https://dx.doi.org/10.22161/ijaers.5.1.7 ISSN: 2349-6495(P) | 2456-1908(O)

Enhancing Strength Properties of Rubberized Concrete using Waste Cement Sacks

Emmanuel Owoichoechi Momoh, Kassar Terungwa, Godwin Joel

Department of Civil Engineering, University of Agriculture Makurdi, Nigeria

***Abstract*— *Low flexibility and brittleness of ordinary concrete limits its use as construction material for buildings prone to earthquake ground vibrations. Rubberized concrete which possesses the needed ductility on the other hand is however of low strength and durability. This study utilized waste polypropylene sacks used for packaging cement. The sacks were used in form of confinements to enhance the strength/ductility of rubberized concrete. Concrete cylinders, cubes and beams at different replacements levels of coarse aggregate with waste tire rubber chips(WTRC) (at 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100% by volumes) were cast and tested for fresh and hardened properties such as slump, compressive strength, flexural strength, and deformation behaviour. The result showed proportional reduction in strengths with increasing replacement of WTRC. Ductile and elasto-plastic deformations were exhibited by WTRC concretes. The use of waste cement sacks confinement as a means of overcoming the reduced strength of the rubberized concrete proved highly feasible and economic for the cylindrical specimens. Optimum performance in failure load (for confined specimens) was obtained at 80% WTRC replacement. The confined 80% WTRC failure load was 45.5 KN, approximately 300% increase in failure load of the unconfined 80% WTRC concrete. This indicates that the use of waste cement sacks to confine rubberized concrete effectively negates the decrease in strength, and retains the advantages of increased ductility and energy-dissipation that characterizes rubberized concrete.*

Keywords*— *rubberized concrete, waste tyre rubber chips, strength

I. INTRODUCTION

Recent occurrences in nature has necessitated structures to resist wind loading, earthquake ground vibration as well as other combined axial and lateral loadings due to extreme events. It becomes imperative that structures be designed and constructed with materials that can accommodate these effects. These structures must possess good dynamic response and must be cheap enough to be afforded by citizens of especially developing countries where the government is unable to provide housing let alone supervise the quality of housing provided by citizens themselves.

In the early 1990s, recycled waste tire usage expanded into a relatively new product called rubberized concrete [1]. Rubberized concrete uses portland cement as its binder. This lead to the discovery that the use of waste tyre as aggregate replacement in concrete shows an improvement in the concrete mechanical properties such as ductility (flexibility), energy dissipation, toughness, increased damping and sound insulation among others [2], [3], [4], [5], [6], [7]. A ductile form of concrete known as rubberized concrete which was hitherto thought to be impossible to achieve has gained interests all over the world.

1.1 Significance of the study

In developing countries, the government is unable to provide decent shelter for her teeming population hence the abundance of many non-engineering houses having one or two storeys. These constructions usually have little to no reinforcement, and collapse at the slightest movement of the ground causing injuries or even death of their occupants [8]. Rubberised concrete provides a cheap source of construction concrete for these regions except for the low strength attributed to it. An approach to negating the drop in strength at the addition of rubber to concrete is through confinement. Several confinement methods and strengthening techniques for reinforced concrete structures have been reported [9],[10],[11],[12],[13] but all these techniques may not be within the reach of the ordinary poor citizen [12]. Aside the strengthening methods being expensive, the technical know-how of using these strengthening methods may not be available to the impoverished non-literate citizens. The use of rubberized concrete confined with waste polypropylene sacks (used for packaging cement) proves cheaper and easier to use.

It is with this in mind that the research aims to enhance the strength properties of concrete by replacement of coarse aggregate with waste tyre chips and providing confinement to the concrete.

The objectives of this investigation are as highlighted below:

- Casting 100x300mm concrete cylinders, 150x150x150mm concrete cubes and

100x100x450mm concrete beams at different replacement levels of coarse aggregate with waste tyre rubber chips,

- Carrying out strength tests on the cast specimens at 7, 14 and 28 days,
- Enhancing the strength properties of rubberized concrete through confinement with waste polypropylene cement sacks recovered after using cement,
- Providing recommendations for the use of polypropylene cement sacks as confinement for rubberised concrete columns.

This research evaluates the need for the use of waste polypropylene cement sacks to enhance strength properties of concrete incorporating WTRC as coarse aggregate. Section II discussed the materials and testing methods to measure the fresh and hardened concrete properties. Results of findings were presented and discussed also in section II as well as necessary graphs showing relationship between the results obtained. Section III highlighted the summary of findings, conclusions and provided recommendation for future findings and analysis. The research was limited to the laboratory investigation of fresh and hardened properties of the concrete as well as confinement to improve strength.

II. MATERIALS AND METHODS

2.1 Materials

- **Cement**

The cement used for the research was ordinary Portland cement (Grade 42R satisfying BS 12:1996) produced by Dangote Cement Company, Nigeria.

- **Aggregates**

Coarse and fine aggregate used were river gravel and sand respectively and were sourced from the river Benue in Makurdi, Nigeria. The coarse aggregate was partially replaced with waste tyre rubber chips (WTRC).

- **Waste Tyre Rubber Chips (WTRC)**

The waste tyres were cut into chips using hand cutter to a size range of between 20mm and 5mm. The chips were used as partial replacement for coarse aggregate in various percentages of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%.

- **Waste Cement Sacks**

These are polypropylene sacks used for packaging cement. They were used for the rubberized concrete cylinder confinement. The waste cement sacks were sourced from the construction site located at the College of Engineering University of Agriculture Makurdi Nigeria.

- **Water**

Fresh water (satisfying ASTM C1602) used for specimen casting was obtained from the university water works. The storage tank beside the Civil Engineering Laboratory served as access point to the water used for the research.

2.2 Methodology of Tests

The various tests carried out were conducted at the Department of Civil Engineering Laboratory, University of Agriculture Makurdi (UAM). The tests include:

2.2.1 Specific Gravity Test

The specific gravity is the fundamental physical characteristic of the material. It is the ratio of the weight of a given material to the weight of equal volume of water. The test was conducted for both fine and coarse aggregate in accordance with BS 4550: Part 3: Section 3:1978 using the density bottle. Apparatus used include Specific gravity bottle, weighing balance, distilled water (water without impurities), trowel and dry oven.

The specific gravity bottle was weighed empty and the weight recorded as W_1. An amount of the sample was poured into the empty specific gravity bottle and weighed and the weight obtained gives the weight of empty bottle plus sample which was recorded as W_2. Distilled water was added to the sample inside the specific gravity bottle and the content was weighed. The weight obtained was recorded as W_3, this comprises of the weight of bottle, sample and water. The Specific gravity bottle was then emptied of its content, rinsed, and filled with distilled water which was weighed and recorded as W_4. The specific gravity was calculated using equation 2.1.

$$G_S = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad \ldots\ldots 2.1$$

For each of the materials, the test was conducted twice and the average value was taken as the specific gravity for that material. Table 2.1 shows the Specific Gravity of WTRC.

Table.2.1: Specific Gravity of WTRC

Bottle Description	Bottle 1	Bottle 2
Weight of bottle (W_1) (g)	25.7	25.7
Weight of bottle + sample (W_2) (g)	31.3	32.2
Weight of bottle + sample + Water (W_3) (g)	102.8	102.6
Weight of bottle + Water (W_4) (g)	102.3	102.3
Specific Gravity (Gs)	1.10	1.05
Average Gs	*1.08*	

From Table 2.1, the average specific gravity of waste tyre rubber was found to be 1.08 which falls between 1.02–1.27 as highlighted in [Rui 2013]. This is less than half of the specific gravity of the coarse aggregate. This implies that, replacement of coarse aggregates with waste tyre rubber in concrete reduces the overall weight of the concrete. Similarly, the specific gravity of both the sand

https://dx.doi.org/10.22161/ijaers.5.1.7 *ISSN: 2349-6495(P) | 2456-1908(O)*

(fine aggregate) and river gravel (coarse aggregate) was found to be 2.62.

2.2.2 Sieves Analysis

The process of dividing the sample of aggregate into fractions of same particles size is known as sieve analysis. Its purpose is to determine the grading or size distribution of the aggregate (Neville 2010). This test was carried out for both fine and coarse aggregate. The apparatus used were sieve mesh, trowel, brush, and weighing scale. Various sieves with sizes 20 mm, 14 mm, 20 mm, 6.3 mm, 5.0 mm, 3.35 mm, 2.36 mm, 1.70 mm, 1.18 mm, 850 µm, 600 µm, 425 µm, 300 µm, 150 µm and 75 µm were used for the experiment. The sieves were arranged vertically in descending order of sizes while conducting the experiment. The 20 mm down to 3.35 mm sieve were used for the river gravel and waste tyre chips (coarse aggregates) while 3.35 mm down to 75 µm sieve were used for the river sand (fine aggregate). Fig 2.1 shows the graph of sieve analysis of WTRC.

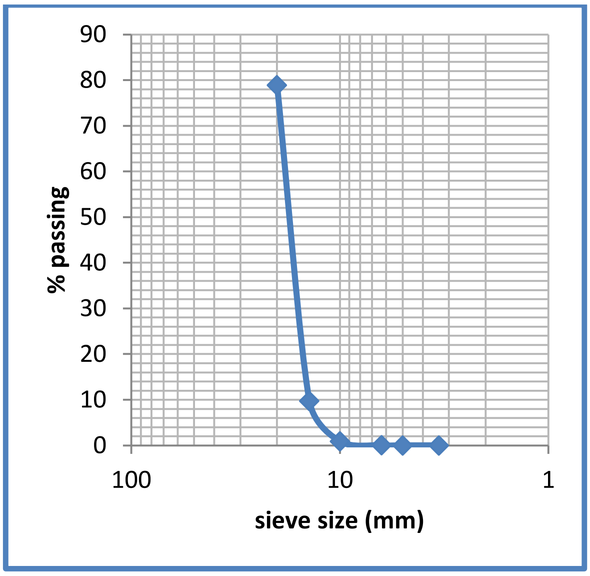

Fig 2.1: Sieve analysis graph of waste tyre rubber chips

The result of sieve analysis of the waste tyre rubber from Fig 2.1 indicates that the aggregates size ranges between 20 mm – 5 mm with about 69% of its whole amount predominantly of size 14 mm. The waste tyre rubber could not meet the grading requirement for coarse aggregate according to BS 882: 1992 due to its poor grading. Fig 2.2 presents the graph of sieve analysis for fine aggregate (river sand).

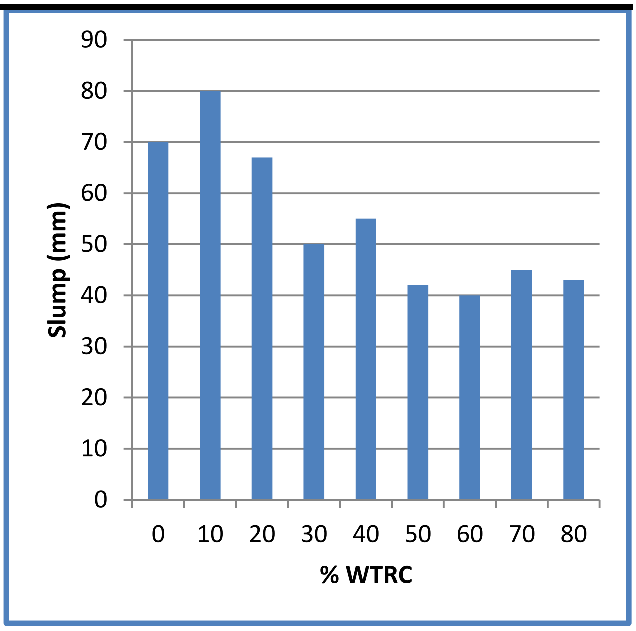

Fig 2.2: Sieve analysis graph of river sand (fine aggregate)

The fineness modulus of the coarse aggregate was computed and found to be 5.82. Generally, the fineness modulus of fine aggregates ranges between 2.3 and 3 [14], aggregates having higher values greater than 3 indicates coarser grading. Though, the fine aggregate meet the grading requirements for fine aggregate according to BS 882: 1992. The fineness modulus (5.82) computed may be due to the increased in the number of sieves used. Fig 2.3 presents the graph of sieve analysis for coarse aggregate (river gravel)

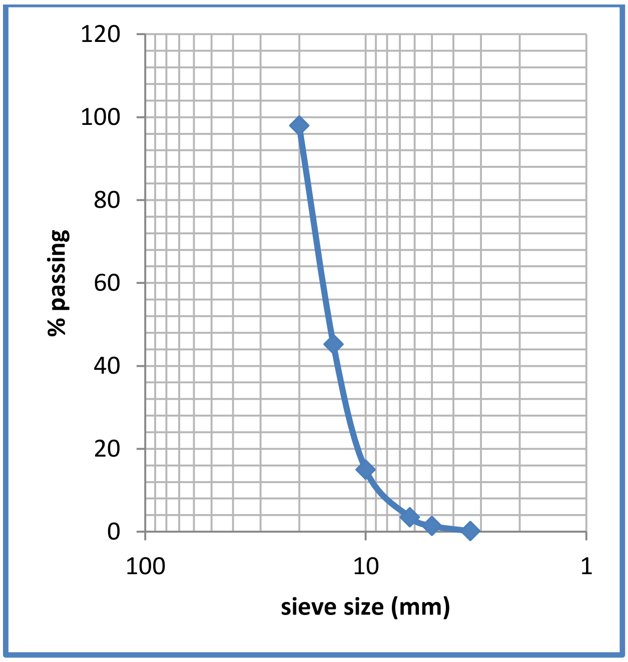

Fig 2.3: sieve analysis graph of river gravel (coarse aggregate)

From Fig 2.3, coarse aggregate sieve analysis, the result shows that majority of the aggregates are of 14 mm size with 1.4% of its weight below 5 mm size. The result of the fineness modulus clearly indicates coarser grading (since it is above 3.0). The coarse aggregate also meet the grading requirement according to BS 882: 1992.

2.2.3 Slump Test

Fig 2.4 shows the result of the slump obtained for each respective amount of WTRC replacement. The test was conducted according to ASTM C143. The slump value on a general note could be said to range between 40 – 80 mm. Concrete mix with less amount of WTR tends to have medium degree of workability, but the workability tends to decrease with increase amount of WTR. This decrease in slump with increasing amount of WTR confirms the report made by [4] and [15].

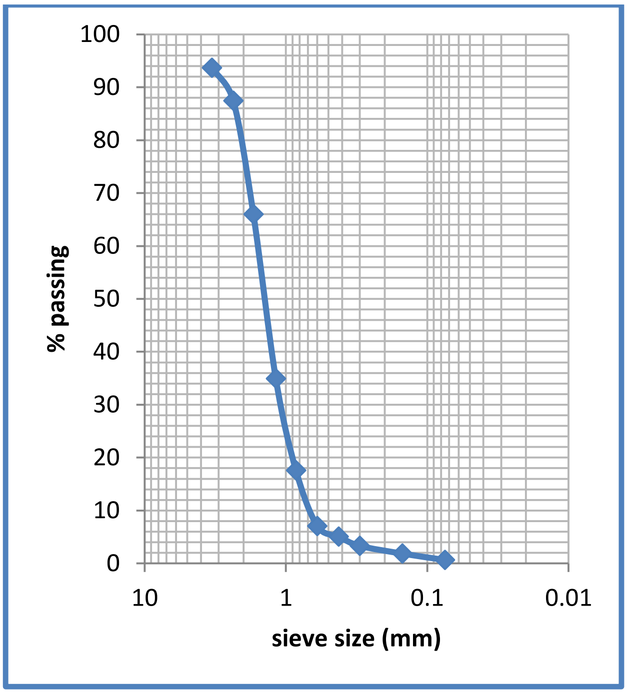

Fig 2.4: Slump relationship with % replacement of coarse aggregate with WTRC

From Fig 2.4, the highest and lowest value of slump was achieved at 10% WTR and 60% WTRC respectively with 50% total decrease in slump when compared between the two WTRC percentage replacements. This decrease in slump then implies that at higher percentage replacement of WTRC in concrete may not be workable for the water/cement ratio of 0.5 used.

2.2.4 Compressive Strength Test

The test was performed at 28 days for cubes and at 7, 14 and 28 days for the unconfined concrete cylinders in order to find out the variation of strength with the age of the concrete. The compressive strength test was conducted in accordance with IS: 516-1959. Eleven mixtures were performed for the cubes and nine mixtures for the concrete cylinders. The compressive strength computed are tabulated and plotted against the % WTRC replacement as shown in Fig 2.5. There was a general decrease in the compressive strength for the cubes and unconfined concrete cylinders. This is in agreement with the report of [5] . The reduction in strength is as a result of poor adhesion between the WTRC and binder. Since one of the objectives is to improve the structural performance of the concrete through confinement, this was done with aid of waste polypropylene sacks after using cement out of the packaging. The outcome of the results indicates a great improvement in the strength and flexibility of the WTRC concrete as seen in section 2.2.5.

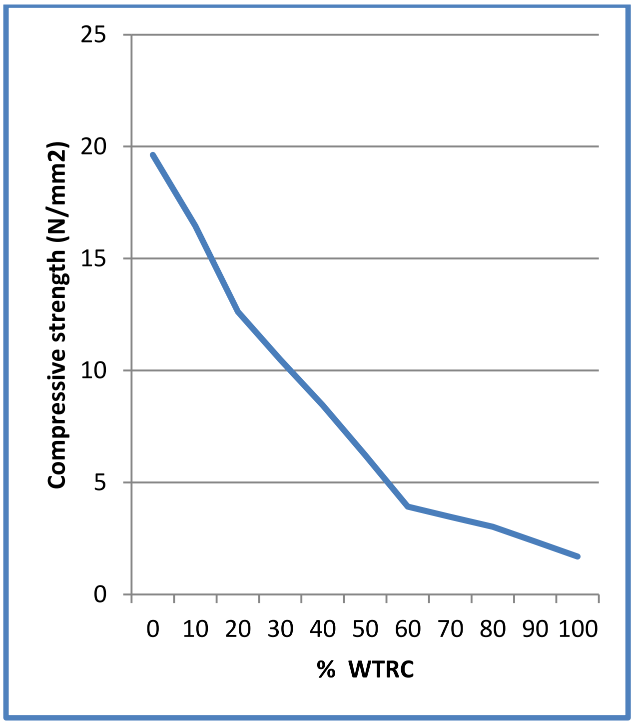

Fig 2.5: *Graph of compressive strength of cubes vs % WTRC*

The compressive strength of cubes for the eleven mixes is plotted against percentage replacement of WTRC as shown in Fig 2.5. The cube strength at 28 days for the control (0% WTRC) is 19.63 N/mm^2. There was a proportional reduction in strength and density with increased WTRC replacement in the concrete mixtures. 10% WTRC mix tends to have the least reduction in cube strength of about 16.2 % as compared to the 100% WTRC having about 91% reduction of the control strength. This implies that the 100% WTRC mixture cannot be used for construction purposes. Concrete mix with 10% WTRC can be effectively used for the replacement with coarse aggregate since reduction in strength is minimal at this point.

https://dx.doi.org/10.22161/ijaers.5.1.7 *ISSN: 2349-6495(P) | 2456-1908(O)*

The desirable ductile effect of including WTRC in the concrete is seen in the failure mode of the concrete as observed during crushing. Plate 2.1(a) and (b) shows the failure mode of the control concrete and WTRC concrete respectively. The mixture with WTRC underwent elasto-plastic deformation during and after failure while the control (0% WTRC) disintegrated in a brittle manner under the failure load. Though the failure load of WTRC concrete was small, elasto-plastic deformation observed at constant loading showed that the cubes tend to absorb more energy with ductile cracks developing.

2.2.5 Confinement

The reduction in the strength of concrete incorporating WTRC can effectively be negated by the use of lateral confinement in various forms. However for the purpose of this research, a very low cost approach is desired. Confinement of the cylindrical concrete specimens was therefore done using waste polypropylene cement sacks. The sacks are the bags used to package Portland cement in Nigeria. At construction sites, these sacks are thrown away after the cement has been used out of them. The confinement test was carried out with these waste cement sacks, wrapped and bonded using modified acrylic adhesive (4-minutes epoxy steel gum). The specimens were wrapped in three layers with aid of the adhesive. See Plate 2.1(E) and (F). The failure loads of the confined concrete cylinders obtained were found to be much greater than the failure load of the unconfined concrete cylinders. High deformations were observed for the confined concrete cylinders; deformation up to 6% of original height of specimens was obtained for the confined concrete cylinder containing 80% WTRC. The result of the confinement is presented in Fig 2.6.

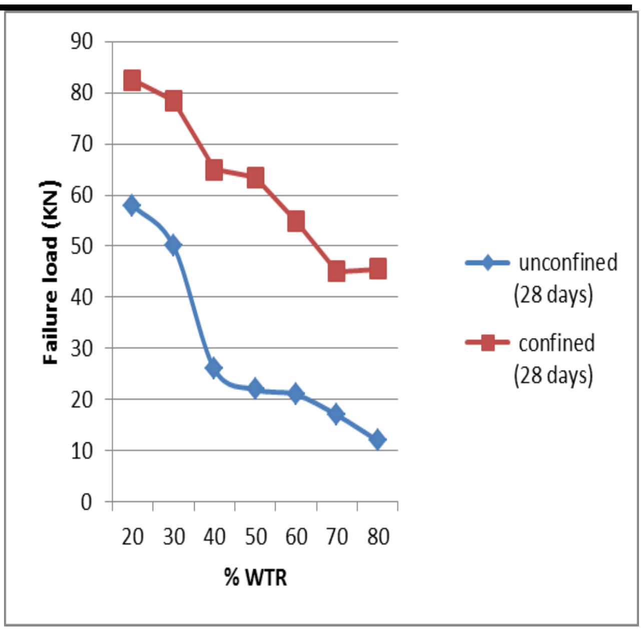

Fig.2.6: Relationship between the failure load of unconfined and confined concrete cylinders

The difference in failure load between the unconfined and confined cylinders is quite large. This shows the effectiveness of the confinement using waste cement sacks. Increase in failure load occurred for each of the WTRC replacement mix. The percentage increase in failure load when comparing the unconfined failure load with that of the confined for each of the WTRC replacement mixes are given as follows:

20% WTRC = 42.2%
30% WTRC = 57%
40% WTRC = 150%
50% WTRC = 188.6%
60% WTRC = 161.9%
70% WTRC = 164.7%
80% WTRC = 279.16%

https://dx.doi.org/10.22161/ijaers.5.1.7 ISSN: 2349-6495(P) | 2456-1908(O)

Plate 2.1: *(A) Brittle failure of control cube (B) Brittle failure of control cylinder (C) Ductile failure of unconfined rubberized concrete cylinder (D) Ductile failure of rubberised concrete (E) Waste cement sack confinement of rubberised concrete cylinders (F) Ductile failure of confined rubberised concrete cylinders.*

Ductile mode of failure was exhibited by the confined concrete cylinders, with high ductility and compressibility. The concrete cylinders could regain their original height after application of load. Elasto-plastic deformations were also observed during loading with the concrete's ability to withstand further loading after seeming failure. The ductile mode of failure is shown Plate 2.1 (C), (D) and (F).

2.2.5 Flexural Strength Test

Flexural test was conducted according to BS 1881: Part 118: 1983. Six mixtures of WTRC were used. Beams of dimension 100 mm X 100 mm X 450 mm were cast and cured for 28 days. The result obtained after crushing was tabulated and plotted against the percentage of WTRC concrete. The result reveals a decrease in flexural strength with addition of WTRC. This confirms the report made by [16], [17] and [18]. The result of flexural strength of the beams for the 20% WTRC and 40% WTR replacement falls within the typical range values of ordinary Portland concrete (which is between 3 – 5.5 N/mm^2). This implies that WTRC replacement up to 40% can provide sufficient flexural strength. The result of flexural strength at 28 days has been presented in Fig 2.7.

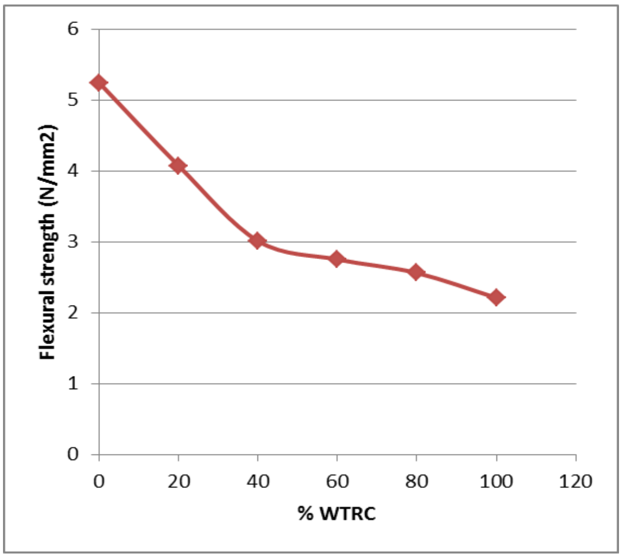

Fig.2.7: Flexural Strength of Beams Vs % WTRC

The graph reveals a proportional decrease in the compressive strength with increasing WTRC content. At

https://dx.doi.org/10.22161/ijaers.5.1.7 *ISSN: 2349-6495(P) | 2456-1908(O)*

100% WTRC, there was a total reduction in flexural strength of 57.8% when compared with the control; this implies a more than half decrease in flexural strength. The percentage reduction in flexural strength of 20% and 40% WTR were 22.3% and 42.6% respectively. The percentage reductions were higher, though the value of their flexural strength fall within the range values of ordinary Portland concrete. In addition, ductile failure was observed for the concrete mixes incorporating WTRC. The failure at ultimate load was gradual not the brittle sudden failure as in the case of the control mix. This then implies that incorporation of WTRC in concrete does not only provide sufficient flexural strength but also can withstand large amount of deformations under flexure before failure.

2.2.6 Axial Deformation

This test was carried out for only the confined concrete cylinders. It was carried out at 7, 14 and 28 days in order to determine the variation of axial deformation with curing age as the WTRC is incorporated in concrete and increased at percentages. The initial length and final length (in the axial direction) of the specimen were measured before and after crushing. The initial and final lengths were taken before and at the point of failure respectively. The results are shown on the plot in Fig 2.8. Deformation increased with increase in WRTC replacement. This observation was also made [17]. Due to the manual hand-methods employed in wrapping the waste cement sacks over the cylindrical specimen, it may be difficult to deduce accurately the behaviour of deformation in Fig 2.8 as the 14 days deformation exceeds the rest after 20%WTRC replacement level. However, in general, it is obvious that confining the rubberized concrete cylindrical specimens results in high deformations.

This indeed is the desired behaviour needed for structural concrete employed in the construction of earthquake resistant structures. There was an increase in deformation with WTRC percentage replacement of the confined specimen. WTRC concrete can act as an elasto-plastic material under loading. After the failure load, the WTRC mixes with high amount of rubber chips could regain up to 95% of their original height after compression. It is evident that the incorporation of WTRC in the concrete influences its physical properties through enhanced flexibility, ductility and energy absorption.

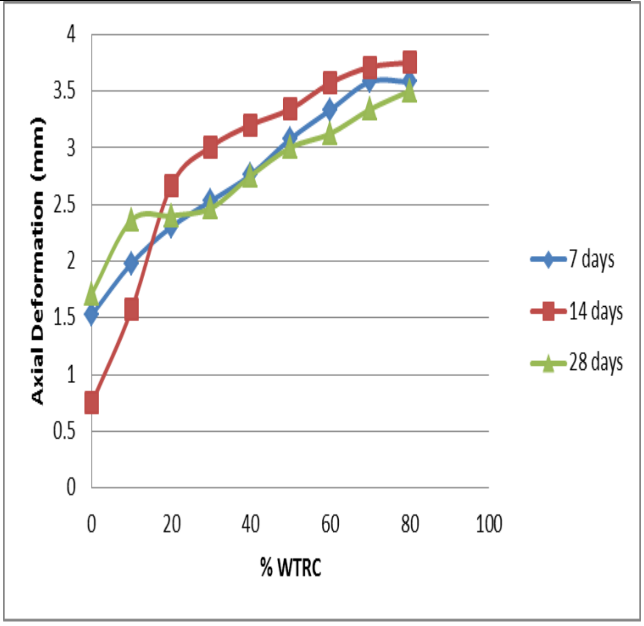

Fig.2.8: Axial deformation of confined concrete cylinders vs % WTRC

III. CONCLUSION

3.1 Summary

High ductility and strength were both achieved in this research through replacement of coarse aggregate with WTRC and through confinement by the use of waste cement sacks. Findings can be summarized as follows:

- The slump decreased with increasing WTRC content. However, the mix with 10% WTRC gave a fair degree of workability.
- There was a proportional decrease in the unit weight of concrete with increasing WTRC content.
- A general reduction in strength was observed with increase of WTRC content.
- The flexural strength of beams with 20% and 40% WTR chips replacement fall within the range of flexural strength of ordinary Portland cement concrete. The flexural strength generally decreased with increased amount of WTRC content.
- Confinement to improve the structural performance of the WTRC concrete through the use of waste cement sacks is feasible.
- Ductile mode of failure was exhibited by concrete containing WTRC. The concrete tends to withstand further loading after failure.
- Concrete with 0% WTRC exhibited a sudden and brittle mode of failure
- Concrete with WTRC exhibit higher deformation than the control concrete (0% WTRC).
- The confined concrete could regain up to 95% of its original height after compression. This

also implies enhanced flexibility, ductility and energy dissipation of the concrete.

3.2 Conclusion

From the experimental study, it can be concluded that

- The strength properties of rubberized concrete can be greatly enhanced in concrete through the use of waste cement sacks-confinement of WTRC concrete.
- Waste cement sacks pose a cheaper alternative to all other materials used for confinement of concrete elements.
- The WTRC concrete can enhance the structure ductility, damping ratio, and the energy dissipation which are the most important parameters in structures built for earthquakes.
- This type of confinement is feasible for strengthening concrete columns and beams of houses built in rural areas with poor quality control.
- The light unit weight qualities of rubberized concrete also makes it suitable for architectural application, false facades, stone baking, interior construction, foundation pads for machinery, railway stations where vibration damping is required and in areas where resistance to impact is needed, such as in jersey barrier, railway buffers, bunkers and for trench filling.

3.3 Recommendations

Future studies on this work will seek to investigate the strength properties of waste cement sacks. For the purpose of this research, the confinement wraps were limited to 3 layers. More layers of confinement wrap will be investigated. Finally, time-dependent strength behaviours of the waste cement sacks will be investigated in future works.

REFERENCES

[1] Rui, L. (2013): “Recycle Tyre as Coarse Aggregate in Concrete Pavement Mixtures”, Report No. CDOT-2013-1. Mat. in Civil Eng, Vol. 19, pp173-178.

[2] Tarun R. N. and Rafat, S. (2002): “Properties of Concrete Containing Scrap Tire Rubber – An Overview”, Report No. CBU-2002-06, REP-459

[3] Momoh Emmanuel Owoichoechi, Kypros Pilakoutas (2017) *"Highly Deformable Energy-Dissipating Reinforced Concrete Elements in Seismic Design of Reinforced Concrete Structures"*Vol. 7 - Issue 6 (June - 2017), International Journal of Engineering Research and Applications (IJERA) , ISSN: 2248-9622 , www.ijera.com

[4] Albano, C., Camacho, N., Reyes, J., Feliu, J. and Hernández, M. (2005): *Influence of Scrap Rubber Addition to Portland Concrete Composites: Destructive and Non-destructive Testing*, Compos. Struct. Vol. 71, pp439–446.

[5] Eldin, N.N. and Senouci, A.B. (1993): *Rubber-Tire Particles as Concrete Aggregates*. Journal of Materials in Civil Engineering, ASCE. Vol. 5, No. 4, 1993, pp. 478- 496.

[6] Topcu, I.B. and Avcular, N. (1997a): *Analysis of Rubberized Concrete as a Composite Material*, Cement and Concrete Research. Vol. 27, No. 8, pp1135-1139.

[7] Kotresh K.M and Mesfin G. B. (2014): *Study on Waste Tyre Rubber as Concrete Aggregates.* International Journal of Scientific Engineering and Technology. Vol.3, No.4, pp433-436

[8] Sathiparan, N., & Meguro, K. (2015). Strengthening of adobe houses with arch roofs using tie-bars and polypropylene band mesh. *Construction and Building Materials*, *82*, 360-375.

[9] Garcia, R., Hajirasouliha, I., & Pilakoutas, K. (2010). Seismic behaviour of deficient RC frames strengthened with CFRP composites. *Engineering Structures*, *32*(10), 3075-3085.

[10] Garcia, R., Pilakoutas, K., Guadagnini, M., Helal, Y., Jemaa, Y., Hajirasouliha, I., & Mongabure, P. (2012). Seismic strengthening of deficient RC buildings using post-tensioned metal straps: an experimental investigation. *Proceedings of the 15WCEE, Lisbon, Portugal*.

[11] Li, G., Pang, S. S., & Ibekwe, S. I. (2011). FRP tube encased rubberized concrete cylinders. *Materials and structures*, *44*(1), 233-243.

[12] Mirmiran, A., & Shahawy, M. (1997). Behavior of concrete columns confined by fiber composites. *Journal of Structural Engineering*, *123*(5), 583-590.

[13] Youssf, O., ElGawady, M. A., Mills, J. E., & Ma, X. (2014). An experimental investigation of crumb rubber concrete confined by fibre reinforced polymer tubes. *Construction and Building Materials*, *53*, 522-532.

[14] Neville, A. M. and Brooks, J. J. (2010): **Concrete Technology.** 2nd edition, Long Man Group UK Limited, Tottenham, London

[15] Batayneh, M., Marie, I. and Asi I. (2008): *Promoting the Use of Crumb Rubber Concrete in Developing Countries,* Waste Manag. Vol. 28, pp 2171–2176.

[16] Ganjian, E., Khorami, M., and Maghsoudi, A. (2009): *Scrap-Tyre-Rubber Replacement for*

Aggregate and Filler in Concrete, Constr. Build Mat. Vol. 23, pp1828-1836.

[17] Parveen, Sachin D. and Ankit S. (3013): *Rubberized Concrete: Needs of Good Environment (Overview).* International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal), Vol. 3, No. 3.

[18] Farhad, A. (2015): *Mechanical Properties of Waste Tyre Rubber*. Journal of Materials in Civil Engineering. https://www.researchgate.net/publication/282120797