Numerical Modeling of Concrete Containing Waste Tyre Rubber as Partial Replacement of Fine Aggregate

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Abstract

In this study, fine rubber was partially substituted with fine aggregates from 0% to 30% in multiples of 10%. The properties of concrete like compressive strength, flexural strength, split tensile strength and modelling in ANSYS was performed and the outcomes were investigated. The results showed that there was slight increase in the flexural and tensile strength of the specimens containing 10% fine rubber when compared to the control mix. Workability of concrete mix decreases with increase in the rubber content. The analytical result from ANSYS was obtained by the outcomes obtained from the experimental investigation and results were verified.
Keywords: Waste Tyre Rubber, Fine Aggregate, Rubber Added Concrete

I. INTRODUCTION

Recycling of tyres in nature is a major issue. In the present situation, these are tried to be utilized as a part of the concrete so that regular assets are spared and at the same time the earth is shielded from waste stores. Usage of waste tyre rubber in concrete as replacement of aggregate might be one of the better answers for the recycling of this waste. Rubber added concrete in this manner can contribute in maintainable development. Properties of concrete are influenced by incorporation of waste tyre. Workability of concrete with fine rubber decreases with the increase of rubber content. These studies have been done and it was seen that compressive strength declines as the measure of rubber particles increases.

Rubber added concrete has been seen for concrete containing rubber as substitution of aggregates.

A. Benefits of Adding Rubber in Concrete

- Rubber added concrete is light in weight.
- Rubber added concrete is environment friendly by using waste rubber instead of natural aggregates.
- It has Low Linear Shrinkage Property.
- Increases concrete Ductility.
- Crack widths are reduced, thus improves durability.
- Improved impact and abrasion resistance.

B. Importance of Numerical Modelling

Nowadays, with the help of advanced PC's and capable strategies for examination, such as the finite element method many efforts are developed analytical solutions which reduces the need for experiments which had to undertake by investigators. The numerical modelling technique has along these lines turned into an intense computational device, which permits complex investigations of the nonlinear reaction of RC structures to be done in a standard manner.

II. EXPERIMENTAL WORK

Mix design of M35 was adopted and four different proportions were made having fine rubber of size up to 4.75mm varying from 0-30 % as a replacement of fine aggregate. Total 96 specimens were casted and cured for 28 days and then tested to identify the various properties of concrete, out of which 48 cubes of size 150 x 150 x 150 mm were tested for Compressive strength and

Poisson's ratio, 24 beams of size 500 x 100 x 100 mm were tested for Flexural strength and 24 cylinders of diameter 150 mm and length 300 mm were tested for Split tensile strength.

Following tests were conducted according to IS code guidelines:

- Slump cone test for workability,
- Compressive strength test
- Flexural strength

Fig. 1: Fine rubber used

A. *Properties of Rubber used in study*

The size of the fine rubber used in this research varies from 0.5 to 4.75 mm.

Table - 1
Sieve analysis and specific gravity

I.S. Sieve Size	*Percentage Passing*		
	Fine Aggregate	*Coarse Aggregate*	*Fine Rubber*
40 mm	-	*100*	-
20 mm	-	*100*	*100*
10 mm	*100*	*33*	*98*
4.75 mm	*97*	*4*	*82*
2.36 mm	*86*	*0*	*38*
1.18 mm	*74*	-	*6*
600 Micron	*42*	-	*0*
300 Micron	*23*	-	-
150 Micron	*5*	-	-
Specific gravity	*2.605*	*2.884*	*1.14*

B. *Numerical Modeling*

Numerical Modelling is a numerical system for finding estimated answers to boundary value problems for differential equations. It utilizes various techniques (the calculus of varieties) to minimize a mistake and deliver a steady solution. FEM programming software like ANSYS is used for building arrangement sets in engineering simulation that helps the design process. Programming software puts a virtual item through a thorough testing technique, for example, smashing an auto into a block divider, or running for quite a while on a landing area street before it turns into a physical object. In this study Mechanical APDL (ANSYS) was used for analysis.

C. *Meshing*

For Solid65 element the mesh was set up such that square elements were created. The volume sweep command was used to mesh the model. This properly sets the width and length of elements concrete portions of the model. The element size for mesh was kept 10 mm. Meshed model of beam is shown in Figure 2

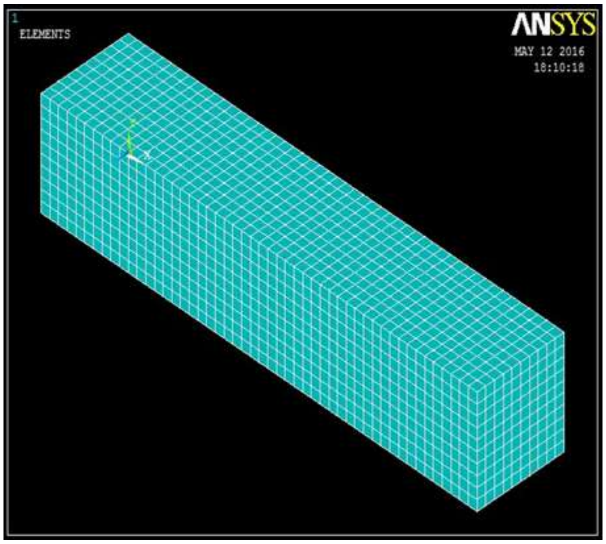

Fig. 1: Meshed model of beam

D. Loads and Boundary Conditions

Boundary conditions were needed to constrain the model to get a one of a kind arrangement. In this research two supports were applied, one of which was constrained from all axis but other support was set free in x-axis. Two point loads were applied on the top surface of the model in y direction. Applies loads and boundary conditions are shown in Fig. 3.

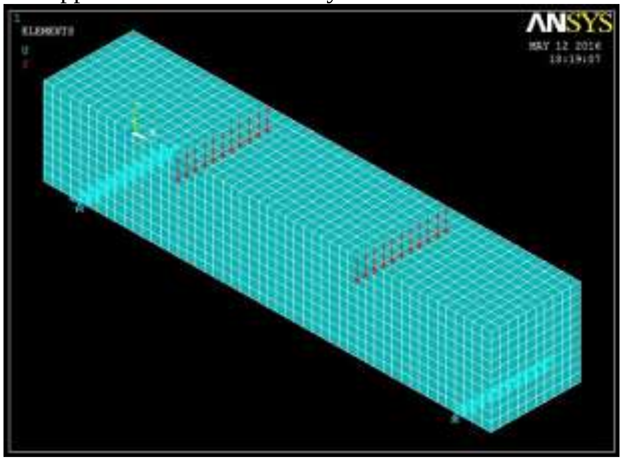

Fig. 2: Isometric showing loads and boundary conditions

E. Parameters Required Defining Material Properties in ANSYS

Following are the parameters required to define material properties:
- Compressive Strength
- Split Tensile Strength
- Modulus of Elasticity
- Poisson's ratio (μ)

III. RESULTS AND DISCUSSION

The experimental testing results of Slump value in Table 2 and Compressive strength, Split tensile strength, Flexural strength, Modulus of elasticity, Poisson's ration and density are listed in Table 3.

Table – 2
Mix proportions and slump value

Type of Concrete mix	*Percentage of Rubber (%)*	*Cement (Kg/m^3)*	*Fine Agg. (Kg/m^3)*	*Fine Rubber (Kg/m^3)*	*Coarse Agg. (kg/m^3)*	*Water Content (litre)*	*Admixture (litre)*	*Slump (mm)*
CC	*0*	*330*	*749*	*0*	*1330*	*140*	*7.0*	*95*
RC10	*10*	*330*	*674.1*	*74.9*	*1330*	*140*	*7.0*	*89*
RC20	*20*	*330*	*599.2*	*149.8*	*1330*	*140*	*7.0*	*83*
RC30	*30*	*330*	*524.3*	*224.7*	*1330*	*140*	*7.0*	*78*

Table – 3
Test Results

Type of Concrete Mix	*Compressive Strength (MPa)*	*Split tensile Strength (MPa)*	*Flexural Strength (MPa)*	*Modulus of Elasticity (MPa)*	*Poisson's Ratio*	*Density (kg/m^3)*
CC	*48.2*	*4.46*	*4.91*	*35100*	*0.19*	*2400*
RC10	*42.5*	*5*	*5.54*	*31906*	*0.17*	*2213*
RC20	*35.6*	*3.77*	*4.25*	*24920*	*0.20*	*2112*
RC30	*26.8*	*2.96*	*3.18*	*20707*	*0.21*	*2053*

A. Slump

The results demonstrated that the slump value of the rubber added concrete decreased with the increase in replacement of fine rubber. As seen in Figure 4, the highest slump value happened of the control concrete with 100% natural fine aggregate, whereas the mixture incorporating 30% fine rubber replacement reached the lowest one. As a result, to improve the workability, admixture (BASF 8341) was added in mix.

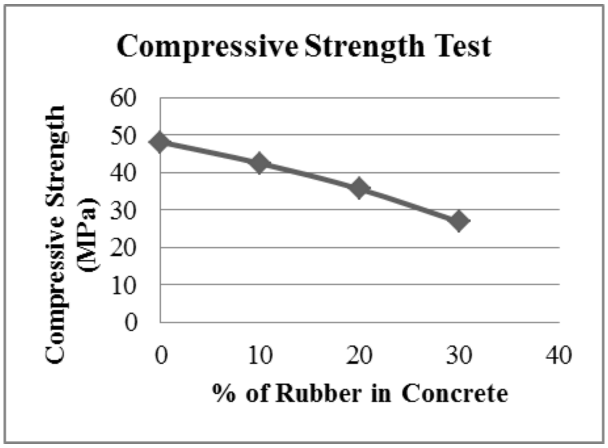

Fig. 4: Graph of Workability

B. Compressive Strength

In the fig. compressive strength of different mix proportion demonstrated a decreasing tendency with increasing mixing ratio of the fine rubber content. The increase in fine rubber content from 0 to 30% resulted in a gradually decrease in the compressive strength from 48.2 MPa to 26.8 Mpa, which is equivalent to It can be seen that most reduction occurred when the replacement ratio was 30%.

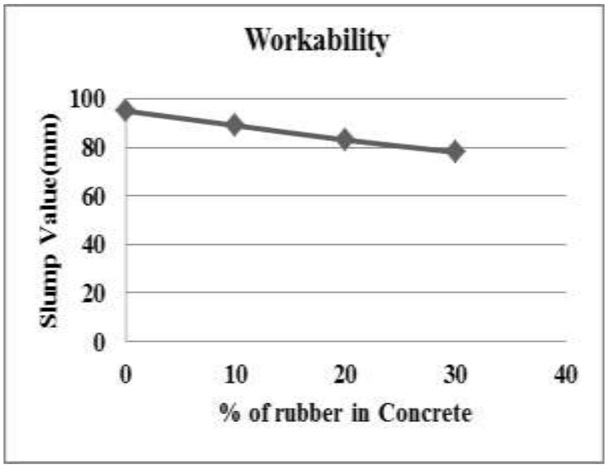

Fig. 5: Graph of Compressive Strength Test

C. Split Tensile Strength

The variations of split tensile strength with replacement of rubber particles at 28 days are listed in Table 3. It can be seen from Figure 6 that the split tensile strength of RC10 mix is more than CC mix at 28 days. It was also seen the reduction of split tensile strength of RC20 and RC30 mix at 28 days.

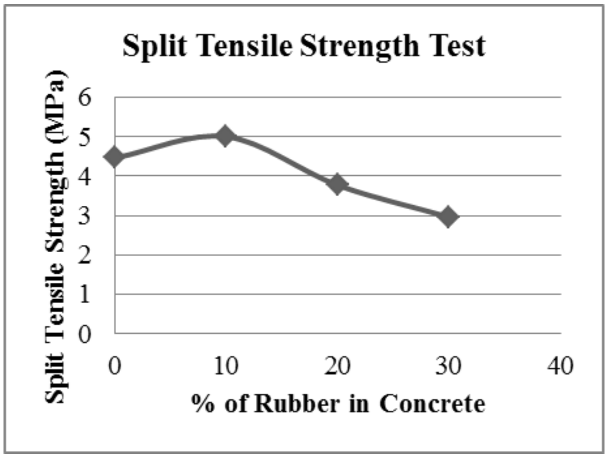

Fig. 3: Graph of Split Tensile Strength

D. Flexural Strength Test

The flexural strength of different mix proportion is presented in Figure 7. The flexural strength values between 5.54 and 3.18 MPa at 28 days were achieved, in which the RC10 had the highest strength value.

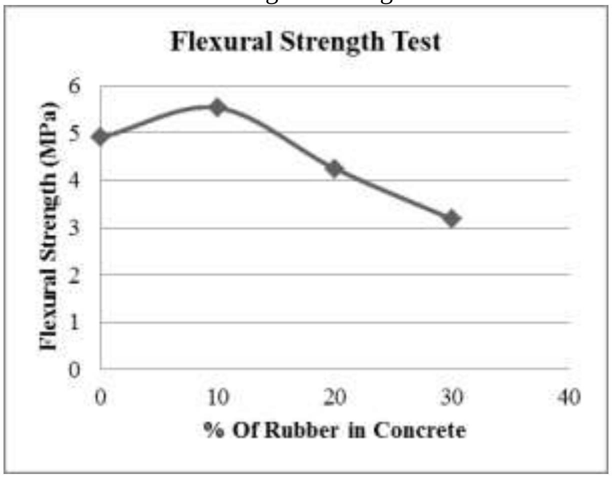

Fig. 4: Graph of Flexural Strength Test

E. Load-Deflection Values Obtained Experimentally and ANSYS

LOAD (N)	CC		RC10		RC20		RC30	
	Deflection (ANSYS) (mm)	Deflection (EXP)(mm)	Deflection (ANSYS)(mm)	Deflection (EXP)(mm)	Deflection (ANSYS)(mm)	Deflection (EXP)(mm)	Deflection (ANSYS)(mm)	Deflection (EXP)(mm)
2000	.01	.009	.011	.009	.015	.013	.016	.014
4000	.02	.019	.021	.018	.028	.027	.033	.03
6000	.03	.027	.032	.030	.043	.041	.050	.046
8000	.041	.038	.043	.039	.058	.055	.064	.062
8500	-	-	-	-	-	-	.065	.063
9240		-	-	-	-	-	.067	-
11000	.051	.049	.054	.050	.070	.069	-	-
11800	-	-	-	-	.071	.070	-	-
12800	-	-	-	-	.072	-	-	-
13000	-	-	.065	.061	-	-	-	-
13500	.061	.060	-	-	-	-	-	-
14080	.062	-	-	-	-	-	-	-
14800	-	-	.072	.062	-	-	-	-
15400	-	-	.074	-	-	-	-	-

IV. CONCLUSIONS

In summary, the numerical modelling of concrete was done with partial replacement of fine aggregate with fine rubber. Based on the findings of this study, the following conclusions may be drawn:

- The flexural strength of beam containing 10% rubber is 5% more than control beam containing 0% rubber and flexural strength of beam containing 20 & 30% of rubber is 26 % and 44 % less than control beam.
- The deflection of beam containing 10 % rubber is 15 % more than control beam and 5-10 % more than beam containing 20 % & 30 % rubber.
- Results shows that as we increase the rubber in concrete it somewhat become light and elastic in behaviour. It was seen about 350 Kg/m^3 weight loss in mix having 30% rubber content.
- The Numerical modelling results shows the values of Modulus of Elasticity, Poisson's ratio, Compressive strength and Tensile strength is found to be in good agreement.
- ANSYS shows that the load deflection curve for 10 % of rubber replacement is more than the control beam. But addition of rubber beyond 10% increases the deflection of the beam but decreases the load carrying capacity.

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