Effect of PVA on Rubberized Concrete

Muhammad Rehan Sadiq[1], Muhammad Faisal Javed[2], Safeer Ullah[3], Naseer ud Din[1], Hasan Raza[1] and Raja Azmat Kamal Khan[1]

1. Corresponding Author. BS student, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus.
   Email: rehansadiq04@gmail.com
2. Assistant Professor, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus.
   Email: arbabfaisal@cuiatd.edu.pk
3. Lecturer, Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus.
   Email: safeer@cuiatd.edu.pk

Abstract

Use of alternative aggregates has become a dire need of today's modern civilization, as they have significantly reduced the socio-economic stresses which the construction industry is facing nowadays. This research is dedicated to studying the behavior of concrete incorporating crumb rubber as a partial replacement of fine aggregate and polyvinyl alcohol fibers as the addition of cement. PVA dosages of 1% and 2% by mass of cement and rubber dosages of 5% and 10% by weight of fine aggregate were incorporated into concrete. The parameters of the study were slump test, the fresh density of concrete, water absorption and compressive strength. Test results show that the density, workability, and strength of concrete took a nosedive as the rubber content increases which is attributed to the fact that rubber is lighter in weight, has a rough texture, increases the viscosity and form a weak bond with cement. On the flip side, PVA has shown a positive influence on the engineering properties of concrete. Hence, PVA can be used to overcome the issues associated with the use of crumb rubber in concrete.

Keywords: Alternative aggregates, rubberized concrete, fiber reinforced concrete, polyvinyl alcohol fibers, crumb rubber, mechanical strength parameters, fresh properties of concrete.

1. INTRODUCTION:

Concrete is the second most widely used material in the world (Gagg, 2014). The annual production of concrete is estimated to be 30 billion tons(Monteiro et al. 2017). In concrete ingredients, aggregates proportion is the highest. It is a fact that these virgin resources are limited and needs to be preserved in order to maintain balance in the ecosystem. Therefore, it has become a dire need of today's world to use alternative aggregates which has dual advantages; that is the reduction of cost and removal of waste. Which benefits the environment and enable us to conserve natural resources(Mannan, April 2004). The investigated alternative aggregates (AAs) includes; recycled concrete aggregate (RCA)(Jin et al. 2015), building rubbles (Khalaf and DeVenny, 2004), etc.

In recent years, preservation of the environment seeks undivided attention of engineers and scientists. Keeping that in mind crumb rubber can be added into concrete to aid preservation of the environment and to conserve natural resources. Crumb rubber is recycled rubber produced from automotive and truck scrap tires. The demand of tire production has increased drastically over the years, but their disposal has been an alarming concern, as these tires cannot be recycled and are dumped which has caused severe threats to the society from environmental impact to health concerns. Among all the methods suggested for the disposal of rubber, its incorporation into concrete has been proved most effective. The only problem associated with the use of crumb rubber as an alternative aggregate is that it causes a reduction of mechanical strength of concrete (Liu et al. 2016). Likewise, they are found to cause an increase in the workability of concrete but had a negative influence on its compressive and tensile strength(Mercy and Ramarao, 2016). However, the aforementioned shortcomings can be regained by using different additives/polymers like re-dispersible polymer powders, liquid resins, monomers, and water-soluble polymers (Eren et al. 2017).

PVA (chemically known as polyvinyl alcohol) are high-performance fibers and are the first synthetic colloid prepared by Herrmann and Haehnel in the year 1924(Finch, 1973). It is water soluble polymer and is always used in concrete for enhancing the mechanical strength and durability of concrete. PVA being a chemically reactive polymer on reaction with cement forms calcium complexes that fills the pores, thus, densifies the structure and improves the properties of the cement paste(Singh and Rai, 2001). PVA fibers increase the ductility, toughness, tensile strength and flexural strength of reinforced concrete and they help in bridging the cracks thus enhance the crack resistance ability of concrete (Noushine et al. 2013).

The significance of this research work is that it would curb the issues or problems associated with tire disposal. Moreover, the rubberized concrete would strike the pay dirt in the construction industry for being comparatively cheaper and readily available. The rubberized concrete is recommended for non-structural applications like sidewalks, etc. In addition, rubberized concrete improves thermal protection and is therefore recommended to be used as general insulation of walls and heat insulation on roofs. Moreover, it can be used as a noise insulator in theatres, cinema halls, noise proof rooms, etc.

2. EXPERIMENTAL PROGRAM

2.1 Materials:

During the research work, Bestway Cement was used i-e type-1 cement. The fine aggregate having a maximum size of 2mm and fineness modulus of 2.64 was used. While the locally available crush with a maximum size of 19 mm and fineness modulus of 2.65 was used as coarse aggregate. A tire rubber, used as an alternative aggregate, was obtained from a recycling industry Swat Tyre & Rubber Co Pvt Ltd Hayatabad, Peshawar. It has a fineness modulus of 2.76. PVA fibers were imported from China and its properties are shown in table 1.

Table 1: Properties of PVA

Colour	Off white
Length	6mm
Diameter	25μm
Density	1.29g/cm^3
Elongation	≤ 40%
Tensile Strength	425MPa

2.2 Specimen designation:

While conducting experiments, two varying abbreviations were used i-e CM and PR. Where CM stands for control mix while in PR, P stands for PVA and R stands for crumb rubber. In PR, the digits 0, 1 & 2 comes before "P" and 0, 5 & 10 comes before "R" that refers to the percentages in which they have replaced the respective ingredients of concrete. For instance, 2P5R states the specimen in which 2% PVA was added for cement and 5% fine aggregate was replaced by crumb rubber.

2.3 Mix proportion:

A total of nine (9) concrete mixes have been used with the ratio of 1:1.5:3 (1 part of cement, 1.5 parts of sand and 3 parts of coarse aggregate). They include one CM (control mix), while the rest of the eight consists of different proportion mixes of PVA and Crumb rubber. The water-cement(w/c) ratio was kept constant i-e 0.45 whereas, the design strength was assumed to be 21 MPa. PVA was used in a proportion of 1 & 2 % while crumb rubber was used in a proportion of 5 & 10 %. The complete mix design is summarized in table 2.

Table 2: Mix Design

Mix	**Cement (kg/m^3)**	**PVA (kg/m^3)**	**w/c ratio**	**Water (kg/m^3)**	**Fine Aggregate (kg/m^3)**	**Crumb Rubber (kg/m^3)**	**Coarse Aggregate (kg/m^3)**
CM	411.11	0	0.45	185	709.49	0	1049.4
0P5R	411.11	0	0.45	185	674.02	35.48	1049.4
0P10R	411.11	0	0.45	185	638.54	70.95	1049.4
1P0R	406.99	4.11	0.45	185	709.49	0	1049.4
1P5R	406.99	4.11	0.45	185	674.02	35.48	1049.4
1P10R	406.99	4.11	0.45	185	638.54	70.95	1049.4
2P0R	402.88	8.22	0.45	185	709.49	0	1049.4
2P5R	402.88	8.22	0.45	185	674.02	35.48	1049.4
2P10R	402.88	8.22	0.45	185	638.54	70.95	1049.4

2.4 Testing

Concrete testing was divided into two phases; the first phase was concerned with fresh properties of concrete that include slump test and fresh density of concrete while the second phase was concerned with hardened properties of concrete that includes water absorption test and compressive strength testing.

The slump test was performed in accordance with ASTM C 143. The densities of concrete were determined in their fresh state by weighing them and subsequently dividing them by their volume. However, the water absorption test was performed using ASTM C 642 – 97. While for assessment of compressive strength of concrete ASTM C 39 was used.

3. RESULTS AND DISCUSSIONS

3.1 Workability

Slump test was performed for evaluating the workability of concrete. Workability reflects the fresh properties of concrete. The results are shown in figure 1, which illustrates that rubber has a negative influence on the workability of concrete i-e upon 5% of rubber replacement there was a reduction of 17% in concrete's workability while for 10% of rubber replacement the reduction was almost 27%. This reduction in concrete's workability was attributed to the rough texture of rubber and to the increase in viscosity of the concrete with the addition of rubber. Unlike rubber, PVA has shown a positive influence on the workability of concrete. Where it can be seen that upon adding 1% and 2% of PVA the workability was increased by 14% and 45% respectively. Likewise, their combined effect has shown an increase in workability i-e upon comparing with 0P5R the increase for 1P5R was 15% while for 2P5R the increase was 25% respectively. The increase in the concrete's workability was attributed to the ball-bearing effect of PVA (Allahverdi et al. 2010).

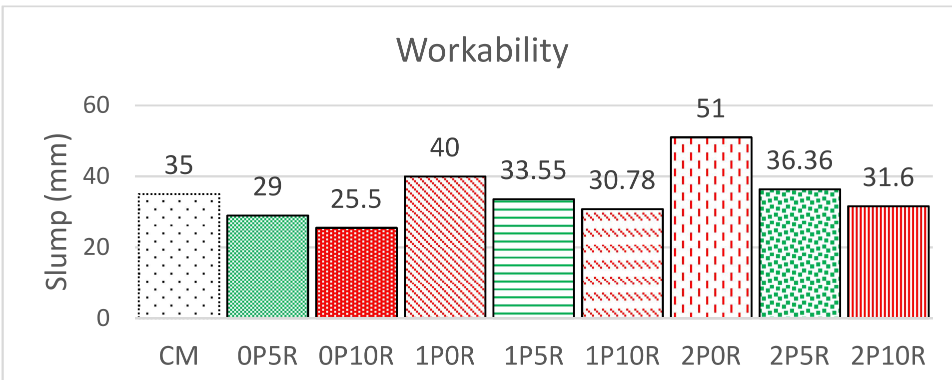

Figure:1 Average slump test of the fresh mixes versus PVA dosages

3.2 Density of fresh concrete

The fresh density of concrete is of extreme importance for its effect on the strength parameters and durability etc. It is the measurement of concrete's solidity. The results of this test are illustrated in figure: 2.

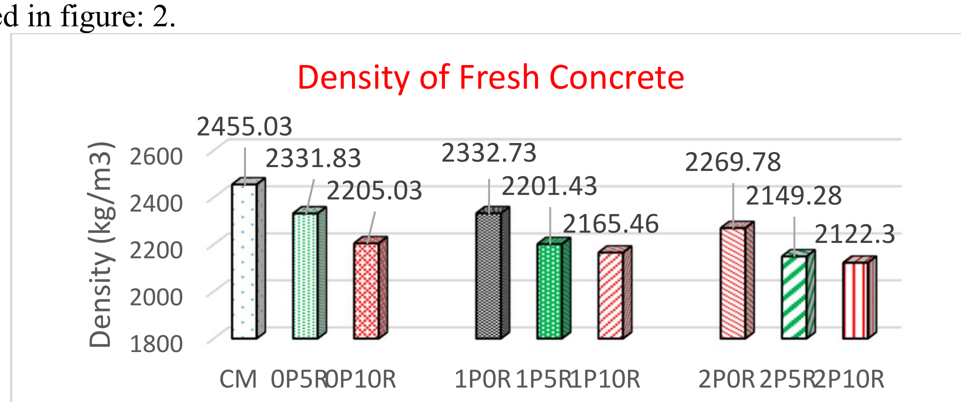

Figure:2 Densities of the fresh mixes at different PVA dosages

Rubber, being lighter in weight, tends to cause reduction of concrete's density. Higher the replacement, lower is the density and vice versa. Likewise, the addition of PVA also tends to cause a reduction of concrete's density.

3.3 Total water absorption

The total water absorption of concrete helps in working out the durability of concrete. The concrete with higher water absorption suggests that it has high porosity and lower durability or vice versa. In this research, the water absorption was evaluated at 7th and 28th day respectively. The results are illustrated in figure 3.

It is clear from the graph that with the addition of rubber the water absorption of concrete increases, this is due to the weak bonding between rubber and concrete material that lead to cracks in concrete, thus making it susceptible to water penetration. Whereas the behavior of PVA was found out to be a bit ambiguous that is at 7 days of curing it doesn't show any significant influence on the water absorption properties of concrete, while at the 28th day it causes a significant reduction in the water absorption of concrete. At the early days of concrete, the PVA hasn't undergone any sorts of chemical interaction, therefore, the voids remain in the concrete and thus the water absorption is high whereas with time it forms calcium complexes that fill the voids, densifies the structure and results in a reduction of water absorption (Singh and Rai, 2001).

From figure 3, upon adding 1% of PVA into rubberized concrete, the reduction in total water absorption was 14% while for 2% of PVA the reduction was 26% respectively. Whereas, when both rubber and PVA is added it tends to cause a significant reduction in the water absorption of concrete i-e when 1% PVA was added to 5R it causes a reduction of 11% while when 2% PVA was added to 5R it causes a reduction of 17%.

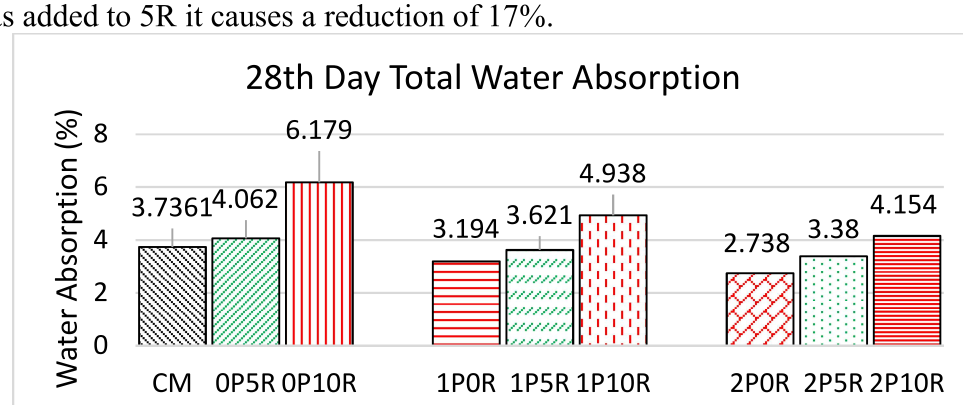

Figure:3 Total water absorption of mixes at different PVA dosages

3.4 Compressive strength

For concrete, compressive strength is of utmost importance. In the following study, compressive strength was evaluated at 7th and 28th day of curing. The experimental results are shown in figure 4. It was witnessed that rubber due to weak bonding tends to decrease the compressive strength of concrete. For 5% and 10% replacement of rubber, there was a reduction of 17% and 22% respectively.

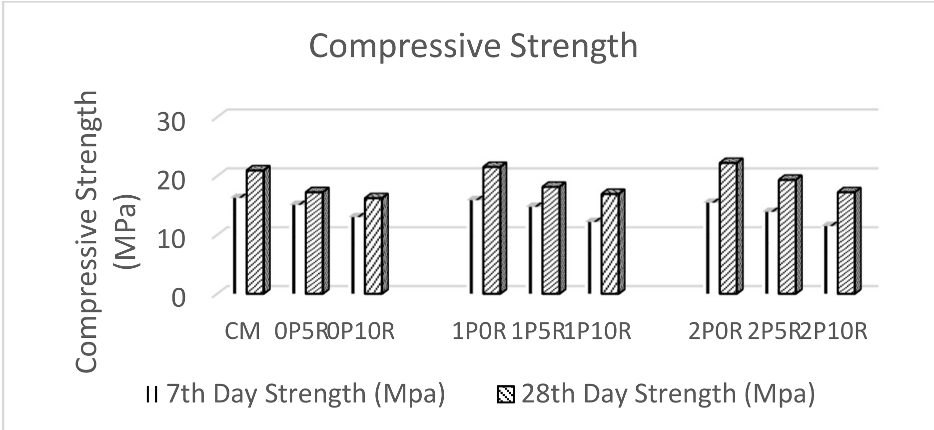

Figure:4 Compressive Strength versus PVA dosages

While the addition of PVA has struck the pay dirt by overcoming the reduction in strength that results from the addition of crumb rubber. Though at the 7th day the effect was negligible as initially PVA hasn't interacted chemically with cement while at the 28th day, after proper chemical interaction PVA enhance the strength significantly. The increase in compressive strength for 1% and 2% of PVA was estimated to be 3% and 6% respectively. Moreover, their combined effect has shown to cause an increase in the compressive strength of concrete. An increase of 5% for 1P5R and 12% for 2P5R was observed upon comparison with 0P5R.

4. CONCLUSIONS:

The overall result indicates that incorporation of crumb rubber causes a decrease in concrete's workability up to 27%, a reduction in concrete's compressive strength of almost 22% and an excessive increase in water-absorption of 64% respectively. Whereas, PVA, a synthetic water-soluble polymer, has overcome these aforementioned problems and has significantly improved the concrete engineering properties i-e an increase of 45% in concrete's workability, a reduction of 26% in water absorption and a tad increase in concrete's compressive strength was observed upon adding PVA into the concrete. Whereas, rubber and PVA both have shown to cause a steady decrease in fresh density of concrete.

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