Compressive strength study performed on M35 grade concrete with crumb rubber used as partial replacement of sand

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***Abstract*—** The disposal of waste tyre is emerging as a major problem for all countries in the world. Waste tyre can neither be dumped nor burnt. Dumping in landfill is not possible as tyre is not an easily biodegradable material. Also burning of such waste releases toxic gases such as carbon monoxide (CO), sulfur oxide(SO_2), oxides of nitrogen (NOX), and volatile organic compounds in air increasing air pollution. Hence the most effective way of saving environment will be recycling these wastes and reusing it. Also the natural resources such as sand, stone and aggregates are depleting with increasing population and construction. For this reason incorporation of waste rubber in the form of crumb rubber is a perfect alternative to be used in construction industry. This study mainly portrays the use of crumb rubber as a replacement of sand. The mix was designed for M35. The replacement proportions are taken as 0%, 5%, 10%, 15% and 20% of fine aggregate. Further, the reaction of sulphuric acid in the crumb rubber concrete (CRC) has been studied. It has been seen that the compressive strength of the crumb rubber concrete decreases with increase in rubber content. There were slight physical changes seen in the cubes cured in sulphuric acid after a curing period of 56 days. With the experiments performed, it is recommended to use CRC in light weight structures and for non-load bearing structures.

Keywords- *crumb ruuber concrete, compressive strength,physical behaviour in acid solution.*

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I. INTRODUCTION

The use of waste material such as waste tyre rubber as a replacement of fine or coarse aggregate in construction can be economically beneficial. The world is now facing a lot of problem regarding dumping of waste tyre rubber. Investigations show that used tyres are composed of materials which do not decompose under environmental conditions and cause serious contaminations. Partial replacement of mineral aggregates in concrete with waste tire rubber could control environmental pollution and save sandstone resources [5]. Finding a way to dispose the rubber in concrete would enhance the understanding on how to incorporate the crumb rubber in greater engineering usage [9].

Crumb Rubber is a term generally used when a rubber is recycled from automotive and truck scrap tyres. The recycling process is generally carried out in a cracker mill and consists of removal of steel and fluff leaving tyre rubber with a granular consistency. This process reduces the size of tyre rubber by passing the material between rotating corrugated steel drums. Crumb rubber consists of particles ranging in size from 4.75 mm to less than 0.075 mm. The crumb rubber used in this project was purchased from Kiran Industries, phase2 , Industrial Area, Chandigarh.

This study mainly concerns the study of compressive strength of concrete using crumb rubber as partial replacement of fine aggregate in the mix proportion of 0%, 5%, 10%,15%, and 20% which has been cured in water and sulphuric for 14, 28 and 56 days. The mix was designed for M35. Also the physical changes in the concrete after being cured in acid solution are studied. A comparative study on the compressive strength and physical changes of the cubes cured in water and sulphuric acid has been portrayed in this study. Sulphuric acid having a concentration of 98% have been used in this study.

II. OBJECTIVE

The main interest of this study is to analyze the physical and mechanical properties of concrete with partial replacement of fine aggregate with Crumb Rubber. The concrete so formed is then dipped separately in Water and Sulphuric acid for a period of 14, 28 and 56 days. Their strength and physical changes due to chemical reactions are further investigated in this study.

The precise objective of this study is as follows:

1. Study the compressive strength of Crumb Rubber mixed concrete cured in water, and sulphuric acid for a period of 14, 28 and 56 days.
2. Study the chemical reaction characteristic of concrete at different curing ages containing different percentage of Crumb Rubber (0%, 5%, 10%, 15%,20%) cured in different solution of water and sulphuric acid.

III. MATERIALS USED

A. CEMENT

Ordinary Portland Cement of grade 53 is used for the preparation of concrete mix. 53 Grade OPC provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure.

B. FINE AGGREGATE

Fine aggregate available from nearby Khizrabad river sand (confirming to IS 383) is used. It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification. The fineness modulous of sand used was obtained as 2.52 and belonged to Zone II.

C. COARSE AGGREGATE

Coarse aggregate available from nearby Nangal Crushed Stone (confirming to IS: 383) was used for this study. In this study coarse aggregate of size 10mm and 20mm are used.

D. WATER

Bore well potable water was used for mixing and curing which was clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials and all other

substances that was harmful to concrete as per clause 5.4 of IS456:2000.

E. ADMIXTURE

In this study 100gm of Superplasticizer admixture named SIKAMENT 2002 NS was used. It imparts high workability and allows a large decrease in water content.

F. CRUMB RUBBER

Crumb Rubber is a term generally used when a rubber is recycled from automotive and truck scrap tyres. The recycling process is generally carried out in a cracker mill and consists of removal of steel and fluff leaving tyre rubber with a granular consistency. This process reduces the size of tyre rubber by passing the material between rotating corrugated steel drums. Crumb rubber consists of particles ranging in size from 4.75 mm to less than 0.075 mm. The crumb rubber used in this project was purchased from Kiran Industries, phase2 , industrial area, Chandigarh. The Fineness modulus test and specific gravity test of the crumb rubber was done whose values were found as 0.73 and 2.01.

Fig a) Crumb Rubber

IV. CASTING OF CUBES

A total number of 90 cubes of size 100mmX100mmX100mm were casted separately. In this study 0%, 5%, 10%, 15% and 20% of fine aggregate are replaced with crumb rubber. The design was first prepared for 1 m^3 which was then used to cast concrete for different replacement proportion on different days. The design details are as follows:

TABLE 1: REPLACEMENT WITH CRUMB RUBBER

	0%	5%	10%	15%	20%
Cement(kg)	10	10	10	10	10
Sand (kg)	16.4	16.49	15.28	14.83	14.18
Water(liters)	5.12	4.43	5.06	4.67	4.46
10mm (kg)	11.53	11.53	11.53	11.53	11.53
20mm (kg)	17.3	17.3	17.3	17.3	17.3
Admixture(mLt)	100	100	100	100	100
Crumb Rubber (kg)	0	0.85	1.70	2.55	3.4

Using the above data, each ingredient were weighed accurately and mixed in a Pan mixer. The mixing process started with the addition of coarse aggregate in the pan mixer, which was followed by sand and then cement. These ingredients were first dry mixed. Water was then weighed and added slowly to the dry mix followed by addition of admixture. The mix so formed was kept for half an hour after which slump test was done. The diameter of slump test apparatus is 10cm on top, 20cm on bottom and 30 cm in height. The concrete mix was poured in three equal layers in the slump apparatus. Each layer was tamped for 25 times. The slump cone was then removed gradually. The height of slump was then noted down. Again the mix as further left for one and half hour and again the slump test was done. It is done to check the workability and retention of the concrete. Finally after two hours the cubes were casted. The steel moulds used were of size 100mm X100mmX100mm . First the moulds were given a coat of engine oil, so that the concrete does not stick to the mould. The cubes were casted in two layers. Each layer were tamped for 25 times and vibrated. Finally the finishing of cubes was done. The finished cubes were kept for a period of 24 hours and removed carefully. Nomenclature of the cubes was carefully done and then 9 cubes were dipped in water and 9 cubes in sulphuric acid. These cubes were kept for curing period of 14, 28 and 56 days.

V. EXPERIMENTAL STUDY

A. SLUMP TEST

The slump test of the concrete is done to assess the workability and consistency of fresh concrete. Consistency refers to the ease with which concrete flows. It is used to indicate degree of wetness [10]. Slump test is done to check the correct amount of water to be added to the mixture. In this study, the test is conducted as per IS specification.

The slump test was done after two hour and the result of the slump test so conducted is as follows:

TABLE 2: SLUMP TEST RESULT

	0%	5%	10%	15%	20%
Result	75mm	65mm	45mm	35mm	27mm

B. COMPRESSION TEST

The limit of compressive strength of the cement concrete depends on both, the strength of the matrix and the particle tensile strength of the aggregate. The strength of the concrete is usually related to the cement content and water to cement ratio. On 14^{th}, 28^{th} and 56^{th} day, 6 cubes (3 cubes which was cured in water and 3 cubes which was cured in sulphuric acid) were tested for their compressive strength. These cubes were first allowed to dry in air. The dried specimens were centered on a compression testing machine of capacity 2000 kN. The load was applied at a uniform rate of 2.3 kN/sec. The test setup and results are shown below:

 ISSN: 2321-8169
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Fig c: Compression Testing machine

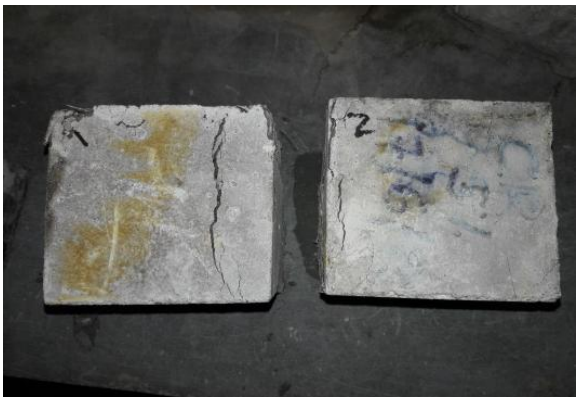
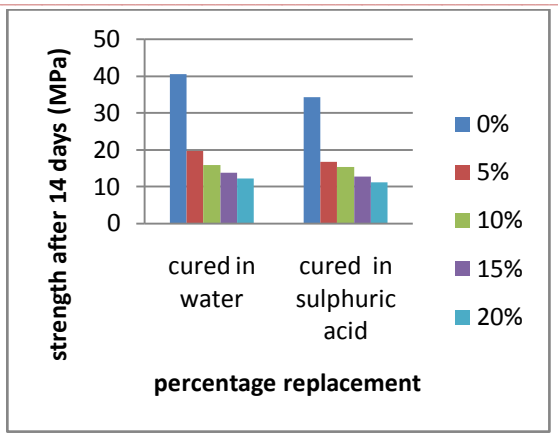


Fig b: 5% Crumb rubber concrete after compression test.

TABLE 3: 14 DAYS COMPRESSION TEST RESULT:

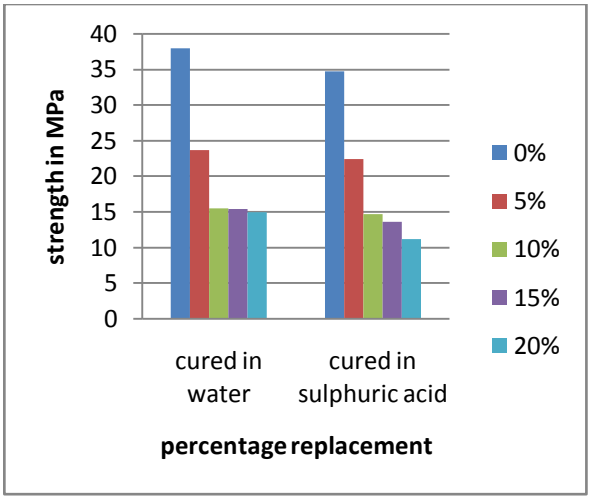
	Dipped in water (N/mm^2)		Dipped in sulphuric acid (N/mm^2)	
0%	42.73	40.45	31.33	34.14
	38.4		37.26	
	40.22		33.84	
5%	19.72	19.7	15.19	16.67
	19.8		18.51	
	19.6		16.31	
10%	15.03	15.72	16.07	15.34
	16.87		14.95	
	15.26		15.0	
15%	12.64	13.77	14.06	12.67
	15.11		11.38	
	13.56		12.57	
20%	10.62	12.08	9.04	11.09
	13.65		13.0	
	11.98		11.25	



GRAPH 1: COMPARISON IN COMPRESSIVE STRENGTH AFTER 14 DAYS

TABLE 4: COMPRESSION TEST RESULT AFTER 28 DAYS

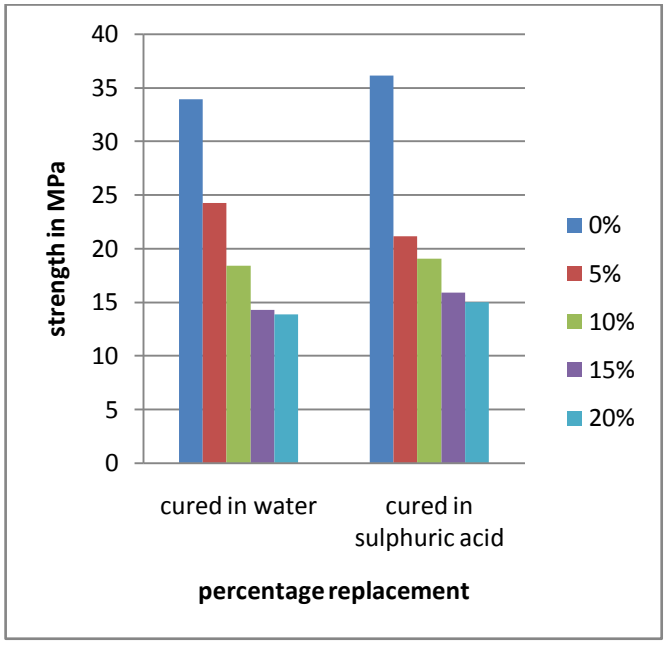
	Dipped in water (N/mm^2)		Dipped in sulphuric acid (N/mm^2)	
0%	39.29	37.92	29.41	34.7
	36.58		39.86	
	37.91		34.85	
5%	24.08	23.68	21.43	22.41
	23.4		23.79	
	23.56		22.02	
10%	15.4	15.44	13.61	14.61
	15.58		15.5	
	15.34		14.72	
15%	14.98	15.38	14.39	13.58
	16.17		13.38	
	15.0		12.98	
20%	14.45	14.92	13.96	11.16
	15.73		8.82	
	14.58		10.69	



GRAPH 2: COMPARISON IN COMPRESSIVE STRENGTH AFTER 28 DAYS

TABLE 5: COMPRESSION TEST RESULT AFTER 56 DAYS

	Dipped in water (N/mm^2)		Dipped in sulphuric acid (N/mm^2)	
0%	40.68	33.89	34.48	36.1
	29.41		38.33	
	31.58		36.49	
5%	25.38	24.22	17.47	21.11
	22.63		25.34	
	24.65		20.53	
10%	16.41	18.4	19.98	19.06
	20.13		18.17	
	18.76		19.04	
15%	13.65	14.24	16.05	15.89
	14.8		16.05	
	14.26		15.57	
20%	14.95	13.84	14.73	14.99
	12.9		15.27	
	13.68		14.96	



GRAPH 3: COMPARISON IN COMPRESSIVE STRENGTH AFTER 56 DAYS

VI. PHYSICAL BEHAVIOUR OF CRUMB RUBBER CONCRETE IN DIFFERENT SOLUTIONS

The chemical reaction between the cubes and acid were gradually seen. The cubes dipped in water and sulphuric acid showed a gradual change in its physical properties. There was no change noticed on the 14th day of test . On 28th day some cubes dipped in sulphuric acid started to gain yellowish colour. No changes were seen in cubes dipped in water. However, strong changes were noticed on 56th day. Cubes dipped in sulphuric acid had completely become yellow in colour. However no certain change was noticed in cubes cured in water. Following are the pictures that will elaborate the reaction between the concrete and acids clearly:

Fig d: cubes dipped in different solution after 28 days

Fig e: cubes dipped in different solutions after 56 days

VII. CONCLUSION

This study mainly aims at utilizing waste tyre rubber in concrete to form Crumb Rubber Concrete. Crumb rubber has been used to replace fine aggregate in a percentage of 5, 10, 15 and 20. Hence the effect on compressive strength of concrete with addition of Crumb Rubber which was cured in different solution of water and sulphuric acid were studied. From the test results, following conclusion can be drawn:

1. The slump test result gives a decreasing slump. However the workability of concrete is satisfying throughout the mix. As per our test conducted, for normal concrete the slump value was found to be 75mm and 65mm for 5% replacement by crumb rubber which comes under medium degree of workability and states its use in flat slabs and normal reinforced concrete which are manually compacted. Further, with 10%, 15% and 20% replacement of fine aggregate with crumb rubber the slump obtained was 45mm, 35mm and 27mm which are categorized as low workability concrete. These concrete can be used for foundation with light reinforcement and roads which are vibrated by hand operated machines.
2. Replacing the fine aggregate with crumb rubber decreased the compressive strength of concrete. The low bonding between crumb rubber and concrete can be assumed as the reason for decrease in compressive strength.
3. It was noticed that none of the cubes cracked properly or in other words the cubes stayed intact (CH V fig b) indicating that the rubber particles may be absorbing forces acting upon it. This kind of behavior can be beneficial for a structure that requires good impact resistance properties.
4. There was reduction in weight of crumb rubber mixed concrete cubes. Hence its light weight can be advantageous in the construction of light weight structures.
5. The cubes were mainly checked for the acidic reaction. There was no certain change noticed up to 14 days. On 28th day, some cubes dipped in sulphuric acid started to gain yellow color. It was noticed that all the cubes cured in sulphuric acid had turned yellow (CH VI fig e) on 56 days. However there was no specific change noticed in cubes cured in normal water on 14, 28 and 56 days. Hence it can be concluded that the reaction of sulphate in concrete is gradual but the problem of acid attack in concrete cannot be simply avoided.

VIII. REFRENCES

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