MECHANICAL PROPERTIES OF CONCRETE WITH RUBBER CRUMB AS FINE AGGREGATE REPLACEMENT

[1]SHAMSHINAR SALEHUDDIN, [2]NUR LIZA RAHIM, [3]NORLIA MOHAMAD IBRAHIM, [4]MOHD ZUHAIDI ZAINOL ABIDIN

[1,2,3,4]School of Environment Engineering, Department of Civil Engineering, Kompleks Pengajian Jejawi 3, Universiti Malaysia Perlis, Arau 02600, Perlis, Malaysia
E-mail: [1]shamshinar@unimap.edu.my, [2]nurliza@unimap.edu.my, [3]norlia@unimap.edu.my, [4]zuhaidizainol@gmail.com

Abstract— Discarded tyres shows increment trend annually. These discarded tyres were piled up in the landfill or burned. The discarded tyres bring various environmental and health issue. Recycling tyre seems the best method to reduce the problem and at the same time conserve valuable resources. This paper present a finding of partially replacing fine aggregates with rubber crumb from inner motorcycle tube by mass. Fresh and hardened concrete properties were evaluated against normal concrete using several tests. Rubberised concrete shows improvement in density and workability but lower value in compressive strength, modulus of rupture and absorption compared to normal concrete when achieved 15% replacement.

Keywords— Rubber Concrete, Rubber Crumb, Inner Motorcycle Tube, Fine Aggregate Replacement.

I. INTRODUCTION

Asian countries are still using motorcycle as a primary transportation, therefore amount of discarded tyres increased in years. With the number of vehicles on the road is growing at an average rate of 600,000 new vehicles registered every year, now tyre is one of the largest waste and most troubled in Malaysia. Tyres are bulky material with large void in the middle. As a result, discarded tyres occupy huge space in landfill. Furthermore, tyres were made from non-biodegradable material, making it taking such a long time to fully compose. Recycling tyres can solve many problems. Valuable natural resources can be saved while at the same time reduces the amount of tyres entering landfill [1].

Currently, construction industry is the major user of these discarded rubber tyres. They were used for heat and sound insulation in buildings and highways, producing asphalt based composites for pavement and as a fuel for cement kilns. The first rubberised concrete idea was initiated in the 1990's [2]. The initiatives were to improve concrete toughness, impact resistance and life span by introducing high strain material such as discarded rubber in concrete [3]. Based on literature, the major findings regarding replacing rubber at any size and type with aggregate in concrete mixture improved several concrete properties while at the same time reduced certain others. Rubberised concrete have lower density, higher toughness and ductility, better resistance against cracking, improved sound insulation, improved fire performance and freeze/thaw cycles, improved electrical resistivity, improved resistant to abrasion and increased capacity to absorb impact. The major disadvantages of rubberised concrete are lower compressive and tensile strength, lower modulus capacity, lower flexural strength and increasing water permeability. All these advantages and disadvantages of using discarded tyres as aggregate are the result of the major difference between volumetric properties in rubberised concrete aggregate [4].

II. MATERIALS AND MIXTURE PROPORTIONING

2.1. Aggregates

The rubber crumb selected from this study was produced from discarded inner motorcycle tube. Tubes are grinded into rubber crumb as shown in Fig. 1. Since inner tube does not contain steel fibre, it is assumed that effect of material other than rubber can be neglected. Aggregate properties were investigated and their value can be viewed in Table 1. It shows that properties of rubber crumb are quite similar to properties of fine aggregate. While Fig. 2 shows sieve analysis according to ASTM C136.



Fig.1: Texture of fine aggregates and rubber crumb.

Table 1: Aggregate properties.

Properties	Coarse Aggregate	Fine Aggregate	Rubber Crumbs
ASTM D2937 Bulk Density [g / cm^3]	1.40	1.64	0.71
ASTM C566 Moisture Content [%]	0.0130	0.0282	0.0032
ASTM C127 C128 Apparent Specific Gravity	2.4547	2.2074	1.3776
ASTM C127 C128 Water Absorption [%]	0.3286	0.9213	0.7791
ASTM C136 Fineness Modulus	-	2.20	3.03

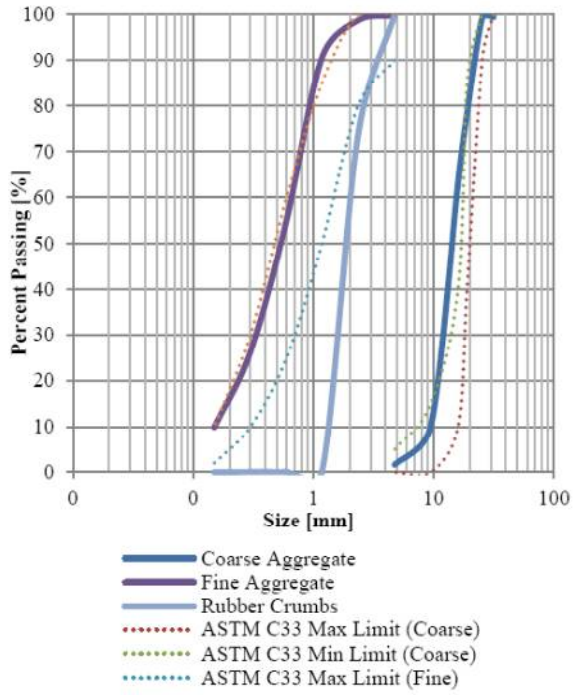


Fig.2: Sieve analysis of aggregates.

2.2. Mix Proportioning and Specimens

Concrete were prepared in the ratio of 1:2:4 (cement: fine aggregate: coarse aggregate) based on BS 1881. Ordinary Portland cement was used as binding agent in the mixture. Water ratio of 0.5 was used for all mixtures. Table 2 shows mixture proportioning for each sample. Control concrete (without rubber crumb) was prepared for comparison purpose. Naming for each sample were made by abbreviation RC (rubber crumb) followed by numbers (mass percentage of fine aggregate replaced by rubber crumbs). 9 x 150 mm cubes and 3 x 100 x 100 x 500 mm beams were cast for each sample. All cubes and beams were wet cured 24 hours after casted.

Table 2: Mixture Proportioning (BS 1881).

Sample	Cement [kg / m^3]	Fine Aggregate [kg / m^3]	Coarse Aggregate [kg/ m^3]	Rubber Crumb [kg / m^3]	Water [kg / m^3]
RC 0	343	686	1372	0	171.5
RC 2.5	343	668.85	1372	17.15	171.5
RC 5	343	651.70	1372	34.30	171.5
RC 7.5	343	634.55	1372	51.45	171.5
RC 10	343	617.40	1372	68.60	171.5
RC 15	343	583.10	1372	102.90	171.5
RC 20	343	548.80	1372	137.20	171.5
RC 25	343	514.50	1372	171.50	171.5

III. RESULTS AND DISCUSSION

3.1. Workability

Slump test were done according to EN-12350-2. Rubber crumb has shown to increase the workability of fresh concrete significantly. Fig. 3 shows value of slump for all samples. Smooth and even surface of rubber crumbs compared to sand decreasing the frictional behaviour between aggregates and cement paste.

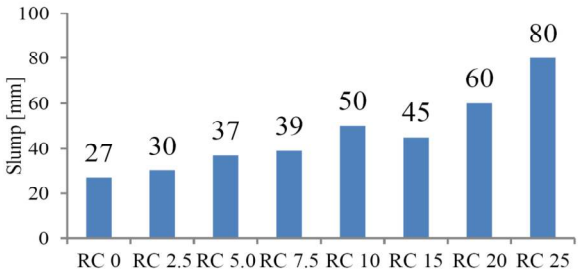


Fig.3: Slump values.

3.2. Density

Density was calculated by dividing mass of cubes (before compression test) to its volume. Density decreases to 14.92 at 25% rubber crumb replacement. Fig. 4 shows average density for all samples. One research shows that high content of air bubbles were clinging to rubber particles during mixing, resulting in entrapping air in the mixture [5]. Furthermore, aggregate density affected the density of concrete mixture. Rubber crumb has much lower specific gravity compared to fine aggregate.

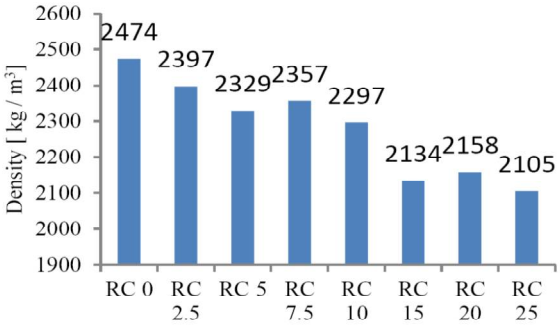


Fig.4. Average Density.

3.3. Water Absorption

Water absorption (by mass) was performed according to BS 1881-122. Three 150 mm cubes were tested at 28 days curing. The test was done for 30 minutes. Fig. 5 shows average water absorption percentages for every sample. Water absorption shows increasing in values as more rubber crumbs were added into the mixture. This is due to concrete porosity increment [6]. Higher water absorption is undesirable in construction point of view.

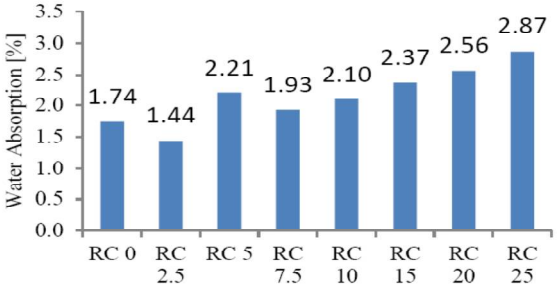


Fig.5. Water absorption (by mass).

3.4. Compressive Strength

Cube compressive strength was performed according to MS EN 12390-3:2012. Tests were performed on each sample at 7 and 28 curing days. Fig. 6 shows average compressive strength for each sample. Results from these tests agree with majority of other researches. Compressive strength decrease with inclusion of rubber crumbs. Adding more rubber crumbs leads to significant compressive strength loss. Several reasons can explain the result.

a. The difference between elastic modulus of concrete aggregates and rubber is significantly high. Consequently, the low stiff rubber particles do not carry the load in the concrete matrix.

b. The weak adhesion of rubber particles and cement paste results in the formation of weak Interfacial Transition Zone (ITZ) between rubber and cement paste [7].

c. The non-homogenous distribution of rubber particles in concrete matrix results in the reduction of the concrete strength.

d. Rubber particles have water repelling nature, thus more likely to entrap air bubbles. This will increase porosity and decreasing its load transmission in the concrete matrix [8].

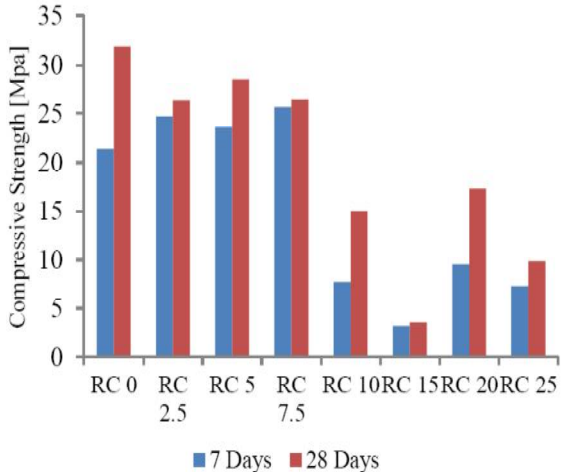


Fig.6. Average compressive strength.

Fig. 7 shows correlation between concrete strength and density.

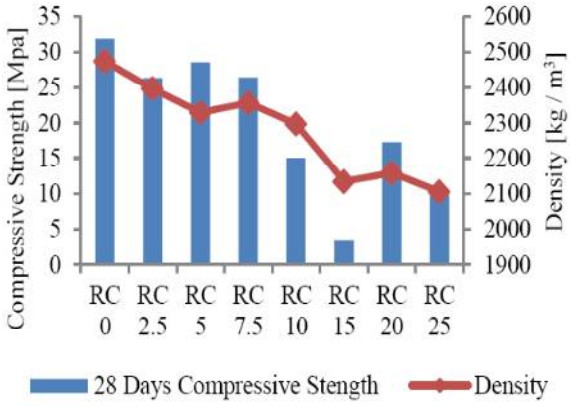


Fig.7. Correlation between compressive strength and density.

3.4. Modulus of Rupture

Concrete modulus of rupture was determined from three point bending test according to ASTM D79010. Tests were performed on beam samples at 28 curing days. Fig. 8 shows average modulus of rupture for each sample. Modulus of rupture shows decreasing value as more rubber crumbs were added into the mixture. The possible reasons for this pattern are similar to the decrement in compressive strength value.

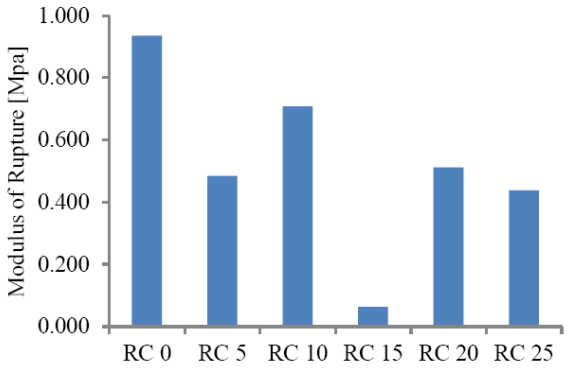


Fig.8. Average modulus of rupture.

CONCLUSIONS

Several conclusions can be concluded for this research.

1. Workability of concrete increase as more sand was replaced by rubber crumb.
2. Density of rubberised are lower compared to normal concrete.
3. Water permeability increase as more rubber was incorporated in the mixture.
4. Compressive strength and modulus of rupture shows reduction in value when rubber crumbs were added into the mix.

Lastly, it is found that maximum replacement of fine aggregate using rubber crumb is around 10%.

ACKNOWLEDGMENTS

This work was financially supported by Geran Pembudayaan Penyelidikan (RAGS) 2013.

REFERENCES

[1] Savas, B.Z., Ahmad, S., Fedroff, D., Freeze-thaw durability of concrete with ground waste tire rubber. Transport Res Rec: J Transpor Res Board.1574,80–88.

[2] Allen F.,2004. Crumb rubber concrete precast of the future. Precast Solut.3, 26–27.

[3] Grinys, A., Sivilevicius, H., Pupeikis, D., Ivanauskas, E.,2013. Fracture of concrete containing crumb rubber. J Civil Eng Manage.19(3),447–55.

[4] Mohammadi, I.,Khabbaz, H.,Vessalas, K.,2014. In-depth assessment of Crumb Rubber Concrete (CRC) prepared by water-soaking treatment method for rigid pavements. Construction and Building Materials.71,456–471.

[5] John, A., Kardos A.J., 2011.Beneficial use of crumb rubber in concrete mixtures. University of Colorado Denver.

[6] Zheng, L., Huo, X.S., Yuan, Y.,2008. Strength, modulus of elasticity, and brittleness index of rubberized concrete. J Mater Civil Eng.20,692–699.

[7] Li, Y., Wang, M., Li, Z.,2010. Physical and mechanical properties of Crumb Rubber Mortar (CRM) with interfacial modifiers. J Wuhan Univ Technol Sci Ed.25,845–848.

[8] Taha, R., El-Dieb, A.S., El-Wahab, Abdel-Hameed, M.E.,2009. Mechanical, fracture, and microstructural investigations of rubber concrete. J Mater Civ Eng . 20,640–649.

★★★