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Determination of the Unit Weight and Compressive Strengthof Rubberized Concrete

Adnan Nawaz[1], Hanif Ullah[1]

[1]Department of Civil Engineering, University of Engineering & Technology, Peshawar, Pakistan

Abstract– *There is a large increase of waste tyres with the recent fast growth of the automobile industry. Serious environmental pollutions are caused by these waste tyres. Research is in progress to utilize these scrap tyres in various fields to cater the pollution problem in a sustainable and environmentally friendly manner. One possible solution is to use this waste material in normalconcrete as a partial replacement of natural aggregates resulting in a new green material called Rubberized Concrete. This research study consists of the uni-axial compression tests on conventional and rubberized concrete to determine the compressive strength. The unit weight of rubberized concrete is also determined through electric balance. 10%, 15% and 20% of ground rubber available locally in Peshawar were used as volume replacement of fine aggregate to obtain Rubberized Concrete. Moreover, the overall fabrication process of normal and rubberized concrete is also discussed.The research can help explore the possible future for use of rubberized concrete for the possible application as a civil engineering material.*

Keywords–*Automobile Industry, Environmental Pollution, Rubberized Concrete, Compressive Strength, Unit Weight.*

I. INTRODUCTION

This research describes the experimental work conducted on normal and rubberized concrete cylindersto obtain their peak compressive strength. The decline in the unit weight of concrete due to addition of light weight ground rubber is also presented in this work. Furthermore, the overall fabrication process of the normal and rubberized concrete cylinders andmodels is also discussed. The main goal of this study is to find alternate environmentally acceptable method for the reuse of waste scrap rubber in normal concrete to obtain rubberized concrete with satisfactory engineering parameters.The reference ratio for the normal concrete is kept as 1:1.80:1.60 with w/c ratio of 0.48 and 10%, 15% and 20% volume of natural fine aggregate is replaced with equal volumes of ground rubber.

II. LITERATURE REVIEW

Environmental pollution is burning issue in today's world with solid waste management as a major one. The transportation sector particularly the auto-mobile sector has increased world-wide in the recent periods.This increase of the use of vehicles particularly carsis producing a huge amount of waste tyres. Around one (01) billion waste tyres are generated every year throughout the world, furthermore by the year 2030, 0.5 billion waste tyres will add to this number each year [1].The inappropriate managing of these waste tyres is linked with a major environmental issue. Unfortunately, no dependable data regarding the yearly production of waste tyres is available in Pakistan [2]. The majority of these waste tyres are either stockpiled / dumped or exported. These waste tyres in its different form may also be used as fuel in kilns as shown in Figure 1 and other industries.A mere percentage of these waste tyres are however recycled for different products as shown in Figure 2. Disposal of waste tyres in these ways are potential threat to the environment.

Figure 1: Brick Kilns at Peshawar

Figure 2: Reuse of Waste Tyre at Peshawar

Rubber from waste tyres are available in the form of chips and ground rubberas shown in Figure 3. Locally in Peshawar, the scrap tyre is used for different purposes. From the market survey in Khyber Bazar, Peshawar it was observed that the rubber in neither of its form is used for production of concrete at commercial level. Moreover, greater amount of this waste in different forms is transported to big cities where large industries are available to use rubber as a raw material.

Figure 3. Different Forms of Rubber Availible Locally

Practically, all the environmentally developed countries, laws have been implemented against the burying of tyres in any of its form [3]. Waste tyres are durable and occupy huge useful volume, thus waste tyres are on the most challenging waste in the modern world [4]. Due to the worldwide urban development, practically no land is available for the stockpiling of waste tyres, thus waste tyres can't be landfilled in the future. It is added that shredding of these waste tyres is also required before landfilling [5].Since these waste tyres are combustible, the stockpiled sites present potential sites for fire which are hazardous for health. Excessive thick volume of black smoke as shown in Figure 3 are produced, once these are agitated. These melted tyres in turn produces huge amount of oil which in turn pollutes the ground water and soil as shown in Figure 4 [5]. In addition to all of this, the stockpiling of these waste tyres collect water / organic wreckage, which in turn provide ideal habitat for some of the disease carrying organisms such as mosquitos.

Figure 3. Thick Black Smoke

Figure 4. Disposed Waste Tyres

This rapid increase of waste tyres and their relating alarming issues provide inspiration to find alternate useful methods to reuse these scrap tyres.Therefore, effectively reusing waste tyres is important for saving natural resources and protecting the environment. To tackle this issue, Rubberized Concrete / Rubber Concrete / Crumb Rubber Concrete are developed in the field of civil engineering, which is a form of concrete that uses scrap tyres in various sizes as aggregates by partially replacing natural aggregates. ASTM D 6270 studied the properties of shredded waste tyres (Practical size of 2 mm and more), but not waste tyre rubber powder.

The earlier experimental study carried out by Eldin et al. in 1993 [6] was mainly focused on finding the compressive and tensile capacity of rubberized concrete. They replaced the fine and coarse natural aggregates with crumb rubber and chips respectively and found a considerable decline in both compressive and tensile capacity. It was moreover concluded, that the rubberized concrete was able to absorb more plastic energy when subjected to compressive and tensile loading, thus was flexible in nature. Different other basic parameters were studied in a research by Neil N. Eldin et al. in 1994 [7] wherein it was found out that there is a reasonable loss in the weight of crumb rubber concrete but the workability was satisfactory as compare to normal concrete. Rubberized concrete behavior was rather plastic and absorbed a fair amount of energy when subjected to split tension and compression loading.The thermal properties of the crumb rubber concrete were studied by S. F. A. Shah et al. in 2014 [2] in a research based on hot-box method. It was concluded that the properties of concrete up to five (5) percent replacement of scrap rubber doesn't changes significantly, however changes substantially above five (5) percent replacement. With the increase in rubber replacement, the compressive capacity, tensile / flexure capacity and stiffness decreases. The unit weight and workability also drop with increase in replacement of rubber as coarse aggregates. It was however concluded that there is increase in the water absorption, air content and impact resistance capacity while increasing amount of rubber.

Many researches have reported the decline in the compressive capacityand unit weight with the addition of rubber as aggregate material in the concrete, the important reasons explained in the researches are; first, since rubber is inert polymer substance, therefore it doesn't take part in hydration process of cement which leads to a week inter-facial bond / adhesion between cement and rubber, ultimately leading to a weak capacity of rubberized concrete [8]. Second, during the mixing / placement / vibration process of concrete, the rubber moves to the top of the surface since the weight / specific gravity of rubber particle is lower as compare to concrete / aggregates. This leads to a non-homogenous mixture, ultimately resulting in reduction of strength of concrete [9] and third rubberized concrete leads to early cracking due to the large relative distortions between concrete and crumb rubber particles. This is in turn due to the higher Poisson ratio (twice that of normal concrete) and lower Young's Modulus (1/3rd of normal concrete) [9].

"II. METHODOLOGY"

This research work comprises of uniaxial compression testson standard concrete cylinders for finding the strength of normal and rubberized concrete. Three (03) cylinders are casted from conventional concrete having reference concrete ratio of 1:1.80:1.60 and water to cement ratio of 0.48. Furthermore, 10%, 15% and 20% of sand volume is replaced by equal volume of ground rubber to find rubberized concrete strength of each series respectively, keeping concrete ratio and water to cement ratio same.The details of standard cylinders tested is shown in Table 1.

Table 1. Different Parameters of Standard Cylinders

S.No	Cylinder Description	Cylinder Label	Rubber Replacement	No of Cylinders
1	Normal Concrete	NC	-	03
2	Rubberized Concrete	10RC	10 %	03
3	Rubberized Concrete	15RC	15 %	03
4	Rubberized Concrete	20RC	20 %	03

The normal and rubberized concrete standard cylinderswere tested under pure monotonic uniaxial compressive load as per the standard method of ASTM. These tests were performed using a 200Ton Universal Testing Machine (UTM) as shown in Figure 5at the Structural Laboratory, Civil Engineering Department, University of Engineering and Technology Peshawar, Khyber Pakhtunkhwa, Pakistan.The applied load was manually controlled through the load cell as shown in Figure 6in the UTM and increased at control increments under standard strain rate.A steel plate was connected to the UTM on bottom and top of each cylinder for the uniform distribution of compressive axial load.

Figure 5. Cylinder Placed in UTM

Figure 6. Load Cell

The decline in unit weight of concrete due to inclusion of rubber is determined from the normal and rubberized concrete samples having dimensions 6 inches x 6 inches x 30 inches. The detail of modelswhich were weighted through electric balance is shown in Table 2 below.

Table 2. Different Parameters of Standard Cylinders

S.No	Model Description	Rubber Replacement	Model Label	No of Models
1	Normal Concrete	-	NC	03
2	Rubberized Concrete	Ten Percent	10RC	03
3	Rubberized Concrete	Fifteen Percent	15RC	03
4	Rubberized Concrete	Twenty Percent	20RC	03

2.1 Materials

The materials used for this research work were Normal Portland cement, Ground Rubber, Water and Fine andCoarse Aggregates. Ordinary Portland Cement namely Kohat Cement available locally in Peshawar was used for fabrication of the models.The fine aggregates and coarse aggregates which were used in the fabrication of models was free from dust and other inorganic impurity so as to avoid unwanted variation in the quality of concrete.As per the requirement of ASTM, clean and portable water was used for making and curing of concrete.The ground rubber form of the waste tyres is used in the research as this work is based on the partial replacement of sand. The ground rubber was available readily in stock of bags but it may contain some large pieces of waste tyre as shown in Figure 7. For this purpose, the rubber was passed from Sieve No. 200 and pure ground rubber was obtained as shown in Figure 8. Formworkmade from plywood sheets as shown in Figure 9is used in this research work as it also does not allow water to evaporate, thus prevents shrinkage cracks.

Figure 7. Sieve Analysis

Figure 8. Ground Rubber & Sand

Figure 9. Formwork for Models

2.2 Fabrication Phase

The normal concrete specimens with reference ratio of 1:1.80:1.60 and w/c ratio of 0.48 were casted as per the standard procedure of ASTM followed by preparation of 10%, 15% and 20% rubberized concrete specimens. The whole procedure is described step wise in the following section.

2.2.1 Weighting of Materials

As per the required concrete ratio of 1:1.80:1.60 and water to cement ratio of 0.48, cement, fine and coarse aggregates and water were weight with the help of electric balance as shown in Figure 10 and Figure 11.It is important to mention that the rubber was added as volume replacement of the fine aggregates only. In the 10% cylinders and models, 10% by weight of fine aggregates was taken out of the total fine aggregates and accordingly this much volume of rubber was added to the mixture as shown in Figure 12. In this way, 15% and 20% cylinders and models were prepared.

Figure 10. Weighting of Cement

Figure 11. Weighting of Water

Figure 12. Addition of Ground Rubber

2.2.2Mixing of Materials

All the constituents were dry mixed manually with the help of shovel at least three turns of mixing as shown in Figure 13. The materials were however later on put to proper mixing in the concrete mixture as shown in Figure 14. Water was added in the mixture to get the final to prepare concrete cylinders and specimens.

Figure 13. Material Mixing through Shovel

Figure 14. Concrete Mixer

2.2.3 Vibration

A steel rod was used for the vibration of the cylinders while 1-inch vibrator was used for vibration of the concrete in the specimen in order to remove any gap or entrapped air, both of the procedures are shown in Figure 15 and 16.

Figure 15. Vibration through Steel Rod

Figure 16. Vibration through Concrete Mixture

2.3.4 Curing

As per the required ASTM standards, the cylinders were kept in drums full of water for at least 28 days in an open environment as shown in Figure 17. The models werecovered with bags for wet curing which were soaked two to three times a day, as shown in Figure 18.

Figure 17. Curing of Cylinders

Figure 18. Curing of Models

The cylinders and samples were white washed so that cracks can be easily observed during the experiments and labelledas shown in Figure 19.Horizontal surface and vertical level are necessary in order to avoid any unwanted P-Δ effects. For achieving vertical level, plumb was used and fully perpendicular models were casted, while in order to obtain a fully horizontal level surface, a cutter with steel blade was used to eliminate any undulations produced during casting as shown in Figure 20 and Figure 21.

Figure 19. Labelling Cylinders

Figure 20. Steel Cutter

Figure 21. Horizontal Plane Surface

III. EXPERIMENTS AND RESULTS

The unit weight of the models was calculated through electric balance to determine the decline in weight due to addition of rubber while the normal and rubberized concrete were tested uniaxially in compression for finding the peak compressive strength.

3.1 Weight

The weight of the reference concrete samples along with the rubberized concrete samples were measured through electronic balance as shown in Figure 22.

Figure 22. Weight of Rubberized Concrete

The weight was calculated in order to find the decline in weight due to adding rubber, being a light material as compare to sand. Additionally, the rubber is hydrophobicin nature i.e. repels water, thus it also induces additional gap, accordingly reducing the weight of concrete. The weight of each sample recorded is presented below in Table 4.

Table4. Detail of Weight of Specimen

S.No	Model Label	Weight (kg)	% Variation wrt Normal Concrete
1	NC	42.01	
		41.51	
		41.97	
	Average Weight	**41.83**	
2	10RC	40.89	
		40.78	
		40.67	
	Average Weight	**40.78**	(-) 2.51
3	15RC	39.78	
		39.37	
		39.19	
	Average Weight	**39.45**	(-) 5.70
4	20RC	38.1	
		38.44	
		38.46	
	Average Weight	**38.33**	(-) 8.36

Thus, it can be observed, that the weight of concrete reduces by 2.51% when 10% of sand is replaced by equal volume of rubber. By replacing 15% volume of total sand by rubber, the weight reduces further to 5.70%. The weight of concrete finally reduces by 8.36% of the reference concrete models when 20% of sand is replaced by equal volume of rubber. Thus, it is concluded that by adding rubber, the weight of concrete reduces, also shown in the Figure 23.

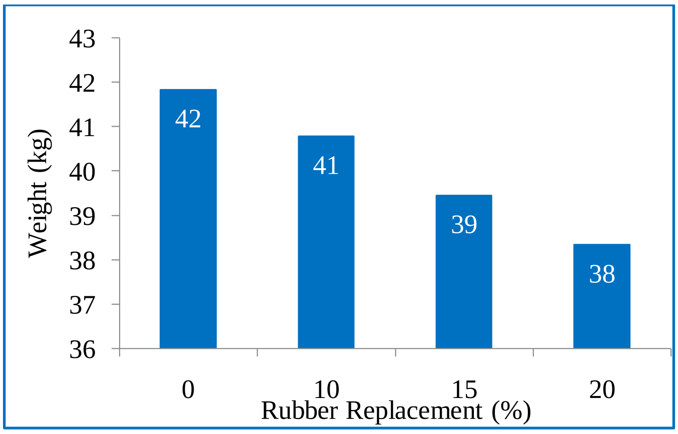

Figure23. Average Weight – Rubber Replacement (%)

4.2 Compressive Strength

Rubberized concrete has significant lower compressive strength than regular concrete. This is mainly due to less adhesive strength between rubber and cement matrix which results in weak bond. Many other important reasons for this decline are presented earlier in the literature review. After thorough investigation of the tests and failed specimen, it was observed that vertical stresses developed in the rubberized concrete as the load increases in the uniaxial compressive test, as shown in Figure 24. A total of twelve standard cylinders were tested in UTM for finding the compressive strength of reference normal concrete, 10%, 15% and 20% Rubberized Concrete.

Figure 24. Cylinders Tested for Compressive Strength

The compressive strength of reference concrete and rubberized concrete cylinders tested recorded are given in Table 5.

Table 5.Compression Test Results of Standard Concrete Cylinders

S.No	Model Label	Compressive Strength (ksi)	% Variation wrt Normal Concrete
1	NC	3.74	
2		3.81	
3		3.8	
	Average	**3.78**	-
1	10RC	3.12	
2		3.21	
3		3.13	
	Average	**3.15**	(-) 16.65
1	15RC	3.01	
2		2.91	
3		2.79	
	Average	**2.90**	(-) 23.26
1	20RC	2.21	
2		2.24	
3		2.33	
	Average	**2.26**	(-) 40.26

Thus, it is observed that by adding 10% rubber to the normal concrete in place of sand aggregates, the compressive peak strength drops from 3.78ksi to 3.15ksi. The strength decline comes to 2.90ksi when 15% volume of the sand is replaced by equal volume of ground rubber. Ultimately, by adding 20% volume of the rubber, the compressive strength drops by 40.26% when compared to reference normal concrete. This drop in compressive strength is shown in the Figure 25below.

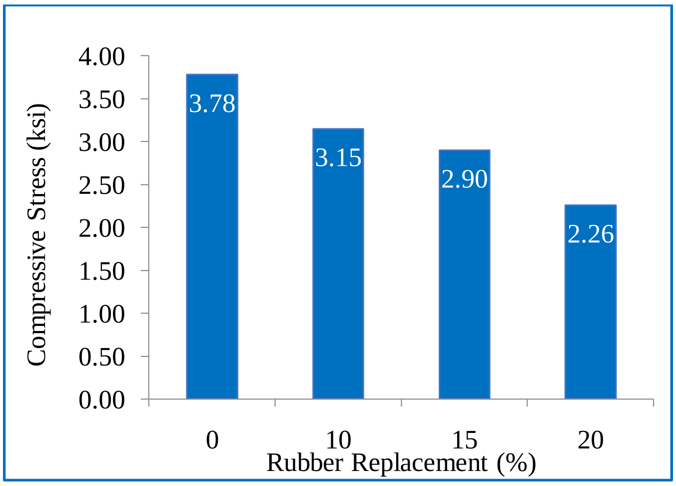

Figure 25. Compressive Strength - % Rubber Replacement

IV. CONCLUSION

1. A decrease in weight was observed with the addition of ground rubber, the weight of concrete reduces by 2.51%, 5.70% and 8.36% as compare to normal reference concrete, when 10%, 15% and 20% of sand is replaced by equal volume of rubber respectively.
2. With the addition of ground rubber as fine aggregates, there is a decline in compressive strength. The compressive strength drops from 3.78ksi to 3.15ksi with 10% volume replacement of sand with rubber. It further drops to 2.90ksi and 2.26ksi with 15% and 20% volume replacement of sand with ground rubber respectively. Thus, a total of 40.26% drop with reference to normal concrete was observed with 20% addition of ground rubber.

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