Durability Properties of Concrete Containing Scrap Tyre as Fine & Coarse Aggregate In Concrete

Musa Adamu, O.A.U. Uche

ABSTRACT: This paper presents the results of using scrap tyre in concrete. Grade 30 concrete with slump between 30 - 60 mm was made using DoE mix design method. 0%, 5%, 10% and 15% replacements of both the fine and coarse aggregates were replaced with tyre particles of size 1 – 4 mm and 5 – 8 mm. The properties of fresh and hardened concrete such as slump and durability test which includes drying shrinkage and water absorption test were measured based on short-term investigation according to ASTM, BS, and BS EN standard. Laboratory results revealed that the workability of 5% and 10% replacement were higher than the control mix, while 15% decrease workability significantly. There was also decrease in water absorption and drying shrinkage, as the percentage replacement increases.

Keywords: Scrap tyre, workability, concrete, drying shrinkage, durability, fine aggregate, and water Absorption.

IJSER

1 INTRODUCTION

Waste tyres need a larger storage space than other waste due to their large volume and fixed shape. They are unlikely to be decomposed, as burying the waste tyres would shorten the service life of the burial ground and have low economic benefit. In addition, long-term buried waste tyres often emerge from the burial ground surface or destroy the anti-leakage cover of the burial ground, and the exposed waste tyres accumulate water that may breed bacteria, molds, insects or mice (Yung, et.al, 2013). In the case of fire, waste tyres generate toxic gases, such as dioxin, that could result in severe pollution problems. Therefore, effectively recovering and reusing waste tyres is an urgent and important issue. Landfill disposal, which is the most common method, will be drastically reduced in the near future due to the recent introduction of European Union directives that include significant restrictions on this practice in favor of alternatives oriented toward material and energy recovery (Yung, et.al, 2013). Furthermore, the disposal of used tyres in landfills, stockpiles or illegal dumping grounds increases the risk of accidental fires with uncontrolled emissions of potentially harmful compounds. In order to properly dispose of these millions of used tyres, the use of innovative techniques to recycle them is important. Rubber tyre can be used in a variety of civil and non-civil engineering applications such as in road construction.

Ganjian, et.al, 2009 reported that scrap tyre management is continuously becoming a significant environmental, health, and aesthetic problem that need to be solved; but is very difficult to solve. The use of scrap tyre in concrete is a possible disposal solution. Scrap tyre is composed of ingredients that are non-degradable in nature at ambient condition, which usually produce environmental mal-effects; one of the methods of utilizing these materials is by using them in concrete and other building products.

Scrap tyre can also be used in civil engineering application for various purposes; in place of some conventional construction material such as clean fill, aggregate and rock. Scrap tyres have been used as lightweight road embankment fill, backfill behind walls, insulation to limit frost penetration beneath roads; aggregate in leachate and gas collection systems in landfills, and the drainage bed for residential septic system. Scrap tyres usually are shredded for use in these applications, with the actual size a function of the intended use. The required size can range from a refined 50 mm or 75 mm square shred (Humphrey and Blumenthal, 1998).

Indeed, many other researchers have studied properties of scrap tyre containing concrete. They mostly used scrap tyre as fine aggregate replacement in form of crumb rubber, coarse aggregate replacement in form of chipped tyre, or cement replacement in form of scrap tyre powder. Most authors have identified a decline in the overall quality of concrete durability properties. Research on incorporating both crumb rubber and chipped rubber as fine aggregate and coarse aggregate in concrete is very scarce, and the study of the durability-related properties of concrete containing scrap tyre is very few and mostly neglected.

According to Sukontasukkul and Tiamlom, (2012), concrete with tyre aggregates mixes had higher shrinkage than plain concrete They observed that the increase due to the incorporation of tyre aggregate (TA) is caused mostly by higher w/c ratios as the replacement ratio of natural aggregate (NA) by TA goes up and by the TA's lower capacity to restrict shrinkage of the cement paste. As the replaced aggregate's size fell the concrete's shrinkage increased, except for the mix with 10% NA/TA replacement of fine and coarse aggregate.

In this study, the effect of replacing 5%, 10%, and 15% by weight of fine aggregate and coarse aggregate with fine scrap tyre and coarse scrap tyre were investigated. The properties of concrete studied both at fresh and hardened state includes: workability, water absorption and drying shrinkage.

2 Materials and Methods

2.1 Materials

In this study, scrap tyres were obtained from Yong Fong Rubber Industries Sdn Bhd Malaysia. Two forms of tyre particles were used; the crumb rubber particles of size ranging from 1mm to 4 mm was used as fine aggregate replacement in concrete. While tyre chips ranging in size between 5 mm to 8 mm was used as coarse aggregate replacement concrete. This particle sizes for both the crumb rubber and for the tyre chips were obtained from sieve analysis of the scrap tyre particles.

2.2 Preparation of Samples and test procedures

The concrete mix consists of cement, fine aggregate, coarse aggregate, water, crumb rubber particles, and chip rubber particles. Concrete mix was designed based on the DOE method of mix design for normal concrete was used. The

IJSER

targeted characteristic strength was 30 MPa at 28 days with 5% defectives. The aggregate types were uncrushed for fine aggregate and crushed for coarse aggregate. The maximum W/C ratio was 0.65, the maximum cement content was 550 kg/m^3, the minimum cement content was 260 kg/m^3. The specific gravity of aggregate used was 2.6, and the percentage of fine aggregate passing 600 µm sieves was 60%. 1% superplasticizer was added to improve the workability of the mix. Fine aggregate was replaced by 5%, 10% and 15% crumb rubber while coarse aggregate was replaced by 5%, 10% and 15% tyre chips in different mixes. Table 1 shows the mix proportions of the various concrete constituent used.

For the fresh concrete properties, the workability of each concrete mix was determined according to BS EN 12350 (2009) Part 2"Testing fresh concrete: Slump test".

The water absorption test was done according to BS 1881 (2011): Part 122: "Method for determination of water absorption". Concrete specimens of size 100 mm × 100 mm x 100 mm cubes were moulded and stored in water for 28 days before testing for water absorption test. Three similar samples will be prepared for each mix proportion. A total of 12 cubes were tested for water absorption.

The drying shrinkage test was done according to BS ISO 1920-8, (2008). Determination of drying shrinkage of concrete samples prepared in the field or in the laboratory". The dimensions of prisms were 75 x 75 x 280 mm. A 250 mm Demec gauge was used for taking strain readings. The at 0,1,3,7,14,21,28,35,42,49,56 and 60 days. Three similar samples will be prepared for each mix proportion and tested for drying shrinkage.

3 Results and Discussions

3.1 Workability

The results of the workability which was done using slump test method are shown in Figure 1. There was an increase in workability with increase in percentage replacement. At 5% and 10% replacement of fine aggregate/coarse aggregate (FA/CA) with fine tyre/coarse tyre (FT/CT) there was an increase in workability compared to the control mix. As the percentage replacement was increased to 15%, a sudden decrease in workability was noticed. When smaller particles of tyre rubber is used in concrete, there is an increase in workability up to a certain percentage replacement of aggregate, then further increase in replacement will result in decrease in workability as was shown in Figure 1, where there was increment in slump up to 10% replacement, then at 15% replacement there was a sudden decrease in slump. In general, the rubberized concrete specimens have acceptable workability in terms of ease of handling, placement, and finishing.

3.2 Water Absorption

Water absorption is one of the important qualities of good concrete, as it determines how permeable a concrete is. A highly impermeable concrete is a durable concrete as it prevents the ingress of water and other chemicals which might by harmful to concrete, and is less susceptible to freeze and thawing effect.

From Figure 2, it was shown that as percentage replacement of FA/CA with FT/CT is increased, the water absorption increased. Even though the increment is little, 5% replacement increased the water absorption from 2.845% to 2.945% i.e. increasing the water absorption by 3.5%. This increase in water absorption is as a result of higher air content in concrete containing tyre rubber particles which is caused due to non-polar nature of rubber particles and their tendency to entrap air in rough surface. This makes air to be entrapped in concrete containing tyre particles and makes the concrete more porous, thereby becoming more permeable and allowing increased absorption of water into the concrete. Smaller tyre rubber particles have less rough surface and less non-polar nature, thereby entrapping less air. This indicates that concrete made with smaller particle tyre aggregate based as fine aggregate replacement or coarse aggregate replacement or fine and coarse aggregate replacement will have less water absorption. According to BS 8007, aggregates should comply with either BS 882 or BS 1047 and have absorption, as measured in accordance with BS 812-2, generally not greater than 3%.

3.3 Drying Shrinkage

The result of drying shrinkage is shown in Figure 3. As expected, the drying shrinkage of concrete increases with drying period, this is due to the continuous loss of capillary water from the concrete. The drying shrinkage for the control mix was found to be lower than that of the rubberized concrete. The drying shrinkage increases with increase in percentage replacement. It was shown that the drying shrinkage of 5% replacement was found to be lower than that of the control after 28 days of drying, but at the

ISSN 2229-5518

early ages the drying shrinkage of 5% was higher than that of the control mix.

This increase in drying shrinkage with increased percentage replacement of FA/CA with FT/CT might be due to the fact that rubberized concrete may contain some entrapped air in it, which results to a porous concrete, thereby increasing the permeability of the concrete. This increment in permeability leads to higher water absorption by the concrete and also higher loss of moisture from the concrete (drying shrinkage).Size of rubber used for replacing fine or coarse, or fine and coarse aggregate in concrete has effect on the drying shrinkage; this is because when smaller sized rubber particles are used, less air will be entrained in the concrete, which leads to less porosity, this in turn results to lower permeability. The lower the permeability, the more difficult will be loss of capillary water from the concrete, Therefore the less the drying shrinkage.

4 Conclusion

Based on the experiment, calculations, analysis and observations of the research, it can be concluded that

1) The workability of the concrete increase with increase in percentage replacement of FA/CA with FT/CT particles for 5% and 10% replacement, then a sudden decrease in workability for 15% replacement
2) The water absorption of the concrete increases with increase in percentage replacement of FA/CA with FT/CT particles, but the percentage increment was very small compared to the control mix. For 5% percent replacement the water absorption was slightly different than that of the control mix. This is due to the smaller particles of FT/CT used for replacing FA/CA.
3) The drying shrinkage of the concrete increase in duration of drying. Also it increases with increase in percentage replacement of FA/CA with FT/CT particles. For the 5% replacement, the early age drying shrinkage was higher than the control. But after 28 days the drying shrinkage was found to be less than the control mix

REFERENCE

ASTM C150M, (2012), "Standard specification for Portland cement".

Bravo, M., and De Brito, J., (2012). Concrete made with used tyre aggregate: durability-related performance. Journal of Cleaner Production, Vol25: 42-50

BS 1881-122, (2011), "Method for determination of water absorption".

BS EN 12350-2, (2009), "Testing of fresh concrete: Slump test".

BS ISO 1920-8, (2009), "Determination of drying shrinkage of concrete for samples prepared in the field and in the laboratory".

Ganjian, E., Khorami.M, and Maghsoudi,A,A., (2009). Scrap tyre replacement for aggregate and filler in concrete. Construction and Building materials, vol 23: 1828-1836

Humphrey, D. andBlumenthal.M., (1998). Civil Engineering applications of scrap tyres.An energy market. North America's Resource Recycling and composting journal

Khaloo. A., Dehestani.M, and Rahmatabadi.P, (2008). Mechanical Properties of Concrete containing high volume of tyre rubber particles. Waste Management, Vol 28: 2472-2482.

Mohammed, BS., Hossain, AMK, Swee, ETJ, Wong, G., and Abdullahi, M., (2012). Properties of crumb rubber hollow concrete block. Journal of cleaner production, Vol 23: 57-67.

Siddique, R., Naik, T.R., (2004), "Properties of concrete containing scrap-tyre rubber –An overview", Waste Management, 24: 563–569.

Sukontasukkul, P., and Tiamlom, K., (2012). Expansion under water and drying shrinkage of rubberized concrete mixed with crumb rubber of different sizes. Construction and Building Materials, Vol 29:520-526

Wang, X., Li, W., Wang, J., and Wang, C., (2013). Experimental study on the properties of the crumb rubber concrete. Advanced Materials Research, Vol 645: 172-175.

Yung, WH., Yung, LC, and Hua, LH. (2013). A study of the durability properties of waste tyre rubber applied to self-compacting concrete. Construction and Building materials, vol 41: 665-672.

IJSER

Table 1:
The mix proportions of the concrete constituent

Material	Type of Samples			
	Control (kg/m3)	Concrete + 5% Fine TR + 5% Coarse TR (kg/m^3)	Concrete + 10% Fine TR + 10% Coarse TR (kg/m^3)	Concrete + 15% Fine TR + 15% Coarse TR (kg/m^3)
cement	340	340	340	340
Fine Aggregate	700	665	630	595
Coarse Aggregate	1140	1083	1026	969
water	190	190	190	190
Fine TR	0	35	70	105
Coarse TR	0	57	114	171
SP (0.5% of cement)	1.7	1.7	1.7	1.7
Reduction in water (12%)	23	23	23	23
Reduced Water	167	167	167	167

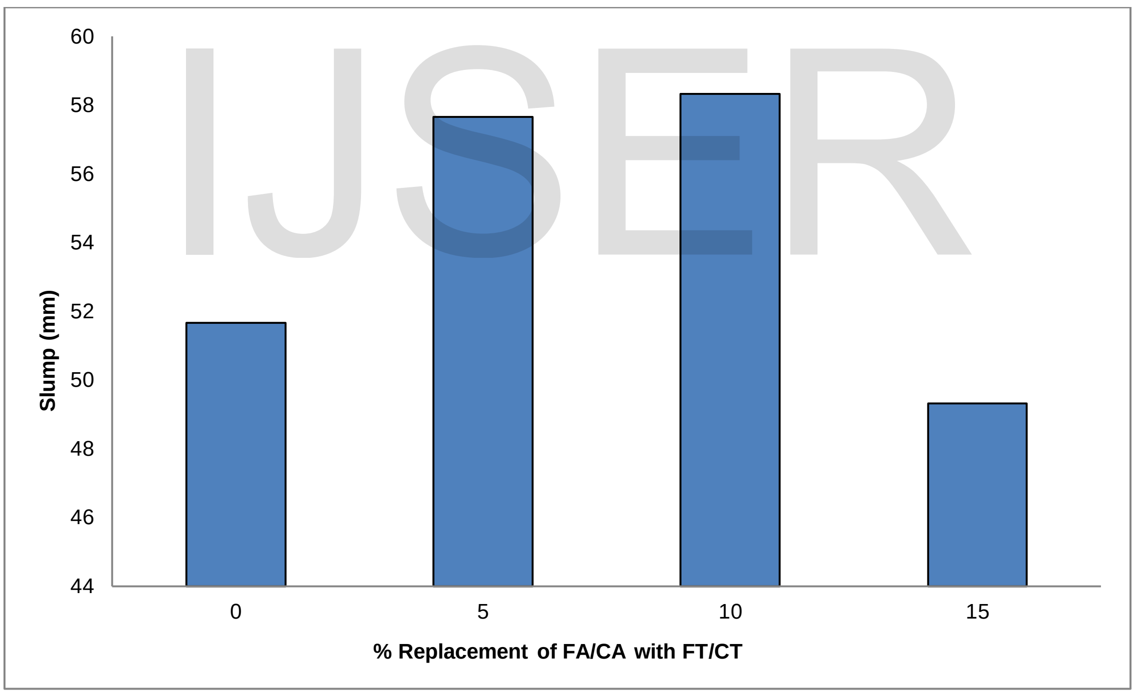

Figure 1: Workability of Concrete

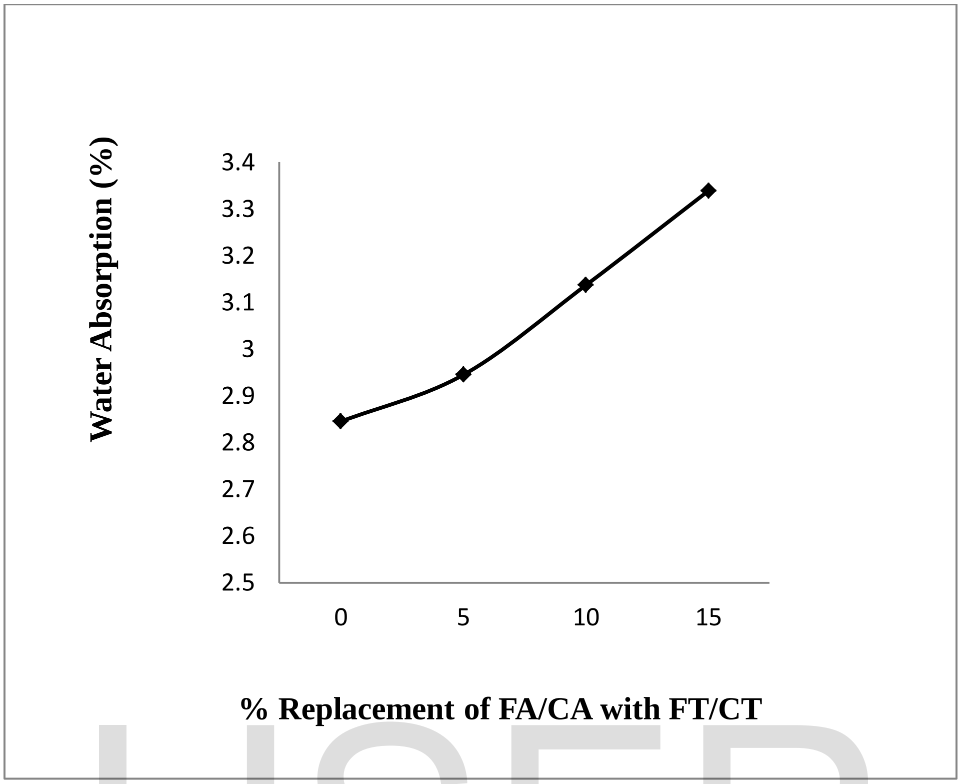

Figure 2: Water absorption of concrete

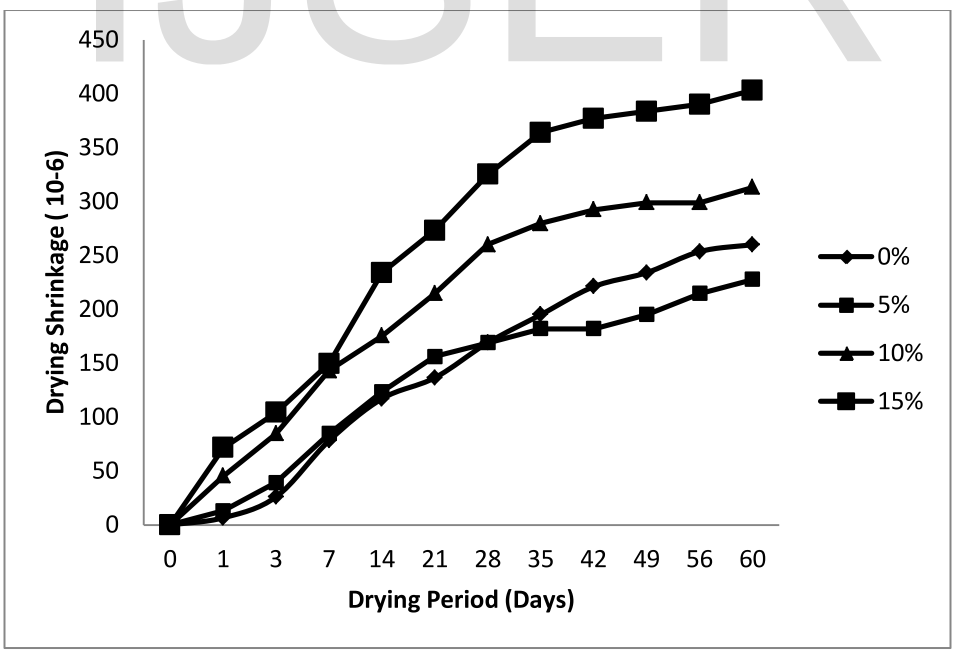

Figure 3: Variation of Drying Shrinkage with time.

Authors

ISSN 2229-5518
***Musa Adamu**-Lecturer, Department of Civil Engineering, Bayero University, PMB 3011 Kano, Nigeria, Phone Number +2348037296214, email-madamu86@gmail.com

O.A.U Uche-Senior Lecturer, Department of Civil Engineering, Bayero University, PMB 3011 Kano, Nigeria, Phone Number-+2348065416822, email-okoauche@yahoo.co.uk
***Corresponding author email: madamu86@gmail.com, Tel: +2348037296214.

IJSER