Safiuddin *et al.*, 2011; Megat *et al.,* 2012). Figure 7 presents the failure mode comparing the Plain concrete and fibre reinforced concrete. The plain concrete without the fibre was observed to exhibit a catastrophical failure under load while the Fibre reinforce concrete displayed a ductile mode of failure when exposed to a static loading system.

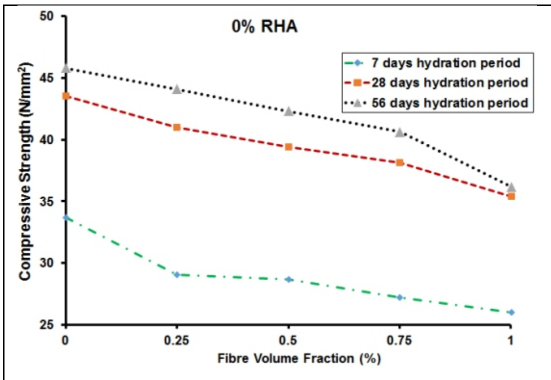


Figure 5: Upshot of WMPF fibre Content on Compressive Strength of Concrete Containing 0% RHA at vaying hydration period

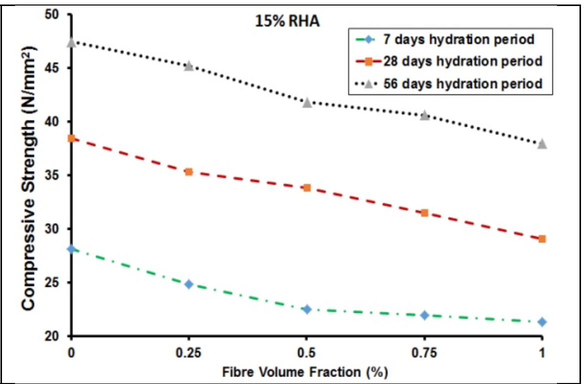


Figure 6: Upshot of WMPF fibre Content on Compressive Strength of Concrete Containing 15% RHA at vaying hydration period

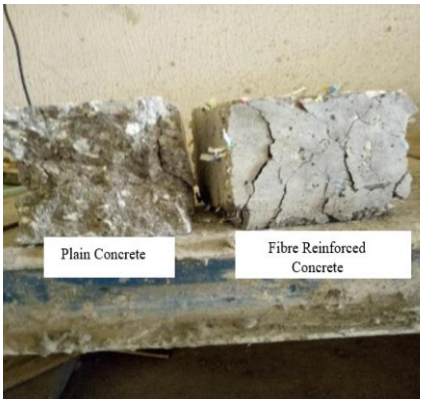


Figure 7: Comparison of failure modes of concrete specimens with (fibre reinforced concrete) and without WMPF fibre (plain concrete) after subjected to compressive load

3.3. Splitting Tensile Strength

The variant in the results of tensile strength against WMPF fibre volume fractions is shown in Figure 8 and 9. The inclusion of WMPF fibres and increased in the fibre content produced a tensile strength values of concrete mixtures that is noticeably higher than those of the control mix (0% RHA/0% Fibre content). When the splitting occurred and was sustained, the WMPF fibres bridging the split portions of the specimens acted over the stress transfer from the matrix to the fibres and then gradually supported the full tensile stress. The resistance against the indirect tension improved the strain capability of the specimens and therefore, results in higher splitting tensile strength of those specimens reinforced with short fibres than those of plain concrete mixture (Hsie *et al*., 2008). The integration of WMPF fibres and RHA contributed to the enhancement of tensile strength. At the age of 56 days, the splitting tensile strength of PC-based concrete mixes increased by 31.10%, 40.13%, 37.12%, and 33.11% for the fibre dosages of 0.25%, 0.5%, 0.75%, and 1%, respectively, associated to that of control concrete mix (0% RHA/0% Fibre content). Whereas, at the same curing period (56 days), the inclusion of RHA to the fibrous concrete, for instance, enhanced the strength values by 34.78%, 44.48%, 43.14%, and 39.13% for the similar fibres content, compared to the control mixture (0% RHA/0% Fibre content). The improvement in the tensile strength could be due to the greater contact surface area amongst WMPF fibres and the binder paste causing from the pozzolanic hydration process, which is in line owing to the good pozzolanic nature of RHA at the ultimate ages (Alsubari et al., 2016). A similar explanation on the enhancement in tensile strength of concrete by the addition of metalized plastic waste fibres has been reported in literature by Bhogayata and Arora (2017).

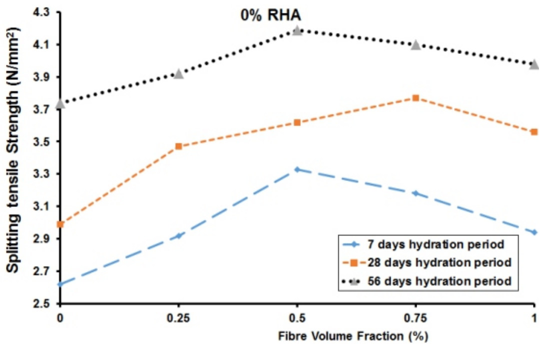


Figure 8: Effect of WMPF fibre Content on Splitting Tensile Strength of Concrete Containing 0% RHA

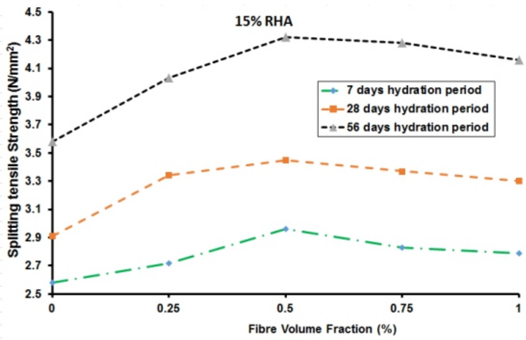


Figure 9: Effect of WMPF Content on Splitting Tensile Strength of Concrete Containing 15% RHA

5. CONCLUSION

This paper probed the effect of the inclusion of WMPF fibre and RHA on the workability, compressive strength and tensile strength properties of concrete composites. Based on the observations made and experimental results, the ensuing conclusion was made. The inclusion of WMP fibres in concrete mixtures affects the workability of fresh concrete mixes. The higher the WMPF fibre content, the lower the slump values and the higher the VeBe times becomes. The compressive strength of the fibre reinforced concrete mixtures reduces as the volume fraction of the fibre is increased. At early ages, the improvement in the compressive strength of mixtures containing RHA is observed to be similar to that of PC concrete mixes. At 56 days of hydration in water, the compressive strength of RHA-based concrete mixtures exceeds the values of PC concrete mixtures. In spite of the reduction in compressive strength, noteworthy developments in tensile strength of concrete composites was observed. The RHA-based concrete mixes reinforced with WMPF fibres attained a superior enhancement in tensile strengths owing to firm fibre-cement matrix boundary and densification of the matrix through the pozzolanic action of RHA. At the curing period of 56 days, the tensile strength increased by 40.13% for the PC-based concrete mixture and 44.48% for the RHA-based concrete mixtures having 0.5% fibre as compared to the plain concrete mixture without any fibres. The development and mass production of green and sustainable concrete composites integrating RHA and WMPF fibres is feasible. Its performance as be demonstrated and is recommendable in the construction of low-cost housing, concrete road pavement sustainable infrastructures, bridge decks, , and other associated applications.

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