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Exploring the Mechanical Properties of Concrete Produced with Tyres as Replacement of Coarse Aggregate

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Abstract: *The natural resources used to produce natural aggregates are being depleted due to the rise in demand for concrete structures. It is necessary to protect these natural resources. A significant amount of labour is also needed in the extraction process of these aggregates. On the other hand, some materials are emerging every day as waste. This research examines waste tyres' usage as a replacement for coarse aggregate in concrete. The replacement was done with 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, and 20%. Different tests (specific gravity, water absorption, sieve analysis) and (slump test, compressive test, split test, and flexural test) were carried out on the constituting materials and concrete respectively. From the result of the findings, recycled rubber tyre aggregates show great promise when used in concrete construction as a partial replacement of coarse aggregates, with up to 5% replacement rate providing the best performance results when compared to granite concrete in terms of reductions in compressive, tensile, and flexural strengths..*

Keywords: Concrete, Tyre, Compressive strength, split tensile strength.

Introduction

Concrete is one of the main materials used in construction, due to its excellent features such as high compressive strength, good durability properties, adaptability and availability, cost-effectiveness, as well as the ability to produce complex geometrical shapes to fit different requirements. Early-strength concrete has a relative high strength at the early age after casting, which is suitable for emergent repairs, especially in cold conditions. One of the challenges facing concrete production is the depletion of natural resources used for aggregates (Babafemi *et al.*, 2022). Recycled aggregate concrete is a kind of concrete which uses recycled materials, usually referred to as aggregate from demolished buildings, to replace natural aggregate for cost-effectiveness and environmental sustainability.

There may be financial and environmental advantages to building with trash and recycled materials. A number of the materials used in the construction, including additions, coarse and fine aggregate, may be recyclable. Employing such materials will not only lower the starting costs but also result in a building method that is significantly more sustainable, which is a compelling selling point for many investors. Through the process of cutting and grinding, tyres may be efficiently employed in various concrete applications.

Many researchers have worked on various materials used as a replacement for aggregate such as broken ceramic tiles (Mujedu *et al.*, 2014; Ajamul *et al.*, 2018; Adeala, & Omisande, 2021), palm kernel shell (Olanipekun, *et al.*, 2006; Emiero, & Oyedepo, 2012; Ayegbusi & Soyemi, 2023), periwinkle shell (Adewuyi, and Adegoke, 2008; Soneye *et al.*, 2016; Ede *et al.*, 2021), PET bottles (Bamigboye *et al.*, 2021; Babafemi *et al.*, 2022; Kuchta *et al.*, 2022), crushed glass (Ganiron Jr, 2013; Olofinnade *et al.*, 2016; Adeala & Soyemi, 2021), waste plastic (Amalu *et al.*, 2016; Aldahdooh *et al.*, 2018; Almeshal *et. al.*, 2020), and many more non-conventional materials (Yoon *et al.*, 2004; Hebhoub *et al.*, 2011; Bamigboye *et. al.*, 2020; Collivignarelli *et al.*, 2020) came up with varying results of compatibility and non-compatibility, leaving the user with the choice of the decision on what and where to apply the results.

Vehicle tyres are another waste product that is produced virtually every day. Many tyres are manufactured as the number of vehicles increases on the roads and disposing of worn out tyres has become a significant environmental issue in cities all over the world. An estimated 1.5 billion tyres are disposed of improperly annually worldwide (Malarvizhi *et al.*, 2012). About five billion trash tyres might be produced yearly by 2030 (Thomas *et al.*, 2016). The car industry's explosive growth has led to a significant increase of trash tyres, which has resulted in a serious issue known as "black pollution." The simplest and least expensive way of disposal, burning tyres, presents a significant risk of fire, and uncontrolled emissions of toxic smoke that is detrimental to people, animals, and plants. Soil is contaminated by the leftover powder that remains after burning (Thomas *et al.,* 2016; Kerekes *et al.,* 2018). Therefore, using used tyres to make crumb rubber (CR) for concrete has emerged as a viable option for maintaining ecological balance while having significant economic benefits (Guo *et al.,* 2014; Almaleeh *et al.,* 2017). Thus, recycling used tyres is a critical requirement for sustainable growth. Several uses have been suggested, including being burned for electricity, utilized in asphalt paving, and used as feedstock for cement kilns.

In general, it has been discovered that concretes containing tyre rubber particles have lower compressive and tensile strengths than regular concretes made with conventional aggregates. The coarse aggregates have been substituted with tyre chips, or shredded rubber, and the fine aggregates with crumb rubber, which is almost a powdered form of rubber. Nevertheless, it has been determined that while still noteworthy, the findings are by no means adequate. Rubber is added to concrete to improve several of its qualities beyond its compressive and tensile strengths. Rubberized concretes have superior ductility compared to regular conventional concretes. This characteristic of rubberized concrete helps build a surface overlay for worn-out or fractured pavements. In new construction, it may also be utilized as a long-lasting, crack-resistant asphalt surface.

In the works of El-Gammal *et al.* (2010), tyre rubber aggregates were added to the concrete instead of natural aggregates and then examined the impact on the final concrete mixture. A significant portion of the compressive strength was found to be decreased. Conversely, research on the concrete specimen with rubber aggregate revealed that a high degree of compressibility enabled the specimen to absorb more energy under compressive stresses. The specimen collapsed beneath the maximum force, yet it still had some structural integrity beyond that, thus, it may be said that the concrete's ductility has risen.

Aiello *et al.* (2010) paper's primary goal is to examine the characteristics of different concrete mixtures in both their fresh and hardened states. These mixtures are created by partially substituting coarse and fine aggregate with varying volumes of recycled tyre rubber particles that have the same dimensions as the original aggregate. The study assessed many aspects of rubberized concrete, including workability, unit weight, compressive and flexural strength, and post-cracking behavior. The results were compared across various rubcrete combinations to determine the optimal mix proportions for achieving the desired mechanical parameters. The data presented in the literature was also compared with the results presented in the research. Furthermore, using scrap tyre rubber shreds, a preliminary geometrical, physical, and mechanical characterization was done.

Akinwonmi, and Seckley (2013) independently used crumb rubber and shredded rubber to substitute the natural aggregates. Following testing of specimens containing varying percentages of shredded rubber and crumb rubber, it was found that the compressive strength of the concrete increased slightly up to the replacement level of 2.5% by shredded tyre, but that the concrete's compressive strength drastically decreased for any replacement level above that point. However, replacing it with crumb rubber had a completely negative effect and was not advised.

Given the enormous amount of waste tyre material that is disposed of in landfills worldwide, the necessity to remove the valuable components from waste tyres gave rise to waste tyre steel fiber (WTSF), an underappreciated resource. Applications for these fibers include slope stabilization, bridge decks, tunnel linings, hydraulic constructions, and pavements. Compressive strength (up more than 10%), flexural strength (up more than 50%), and split-tensile strength (up more than 30%) are all positively impacted by fibre length, whereas slump and flow (up more than 80%) are negatively impacted but can be prevented with careful mixing, a reduction in coarse aggregates, and the use of short fibers. The building business is more sustainable when WTSF is utilized (Awolusi *et al.,* 2021).

This research aims to examine the mechanical properties (workability, water absorption, density, compressive strength, split tensile strength, and flexural strength) of concrete including rubber aggregates derived from discarded tyres as a partial substitute for coarse aggregate at the 0% (control mix), 2.5%, 5%, 7.5%, 10%, 12.5% and 15% replacement levels.

Materials and Methods

The materials were batched by weight. In this experiment, a mix proportion of 1:2:4 cement-sand-coarse aggregate ratios was used. For this study, a cement/water ratio of 0.5 will be used. The target mean strength, the cement strength class, and the kind of aggregates are all taken into consideration when picking the water cement ratio. In a mechanical mixer that has been inter-surface wetted, the appropriate amounts of each material were precisely weighted out and added in the following order: coarse aggregate, fine aggregate, cement, and rubber aggregate. In order to get a thorough mix, the components were combined for five minutes with the mixer turned on before the water was added. After that, add half of the water to the mixer and blend for a further five minutes. The second half of the water then come next. When the ingredient combination seems uniform, the mechanical mixer will be turned off, after which the slump of the concrete will be ascertained by slump test.

For this study, Dangote Ordinary Portland Cement—which is produced in accordance with Nigerian Industrial Standard (NIS) 444-1:2003, which is comparable to BS EN 197-1:2000—was utilised. For this study, Sharp River sand with a maximum size of 4.75 mm and no clay, mud, or other organic or chemical materials was used as fine aggregate. The coarse aggregates utilized are 20 mm maximum size crushed granite with a specific gravity of 2.75; they are devoid of dust, clay particles, biological matter, and other contaminants. This research also uses fresh, colorless, odorless, and tasteless drinkable water that complies with BS EN 1008:2002 and is devoid of harmful concentrations of oils, alkalis, salts, sugar, organic matter, and other contaminants. And finally, the rubber chips were gotten from shredding vehicle tyres which contained thread fibres inside. The tyres were cut into small cuboids of 20× 20 ×10mm (Figure 1). This study is restricted to assessing the strength characteristics of concrete at the 0% (control mix), 2.5%, 5%, 7.5%, 10%, 12.5% and 15% replacement levels when rubber aggregate is used to partially replace granite.

Picture 1: Tyre Cut into Pieces

The purpose of the slump test carried out was to evaluate the concrete samples' consistency and workability in compliance with BS EN 12390-3:2002. Three layers of the mix were made and pushed into a clean slump cone mold using 25 strokes each. The top of the cone was then smoothed off. After that, the mold was raised vertically, and the height difference between the slump cone and the concrete mix was measured. To determine if the concrete samples are workable, the type of slump is then examined.

Table 3: Particle Size Distribution of sand

Sieve Size (mm)	Wt Retained (g)	% Retained	Cumulative % Retained	% Passing
5.00	3.85	0.77	0.77	99.23
3.35	12.55	2.51	3.28	96.72
2.36	32.70	6.54	9.82	90.18
1.18	45.14	9.02	18.84	81.16
0.60	105.00	21.00	39.84	60.16
0.30	170.84	34.17	74.01	25.99
0.15	43.54	8.71	82.72	17.28
0.075	60.36	12.07	94.80	5.20
Pan	26.02	5.20	100.00	0.00

The dimensions and shape of the moulds are 150mm cube, and 36 cubes in all was cast. Before pouring, the inner surfaces of the moulds were oiled to prevent the concrete from sticking to the mould. All of the moulds were then filled with fresh concrete in two equal layers, and each layer was compacted using the rod stroke to remove as much air as possible. This was continued for 30 strokes to ensure a smooth and even surface film, and then the exposed surface was trowelled to a clean finish. A 100×100×400mm beam and a 150×300mm cylindrical specimen were cast to determine the flexural and split tensile strength of the concrete produced respectively.

After 24-hour casting has been performed, the samples were demoulded and placed in a curing tank. Over the next several days, they were weighed, and dried to determine the water absorption and placed in the Universal Testing Machine (UTM) for crushing in order to assess their compressive strength. The resulting samples were cured for 7, 14, and 28 days.

Results

The naturally existing clean sand in Ilaro, was used as the fine aggregate (sand). The specific gravity, bulk density, particle size distribution, and water absorption capacity of the aggregates are among the tests conducted on them.

Table 1: Specific gravity of fine aggregate (sand)

Samples	Specific gravity	Average specific gravity
1	2.69	
2	2.63	2.66
3	2.65	

The specific gravity was 2.66, the bulk density was 1535.67 kg/m3, and the sieve analysis showed that it is in Zone 1. According to BS 812 part 2, 1995, BS 812 part 101, 1990, and BS 812 part 103, 1989, respectively, these tests were conducted. The outcomes are displayed in Tables 1-3.

Table 2: Bulk density of fine aggregate

Samples	Nominal aggregate size (mm)	Bulk density Kg/m^3	Average bulk density Kg/m^3
1	2.5mm	1532	
1	2.5mm	1535	1533
1	2.5mm	1534	
2	2.5mm	1535	
2	2.5mm	1538	1538
2	2.5mm	1540	
3	2.5mm	1536	
3	2.5mm	1542	1536
3	2.5mm	1534	

From Table 2 the value of bulk density of sand ranges between 1532kg/m3 and 1540kg/m3. The result conformed to BS 812: Part 2: 1990.

Table 6: Physical properties of Rubber Chips

Specific Gravity (g/cm3)	1.11
Bulk Density (kg/m3)	480

The particle size distribution test was carried out in accordance with BS 812: Part 103, 1989. The results are shown in Table 3. Hence, sand is uniformly graded.

The coarse aggregate has a nominal size of 20 mm and is a normal weight aggregate. The specific gravity, bulk density, and particle size distribution of the coarse aggregate were determined.

Table 4: Specific Gravity of Granite

Samples	Nominal aggregate size (mm)	Average aggregate specific gravity value
1	20	2.65
2	20	2.63
3	20	2.63

The specific gravity results for the granite is presented in Table 4. The results indicated that the granite used has specific gravity of 2.63 which is within the stipulated range of 2.6 to 2.7 by BS 1330: Part 2: 1995.

Table 5: Bulk Density of Granite

Samples	Nominal aggregate size (mm)	Average Bulk Density Kg/m^3
1	20	1366
2	20	1369
3	20	1367

The test results of 1367.3 kg/m3 for average bulk density of the nominal coarse aggregate is shown in Table 5 and it is within specified limit.

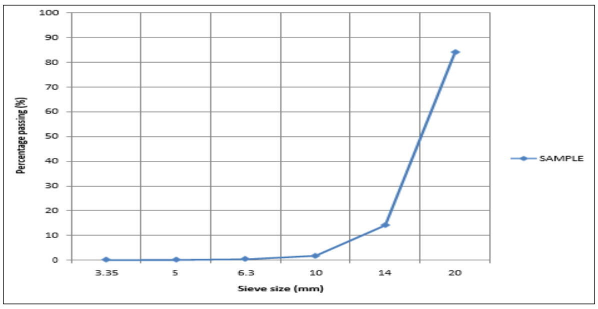

Figure 2: Graph of Particle size distribution of Granite

To achieve optimum concrete workability and compatibility, the coarse aggregate particle size distribution is crucial. The findings are displayed in the Figure 2, the graph of the particle size grading distribution.

The physical properties (Specific Gravity and Bulk Density) of the rubber chips made from the waste tyre are displayed in Table 6. The values are lower than that of Granite by 58% and 65% for specific gravity and bulk density respectively.

The outcome displayed in Table 7 indicates that the inclusion of rubber aggregate reduces the new concrete's slump. The primary reason for the decrease in slump is the uneven surface of rubber aggregate as opposed to the even surface of natural aggregates.

Table 7: Result of workability test

Percentage replacement (%)	Slump value
0.0	80
2.5	70
5.0	50
7.5	40
10.0	30
12.5	27
15.0	25
17.5	21
20.0	15

It resulted in a decrease in slump and an incompatible mix due to increased friction between the newly mixed concrete's constituent parts. When the amount of rubber in the coarse aggregate increases, the workability of rubber concrete shows a decrease in slump. The slump is more workable at 0% (control) and 2.5% than it is at 5%, 7.5%, 10%, 12.5%, 15%, 17.5% and 20% replacement levels. As the proportion of rubber in concrete increases, the workability is observed to decrease.

Table 8: Water Absorption

Percentage replacement (%)	Water Absorption (%)
0.0	5.3
2.5	6.1
5.0	7.0
7.5	7.4
10.0	8.2
12.5	9.0
15.0	10.0
17.5	11.3
20.0	12.2

According to the result in Table 8, as the percentage of rubber in the concrete grew, so also the water absorption. This might be because voids were formed and became more permeable to water when more rubber aggregate was added to the concrete mix. The primary cause is because rubber materials are non-polar, meaning they have a tendency to reject water and retain air on the surface. As the mixes solidify, voids appear between the rubber particles and matrix. The additional air content causes a change in the microstructure and an increase in porosity in regular concrete.

Table 9: Specific gravity

Percentage replacement (%)	Specific gravity
0.0	1.64
2.5	1.60
5.0	1.56
7.5	1.53
10.0	1.49
12.5	1.43
15.0	1.32
17.5	1.30
20.0	1.29

The concrete specific gravity is presented in Table 9. As the percentage of rubber replacement increases, the specific gravity of the rubberized concrete, this may be the result in the decrease in the weight of the rubberized concrete. This makes sense given that rubber and natural aggregate have different unit weights. As a result, the weight per unit volume will drop when rubber aggregate replaces natural aggregate by volume.

Table 10: Compressive strength results

Percentage replacement (%)	Compressive strength (N/mm^2)		
	7days	14dyas	28days
0.0	15.41	22.13	25.87
2.5	16.52	21.13	24.73
5.0	18.54	19.98	23.45
7.5	17.34	18.11	21.75
10.0	15.12	16.12	20.34
12.5	14.46	15.48	18.44
15.0	13.21	14.21	17.12
17.5	12.65	13.87	15.67
20.0	11.23	12.34	13.84

As the percentage of rubber aggregate increased, the compressive strength decreased, according to the results shown in Table 10. The proportion of rubber in the concrete mix has been found to decrease the concrete's compressive strength. After 28 days of curing, it was found that replacing 2.5% of the granite with rubber reduced its compressive strength by 4.4%; at 10% of the granite replacement, reduced its compressive strength by 21.4%, and 20% of the granite reduced its compressive strength by 51%. When M20 strength is required in construction, up to 10% replacement is acceptable. In addition to creating cavities in the matrix, the rubber chips cause the link between the waste tyre rubber aggregate and the concrete mix to deteriorate. Moreover, rubber aggregate is also less rigid than natural aggregate, therefore rubber particles in a concrete mixture might be thought of as voids. The contact between rubber particles and the concrete matrix is where stress concentration often occurs.

Table 11: Split tensile strength

Percentage replacement (%)	Split tensile strength	
	7days	28days
0.0	2.0	3.0
2.5	2.0	2.8
5.0	2.0	2.7
7.5	1.8	2.4
10.0	1.7	2.0
12.5	1.5	1.9
15.0	1.2	1.8
17.5	1.2	1.7
20.0	1.2	1.7

The split tensile strength test results for several concrete cylinders are displayed in the Table 11. Tensile strength was shown to decrease with an increase in the proportion of tyre rubber in concrete. There was a 10% decrease in tensile strength at 5% substitution of granite, a 33.3% loss at 10% replacement, and a 43.3% drop at 20% replacement of granite.

Another type of indirect tension test is the flexural test, also known as the modulus of rupture. This approach produces the pure bending moment by applying two loadings to the beam, equally spaced from the center, until the outermost fiber of the tensioned beam specimen reaches the maximum tensile stress.

Table 12: Flexural strength

Percentage replacement (%)	Split tensile strength	
	7days	28days
0	3.4	4.3
2.5	2.8	4.0
5.0	2.2	3.7
7.5	2.0	3.2
10.0	1.9	2.9
12.5	1.6	2.6
15.0	1.3	2.5
17.5	1.2	2.3
20.0	1.2	2.1

Table 12 illustrates the flexural strength of concrete that contains different amount of tyre rubber aggregate. It was discovered that the flexural strength dropped as the proportion of rubber tyres in concrete rose. There was a 6.7% drop in flexural strength at the 2.5% replacement of aggregates; this reduction was also noted at the 10% and 20% replacements, where it was 32% and 49%, respectively, in flexural strength.

Rubber aggregate decreases concrete's splitting tensile and flexural strengths, as would have been predicted. Both splitting tensile strength and flexural strength drop as the amount of rubber increases, and the degree of this loss is quite close. The factors influencing compressive strength also contribute to the loss of splitting tensile and flexural strength.

Conclusion

Rubber tyre aggregate has the potential to be used as coarse aggregate in the manufacturing of concrete, according to the findings of this experiment, research, and discussions conducted to examine the qualities of concrete that has been partially replaced by rubber tyre aggregate. Test results showed that when the amount of rubber aggregate in fresh concrete increased, its workability dropped. When rubber aggregate content in concrete increases, so does its specific gravity. Comparably, as the replacement of rubber aggregate increased, so did the compressive, tensile, and flexural strengths; nevertheless, at up to 10% replacement, the findings were within acceptable bounds. Rubberized concrete mixtures may offer a viable substitute in situations where low unit weight, medium strength, etc. are required for non-load bearing elements, such as lightweight concrete walls.

References

Adeala, A. J., & Omisande, L. A. (2021). Structural performance of broken ceramic tiles as partial replacement of coarse aggregates in concrete. *International Journal of Research and Scientific Innovation (IJRSI), 8(1),* 62-65.

Adeala A.J and Soyemi O.B. (2021). Engineering Properties of Crushed-Fine Glass as Partial Replacement for Fine Aggregate in Concrete. *International Journal of Women in Technical Education and Employment [IJOWITED]*. 2(1). 86-94. ISSN: 2811-1567

Adewuyi, A. P., and Adegoke, T. (2008). Exploratory study of periwinkle shells as coarse aggregates in concrete works. *ARPN Journal of Engineering and Applied Sciences,* 3(6), 1-5.

Aiello, M. A., & Leuzzi, F. (2010). Waste tyre rubberized concrete: Properties at fresh and hardened state. *Waste management,* 30(8-9), 1696-1704.

Ajamul, S. O., Oluremi, J. R., & Ogunyemi, E. S. (2018). Impact of replacement of coarse aggregates with ceramic tile waste on the strength characteristics of concrete. *Journal of Research Information in Civil Engineering,* 15(3), 2228-2244.

Akinwonmi, A. S., & Seckley, E. (2013). Mechanical strength of concrete with crumb and shredded tyre as aggregate replacement. *Int. J. Eng. Res. Appl,* 3(2), 1098-1101.

Aldahdooh, M. A. A., Jamrah, A., Alnuaimi, A., Martini, M. I., Ahmed, M. S. R., & Ahmed, A. S. R. (2018). Influence of various plastics-waste aggregates on properties of normal concrete. *Journal of Building Engineering,* 17, 13-22.

Almaleeh, A. M., Shitote, S. M., & Nyomboi, T. (2017). Use of waste rubber tyres as aggregate in concrete. *Journal of Civil Engineering and Construction Technology,* 8(2), 11-19.

Almeshal, I., Tayeh, B. A., Alyousef, R., Alabduljabbar, H., Mohamed, A. M., & Alaskar, A. (2020). Use of recycled plastic as fine aggregate in cementitious composites: A review. *Construction and Building Materials*, 253, 119146.

Amalu, R. G., Ashraf, A., Hashim, M., Rejith, K. U., Vijitha, V. R., and Kurup, N. (2016). Use of waste plastic as fine aggregate substitute in concrete. *International Journal of Scientific & Engineering Research,* 7(4), 172-7.

Awolusi, T. F., Oke, O. L., Atoyebi, O. D., Akinkurolere, O. O., & Sojobi, A. O. (2021). Waste tyres steel fiber in concrete: A review. Innovative *Infrastructure Solutions,* 6, 1-12.

Ayegbusi O. and Soyemi O.B (2023). Mechanical Properties of an Impervious Concrete Using Palm Kernel Shell (PKS) as a Substitute for Coarse Aggregate. 4th International Conference, The Federal Polytechnic, Ilaro at Takoradi Technical University, Takoradi. Ghana.

Babafemi, A. J., Sirba, N., Paul, S. C., & Miah, M. J. (2022). Mechanical and durability assessment of recycled waste plastic (resin8 & pet) eco-aggregate concrete. *Sustainability,* 14(9), 5725.

Bamigboye, G. O., Okara, O., Bassey, D. E., Jolayemi, K. J., & Ajimalofin, D. (2020). The use of Senilia senilis seashells as a substitute for coarse aggregate in eco-friendly concrete. *Journal of Building Engineering,* 32, 101811.

Bamigboye, G. O., Tarverdi, K., Umoren, A., Bassey, D. E., Okorie, U., & Adediran, J. (2021). Evaluation of eco-friendly concrete having waste PET as fine aggregates. *Cleaner Materials,* 2, 100026.

Collivignarelli, M. C., Cillari, G., Ricciardi, P., Miino, M. C., Torretta, V., Rada, E. C., & Abbà, A. (2020). The production of sustainable concrete with the use of alternative aggregates: A review. *Sustainability,* 12(19), 7903.

Ede, A. N., Gideon, P. O., Akpabot, A. I., Oyebisi, S. O., Olofinnade, O. M., & Nduka, D. O. (2021). Review of the properties of lightweight aggregate concrete produced from recycled plastic waste and periwinkle shells. *Key Engineering Materials,* 876, 83-87.

El-Gammal, A., Abdel-Gawad, A. K., El-Sherbini, Y., & Shalaby, A. (2010). Compressive strength of concrete utilizing waste tyre rubber. *Journal of Emerging Trends in Engineering and Applied Sciences,* 1(1), 96-

99.

Emiero, C., & Oyedepo, O. J. (2012). An investigation on the strength and workability of concrete using palm kernel shell and palm kernel fibre as a coarse aggregate. *Int. J. Sci. Eng. Res,* 3(4), 1-5.

Ganiron Jr, T. U. (2013). Use of recycled glass bottles as fine aggregates in concrete mixture. *International Journal of Advanced Science and Technology*, 61(2013), 17-28.

Hebhoub, H., Aoun, H., Belachia, M., Houari, H., & Ghorbel, E. (2011). Use of waste marble aggregates in concrete. *Construction and Building Materials,* 25(3), 1167-1171.

Kerekes, Z., Lubloy, E., & Kopecsko, K. (2018). Behaviour of tyres in fire: Determination of burning characteristics of tyres. *Journal of thermal analysis and calorimetry,* 133(1), 279-287.

Kuchta, W. C. S., Mazer, W., & Domingos, M. D. I. (2022). Mechanical properties of interlocking concrete paving blocks prepared with waste PET bottles. *Semina: Ciências Exatas e Tecnológicas,* 43(1), 63-74.

Malarvizhi, G., Senthil, N., & Kamaraj, C. (2012). A study on recycling of crumb rubber and low density polyethylene blend on stone matrix asphalt. *International Journal of Scientific and Research Publications,* 2(10):1-16. 10.13140/RG.2.2.35422.95042

Mujedu, K. A., Lamidi, I. O., & Ayelabola, D. O. (2014). An investigation on the suitability of the broken tiles as coarse aggregates in concrete production. The *International Journal of Engineering and Science (IJES)*, 3(4).

Mushunje, K., Otieno, M., & Ballim, Y. (2018). A review of waste tyre rubber as an alternative concrete consituent material. *In MATEC web of conferences* (Vol. 199, p. 11003). EDP Sciences.

Olanipekun, E. A., Olusola, K. O., & Ata, O. (2006). A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates. *Building and Environment*, 41(3), 297-301.

Olofinnade, O. M., Ndambuki, J. M., Ede, A. N., & Olukanni, D. O. (2016, September). Effect of substitution of crushed waste glass as partial replacement for natural fine and coarse aggregate in concrete. *In Materials Science Forum (*Vol. 866, pp. 58-62). Trans Tech Publications Ltd.

Soneye, T., Ede, A. N., Bamigboye, G. O., & Olukanni, D. O. (2016, May). The study of periwinkle shells as fine and coarse aggregate in concrete works. *In 3rd International Conference on African Development Issues* (pp. 361-364).

Thomas, B. S., Gupta, R. C., Kalla, P., & Csetenyi, L. (2014). Strength, abrasion and permeation characteristics of cement concrete containing discarded rubber fine aggregates. *Construction and Building Materials*, 59, 204-212.

Yoon, H., Park, S., Lee, K., & Park, J. (2004). Oyster shell as substitute for aggregate in mortar. *Waste Management & Research*, 22(3), 158-170.