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Evaluation of Performance of Rubber Concrete

Suraj Shah [a], Saurav Shrestha [b], Sujan Maharjan [c], Nishma Karki [d], Rameswor Shrestha [e]

[a, b, c, d, e] *Khwopa College of Engineering, Bhaktapur, Nepal*
Corresponding Email: [a] shah.suraj @khwopa.edu.np, [b] sauravshrestha00001@gmail.com, [c] sujanmahrjan@gmail.com, [d] nish.karki001@gmail.com, [e] shrestha.rameswor@khwopa.edu.np

Abstract
Nepal, along with the whole world facing a big environmental issue of non-degradable rubber Tyre (crumb rubber). Department of Transport Management (DoTM) Nepal, (2014) has said that number of vehicles registered in the country has reached 2,551,138 units and rubber Tyre which cannot be discharged off-easily in the environment as its decomposition takes much time and burning produces air pollution with emission of carbon monoxide and the ash produced from burning material that contains plastic and rubber could be hazardous. In such a case, reuse of rubber wastes would be better choice. Paper works on the reuse of rubber in concrete as a fine and coarse aggregate in proportion in the concrete. Different index properties like dry weight , thermal conductivity , Compressive strength, tensile strength are investigated and compared with ordinary concrete's above mentioned properties.Better bonding between the molecules of rubber and cement in the mix is established with the use of NaOH solution as admixtures which has made improvement in Compressive strength,tensile strength by maximum of 6 %.

Keywords
Rubber, Coarse Aggregate, Index properties, NaOH solution, Environment

1. Introduction

According to The Freedonia Group Report, it is estimated that the world demand for tires is forecast to rise 4.7 percent per year through 2015 to 3.3 billion units, approximately same number of tires are disposed of every year and almost 20 percent of them are illegally dumped in landfills, or just thrown away on roadsides [1]. At present enormous quantities of tyres are already stockpiled (whole tyre) or landfilled (shredded tyre), 3000 million inside EU and 1000 million in the US, by the year 2030, the number of tyres from motor vehicles is expect to reach 1200 million representing almost 5000 million tyres to be discarded in a regular basis [2].Generally, the cheapest and easiest way to decompose used tire is by burning them. However, the pollution and enormous amount of smoke generated by this method makes burning quite unacceptable and, in some countries, it is prohibited by law. Thus, one of the most popular methods is to pile used tires in landfills, as due to low density and poor degradation they cannot be buried in landfill [3]. These tires can also be placed in a dump, or basically piled in a large hole in the ground. However, these dumps serve as a great breeding ground for mosquitoes and due to the fact that mosquitoes are responsible for the spread of many diseases, this becomes a dangerous health hazard [4]. In industry higher amounts of rubber tire waste can be utilized as fuel, pigment soot, in bitumen pastes, roof and floor covers, and for paving industry [5].

Crumb rubber (CR) is a commodity made by re-processing (shredding) disposed automobile tires [6] .CR is fine rubber particles ranging in size from 0.075-mm to no more than 4.75-mm. Shredding waste tires and removing steel debris found in steel-belted tires generates crumb rubber. There are three mechanical methods used to shred apart these tires to CR: the cracker mill, granulator, and micro mill methods [7].

Cement-based concrete is a brittle material in general and is of high rigidity. In some applications such as foundation pads and traffic barriers, it is desirable for concrete to have high toughness and good impact resistance. Although concrete is the most commonly used construction material, it does not always fulfill these requirements. It has been observed from previous research that the properties of concrete would change when used automobiletire chips are added into concrete [8].Topçu,1995 [9], Eldin and Senouci 1993 [10] reported that adding rubber to traditional concrete could increase the deformability or ductility of rubberized concrete members. (Fattuhi and Clark, 1996) [11] suggested various interesting applications where rubberized concrete could possibly be used. These include the following areas: where vibration damping is required, such as in foundation pads for machinery and in railway stations;where resistance to impact or explosion is required, such as in road traffic barriers and railway buffers; and where high strength requirement is not crucial, such as trench filling, pipe bedding, artificial reef construction, pile heads, and paving slabs. Researcher have done number of researches in the field of waste rubber uses in concrete. In the concrete mix, CR constitutes a portion of the aggregate in the concrete mix. Early studies by Eldin and Federoff explored the effect of rubber chips on the compressive and flexural strength of CRC mixes [10, 12]. Toutanji's study focused on replacing mineral coarse aggregate with rubber tire chips [13]. Freeze–thaw durability of rubber concrete was investigated by Fedroff et al. [12]. Lee and Moon investigated adding crumb rubber into latex concrete [14]. Khatib and Bayomy proposed a compressive strength reduction model of concrete mixes with added rubber content [15]. Thong-On reported on the mechanical behavior of crumb rubber cement mortar [16].

The major findings were that rubber concrete would suffer a reduction in compressive strength while it may increase ductility. Some concrete properties improve but compressive, flexural and tensile strengths decrease perhaps because rubber hydrophobicity reduces interfacial bonding between the rubber and cement.Studies were done to modify the rubber surface, make rubber particles more hydrophilic and increase the bonding between the rubber and cement.One of the ideas to modify surface is dissolving rubber into sodium hydroxide (NaOH).When sodium hydroxide (NaOH) is dissolved into water,thermal energy is generated [17]. During treatment, zinc stearate turns to sodium stearate, which is more soluble in water and would be removed from the surface during the rinsing of the rubber after the treatment.This removal causes significant changes in the surface chemistry of the treated rubber by increasing the contact surface between rubber and the cement paste and making the bond between them stronger [18].

2. Methodolgy

2.1 Material Used

Crumb rubber was collected from local disposal of tyres.The tyres were cut longitudinally using hacksaw and then shredded using a mechanical shredder as shown in Figure 1 .Square to rectangular rubber pieces of size not more than 20 mm was used as Recycled coarse aggregate.
As per IS 383-1970 [19] the following materials as shown in Table 1 and Table 2 were used.

Table 1: material used

SN	material type	specific gravity	size
1	fine aggregate	2.61	<4.75 mm
2	coarse aggregate	2.67	<20mm and >4.75 mm
3	cement	3.1	fineness 5.01%
4	rubber		<20mm and >4.75 mm

Table 2: Mix proportion

	water	cement	FA	CA
In kg/cu.m	180.42	360.84	594.6	1263.83
in proportion	0.5	1	1.65	3.5

2.2 Material Setup

The moulds used for the preparation of samples were cubes of size (15cm x15cm x 15cm) for compressive strength testing.
Treatment of rubber wastes involves its surface modification to improve the bond between rubber and

Figure 1: rubber specimen

concrete components like cement paste and aggregates and it was done by soaking rubber particles in1 N Solution of NaOH for about 1 hour just before using them in concrete. When treated with cement paste showed that addition of rubber particles improved toughness and reduced the porosity of the specimens.When the rubber particles are dipped in cement water suspension, cement adheres to its surface thus developed adhesive properties in it and helped in improving the bond in concrete.

2.3 Experimental Test Method

2.3.1 Compression test

Figure 2: compression test

Compression test is conducted on 150*150*150 mm cubes in UTM as shown in Figure 2. The specimens are casted and are tested on 28th day. The strength is computed using $Fc = p/a$ where p is the maximum load and A- cross sectional area.
Permissible compressive stress $= 0.67 * Fck = 0.67 * 20 = 12.66N/mm2$,where Fck=20MPa and Fm=26.6MPa .
Measured compressive strength of standard samples=24.63MPa (>12.66MPa) where Percentage error=$(26.6-24.63)/26.6$ *100=7.39%

3. Results and Discussion

3.1 Dry weight

Dry weight of rubber concrete is measured and decreases by 36.04% over the displacement of aggregate by rubber on the range of 0-15% as shown in Figure 3 .

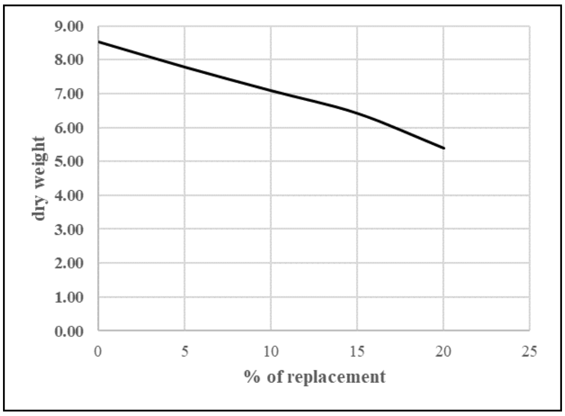

Figure 3: Dry weight and rubber replacement

3.2 Compressive Strength

Table 3: compressive strength of Rubcrete without NaOH addition

% of rubber in concrete	mean ultimate load	surface area (cm2)	comp. strength (N/mm2)	% variation wrt.std. concrete mix
0	554.32	225	24.63	0
5	423.24	225	18.81	23.62
10	369.55	225	16.42	33.33
15	273	225	12.13	50.75

Table 4: compressive strength of Rubcrete witht NaOH addition

% of rubber in concrete	mean ultimate load	surface area (cm2)	comp. strength (N/mm2)	% variation wrt.std. concrete mix
0	554.32	225	24.63	0
5	459.8	225	20.43	17.02
10	372.9	225	16.57	32.71
15	302.8	225	13.45	45.36

The mechanical properties of crumb rubber concrete were tested and are listed. The compressive strength of crumb rubber concrete cured for 28 days without NaOH and with NaOH. When 5 percent rubber was used, the compressive strength decreased by 23.62% compared to the standard concrete. When the rubber was kept in 10, 15 percent instead of coarse aggregate reduction in compressive strength are 33.33% and 50.75% as seen in table3. But with the treatment of NaOH for rubber by soaking for 1 hour before mixing Compressive strength is seen to improve reduction by 6% at 5% reduction. And similar improve trend for compressive strength which shows improvement by 1% and 5% over untreated rubber replacement of 10 and 15 % of replacement.

3.3 Tensile Strength

The direct tensile strength for all mixes was derived using relation at an expression used in British Code of practice BS 8007:1987 $ft = 0.12(fc)^{0.7}$ [20]

Table 5: Tensile strength of rubberized concrete withou NaOH

% of rubber in concrete	mean ultimate load(kN)	surface area (cm2)	direct tensile strength	% variation wrt.std concrete mix
0	554.32	225	1.13	0.00
5	423.24	225	0.94	17.17
10	369.55	225	0.85	24.67
15	273	225	0.69	39.06

Table 6: Tensile strength improvement after soaking in NaOH

% of rubber in concrete	mean ultimate load	surface area (cm2)	direct tensile strength	% variation wrt.std. concrete mix
0	554.32	225	1.13	0.00
5	459.8	225	0.99	12.24
10	372.9	225	0.86	24.21
15	302.8	225	0.74	34.50

When 5 percent rubber was used, the tensile strength decreased by 17.7% compared to the standard concrete. When the rubber was kept in 10, 15 and 20 percent instead of coarse aggregate reduction in tensile strength are 33.33%, 24.67% and 39.06% as seen in Table 5. But with the treatment of NaOH for rubber by soaking for 1 hour before mixing tensile strength is seen to improve reduction by 5% at 5% replacement.And similar improve trend for tensile strength which shows improvement by 1% and 5% over untreated rubber replacement of 10 and 15 % of replacementas shown in Table 6 .

3.4 Thermal Conductivity

Thermal conductivity is the ability of the material to absorb heat.It can also be defined as the ratio between the heat flux and the temperature gradient. Conductivity of concrete depends on its composition. In case of saturated concrete, conductivity ranges from 1.4 to 3.6 joule/meter square per second. Since

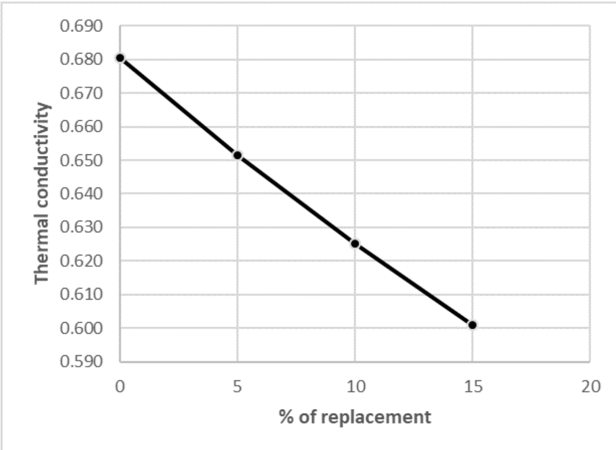

Figure 4: thermal conductivity and percentage of rubber replacement

weight can be reduced by using rubber replacement and thermal conductivity improves as shown in Figure 586 so it can be better option in partition wall and exterior wall which is exposed to sunlight .

4. Conclusion

Rubber has great capability of becoming a permanent member of concrete family because of its wide variety of decent properties like better flexibility, light weight and easy availability. It can be very environmental friendly to use this waste material in construction industry.Results have concluded that there is a gradual improvement in thermal conductivity as shown in Figure 586, however structural aspector index properites like Dry weight, compressive and tensile strengths of rubber derived concrete do limit its uses but it has few desirable benefits like Reduction in dead loads as show in Figure 585, which can be used in making savings in foundations and reinforcements, better sound insulation, lower density, the lower the density the better the heat insulation, Less water absorption, Partition walls in building as an earthquake shock wave absorber, Rendering of roof top surfaces for insulation and water proofing ,Highway embankments, Pipe bedding, paving slabs and retaining walls.

Since, compressive and tensile strengths of rubber derived concrete decreased which is shown in Table 3 and Table 5 respectively but with the use of chemical like NaOH has made improvement in the compressive strength capacity and tensile strength as shown in Table 4 and Table 6 respectively.
Studies and research works need to be carried out in this area for more detailed analaysis including improvement in chemical bonding. Further, some researcher have suggestedd silica fume for enhancement of compressive strength of rubberized concrete so comparitive analysis should be made for effectiveness of admixture.

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