Utilization of Crumb Rubber in Rigid Pavement

Harshit B. Prajapati[1], Dr. J. R. Pitroda[2]

[1]*M. Tech final year Student, Construction Engineering and Management, BVM Engineering College, Vallabh Vidyanagar (Gujarat), India.*
[2]*Associate Professor, Department of Civil Engineering, BVM Engineering College, Vallabh Vidyanagar (Gujarat), India.*

---***---

Abstract - *In many countries around the world, the adversative environmental impacts of amassing waste tyres have led to investigate different options for disposal of waste tyres. Waste rubber is a foremost concern worldwide. In 2005, more than 10 billion tires were disposed of worldwide and around one billion tires are pulled back from utilize every year. By 2030, this amount could reach up to 1200 million tires being disposed of. In 2011, it was evaluated that, around the world, roughly four billion waste tires were in landfills and reserves. One opportunity to reduce this environmental concern is for the construction industry to consume a high number of recycled tyres accumulated in stashes. There are different concerns regarding the introduction of rubber into concrete. Making a homogenous mix containing even distribution of rubber is a complicated task and also severe decrease of concrete strength limits the rubber content. Moreover, replacing a portion of fine aggregates with low-stiffness rubber particles raises concerns regarding the generated shrinkage and cracking of crumb rubber concrete. This research investigates these concerns thoroughly and provides a comprehensive know-how of crumb rubber concrete characteristics, using crumb rubber in terms of coarse aggregate (CA) as well as fine aggregate (FA).*

Key Words: Crumb Rubber Concrete (CRC), Rigid Pavement, Compressive Strength, Water Absorption, Cost Analysis, Crumb Rubber, Crumb Aggregate.

1. INTRODUCTION

Concrete is a material of construction industry which is widely using all over the world. It is versatile, has desirable engineering properties, produced with cost effective materials which can be molded into any shape. It is also brittle in nature. More than ten billion tons of concrete are consumed annually. Based on global usage, it was placed in second position next to water. The word concrete comes from the Latin word "concretus" whose meaning is compact or condensed. The basic ingredients like sand (fine aggregate- FA) and gravel (coarse aggregate- CA), cement – used as a binder and water are used for making concrete. Concrete with waste rubber as aggregate has emerged in the past decades. As the quantity of vehicles increments, many waste tires will be created, and the removal of waste tires has been a significant ecological issue in urban communities around the globe. Rejected waste tires frequently create "black pollution‟ because they are not readily biodegradable and pose a potential threat to the environment. There for this leads to use crumb rubber from the external part of scrap tires is used as a partial replacement for FA in concrete, and the concrete produced from this replacement is known as CRC, rubberized concrete, rubber tire concrete, elastic concrete, rubber concrete, rubbercrete, and concrete with ground waste tire rubber.

2. Experimental Materials

The materials utilized during the present research are as follows;

2.1. Crumb Rubber

Crumb rubber is being used in concrete as a partial replacement to fine aggregate to produce rubbercrete. In comparison to fine aggregate it has lower specific gravity ranging from 0.51 to 1.2, bulk density ranging from 524 kg/m3 to 1273 kg/m3, lower water adsorption, strength and stiffness. Crumb rubber is hydrophobic and non-polar material which repels water and entraps air into its surface. It also has a different gradation compared to fine aggregate which falls below the lower limit of the curve in particle size analysis. Therefore, when it partially replaced fine aggregate in rubbercrete, it changes the grading to a non-continuous aggregate gradation. Partial replacement of fine aggregate with crumb rubber in rubbercrete is normally done by volume of the materials due to the lower specific gravity of crumb rubber compared to fine aggregate.

Table- 1: Chemical and physical properties of crumb rubber

Chemical properties	Values (%)	Physical properties	Values
SBR	48.0	Specific gravity	0.51 To 1.2
Carbon black	47.0	Density	1.15 gm/cm^3

Extender oil	1.9	Color	Black, Gray
Stearic acid	0.5		
Accelerator	0.7		
Sulphur	0.8		
Zink oxide	1.1		

2.2. Cement

The broadly and most generally utilized cement in all types of construction works is Ordinary Portland Cement (OPC). The OPC 53 Grade cement conforming to IS: 12269-1987 was utilized for all concrete mixes. Whereas the water is included in the Portland cement, chemical reactions happen between the cement and water and thus coming about within the energy release and the cement paste event which is mindful for making hardened substance. This process of response happens between cement and water is named as the hydration process and the help of the energy during this process is named as the heat of hydration. For the research work, the Ordinary Portland Cement of 53-grade use. Figure 1 and Table 2 shows properties of cement which procured from local market, Anand, Gujarat.

Table- 2: Physical properties of cement

Property	Values for Cement	IS: 12269:1987
Initial setting time	35 min	30 minutes min
Final setting time	178 min	600 minutes max
Specific Gravity	3.15	3.10-3.15

2.3. Coarse aggregate 20 mm

As per IS 383:1970 an aggregate which is retain on IS 20mm sieve is called coarse aggregate. Coarse aggregates are responsible for providing 70-75% bulk within the constituents of concrete.it is the prime ingredient within the concrete. When it blended with cement and water it gets to be glued and therefore the entire strong matrix is bound during a strong mass which called concrete. Coarse aggregates are larger size filler materials in construction. As the name indicates, they are classified depending on the sizes of aggregate particles. The surface area of the coarse aggregate is less than fine aggregates. Coarse aggregates are utilized in concrete, railroad track ballast, etc. Coarse aggregate size 20 mm graded as per IS 383:1970 locally available is utilized for CRC. Figure 1 and Table 3 shows properties of 20mm graded coarse aggregate which procured from local market, Sevaliya, Gujarat.

Table- 3: Physical properties of coarse aggregate

Property	Values
Source	Sevaliya, Gujarat
Fineness modulus	6.94
Specific gravity	2.81

2.4. Fine aggregate

As per IS 383:1970 an aggregate which is retain on IS 4.75mm sieve is called fine aggregate. Sand is shining yellow, off white, and rounded. The cost of Construction Sand is nil due to its normal availability but its transportation cost is more. Processing is easy by normal machines without using and Blast materials or any Crushing machines. Sand is free of any Organic Materials or any radiation or big blocks or concrete stones. Sand is utilized for backfilling, mortar, and concrete, road paving, Plastering, Filling under Foundations, reinforced ready-mix concrete, Building Blocks, and manufacturing masonry blocks. Figure 1 and Table 5 shows the properties of fine aggregate which procured from the local market, Bodeli, Gujarat.

Table- 4: Physical properties of fine aggregate

Property	Values
Source	Bodeli, Gujarat
Fineness modulus	3.16

2.5. Water

Water is a universally adopted key ingredient liquid for all types of work.in this research potable water is utilized for casting and curing purposes respectively. When water is mixed with cement it forms a paste that binds all aggregate together. The role of water within the concrete is most critical because of the water-cement ratio (w/c proportion). In this research w/c ratio is 0.40 taken out. Figure 1 Shows experimental materials used in this research are shown in below.

3. Design Mix

For all mix proportions, the water-cement ratio (w/c ratio) 0.40 is adopted for all mix proportions. Crumb rubber as FA, CA, FA+CA are replaced in a proportion of (10%,20%,30%) FA, (10%,20%,30%) CA and (5%+5%, 10%+10%, 15%+15%) FA+CA by volume of fine aggregate(FA) and coarse aggregate(CA) were designed at single water cement ratio (w/c ratio) is 0.40. The Design mix nomenclature are shown in Table 5 and Design mix properties for 1m^3 concrete mix shown in Table 6.

Figure- 1: Various experimental materials used in research

Table- 5: Shows Nomenclature for design mix properties

Concrete Mix	Meaning
A0	Control Mix concrete design for M40
B1 (FA-10%)	Mix Design with replacement of 10% Crumb rubber as FA
B2 (FA-20%)	Mix Design with replacement of 20% Crumb rubber as FA
B3 (FA-30%)	Mix Design with replacement of 30% Crumb rubber as FA
C1 (CA-10%)	Mix Design with replacement of 10% Crumb rubber as CA
C2 (CA-20%)	Mix Design with replacement of 20% Crumb rubber as CA
C3 (CA-30%)	Mix Design with replacement of 30% Crumb rubber as CA
D1 (FA-5%, CA-5%)	Mix Design with replacement of 5% + 5% Crumb rubber as FA + CA
D2 (FA-10%, CA-10%)	Mix Design with replacement of 10% + 10% Crumb rubber as FA + CA
D3 (FA-15%, CA-15%)	Mix Design with replacement of 15% + 15% Crumb rubber as FA + CA

Table- 6: Design Mix Properties in 1 m^3 concrete (kg)

Concrete Mixes (M40)	MATERIALS				
	Cement (Kg)	FA-Crumb rubber (Kg)	CA-Crumb rubber (Kg)	Fine aggregate (Kg)	Coarse aggregate (Kg)
A0	479.00	0.00	0.00	661.00	1155.78
B1 (FA-10%)	479.00	2.86	0.00	658.14	1155.78
B2 (FA-20%)	479.00	5.73	0.00	655.27	1155.78
B3 (FA-30%)	479.00	8.60	0.00	652.40	1155.78
C1 (CA-10%)	479.00	0.00	4.68	661.00	1151.10
C2 (CA-20%)	479.00	0.00	9.36	661.00	1146.42
C3 (CA-30%)	479.00	0.00	14.70	661.00	1141.08
D1 (FA-5%, CA-5%)	479.00	1.43	2.34	659.57	1153.44
D2 (FA-10%, CA-10%)	479.00	2.86	4.68	658.14	1151.10
D3 (FA-15%, CA-15%)	479.00	4.30	7.02	656.70	1148.76

4. Experimental Methodology

The test examination carried out on CRC by replacement of FA/CA or both with crumb rubber (FA/CA or both) at different extents by volume of cement. For all mixes, w/c ratio is 0.40. CRC contains cement, fine aggregate, coarse aggregate, crumb rubber. Determination of compression test and Water absorption test both three cube tests were cast on mould size 150X150X150 mm for each concrete mix with partial replacement of FA/CA or both by crumb rubber (FA/CA or both) for compression test and Water absorption test.

4.1 Compressive strength test

When a specimen of material is stacked in such a way that within the event that the material compresses and shortens it is said to be in compression. Compressive strength is frequently measured on a universal testing machine. Compressive strengths are usually reported concerning a particular specialized standard. Compressive strength is one of the foremost critical engineering properties of concrete. It is a standard mechanical practice that the concrete is classified based on grades. Fig. 2 shows the universal testing machine which is conducted compressive strength test at BVM Engineering College, V.V.Nagar, Gujarat. For the compression test, a specimen of the size of 150mm X 150mm X 150 mm was cast and tested in a compression testing machine concerning the test procedure given in IS: 516-1959. The equation for finding out compression test is given underneath,

Compressive Strength (N/mm^2) = P / Δ ……… (1)

Where, P =Failure load of specimen (N)

Δ = Area of specimen (mm^2)

Figure- 2: Compressive strength test

4.2 Water absorption test

Standard measure concrete blocks ought to be completely submerged in clean water at room temperature for 24 hours. All concrete blocks should be dried in a ventilated oven at 100 to 1150°C for not less than 24 hours, and measuring the saturated weight. After that the tests were kept in oven by keeping up 100 ± 5° C for one day. Oven dry weight of the samples is recorded and the water absorption is assessed.Fig.3 shows cube curing in curing ponds.

Water absorption = $(W_1-W_2) / W_2 X 100$...... (2)

Where, W_1=Wet mass unit (kg)

W_2=Dry mass of unit in (kg)

Figure- 3: Water absorption test

5. Experimental results and discussion

The following table 7 and Figure 4 appears Compressive strength force against deformation at 7, 28, and 56 days and following table 8 and Figure 5 shows water absorption in percentage at 28 days which are as follows.

5.1 Compressive strength test

The following table 7 and Figure 4 and appears Compressive strength force against deformation at 7, 28, and 56 days and following table 8 and Figure 5 shows water absorption in percentage at 28 days which are as follows.

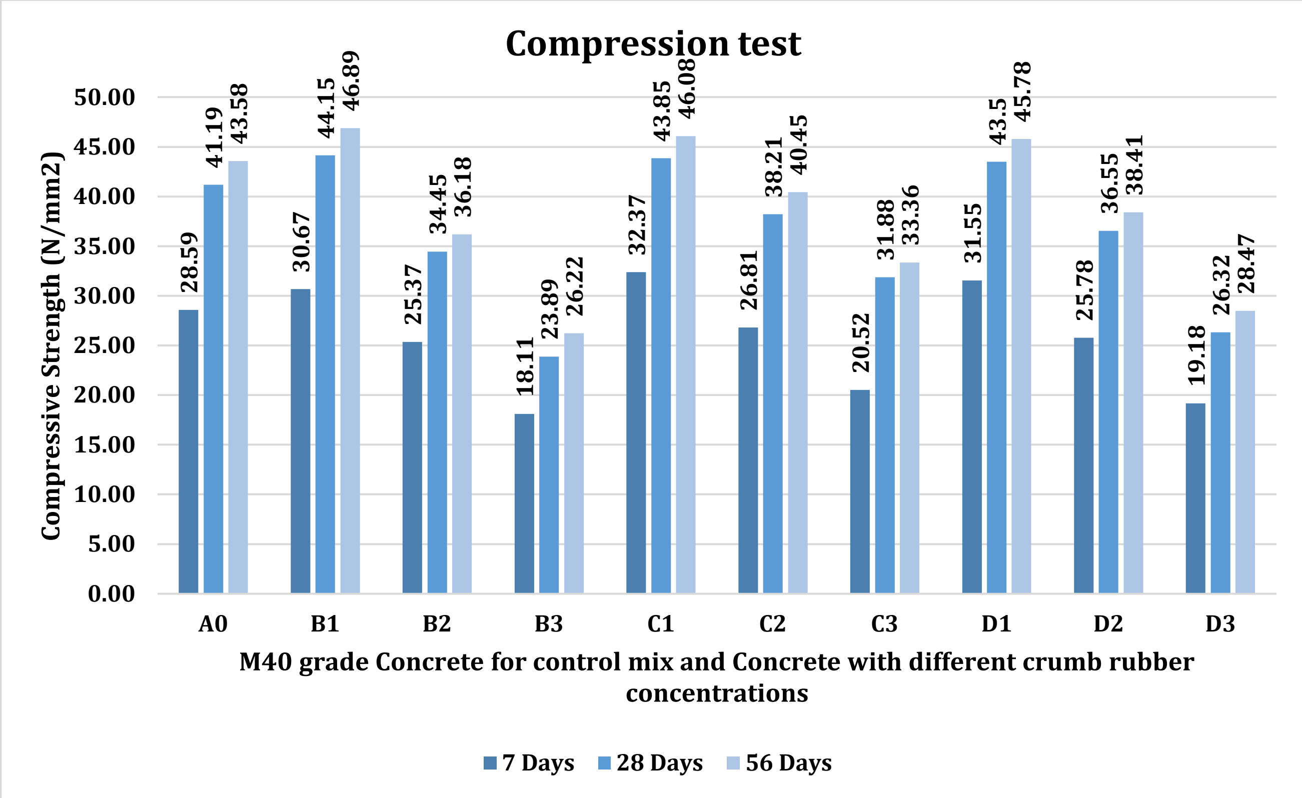

Figure- 4: Compressive Strength Results for M40 Concrete Mixes: Control mix Concrete and Concrete with replacement of fine aggregate and coarse aggregate with crumb rubber (FA/CA or both) in Different Proportions at 7, 28 and 56 days

Table- 7: Compressive strength at 7, 28, and 56 days

COMPRESSION TEST (N/mm²)			
Concrete Mixes	**7 Days**	**28 Days**	**56 Days**
A0	28.59	41.19	43.58
B1 (FA-10%)	30.67	44.15	46.89
B2 (FA-20%)	25.37	34.45	36.18
B3 (FA-30%)	18.11	23.89	26.22
C1 (CA-10%)	32.37	43.85	46.08
C2 (CA-20%)	26.81	38.21	40.45
C3 (CA-30%)	20.52	31.88	33.36
D1 (FA-5%, CA-5%)	31.55	43.5	45.78
D2 (FA-10%, CA-10%)	25.78	36.55	38.41
D3 (FA-15%, CA-15%)	19.18	26.32	28.47

Table 7 appears Compressive strength at 7, 28, and 56 days for different CRC mixes. A0 represent 43.58 N/mm² at 56 days. B1 is made with replacement of 10% (FA) crumb rubber shows 46.89 N/mm² at 56 days. C1 is made with replacement of 10% crumb rubber (CA) shows 46.08 N/mm² at 56 days. D1 is made with replacement of 5% (FA) + 5% (CA) crumb rubber shows 45.78 N/mm² at 56 days. It shows that the percentage of crumb rubber increase up to 10% of crumb is to increase the compressive strength of in CRC.

5.2 Water absorption test results

Following table 8 appears the results of percentage water content submerged in cubes for the water absorption test done on concrete cubes at 28 days for M40 grade concrete control mix concrete and concrete with replacement with FA or CA or both in several proportions.

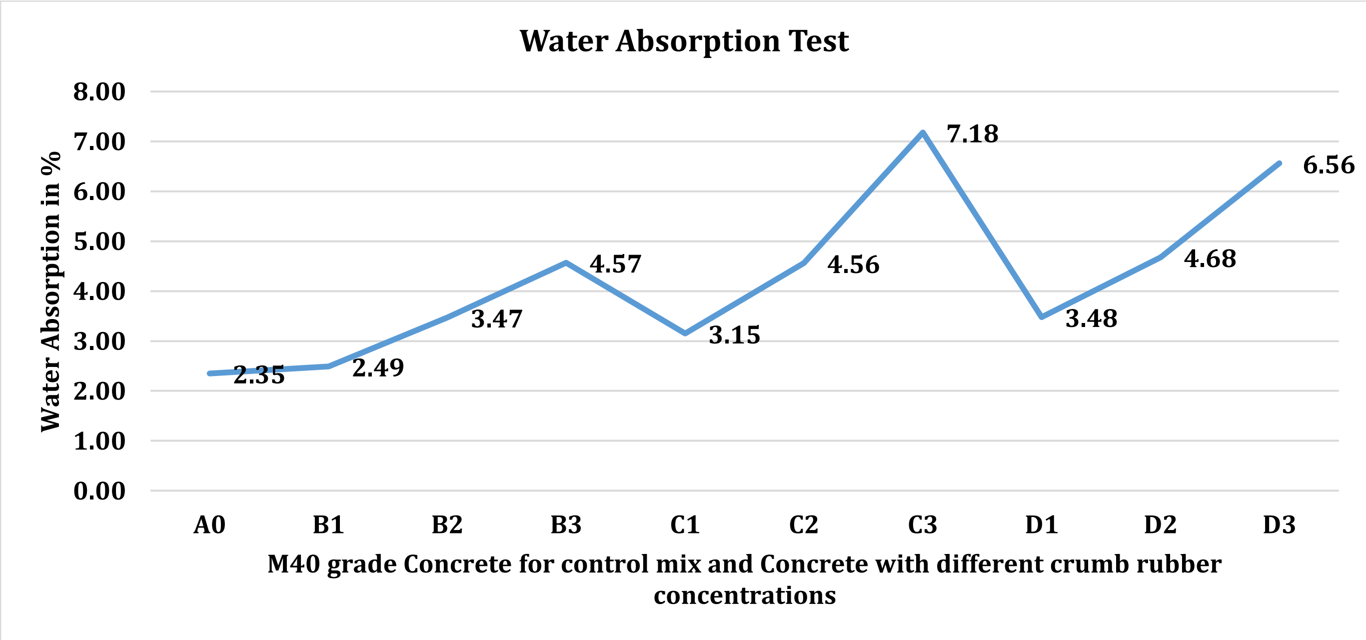

Figure- 5: M40 grade Concrete for control mix and Concrete with different crumb rubber concentrations

Table- 8: Water absorption test results for M40 concrete mixes with inclusion of BF and MK in different proportions at 28 days.

WATER ABSORPTION TEST	
Concrete Mixes	**Water Absorption % age**
A0	2.35
B1 (FA-10%)	2.49
B2 (FA-20%)	3.47
B3 (FA-30%)	4.57
C1 (CA-10%)	3.15
C2 (CA-20%)	4.56
C3 (CA-30%)	7.18
D1 (FA-5%, CA-5%)	3.48
D2 (FA-10%, CA-10%)	4.68
D3 (FA-15%, CA-15%)	6.56

Figure- 6: Percentage Water Absorbed for M40 Concrete Mixes: Conventional Concrete and Concrete with different crumb rubber concentrations

From above figure 5, it is observed that for CRC mix percentage water absorption is increase with increase in FA/CA or both in concrete.

The highest water absorption ratio is 7.18 observed at the C3 concrete mix and the lowest water absorption ratio is 2.49 observed at the B1 concrete mix.

6. COST COMPARISON

Following table 9 shows the rate analysis as per distinctive number of items as per current market rates for different concrete mixes.

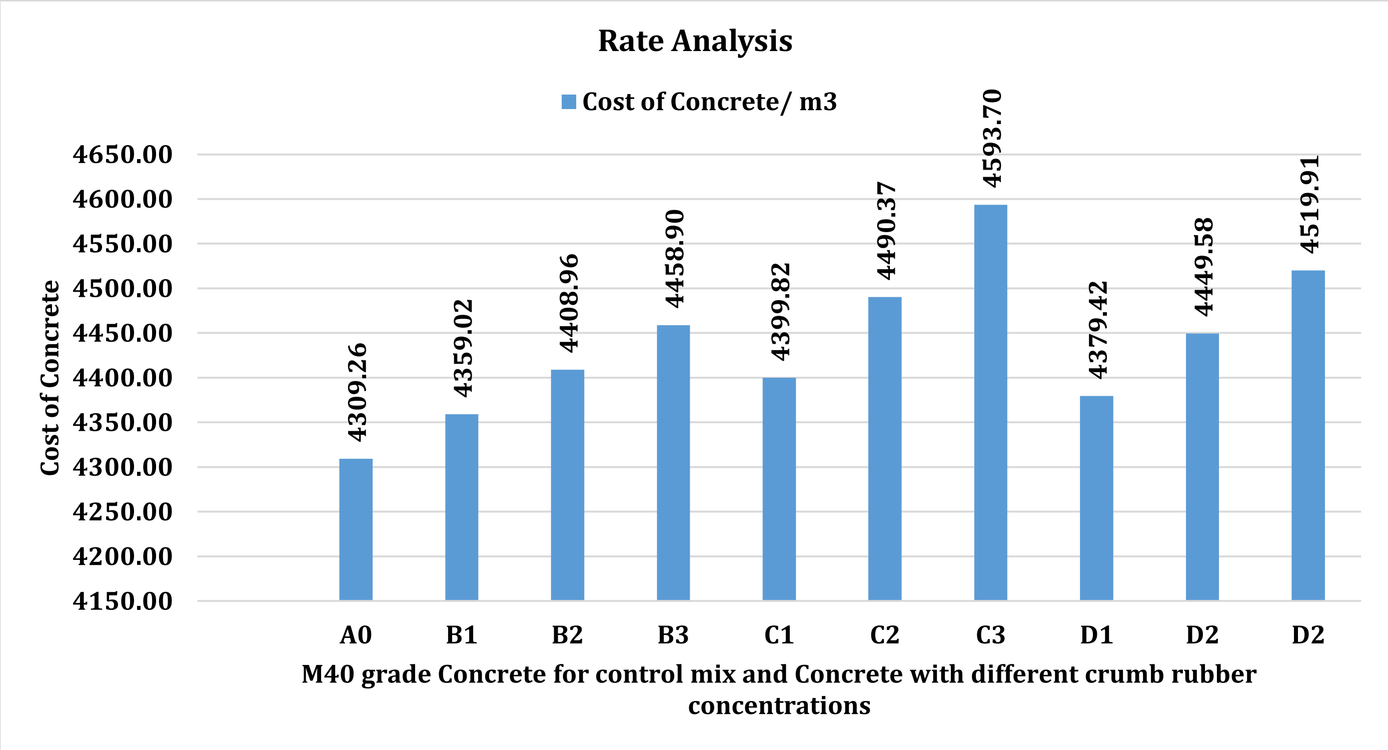

Figure- 6: Rate analysis of M40 grade Concrete for control mix and Concrete with different crumb rubber concentrations

Table- 9: Material cost per kg

Materials	Rupees (₹) per kg
Cement (Kg)	6.60 ₹
Fine Aggregate (Kg)	0.60 ₹
Coarse Aggregate - 20mm (Kg)	0.65 ₹
Crumb Rubber - FA	18 ₹
Crumb Rubber - CA	20 ₹

Table- 10: Total Cost of Concrete Mixes for 1 m³ with Replacement of FA/CA or both with crumb rubber (FA/CA or both) in Different Proportions

Concrete Mixes	Cost of Material of Concrete/ m³	% Change in total cost
A0	4309.26	0.00
B1 (FA-10%)	4359.02	1.15

B2 (FA-20%)	4408.96	2.31
B3 (FA-30%)	4458.90	3.47
C1 (CA-10%)	4399.82	2.10
C2 (CA-20%)	4490.37	4.20
C3 (CA-30%)	4593.70	6.60
D1 (FA-5%, CA-5%)	4379.42	1.63
D2 (FA-10%, CA-10%)	4449.58	3.26
D3 (FA-15%, CA-15%)	4519.91	4.89

7. Conclusions

The conclusions based on experimental work are as follows;

1. It is absorbed for CRC at the time of compaction of concrete in mould getting difficult with increasing crumb rubber content. It gets more complicated when we replace CA with crumb aggregates. There is a problem in mix the proportion and it gets more complex with increasing crumb aggregate
2. The compressive strength increases with the replacement of crumb rubber up to 10%. It is observed that the percentage of crumb rubber is less, the strength to begin with increases, and with increasing the content of rubber above 10% as FA or CA or both the strength is in decreasing term.
3. The strength has been appearing the most extreme at B1. When the proportion of crumb rubber (FA-10%), the compressive strength is decreased with increases crumb rubber proportion increasing.
4. Up to 10% of crumb rubber replacement by volume increases the compressive strength of CRC. The results indicate that the B1 concrete mixes exhibit the compressive strength of 46.89 N/mm^2 (at 56 days), C1 concrete mixes exhibit the compressive strength of 46.08 N/mm^2 (at 56 days), D1 concrete mixes exhibit the compressive strength of 45.78 N/mm^2 (at 56 days),which is higher than that of the A0 control mix concrete 43.58 N/mm^2 (at 56 days).
5. The replacement crumb rubber significantly increases the water absorption properties of concrete. The highest water absorption ratio is 7.18 observed at the C3 concrete mix and the lowest water absorption ratio is 2.49 observed at the B1 concrete mix.
6. It is observed that water abortion rate if higher of CRC with replacement of crumb aggregate (CA) as compared to replacement of crumb rubber (FA).
7. In B batch of concrete mixes with replacement of FA, B1 mix made with 10% replacement of crumb rubber shows 4359.02 ▯ and control mix concrete A0 mix shows 4381.10 ▯ Which is 60.27% higher than control mix concrete 4309.26 ▯. Which shows 1.15% increase in cost/m^3 as compared to conventional concrete.
8. In C batch of concrete mixes with replacement of CA, C1 mix made with 10% replacement of crumb rubber shows 4399.82 ▯ and control mix concrete A0 mix shows 4381.10 ▯ Which is 60.27% higher than control mix concrete 4309.26 ▯. Which shows 2.10% increase in cost/m^3 as compared to conventional concrete.
9. In D batch of concrete mixes with replacement of FA+CA, D1 mix made with 5%+5% replacement of crumb rubber shows 4379.42 ▯ and control mix concrete A0 mix shows 4381.10 ▯ Which is 60.27% higher than control mix concrete 4309.26 ▯. Which shows 1.63% increase in cost/m^3 as compared to conventional concrete.
10. As a result of its characteristics, CRC is truly considered as a material of our future for a green and sustainable development.

Acknowledgment

I would like to express my special thanks to Prof. (Dr.) I. N. Patel (Principal) BVM Eng. College, Prof. (Dr.) L. B. Zala, Head and Teacher Civil Engineering Department, Birla Vishvakarma Mahavidyalaya Engineering College, Dr. Jayeshkumar Pitroda, Associate Professor and P.G. Coordinator Construction Engineering And Management BVM Building College Vallabh Vidyanagar, Anand; for giving me this valuable opportunity to do this research. Furthermore, I would like to thank my friends who offer help to me with a part of motivation and support for finishing this research.

References

[1.] Iman Mohammadi; "Investigation on the Use of Crumb Rubber Concrete (CRC) for Rigid Pavements"; University of Technology Sydney School of Civil end environmental engineering Centre for Built Infrastructure Research, June 2014; Australia.
[2.] Harshit Prajapati; "Utilization of Crumb Rubber in Rigid Pavement: A Review" EDU Index, ISSN: 2394-3114 Vol-40-Issue-70- March -2020.
[3.] Al Sayed M. Abdullah; "Investigation on improving rigid pavement properties by Adding recycled rubber"; Journal of Engineering Sciences Assiut University Faculty of Engineering Vol. 46 No. 1 January 2018 PP.
[4.] Yogender Antil; "Rubberized Concrete Made with Crumb Rubber"; International Journal of Science and Research (IJSR), Volume 3 Issue 5, May 2014, India.
[5.] M. Hossain, "A study of chunk rubber from recycled tires as a road construction material"; 10th Annual Conference on Hazardous Waste Research, 1Department of Civil Engineering, Kansas State University, Manhattan.
[6.] Bashar S Mohammed, "A review on the effect of crumb rubber on the properties of rubbercrete" International Journal of Civil Engineering and Technology (IJCIET); September 2017. Perak, Malaysia.
[7.] Rohit Sharma, "Partial replacement of fine aggregate by waste tyre crumb rubber in concrete"; International Journal of Civil Engineering and Technology (IJCIET) Volume 9, Issue 7, July 2018; Gharaun,
[8.] Punit.Ishwariya, "An Experimental Study On Partial Replacement Of Coarse Aggregate By crumb Rubber"; International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 06 | June-2016; Structural Engineering of Agni college of Technology, Tamilnadu, India.
[9.] S.Naveen Kumar, "A review on utilization of crumb rubber in various ingredients of concrete"; International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-7 Issue-5S2, January 2019.
[10.]Vidat Choudhary, "Use of tyre waste in concrete"; International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 04 Issue: 10 | Oct - 2017; JK Lakshmipat University / Civil Department, Jaipur, 302026, India.
[11.]Mohammed Islamuddin Faraz, "Effect of Crumb Rubber Material on Concrete Mix"; SSRG International Journal of Civil Engineering (SSRG-IJCE) – volume 2 Issue 4 April 2015; Civil Engineering Department, IIST/ R.G.P.V., India.
[12.]B.S. Thomas, R.C. Gupta, P. Kalla, L. Cseteneyi, Strength, abrasion and permeation characteristics of cement concrete containing discarded rubber fine aggregates, Constr. Build. Mater. 59 (2014) 204–212.
[13.]G. Malarvizhi, N. Senthil, C. Kamaraj, A study on recycling of crumb rubber and low-density polyethylene blend on stone matrix asphalt, Int. J. Scient. Res. Publicat. 2 (10) (2012).
[14.]B.S. Thomas, R.C. Gupta, A comprehensive review on the applications of waste tire rubber in cement concrete, Renew. Sustain. Energy Rev. 54 (2016) 1323– 1333.
[15.]M. Nehd, A. Khan, Cementitious composites containing recycled tire rubber: an overview of engineering properties and potential applications, Cem. Concr. Aggreg. 23 (1) (2001) 3–10,
[16.]A.Benazzouk, O. Douzane, T. Langlet, K. Mezreb, J.M. Roucoult, M. Quéneudec, Physico-mechanical properties and water absorption of cement composite containing shredded rubber wastes, Cem. Concr. Compos. 29 (10) (2007) 732–740.
[17.]Y.C. Guo, J.H. Zhang, G. Chena, G.M. Chena, Z.H. Xie, Fracture behaviors of a new steel fiber reinforced recycled aggregate concrete with crumb rubber, Constr. Build. Mater. 53 (2014) 32–39.
[18.]B.S. Mohammed, A. Awang, S.S. Wong, C.P. Nhavene, Properties of nano silica
[19.]I.B. Topçu, The properties of rubberized concretes, Cem. Concr. Res. 25 (25) (1995) 304–310.
[20.]H.A. Toutanji, The use of rubber tire particles in concrete to replace mineral aggregates, Cem. Concr. Compos. 18 (1996) 135–139,

[21.]Y. Osama, A.E. Mohamed, E.M. Julie, M. Xing, An experimental investigation of crumb rubber concrete confined by fibre reinforced polymer tubes, Constr. Build. Mater. 53 (2014) 522–532.
[22.]M.M. Reda Taha, A.S. EI-Dieb, M.A. Abd EI-Wahab, et al, Mechanical, fracture, and microstructal investigations of rubber concrete, J. Mater. Civ. Eng. 20 (10) (2008) 640– 649.
[23.]B.Z. Savas, S. Ahmad, D. Fedroff, Freeze-thaw durability of concrete with ground waste tire rubber, Transp. Res. Rec. 1574 (1997) 80–88.
[24.]H. Zhu, Crumb rubber concrete, Rapra handbook on polymers use in construction, Rapra Technology Limited, UK, 2004. I.B. Topçu, Assessment of the brittleness index of rubberized concretes, Cem. Concr. Res. 27 (2) (1997) 177–183,
[25.]Y Raja Latha, Damera Ramachander, "Experimental studies on high performance concrete using Mk", International Journal of Research and Innovation (IJRI) , Published: April 22, 2016 Volume: III, Issue : II .
[26.]K.Sathes Kumar, "Strength andAnalysis of Basalt Fiber in Concrete", IJCRGG,Vol.10, pp.376-381, 2017.Algin, Z., & Ozen, M. (2018). The properties of chopped basalt fibre reinforced self-compacting concrete. Construction and Building Materials, 186, 678–685.
[27.] L.H. Yang, Study on brittleness and ductility of CRC and the application in the cover layers of bridges. Master"s Degree Thesis, (2007) (in Chinese).
[28.] Zhu H. New Development in Crumb Rubber Research[C]. First International Symposium on Crumb rubber Asphalt Pavement, Temqe, AZ. USA, 2000, 78-181.

Author's biography

	**Er. Harshit Prajapati** received his Bachelor of Engineering Degree in Civil Engineering from Sardar Vallabhbhai Patel Institute of Technology, Vasad, Gujarat in 2018. At present, he is pursuing Master of Technology degree in Construction Engineering and Management from Birla Vishwakarma Mahavidyalaya Engineering College (Vallabh Vidyanagar, Gujarat- India)
	**Dr. Jayeshkumar Pitroda** received his Bachelor of Engineering Degree in Civil Engineering from Birla Vishwakarma Mahavidyalaya Engineering College, Sardar Patel University (Vallabh Vidyanagar, Gujarat-India) in 2000. In 2009 he received his master's degree in Construction Engineering and Management form Birla Vishwakarma Mahavidyalaya Sardar Patel University (Vallabh Vidyanagar, Gujarat-India). In 2015 he received his Doctor of Philosophy (Ph.D.) Degree in Civil Engineering from Sardar Patel University (Vallabh Vidyanagar, Gujarat-India). He has joined Birla Vishwakarma Mahavidyalaya Engineering College as a faculty in 2009, where he is lecturer of Civil Engineering Department and at present working as Associate Professor from February 2018 having total experience of 19 years in the field of Research, Designing and Education. At present holding charge of PG Coordinator Construction Engineering and Management. He is guiding M.E. / M. Tech (Construction Engineering and Management/ Construction Project Management/ Environmental Engineering) thesis work in the field of Civil / Construction Engineering/ Environmental Engineering. He is also guiding Ph.D. students (Civil Engineering). He has published many papers in National / International Conferences and Journals. He has published nine Research Books in the field of Civil Engineering, Rural Road Construction, National Highways Construction, Utilization of Industrial Waste, Fly Ash Bricks, Construction Engineering and Management, Eco-friendly Construction.