RUBBER METAMORPHOSED SELFCOMPACTING CONCRETE

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Abstract -Due to modernization, number of motor vehicles is accumulating every day and presence of these not only degrade the air quality but also create a problem of damping the waste scrap tyres. Damping of waste tyres requires a lot of landfill area, as it is not possible to remove these tyre from the surrounding without giving any threat to environment. So in this study efforts have been made to check the suitability of these waste scrap tyres in the form of crumb rubber (tyre crumb rubber) in the formation of self-compacting concrete (SCC) and notice the effect on green and hardened properties of SCC. In this presented work fine aggregates was substituted with tyre crumb rubber in different proportion varying from 0% to 20%. Supplanting of fine aggregate with squander crushed tire can have an unwanted effect on the mechanical properties of self-compacting concrete, i.e., splitting tensile strength, modulus of elasticity, compressive strength and flexural strength, but it improves fatigue resistance, improve impact resistance and ductility.This report also displayed the comparison between the basic SCC and the rubber metamorphosed SCC (RMSCC) on the basis of various tests performed for green and hardened properties.

***Key Words*:** scrap tyres,tyre crumb rubber, rubber metamorphosed self-compacting concrete.

1. INTRODUCTION

Advancements in civilization is accumulated steadily by virtue of industrialization. Hasty gain in infrastructure requires new types of building materials that must be cheap and sustainable and according to the requirements of construction and location. Concrete is primarily used for the works related to construction practice because it enhance the lifespan of the structure and also possess low maintenance cost. The upcoming race of human being is precisely related with the threats of environmental sustainability. Current construction practices are act as a major threat to environment safety because of uncontrollable usage of natural ingredients required for the construction of concrete.

Various hazardous materials present in the environment that makes the environment polluted. These materials are non-biodegradable and put great impact on environment health, these includes plastics, glass, tyres etc. Times of India has reported that "*Approx. 1.5 billion tyre waste are generated globally every year out of which 6 per cent are generated in India*".The utilization of these scrap tyre waste as fine aggregate in concrete reducesthe trouble related to waste tyre disposal, prevent the environment from its impact and provide a source of eco-friendly concrete.

Like traditional concrete, rubber metamorphosed self-compacting has lower levels of transmitted radiation and hence more secure for building users. Due to its improved impact resistance, high ductility and energy dissipation properties, rubber metamorphosed concrete has been utilized in some applications until now, i.e., sidewalks or walkways, road barriers and pavement.Concluded that the rubber metamorphosed concrete could be utilized in walkways, sport courts, and traffic commotion obstructions on highways, i.e., non-structural applications. Many researchers also proposed that "Due to good ductility and impact resistance of rubber metamorphosed concrete can be used for structural elements subjected to dynamic loads". Before this can be practiced, it is recommended that test examination on self-compacting rubber metamorphosed concrete should be completed.

2. MATERIAL PROPERTIES

Properties of material used in the study is presented along with the procedure of various test conducted on different mixes of SCC are:-

2.1Cement:-Ultra tech Cement of type OPC having grade 43 was used in the formation of desired SCC. Cement used must be free from lumps and impurities.

Table 2.1 Properties of cement

Sr. No.	Properties	Value
1.	Type	OPC
2.	Grade	43
3.	Specific gravity	3.10

2.2Coarse Aggregate:-These aggregates are feasible locally. All the tests that were conducted on CA are according to IS: 383-1970.

Table 2.2 Properties of CA

Sr. No.	Properties	Value
1.	Maximum Size and Type	20mm and crushed
2.	Bulk Density	1580 kg/m^3
3.	Specific gravity	2.65
4.	Water Absorption	0.65
5.	Fineness modulus (FM)	6.92

2.3Tyre Crumb Rubber :-It is recycled rubber produced from vehicles scrap tyres. Steel parts are removed while recycling is done and rubber tyre converts to granular consistency.

Cracker mill process, granulator process and micro mill process are three method available that convert scrap tyres into crumb rubber.

Table 2.3 Properties of TCR

Sr. No.	Properties	Value
1.	Size range	0.15mm-4.75mm
2.	Bulk Density	350 kg/m^3
3.	Specific gravity	1.02 – 1.07
4.	Water Absorption	2% - 4.3%
5.	Fineness modulus (FM)	6.90

Fig. 2.1 Different types of TCR

2.4Fine Aggregate:-FA are locally accessible. All the Experiments that were operated on CA are according to IS: 383-1970.

Table 2.4 Properties of FA

Sr. No.	Properties	Value
1.	Maximum Size	4.75mm
2.	Bulk Density	1500 kg/m^3
3.	Specific gravity	2.13
4.	Water Absorption	1.2%
5.	Fineness modulus (FM)	3.05

2.5Fly Ash :-Fly ash used in the presented study is of class F and achieved from thermal power plant, Panipat, Haryana. Fly ash is manufactured by heating the older and harder bituminous and anthracite at burning temperature. Fly ash is of pozzolonic nature having less than 7% lime content. Fly ash slightly increases the setting time whereas early compressive strength of concrete is decreased slightly. Due to high content of calcium present in the fly ash it is not suitable to use fly ash in hydraulic condition. Many experimental result shows that high content of fly ash impart negative effect on various properties of concrete, so many researchers resulted that fly ash can be replaces up to 30% by the weight of cement.

Table 2.5 Properties of Fly Ash

Sr. No.	Properties	Value
1.	Type	F Class
2.	Colour	Grey
3.	Specific gravity	2.13

2.6 Water :-In general, water is one of the main ingredient in the formation of concrete, as it is helpful in the hydration of cement which impart strength to the concrete. Water used must be free from impurities, as these impurities impart negative effect on the properties of concrete. So water used in the presented study is clean and free from impurities.

2.7 Admixture :-Chemical admixtures such as SPs (Super plasticizers) are the water reducers which enhance the workability of concrete without any reduction in water/ cement ratio or reduce the water/cement ratio without compromising with the workability of concrete. By appropriate dosage of SP segregation can be effectively prevented up to great extent and also it enhances the flow properties of concrete. SP includes long chain polymers, these polymers wraps around the cement particles and provide them a negative charge. These all negatively charged cement particles repel each other and release the entrapped water thus enhance the workability. Addition of rubber reduces the workability, so this leads to increase the dosage of SP. Researchers resulted that for 20% addition of rubber, super plasticizer dosage is increased up to 14.85%. So SP is added in accordance with the rubber content by hit and trial method. These new generation admixtures can reduce up to 40% water/cement ratio. Use of SP in the presented study is according to the term of IS: 9103:1999.

Table 2.6 Properties of Admixtures

Sr. No.	Properties	Value
1.	Name	SikaViscocrete
2.	Type	Poly Carboxylate Ether Based
3.	Colour	Brown
4.	Solid Content	40%
5.	Relative Density	1.07 kg/l

3. DESIGN MIX

Various trial mixes were adopted to get the appropriate water content, water/cement ratio and dosage of SP etc. These alterations were made to get the required properties of SCC like workability, flow ability, passing ability and filling ability. Dosage of SP was altered in accordance with the percentage of TCR to prevent the SCC against segregation. In the presented study five design mixes (R0, R1, R2, R3 and R4) are used. These mixes are as follow:

Mix R0: In this Design Mix 0% FA are getting replaced by TCR volumetrically.

Mix R1: In such Design Mix 5% FA are getting replaced by TCRvolumetrically.

Mix R2: In this Design Mix 10% FA are getting replaced by TCRvolumetrically.

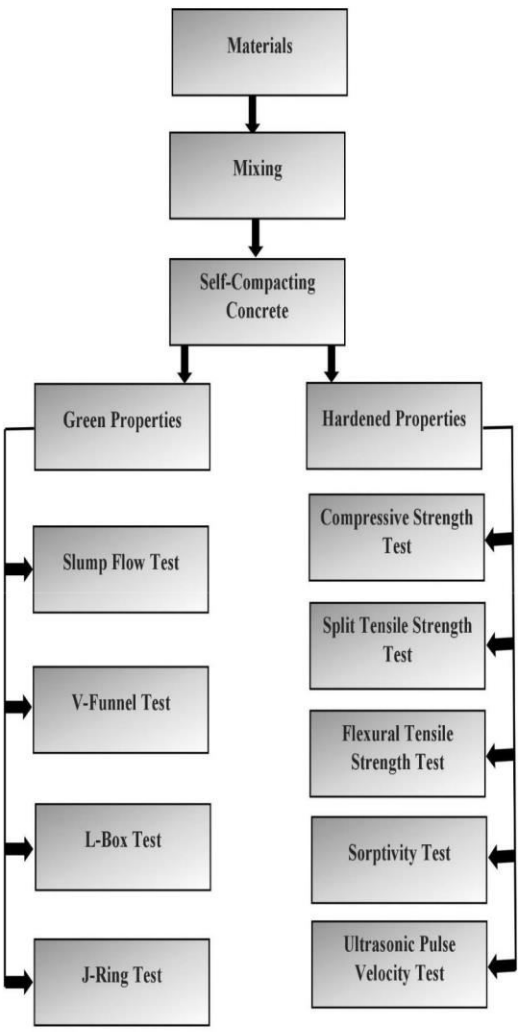
Mix R3: In this Design Mix 15% FA are getting replaced by TCRvolumetrically.

Mix R4: In this Design Mix 20% FA are getting replaced by TCRvolumetrically.

Table 2.7 Properties of different mixes

Mix	**Cement kg/m^3**	**Fly Ash (kg/m^3)**	**CA (kg/m^3)**	**FA (kg/m^3)**	**TCR (kg/m^3)**	**SP (kg/m^3**	**Water (kg/m^3)w/c =0.45**
R0	430	129	783	940	0	5.59	195
R1	430	129	783	893	11	5.81	195
R2	430	129	783	846	22	5.92	195
R3	430	129	783	799	32.9	6.16	195
R4	430	129	783	750	44	6.34	195

4. EXPERIMENTAL WORK



4.1 TESTS FOR GREEN PROPERTIES:-

4.1.1 Slump Flow Test and T50cmm Test:-This test is used to find out the horizontal free assess of SCC without any obstruction. This test was firstly invented in japan for the underwater concreting. This test is similar to the slump test of conventional concrete. Ability to fill the congested form work is also assessed with the help of circular concrete diameter. This test gives no idea about the passing ability of concrete through narrow reinforcement but gives a positive sign of resistance against segregation.

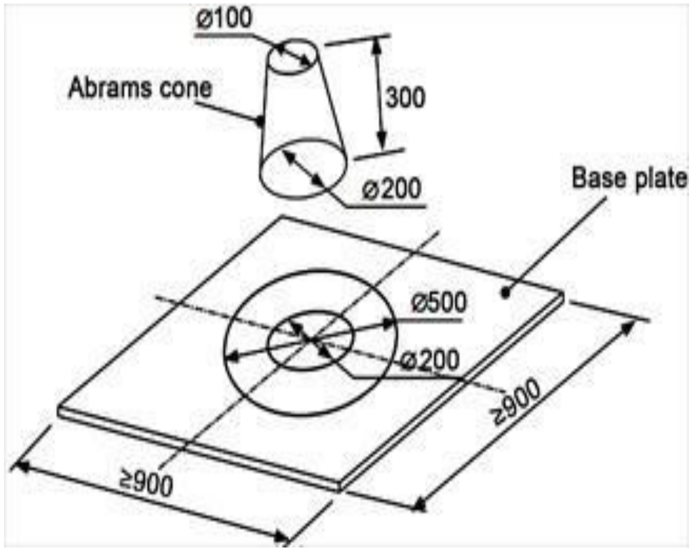


Fig. 4.1.1 Schematic diagram of slump cone and base plate

- ***Experimental outcomes*** **:-**

Table 4.1 Experimental outcomes of slump flow test and T50cm test

Design Mix	**Flow diameter (mm)**		**T50cm (sec)**	
	Experimental outcomes	**EL**	**Experimental outcomes**	**EL**
R0	735	650-800	2.5	2-6
R1	720	650-800	3.2	2-6
R2	698	650-800	4.0	2-6
R3	675	650-800	5.2	2-6
R4	662	650-800	6.3	2-6

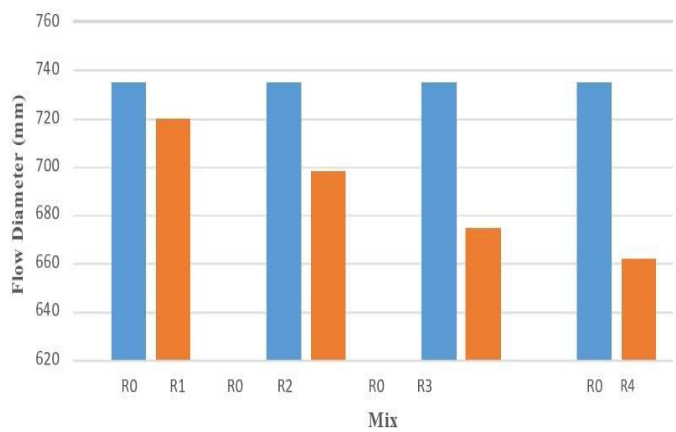


Fig.4.1.2 Flow diameter of RMSCC compared with SCC

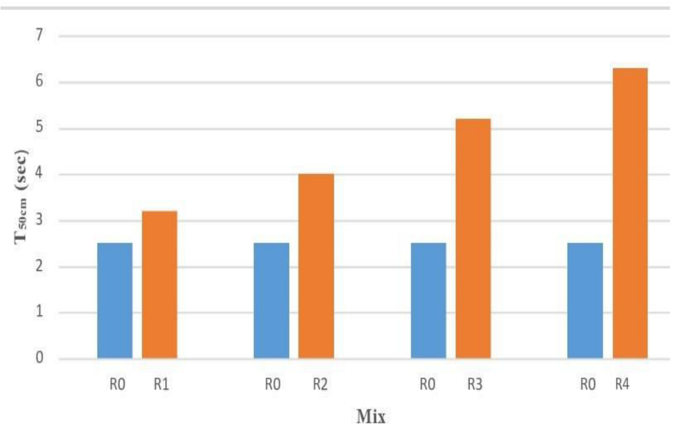


Fig.4.1.3 T50cm time of RMSCC compared with SCC

- ***Results*** **:-**

Greater the value of SF greater is the ability of SCC to fill the congested form work under its self-weight. Slump flow value for the SCC should at least 650mm or greater. T50 time is the secondary measure of the flow. Lower the value of T50 time indicates high flow ability. EFNARC suggested this time range is 3-7 sec.

4.1.2L- Box Test :-This test is helpful in assessment of passing characteristics of SCC. This apparatus includes horizontal and vertical section, separated by a gate movable in vertical direction and in front of this gate vertical steel bars are fitted. This test is also used to detect the risk of segregation by visually inspecting the sample.

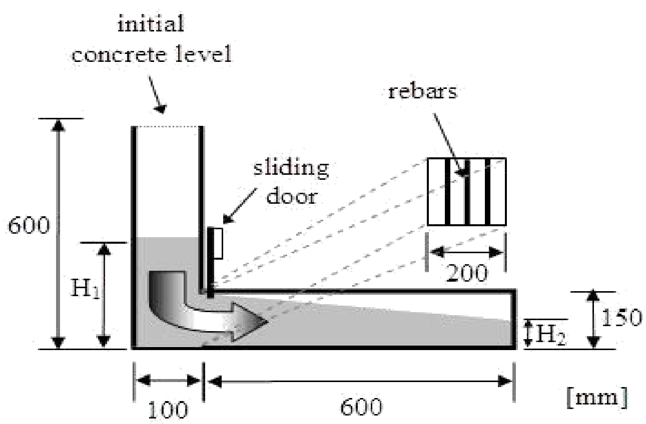


Fig. 4.1.4 Schematic diagram of L-Box apparatus

- ***Experimental outcomes*** **:-**

Table 4.2Experimental outcomes of L-Box test

Design Mix	H2/H1 ratio	
	Experimental Outcomes	EL
R0	0.92	0.8-1
R1	0.9	0.8-1
R2	0.87	0.8-1
R3	0.82	0.8-1
R4	0.76	0.8-1

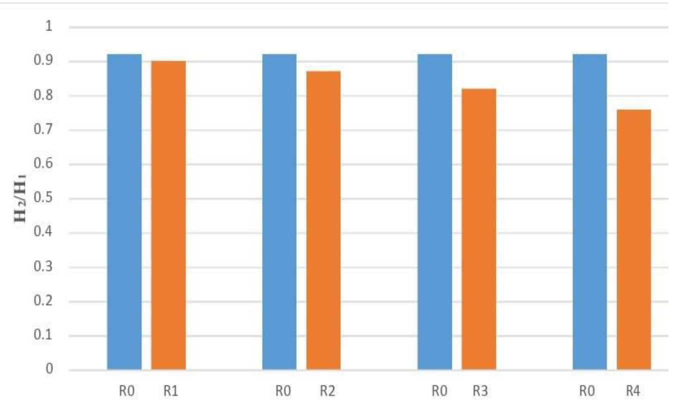


Fig. 4.1.5 H2/H1 ratio of RMSCC compared with SCC

- ***Results*** **:-**

The ability of SCC to flow through steel bars is depend upon the blocking ratio H2/H1. Passing ability increases as the blocking ratio reaching towards unity. EFNARC suggests the minimum value of blocking ratio is 0.8 and maximum value is unity. So blocking ratio of SCC lies between 0.8-1.

4.1.3V–Funnel Test:-This test is used to assess the filling ability or flowability of SCC having maximum size of aggregate limited to 20mm. In this test concrete is passed through a V shape funnel as shows in the Fig. 4.1.3 and time of discharge is noted. High value time is also related with other properties of concrete like low workability and high internal friction between particles etc.

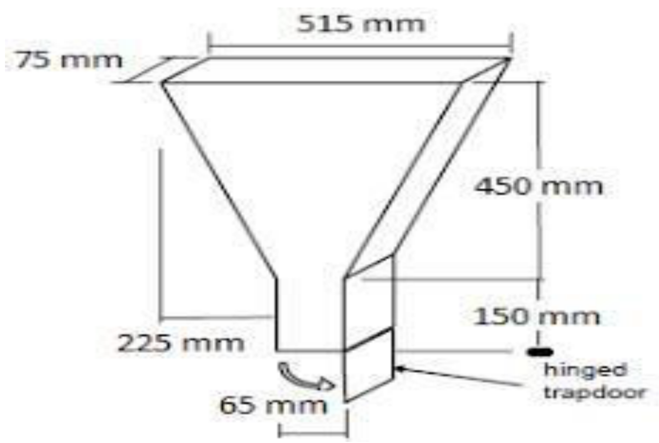


Fig. 4.1.3 Schematic diagram of V-Funnel apparatus

- ***Experimental outcomes*** **:-**

Table 4.3Experimental outcomes of V-Funnel test

Design Mix	tv (sec)	
	Experimental Outcomes	EL
R0	9	6-12
R1	10.3	6-12
R2	10.9	6-12
R3	11.6	6-12
R4	12.7	6-12

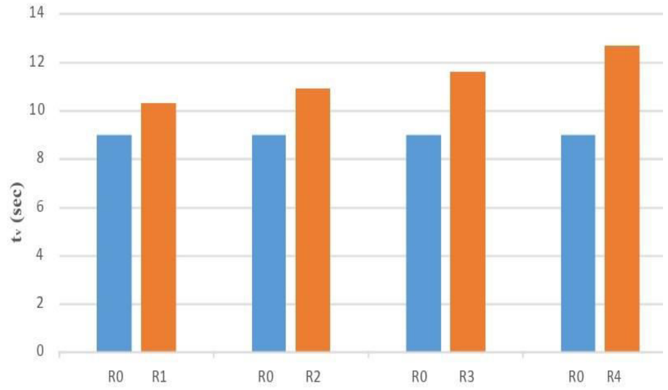


Fig. 4.1.6 tv time of RMSCC compared with SCC

- ***Results*** :-

The ease with which SCC can flow under its own weight is depends upon the discharge time. As the flow time decreases ability to flow increases. For SCC flow time is lies between 6-12 seconds.

4.1.4J-Ring Test :-This test is conducted in conjointment with the slump flow test. This test measures both the passing and filling characteristics of SCC. In this test concrete is passed through the J-Ring bars. Severity of test depends upon the spacing of the bars of J-Ring apparatus as shown in the Fig. 4.1.4.

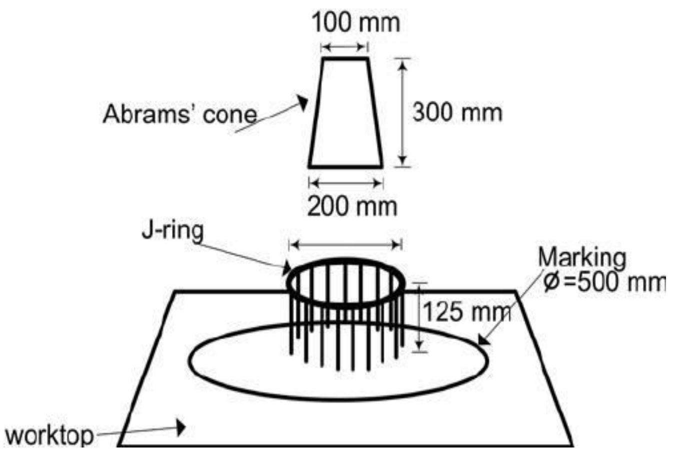


Fig. 4.1.4 Schematic diagram of slump cone and J-Ring apparatus

- ***Experimental outcomes*** :-

Table 4.4 Experimental outcomes of J-Ring test

Design Mix	PJ (mm)	
	Experimental Outcomes	EL
R0	5	0-10
R1	7	0-10
R2	8	0-10
R3	10	0-10
R4	11	0-10

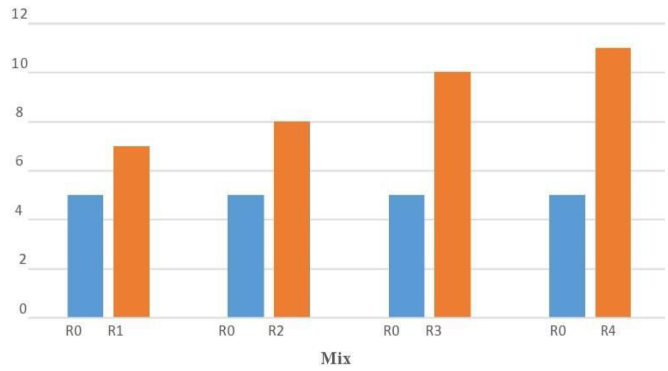


Fig. 4.1.7PJ of RMSCC compared with SCC

- ***Results*** :-

Higher difference between heights indicates lower passing ability of SCC. The flow of SCC depends upon the spacing of bars, as these bars act as a blockage in the flow of concrete. For SCC this value is lies between 0-10.

4.2TESTS FOR HARDENED PROPERTIES:-

4.2.1 Compressive Strength Test:- Strength of SCC under compressive load is assessed with the help of Universal Testing Machine (UTM) in accordance with the IS: 516-1959. This is the essential test to find out the strength of concrete under compression. In this test cubes of side 150mm each is prepared with concrete and after proper curing, tested under UTM. Minimum three samples are required to conduct this test.

Fig. 4.2.1UTM for compressive strength test

- ***Experimental outcomes*** :-

Table 4.5 Experimental outcomes of compressive strength test

Design Mix	fck (N/mm^2)	
	7 Days Strength	28 Days Strength
R0	28.4	42.6
R1	27.2	38.6
R2	25.4	35.3

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R3	23.8	33.4
R4	21.3	31.5

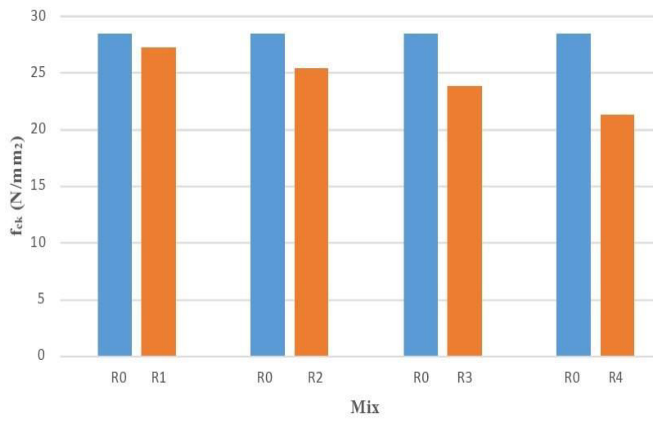

Fig. 4.2.2 fck of RMSCC compared with SCC after 7 days of curing

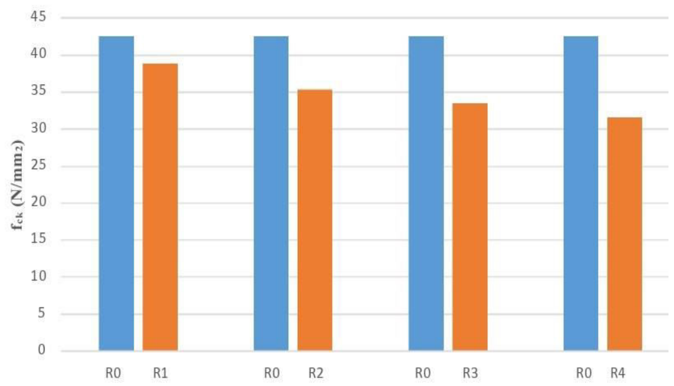

Fig. 4.2.3 fck of RMSCC compared with SCC after 28 days of curing

4.2.2 Splitting Tensile Strength :-This is the important test for finding the strength of concrete under tension, direct measurement of tensile strength is very difficult so it is measured indirectly in terms of split tensile strength or flexural tensile strength. This test is conducted on cylindrical specimen of diameter 100mm and height 200mm according to IS 5816:1999. Minimum three specimens are required to perform this test and average of these three values gives the split tensile strength of the mix.

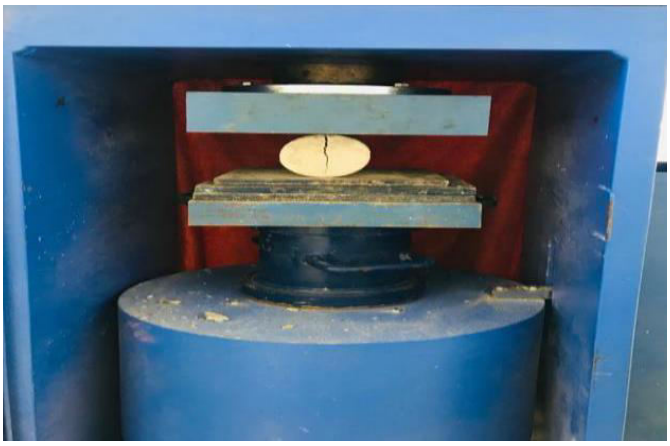

Fig. 4.2.4UTM for split tensile strength test

- ***Experimental outcomes*** **:-**

Table 4.5 Experimental Outcomes of Split Tensile Strength Test

Design Mix	fcr (N/mm^2)	
	7 Days Strength	28 Days Strength
R0	4.12	5.24
R1	3.98	5.04
R2	3.65	4.86
R3	3.18	4.57
R4	2.95	3.84

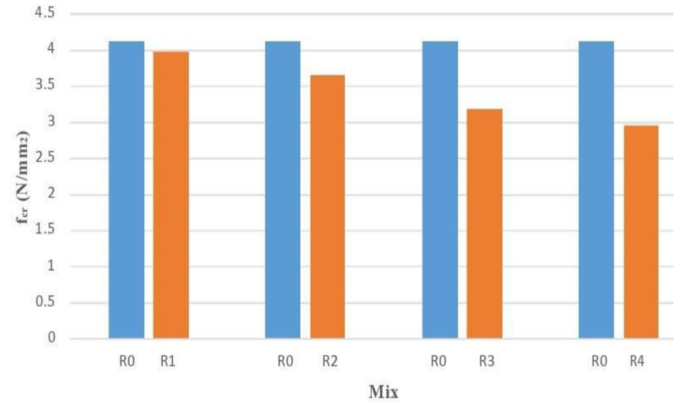

Fig. 4.2.5 fcr of RMSCC compared with SCC after 7 days of curing

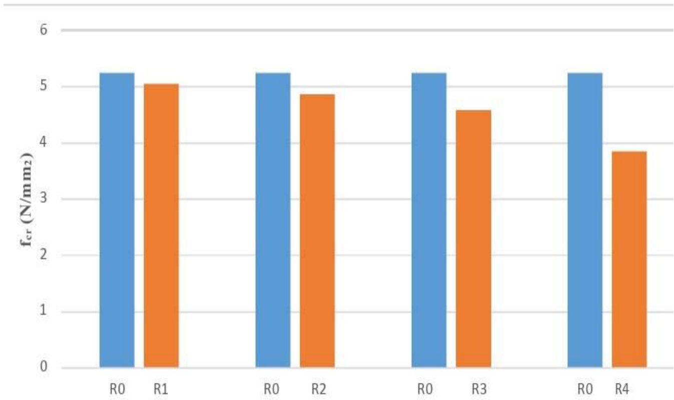

Fig. 4.2.6 fcr of RMSCC compared with SCC after 28 days of curing

4.2.3 Flexural Tensile Strength Test:-This is the indirect test to measure the strength of concrete under tension, this is also known as modulus of rupture. As it is very difficult to directly measure the tensile strength of concrete, so indirect methods like split tensile strength and flexural tensile strength test is used to measure the tensile strength. This test is conducted on beam shape specimen of size 100mm×100mm×500mm in accordance with the IS 516:1959.

Fig. 4.2.7Flexural tensile strength apparatus

- ***Experimental outcomes*** **:-**

Table 4.6 Experimental outcomes of flexural tensile strength test

Design Mix	fb (N/mm^2)	
	7 Days Strength	28 Days Strength
R0	5.44	6.84
R1	5.23	6.54
R2	4.8	6.12
R3	4.53	5.84
R4	4.12	5.53

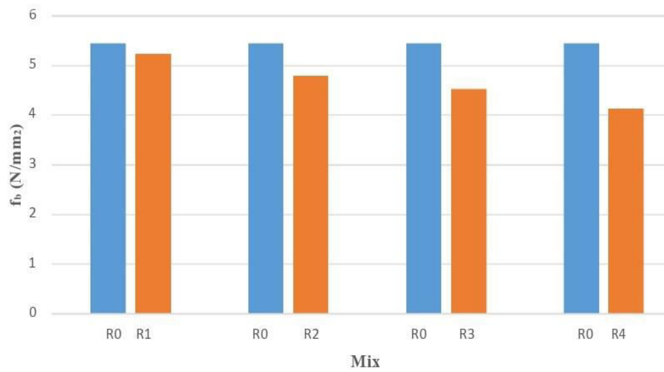

Fig. 4.2.8 fb of RMSCC compared with SCC after 7 days of curing

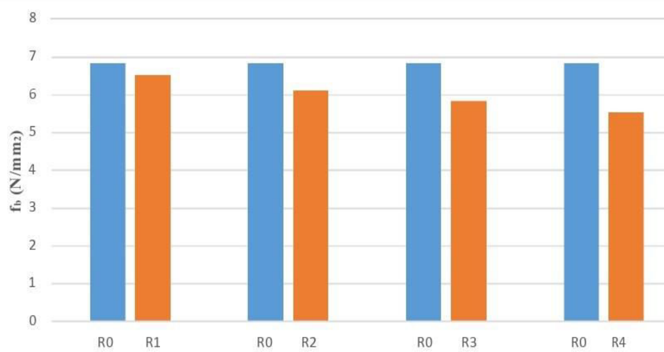

Fig. 4.2.9 fb of RMSCC compared with SCC after 28 days of curing

4.2.4SorptivityTest :-This test is helpful in finding the rate of absorption (that is also known as Sorptivity) of water through the capillary action within the pores present in the concrete. In this test the surface of the concrete is exposed to water and the increase in the mass of concrete due to absorption of water is noted down. Poor interconnectivity of pores resulted in the lower absorption rate.

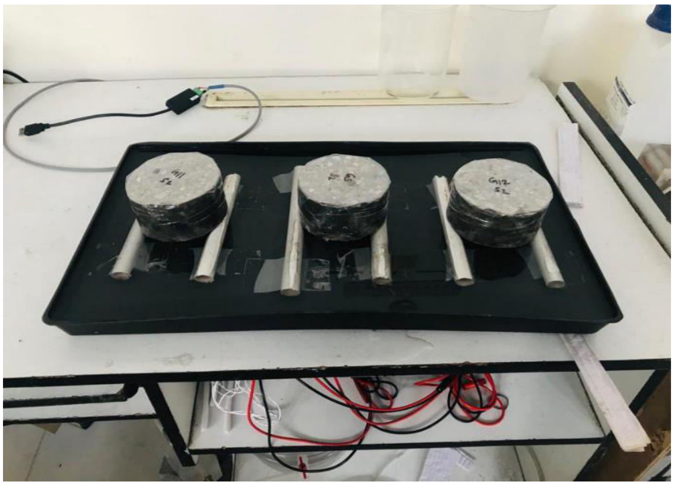

Fig. 4.2.10Sorptivity test apparatus

- ***Experimental outcomes*** **:-**

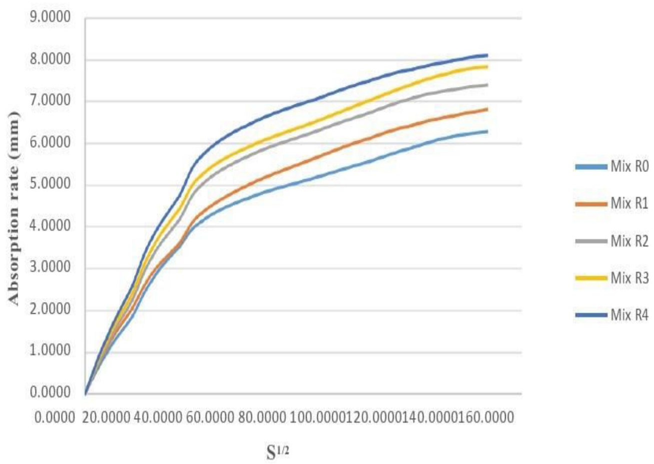

Fig. 4.2.11 Variation of absorption rate vs square root of time for all mixes of SCC

4.2.5Ultrasonic Pulse Velocity Test :-This is non-destructive test used to find out the quality or homogeneity of concrete by measuring velocity of pulse passing through the concrete in accordance with IS 13311 (part 1): 1992. This test also gives the idea about presence of cracks and imperfections in the concrete. Pulse is generated through transducer and when this pulse is passes through the concrete it goes through multiple refraction at the boundaries. System of complex stress waves is generated which have compressional (longitudinal) wave, transverse (shear) wave and surface wave. Transducer at thereceiving end only detects the compressional (longitudinal) wave because this wave is fastest among the three waves

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Table 4.7 Gradation of Quality of Concrete

Sr. No.	Pulse velocity (kmps)	Quality grading
1.	Above 4.5	Excellent
2.	3.5 to 4.5	Good
3.	3.0 to 3.5	Medium
4.	Below 3.0	Doubtful

Fig. 4.2.12Performing ultrasonic pulse velocity test

- ***Experimental outcomes*** **:-**

Table 4.8 Experimental outcomes of UPV test

Mix	UPV (km/s)	Quality Gradation
R0	4.67	Excellent
R1	4.23	Good
R2	3.78	Good
R3	3.56	Good
R4	3.47	Medium

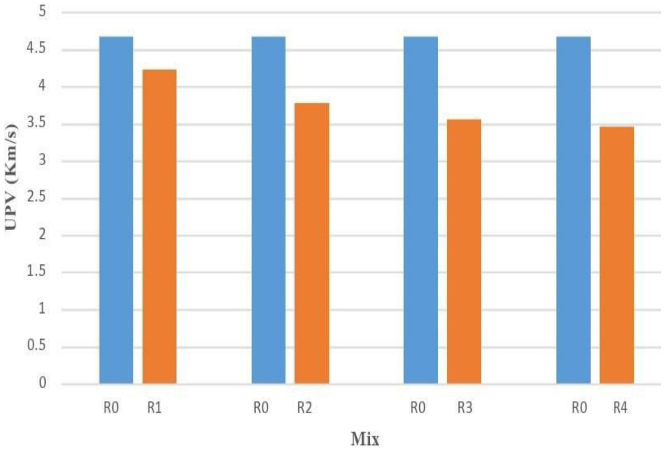

Fig. 4.2.13 UPV of RMSCC compared with SCC

5. CONCLUSIONS

5.1 Conclusions Drawn from Green properties :-

- Flow Diameter results are helpful in the estimation of horizontal free assess of SCC. The deterioration in flow diameter on adding TCR content to SCC in varying proportions increases because TCR induced harshness in SCC and thus imposed limits to its free flow. Increases dosage of SP overcome this negative effect of TCR. Mix R1 and R2 showed improved flow characterizes on increasing the dosage of SP. Thus with careful dosage of SP TCR can be replaced up to 10% with FA.

- Passing characteristics of SCC showed decrement with the increased percentage of TCR from 0% to 20% because presence of TCR reduced the workability of the rubberized mixes because of poor interfacial bonding of cement with TCR particles. Mix R4 showed very less passing ability but mix R1 and R2 showed satisfactory outcomes.

- Filling characteristics followed the same trend as that of the passing characteristics of SCC and RMSCC. Time required to empty the funnel for mix R4 does not fulfil the EFNARC limits but mix R1 and R2 on comparison with R0 showed decent results and mix R3 is on the verge of acceptance.

From the above specified conclusion of green properties mix R2 showed reasonable results.

5.2Conclusions Drawn from Hardenedproperties :-

- Compressive strength results showed decrement in the strength of rubberized mixes as compared with the basic mix of SCC. This was due to the presence of TCR particles as these possess low value of E and high value of υ. Value of υ for the TCR lies in the range of 0.45-047 where as that of concrete is in the range of 0.15-0.2. Thus this supports the pre mature crack formation also the poor interfacial bonding of cement with TCR particles. RMSCC is used where strength is not the major concern but to make the concrete environment friendly. Mix R2 showed 17 % decrement in the strength as compared with the R0. Mix R2 possess strength of 25.4 N/mm2 after 7 days of curing and this value raised to 35.3 N/mm2 after 28 days of curing for design mix of M30. So mix M2 showed satisfactory results.

- Results of tensile strength followed the same trend of compressive strength. These also resulted deterioration in the strength on adding TCR to SCC. On comparing rubberized mixes with SCC we concluded that the Mix R1 and R2 showed favourable results on comparison with mix R0.

- Water absorption capacity of SCC got increased on adding TCR to SCC, as TCR particles made the SCC more porous and thus increase the capacity to store more water through capillary action. On comparing rubberized mixes with basic mix of SCC, mix R1 gave favourable outcome.

- UPV test is helpful in the assessment of quality and uniformity of SCC. Addition of TCR particles in different proportions deteriorate the quality of concrete as compared with the basic mix of SCC.

This is because addition of rubber supports the pre mature crack formation thus decreasing the quality of SCC.

On the basis of above mentioned conclusions mix R2 fulfils all the requirements of the RMSCC on comparison with basic mix R0. Optimum content of TCR that can be successfully substitute the FA without much compromising with the required properties is 10%.

ACKNOWLEDGEMENT

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