ASIAN JOURNAL OF CIVIL ENGINEERING (BHRC) VOL. 16, NO. 7 (2015)
PAGES 933-941

A STUDY ON PROPERTIES OF CRUMB RUBBER CONCRETE BY DESTRUCTIVE AND NON-DESTRUCTIVE TESTING

K.J. Rao[1*] and M.A. Mujeeb[2]
[1]Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad, Telangana, Hyderabad-500075, India
[2]Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad, Telangana, India

Received: 15 January 2015; **Accepted:** 23 May 2015

ABSTRACT

Utilization of industrial waste products in concrete is gaining importance all around the world due to the rise of environmental consciousness. Rubber from worn out tyres is one such waste material thought of by the researchers. Recycled rubber aggregates produce more elastic concrete, which has higher resistance to specific loads (impact loads, vibration and cyclic loads) compared to conventional concrete. Therefore, in this paper, the effect of crumb rubber on properties of Ordinary Portland Cement (OPC) Concrete and Ternary Blended Cement (TBC) Concrete of M40 grade are investigated with fly ash and silica fume as powders along with cement. TBC concrete has shown high energy absorption and higher strengths compared to OPC concrete.

Keywords: Ternary blended concrete; fly ash; silica fume; crumb rubber; compressive strength; ultrasonic modulus; water absorption.

1. INTRODUCTION

Modifications of construction materials have an important bearing on the building sector. Several attempts have been made in the building material industry to put to use waste material products, e.g., worn-out tyres, into useful and cost effective items. Success in this regard will contribute to the reduction of waste material dumping problems by utilizing the waste materials as raw material for other products. One of the major environmental challenges facing municipalities around the world is the disposal of worn out automobile tyres. Accumulations of stockpiles of tyres are dangerous because they pose a potential environmental concern, fire hazards and provide breeding grounds for mosquitoes that may carry disease. Tyre pile fire can burn for months, sending up an acrid black plume that can

*E-mail address of the corresponding author: kjagannadharao@cbit.ac.in (K. Jagannadha Rao)

be seen for dozens of miles, releasing toxic chemicals into the atmosphere. Thus environmental factors make the need more important as dumping grounds filled with rubber waste make the sites unfit for future construction and block natural ground water recharge path. It has been estimated that around one billion tyres are withdrawn from use in the world every year. To address these global problems, several studies have been conducted to examine various applications of recycled tyre rubber (fine crumb rubber and coarse tyre chips).

Eldin and Senouci [1] concluded from his investigations that concrete mixtures with tyre chips and crumb rubber aggregates exhibit lower strengths than regular PCC. The residual strengths were only 15% and 50% respectively in compression and split tension when coarse aggregate was fully replaced by coarse crumb rubber chips. Gintautas, et al. [2] used crumb rubber as an additive and observed that rubber added at 1% by volume of concrete reduces the compressive, bending and split tensile strengths by 4%, 2.4% and 0.9% respectively. Khatib and Bayomy [3] demonstrated that the failure of concrete with crumb rubber as fine aggregate is ductile though there is a substantial reduction in compressive and splitting tensile strengths.

Topcu [4] also showed that the addition of coarse rubber-chips in concrete lowered the compressive strength more than that of the addition of fine crumb rubber. However, the results of Ali et al [5], and Fattuhi and Clark [6] indicated the opposite trend. Studies have indicated that if the rubber particles have rougher surface or given a pretreatment, then better and improved bonding may develop with the surrounding matrix and therefore, that may result in higher compressive strength. Pretreatments may vary from washing rubber particles with water to acid etching, plasma pretreatment and various coupling agents [7]. Acid treatment enhances the strength of concrete containing rubber particles through a microscopic increase in the surface texture of the rubber particles.

Tung-Chai Ling and Hasanan [8] observed that an increase in rubber content increases the air content, which in turn reduces the unit weight of the mixtures. Gintautas, et al. [9] concluded from their investigations that the addition of crumb rubber to cement matrix increases the porosity of the matrix due to the air-entrainment in the fresh concrete. The results of Piti and Chalermphol [10] show that the abrasion resistance of crumb rubber concrete is very less compared to conventional concrete. Herna´ndez-Olivares et al. [11] concluded from the investigation that the ultra-sonic modulus is a good index of the stiffness of the material and is useful as a comparison value. It can be observed that the higher the amount of rubber, the lower the ultrasonic modulus and therefore the stiffness. Camille A. ISSA [12] found from his research that as the rubber content in the concrete increases, the time of travel increases and conductivity decreases, thus creating better insulation properties. He also concluded that enhanced ductility and damping properties of rubber can better be used in highway barriers or other similar shock-resisting elements as rubber absorbs vibration to a large extent. Sallam, et al. [13] concluded that the replacement of fine aggregate by crumb rubber to the extent of 10% caused no appreciable decrease in concrete compressive strength. The presence of crumb rubber of small size in concrete increased the resistance of concrete to crack initiation under impact load but the mode of failure of rubberized concrete under static and impact compression was the same as that of plain concrete.

A significant amount of compressibility was observed allowing the concrete specimens with rubber as aggregate to absorb a large amount of energy under compressive loads [14]. Addition of rubber to concrete resulted in a more ductile failure and better energy adsorption capability [15]. Sara, et al. [16] also observed ductile failure in concrete with crumb rubber and Improvement in mechanical properties of rubcrete mix with latex coating of the particles surface.

2. SIGNIFICANCE OF THE WORK

The disposal of used tyres has become a major concern throughout the globe. Environmental factors make the need of effective disposal of tyres more important, as dumping grounds filled with rubber waste make the sites unfit for future construction and block natural ground water recharge path. Also, it is known from the literature that the introduction of crumb rubber in concrete improves energy absorption characteristics of OPC concrete. In the present study, crumb rubber powder is used in OPC and TBC to improve energy absorption characteristics of concrete and to determine the optimum quantity of crumb rubber in concrete. Thus, by using fly ash, silica fume and crumb rubber in concrete, environmental problem of disposal of these waste materials can be solved to some extent while improving certain properties of the concrete.

3. EXPERIMENTAL INVESTIGATION

The present experimental work is carried out on the compressive and impact strengths, and Ultrasonic Pulse Velocity (UPV) of M40 grade concrete using OPC concrete and TBC concrete with varying percentages of crumb rubber.

3.1 Materials used for investigation

3.1.1 Cement: ordinary Portland cement of 53 grade, with Specific gravity 3.05 and consistency 34%, was used.

3.1.2 Fine aggregate: locally available natural river sand confirming to grading zone-ii (is 388-1970) with specific gravity 2.62 was used as fine aggregate.

3.1.3 Coarse aggregate: machine crushed granite confirming to is: 383-1970, consisting of 20 mm maximum size of aggregates and with specific gravity 2.67, was obtained from the local quarry.

3.1.4 Fly ash and silica fume: fly ash was obtained from national thermal power corporation at kothagudem in andhra pradesh. silica fume was obtained from elkem india pvt ltd company, navi mumbai. physical properties of fly ash and silica fume are shown in Table 1.

Table 1: Properties of Fly Ash and Silica Fume

S. No	Material	Normal Consistency	Specific Gravity	Fineness
1	Silica Fume	30%	2.23	2.4%
2	Fly Ash	35%	2.11	2.0%

3.1.5 Water: locally available potable water was used
3.1.6 Super plasticizer: conplast sp-430 from fosroc chemicals was used as super plasticizer
3.2 Methodology
The experimental investigation was divided into two groups namely OPC and TBC concrete. Each group consists of four batches of concrete using crumb rubber with various percentages 0%, 5%, 10% and 15%. Six cubes and three discs were cast corresponding to each batch of concrete to determine the compressive and impact strengths of concrete, density, ultrasonic pulse velocity and water absorption. Cylindrical discs with 150 mm diameter and an average depth of 63 mm were tested for Impact strength and Cubes with 100 mm X 100 mm X 100 mm were used for compressive strength, water absorption and NDT test. The tests were carried out according to IS: 516-1959, IS: 13311 (Part-1)-1992 and ACI: 544 (modified). Compressive strength tests were carried out in a digital compression testing machine of 3000 kN capacity. The impact tests were carried out on modified drop weight test equipment developed for testing high strength concrete. Conductivity and ultra-sonic modulus were calculated.

4. TEST RESULTS AND DISCUSSION

The results of the investigations are shown in tables 2 and 3 and figures 1 to 7. Based on the results obtained from the experimental investigations, a comparative study between OPC concrete and TBC concrete is made.

4.1 Compressive strength
Compressive strength decreased as the percentage crumb rubber increased in both the groups of concretes (Fig 1). However, the reduction in strength is more in OPC concrete compared to that of TBC concrete. The maximum losses in compressive strength at 28 days are 30% and 21.8% respectively in OPC and TBC concrete with 15% of crumb rubber (Table 2).

The strength reduction at higher percentages of crumb rubber may be due to the fact that rubber particles move towards the upper surface of the mould due to the vibration of concrete samples, resulting in a high concentration of rubber particles at the top layer of the specimens. This is due to the lower density of rubber materials compared to the other ingredients of the concrete. Thus, non- uniform distribution of rubber particles at the top surface and the entrapped air might have contributed to the reduction in strength.

4.2 Density
There is a marginal decrease in density of concrete with crumb rubber due to the lower density of rubber materials compared to the other ingredients of the concrete (Fig 2). The maximum loss in density of fresh concrete are 4.63% and 6.13% respectively in OPC and TBC concrete when 15% of crumb rubber is used (Table 2).

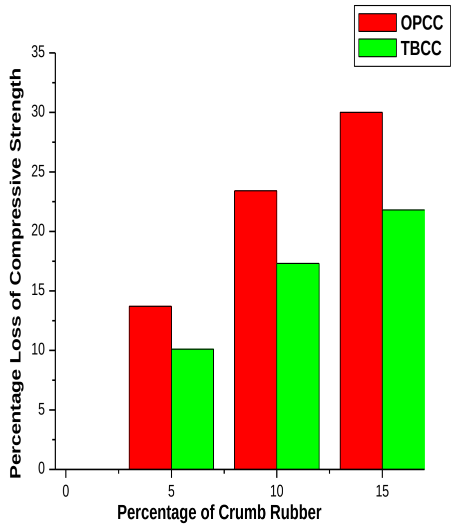

Figure 1.Variation of percentage loss of Compressive Strength of Concrete with crumb rubber

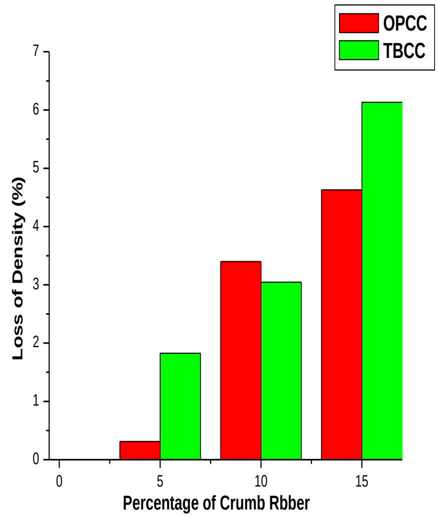

Figure 2. Variation of percentage reduction in density of concrete with crumb rubber

4.3 Impact strength

The impact energy absorbed by OPC and TBC concretes are given in Table 3. The impact strength is found to increase as the percentage of crumb rubber increased from 0 to 15%. The toughness of the material increases to about 14 times in OPC concrete and 9 times in TBC when15% of crumb rubber is added in concretes (Fig 3).

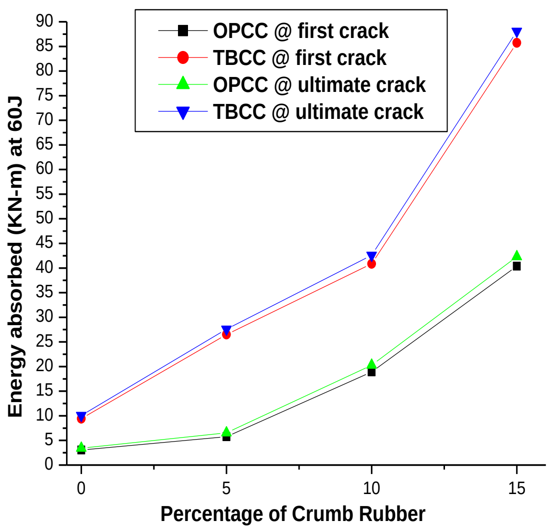

Figure 3. Variation of Impact Strength of Concrete due to the addition of crumb rubber

Table 2: Compressive Strength of Concrete and Unit Weight of Fresh Concrete

Mix ID	Compressive Strength (N/mm^2) 28 days	Unit Weight of Fresh Concrete (kN/m^3)
OPCC	52.50	25.60
OPCC-CR5	45.30	25.52
OPCC-CR10	40.20	24.73
OPCC-CR15	36.75	24.41
TBCC	57.75	24.62
TBCC-CR5	51.91	24.17
TBCC-CR10	47.75	23.86
TBCC-CR15	45.15	23.12

Table 3: Number of blows at first crack and ultimate failure

Mix ID	Number of blows	
	At first crack	At ultimate
OPCC	51	57
OPCC-CR5	96	109
OPCC-CR10	315	338
OPCC-CR15	673	705
TBCC	157	168
TBCC-CR5	442	460
TBCC-CR10	681	710
TBCC-CR15	1429	1468

4.4 Ultrasonic pulse velocity, ultra sonic modulus, water absorption and conductivity

The conductivity test was performed in order to check if rubber, being a good insulator, would play a good role in electrical/sound insulation when placed as crumbs in OPC and TBC concrete. Ultrasonic pulse velocity tests were performed on all the specimens before testing. The ultra-sonic pulse velocity and ultrasonic modulus decreased as crumb rubber content increased from 0% to 15% in OPC and TBC concretes at 28 days age (Fig 4 & Fig 5). It was observed that as the percentage of crumb rubber content increases, water absorption also increases for both OPC and TBC concretes (Fig 6). Also, it was observed that as the rubber content in the concrete increases, the time of travel increases and conductivity decreases, thus imparting better insulation properties (Fig 7).

The results of ultrasonic modulus were obtained with the equation (Eq. 1) given by Herna´ndez and Barluenga [17]

$$Es = qv^2/1000 \quad (1)$$

where 'Es' is the ultrasonic modulus (MPa), 'q' is the density and 'v' is the velocity of ultrasonic pulse propagation. The ultrasonic modulus is a good index of the stiffness of the material and is useful as a comparison value [18]. It can be observed that the higher the amount of rubber, the lower the ultrasonic modulus and therefore the stiffness.

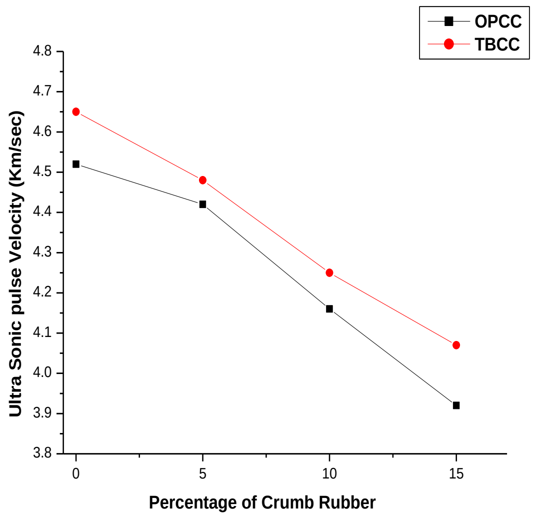

Figure 4. Variation of Ultrasonic Pulse Velocity of Concrete due to the addition of crumb rubber

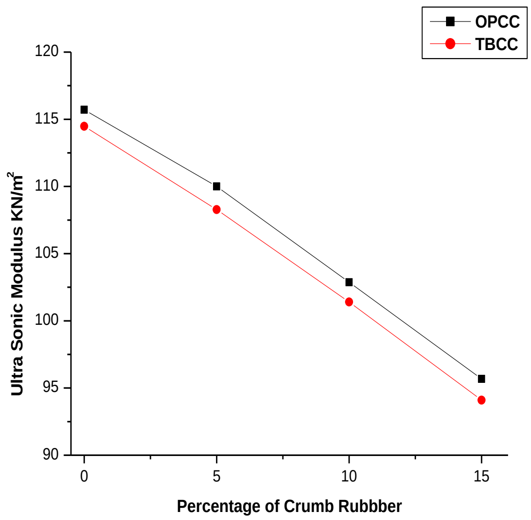

Figure 5. Variation of Ultra Sonic Modulus of Concrete due to the addition of crumb rubber

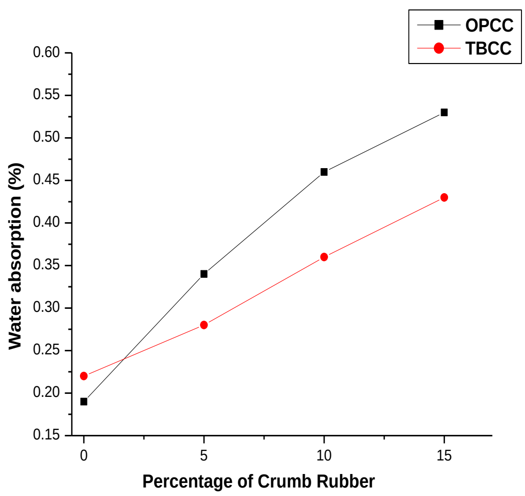

Figure 6. Variation of Water Absorption of Concrete due to the addition of crumb rubber

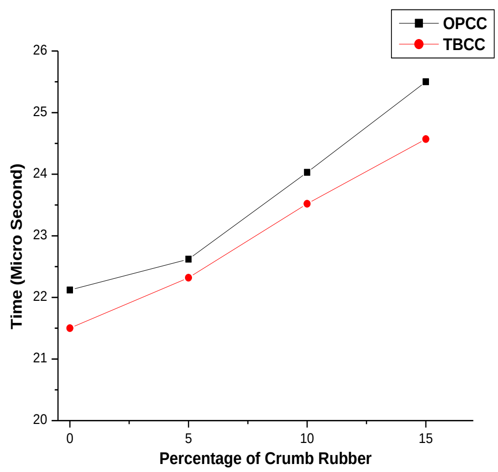

Figure 7. Variation of Conductivity of Concrete due to the addition of crumb rubber

5. CONCLUSIONS

The introduction of crumb rubber into the concrete lead to reduction in the compressive strength and density of fresh concrete. Though there is a little decrease in compressive strength, the impact strength is improved by 2 to 2.5 times at 5% addition of crumb rubber in both OPC and TBC concretes.

The average pulse velocity of the concrete decreased with the addition of the crumb rubber. The time of travel increased due to non-polar nature of the rubber particles and their tendency to entrap air in their rough surfaces.

The conductivity of the concrete with increasing crumb rubber is found to decrease, imparting better insulation properties to the concrete.

The ultrasonic modulus of the concrete was observed to decrease with the addition of crumb rubber and thus decreased the stiffness of concrete.

The water absorption of the concrete also increased marginally with the increase in the percentage of crumb rubber.

REFERENCES

1. Eldin NN, Senouci AB. Rubber-tyre particles as concrete aggregate, *Journal of Materials in Civil Engineering, ASCE*, No. 4, **5**(1993) 478-96.
2. Gintautas Skripkiūnas, Audrius Grinys, Benjaminas Černius. Deformation properties of concrete with rubber waste additives, *Materials Science (Medžiagotyra)*, No. 3, **13**(2007) 219-23.
3. Khatib ZK, Bayomy FM. Rubberized portland cement concrete, *Journal of Materials in Civil Engineering, ASCE*, No. 3, **11**(1999) 206-13.
4. Topcu IB. The properties of rubberized concrete, *Cement and Concrete Research*, No. 2, **25**(1995) 304-10.
5. Ali NA, Amos AD, Roberts M. Use of ground rubber tyres in Portland cement, *International Conference on Concrete* (2000), University of Dundee, UK, pp. 379-390.
6. Fattuhi N, Clark L. Cement based materials containing tyre rubber, *Construction and Building Materials*, No. 4, **10**(1996) 229-36.
7. Naik TR, Singh SS. Utilization of discarded tyres as construction materials for transportation facilities, Report No. CBU-1991-02, UWM centre for By-Products Utilization, University of Wisconsin-Milwaukee, Milwaukee, 16, 1991.
8. Tung-Chai Ling, Hasanan Md Nor. Granulated waste tyres in concrete paving block, *6th Asia-Pacific Structural Engineering and Construction Conference* (APSEC 2006), 5-6 September 2006, Kuala Lumpur, Malaysia.
9. Gintautas Skripkiūnas, Audrius Grinys, Eugenijus Janavičius. Porosity and durability of rubberized concrete, *Second International Conference on Sustainable Construction Materials and Technologies*, June 28-June 30, 2010 Universita Politecnicadella Marche, Ancona, Italy.

10. Piti Sukontasukkul, Chalermphol Chaikaew. Concrete pedestrian block containing crumb rubber from recycled tyres, *Thammasat International Journal of Science and Technology*, No. 2, **10**(2005) 1-8.
11. Herna´ndez-Olivares F, Barluenga G, Bollati M, Witoszek B. Static and dynamic behavior of recycled tyre rubber-filled concrete, *Cement and Concrete Research*, **32**(2002) 1587-96.
12. Camille A Issa. Utilization of recycled rubber in concrete mix design, *34th International Symposium on Bridge and Structural Engineering*, Venice, 2010.
13. Sallam HEM, Sherbini AS, Seleem MH, Balaha MM. Impact resistance of rubberized concrete, *Engineering Research Journal*, No. 3, **31**(2008) 265-71.
14. El-Gammal A, Abdel-Gawad AK, El-Sherbini Y, Shalaby A. Compressive strength of concrete utilizing waste tyre rubber, *Journal of Emerging Trends in Engineering and Applied Sciences*, No. 1, **1**(2010) 96-9.
15. Sohrabi M.R, Karbalaie M. An experimental study on compressive strength of concrete containing crumb rubber, *International Journal of Civil and Environmental Engineering*, No. 3, **11**(2011) 24-8.
16. Sara Sgobba, Giuseppe Carlo Marano, Massimo Borsa, Marcello Molfetta, RaffacleTusto. Experimental investigation on degradation processes in concrete with recycled-tyre rubber aggregate, *Fib Symposium Prague*, (2011) 1245-8.
17. Herna´ndez-Olivaresa F, Barluenga G. Fire performance of recycled rubber-filled high-strength concrete, *Cement and Concrete Research*, **34**(2004) 109-17.
18. Wang JC. Young’s modulus of porous materials, *Journal of Material Science*, **19**(1984) 809-14.