

Influence of Waste Tyre Crumb Rubber on Compressive Strength, Static Modulus of Elasticity and Flexural Strength of Concrete

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Abstract. In this paper, the experimental investigations was carried out to find the compressive strength, static modulus of elasticity and flexural strength of concrete mixtures, in which natural sand was partially replaced with Waste Tyre Crumb Rubber (WTCR). River sand was replaced with five different percentages (5%, 10%, 15%, 20% and 25%) of WTCR by volume. The main objective of the experimental investigation is to find the relationship between static modulus of elasticity and flexural strength with compressive strength of concrete with WTCR. The experimentally obtained static modulus of elasticity and flexural strength results comparing with the theoretical values (various country codes recommendations).

1. Introduction

Recent years the rapid development is noticed in the construction industry due to urbanization. Concrete is one of the widely used materials in the construction industry. In the concrete preparation 70% to 80% occupying natural aggregates like crushed rock (coarse aggregate) and river sand (fine aggregate). The commonly used coarse aggregate and fine aggregate is likely becoming huge demand and scared it is today. Now construction people need the alternatives to natural aggregates. Therefore, finding alternatives to naturally available materials is important to sustaining construction industry. On the other hand a large quantity of waste materials is being produced by various industries and the governments are seeking ways to reduce the problem of disposal and to control the health hazard from the accumulation of waste materials. Some of the waste materials, such as coal fly ash, bottom ash, glass granules, plastic granules, copper slag, and crushed rock dust were used in the concrete. So such waste materials are utilized to alter the mechanical and durability characteristics of concrete so as to make it fit for any condition, this would also give some more benefits in terms of cost reduction, promoting environmental sustainability, energy savings, and reduction in the use of natural resources [1-3].

In this paper, waste tyre crumb rubber partially replaces the fine aggregate by volume with different percentage (5%, 10%, 15%, 20% and 25%) and study to the main characteristics of the concrete made of crumb rubber and to compare the test results with the normal concrete (without



rubber). The compressive strength, flexural strength and static modulus of elasticity are the main properties of concrete. In fact, these are very important properties for designing and analysing the concrete structures. Design codes of various countries are recommended the empirical relationship between static modulus of elasticity; flexural strength and compressive strength of concrete at 28 days are shown in Table 1.

Table 1. Empirical relationship between static modulus of elasticity; flexural strength and compressive strength of concrete at 28 days

S. No	Empirical relationship between static modulus of elasticity and compressive strength	Empirical relationship between flexural strength and compressive strength	Code details
1	$E_c = 5000\sqrt{f_c}$	$f_r = 0.7\sqrt{f_c}$	IS 456 [4]
2	$E_c = 4734\sqrt{f_c}$	$f_r = 0.62\sqrt{f_c'}$	ACI 318 [5]
3	$E_c = 3320\sqrt{f_c'} + 6900$	$f_r = 0.6\sqrt{f_c'}$	NZS 3101 [6]
4	$E_c = 9500(f_c' + 8)^{0.33}$	$f_r = 0.3(f_c')^{0.67}$	EC 02 [7]
5	$E_c = 4500\sqrt{f_c'}$	$f_r = 0.6\sqrt{f_c'}$	CSA A23.3-04 [8]

Where, E_c is the static modulus of elasticity at 28 days in MPa, f_r is flexural strength of concrete in MPa, f_c is cube compressive strength of concrete at 28 days in MPa and f_c' is cylinder compressive strength.

The above empirical relationship is only for conventional concrete. Therefore, in this paper the tests were made to establish a new empirical relationship between static modulus of elasticity, flexural strength based on the compressive strength of concrete incorporating waste tyre crumb rubber.

2. Experimental Program

2.1 Material properties

Ordinary Portland cement 53 grade (OPC 53) conforming to IS 12269 [9] was used in this study. The properties of cement presented in Table 2. Properties of cement test results satisfied the requirements.

Table 2. Properties of Cement

S. No.	Property	Results	Requirements as per IS 12269
1	Specific surface (m^2/kg)	320	225 (Min.)
2	Normal consistency	31%	---
3	Specific gravity	3.14	---
4	Setting time	Initial	Not less than 30 min
		Final	Not more than 600 min
5	Compressive strength (N/mm^2)	7 days	37.00
		28 days	53.00

Locally available river sand was used as a fine aggregate. The properties are confirmed as per IS 383. River sand confirms grading Zone II with specific gravity of 2.65 and fineness modulus of 2.45 were used. Crushed granite stone having a maximum size of 20mm and down with specific gravity of 2.63 and fineness modulus of 7.2 were used. The properties are confirmed to IS 383

[10].Shredding of waste tyres were to produce crumb rubber having a maximum size of 4.75mm down with specific gravity of 0.689.

2.2 Mix Proportion

The mix designed was designed for M40 grade concrete as per IS 10262 [11] which yielded proportions of 1:2.22:2.66 with water- cement ratio of 0.5. The dosage of super-plasticizer 1% (by weight of cement) was added to improve the workability. Replacing 5%, 10%, 15%, 20% and 25% of fine aggregate with waste tyre crumb rubber by volume and re-proportioning the conventional concrete mixes gave the waste tyre crumb rubber concrete mixes. Water – cement ratio and dosage super plasticizer was kept constant for all the mixtures. The details of mix proportions designed for both conventional and waste tyre crumb rubber based concrete is shown in Table 3.

Table 3. Mix proportions

S. No.	Mix ID	Details of replacement	Ratio
			C: S: CA: CR
1	R0	Conventional concrete	1: 2.2:2.66:0.00
2	R5	5% fine aggregate replaced by waste tyre crumb rubber	1:2.09:2.66:0.09
3	R10	10% fine aggregate replaced by waste tyre crumb rubber	1:1.98:2.66:0.18
4	R15	15% fine aggregate replaced by waste tyre crumb rubber	1:1.87:2.66:0.27
5	R20	20% fine aggregate replaced by waste tyre crumb rubber	1:1.76:2.66:0.36
6	R25	25% fine aggregate replaced by waste tyre crumb rubber	1:1.65:2.66:0.45

Note: C – Cement, S – sand, CA – Coarse aggregate and CR – Crumb rubber.

2.3 Casting of Test Specimens

Cube specimens of size 150 mm×150 mm×150 mm were cast for cube compressive strength. Cylinder specimens of 200mm length and 100 mm diameter were cast for cylinder compressive strength and static modulus of elasticity. Prism of size 500 mm× 100 mm× 100 mm was cast for flexural strength.

3. Results and Discussion

3.1 Compressive Strength

The concrete cube and cylinder compressive strength test results as shown in figure 1. The test result shows that the concrete cube and cylinder compressive strength were decreased with increasing crumb rubber content in the concrete mix. The reduction in the compressive strength of cubes with the addition of 5%, 10%, 15%, 20% and 25% of WTCR was observed 4.09%, 7.73%, 13.72%, 23.64% and 33.85% for concrete cubes 4.26%, 9.85%, 16.22%, 27.20% and 36.02% for concrete cylinders at 28 days respectively as compared to normal concrete (without WTCR).

The major cause for the drop in the strength is the softness of the rubber particles are much softer due to this while compressive load applied to the specimen the crack propagation was very fast around the rubber particles which will affect the rubber-cement matrix and leads to the failure [12-13].

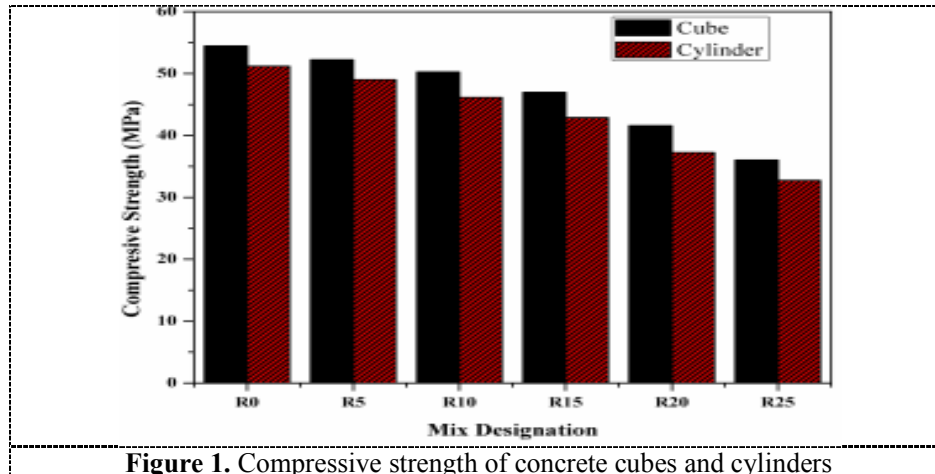


Figure 1. Compressive strength of concrete cubes and cylinders

3.2 Flexural Strength

Figure 2 represents the comparison of experimental and theoretical (Various country codes, recommendations) obtained flexural strength for both normal concrete and WTCR mixed concrete is presented in Figures 2.

Two point load was applied to the specimens and the breaking load for the specimens were measured. From the breaking load the flexural strength was calculated. The test results show that the flexural strength was increased up to 15% WTCR replacement. This might be because of the improved tensile load carrying capacity of the rubber particles [14].

Figure 2 shows the experimentally obtained flexural strength value is higher than comparable to other codal provision. The experimentally obtained flexural strength of concrete higher than 4.35 to 13.74 percent for IS 456, 17.87 to 27.16 percent for ACI 318, 19.12 to 32.01 percent for EC 02 and 20.52 to 29.51 percent for NZS 3101 and CSA A23.3-04 codes for all concrete mixes.

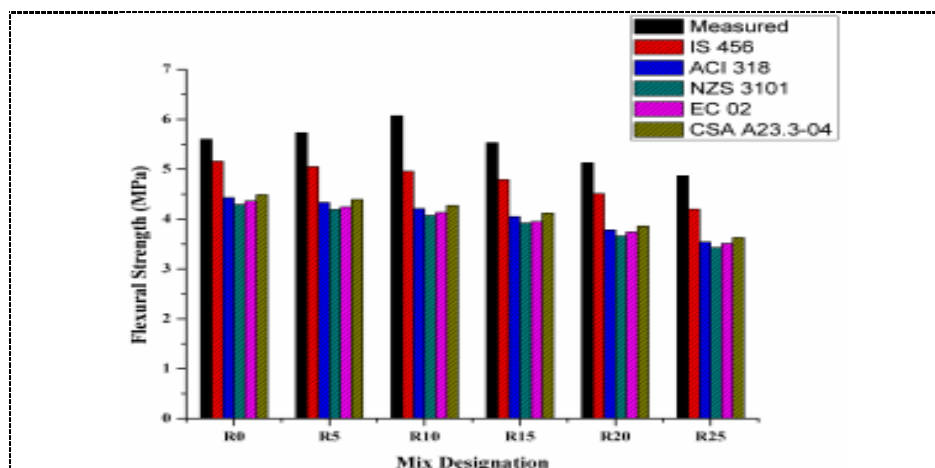


Figure 2. Comparison of experimental and theoretically obtained flexural strength for control and WTCR mixed concrete

3.3 Modulus of Elasticity

Figure 3 clearly shows that the experimentally obtained modulus of elasticity at 28 days and calculated values from the empirical equation given in the various country codes for both normal and rubberized concrete. The figure clearly shows that the measured modulus of elasticity is lower than the theoretical one.

The modulus of test procedure was followed the guidelines of ASTM C 469-02 [15]. The Static modulus of normal and rubberized concrete was determined as the secant modulus measured at a stress level equal to 40 percent of the average compressive strength of concrete cylinders. The gauge length of the cylinder was marked on the central height of specimens. Longitudinal extensometer was attached to the specimen such that gauge length is 200mm, placed the cylinder with a longitudinal extensometer on the compression testing machine and adjusted the deflect meter reading to zero. The load is increased in increment up to 40% of the cylinder compressive strength of concrete. The deflect meter readings are tabulated and the static modulus of elasticity was found. The reading of one unit in the extensometer is equal to 1/100 mm.

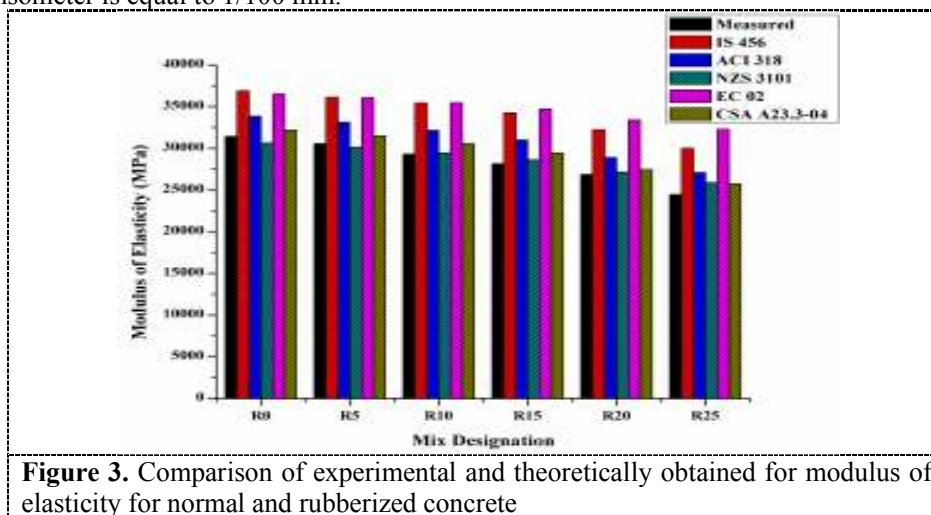


Figure 3. Comparison of experimental and theoretically obtained for modulus of elasticity for normal and rubberized concrete

The figure 3 shows the modulus of elasticity calculated by EC 02 and IS 456 is higher than those predicted by NZS 3101, ACI 318 and CSA A23.3.04. The figure 3 also shows the measured modulus of elasticity is lower than the theoretical values. The difference between experimentally obtained modulus of elasticity and calculated modulus of elasticity increased as the strength of concrete decreased with increasing the percentage of WTCR content.

4. Conclusion

- The concrete cubes and cylinder compressive strength were decreased with increasing in WTCR content..
- Flexural strength of concrete was increased up to 15% of WTCR replacement. If the percentage of WTCR replacement increases over 15% the flexural strength was decreased. The measured flexural strength was more than the predicted flexural strength by various country codes for all the percentage replacements of sand by WTCR.
- Static modulus of elasticity of WTCR mixed concrete was less than control concrete, but there was withstanding large deformation and displacement due to the properties of rubber. Normally rubber having more ductile or flexible in that it has the ability to withstand larger deformation. The experimentally obtained modulus of elasticity of control and WTCR mixed concrete was less than predicted from the theoretically obtained values..

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