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Effect of Nano Silica Fume and Crumb Rubber on the Mechanical Properties of Concrete

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***Abstract:** Nanotechnology is an advanced technology that has received a lot of attention for its ability to make use of the unique properties of nano-sized materials. The grain size of the nano particles will be in the order of 10-9 m (1-100nm). Due to the very small particle size of 10-9 m and extremely large specific surface area, nano particles have same remarkable properties. The use of nano materials for making concrete is of recent origin. Application of nano materials into the production of concrete can lead to significant improvements in the strength and life of concrete. Recent year's enormous work is executed by incorporating urban wastes in building materials. Disposal of used tyre is a major problem faced by the present world. The growing problem of waste tyre disposal can be alleviated if new recycling routes can be found for the surplus tyres. The incorporation of waste materials in concrete benefits the environment and modifies the properties of concrete. An attempt has been initiated to study the properties of concrete by incorporating the potential utilization of crumb tires as a partial replacement of fine aggregate and nano silica fume(NSF)as the partial replacement of ordinary Portland cement of 53 grade. M sand free of debris and good gravel was used. Nano silica fume are produced by grinding the commercially available micro silica in the ball grinding mill. Crumb rubber is produced by shredding process. Mix design for M30 grade of concrete was done as per IS10262-2009. Cement is replaced with 10%, 20%, 30% 40% and 50% of nano silica fume and fine aggregate was replaced with 20%, 40%, 60%, 80% and 100% of crumb rubber. Test on compression, tension and bending was studied. It was found that concrete with crumb rubber has lowered workability. The optimum replacement of fine aggregate with crumb rubber was found to be 20% without nano silica fume and 40% with nano silica fume*

***Keywords:** Nano technology, nano silica fume, crumb rubber, fine aggregate, compressive strength, split tensile strength, flexural strength.*

I. INTRODUCTION

Nanotechnology is an advanced technology, which deals with the study and application of extremely small particles of size 10-9m. These extremely small particles are called Nano particles and when incorporated in concrete, the property of the composite is enhanced. The mechanical behaviour of concrete materials depends largely on structural elements and phenomena, which are effective on a micro and nano scale. Nanotechnology allows for the control and intervention in material properties at the nano scale. It improves the mechanical, electrochemical properties, durability, surface protection, workability long-term maintenance and monitoring of construction materials. Crumb rubber is a term usually applied to recycled rubber from automotive and truck scrap tires. It is very difficult to remove tyres which are a major environmental problem and this can be reduced by converting them to crumb rubber and using in different application. During the recycling process steel and fluff is removed leaving tire rubber with a granular consistency. Continued processing with a granulator and/or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles further. Crumb rubber is light in weight and is durable. It can last for a long period of time in a natural environment. Crumb rubber is a non-toxic and inert material. Crumb rubber particles can considerably reduce the thermal conductivity of the concrete. N. J. Azmi et al1 conducted study on mechanical properties of rubberized concrete. Crumb rubber contents of 10, 15, 20 and 30% by volume were chosen for partially replacing the fine aggregate and different water cement ratio (0.41, 0.57 and 0.68) was used. The strength properties were found. It was noted that a reduction in strength on concrete for crumb rubber mixture. Slump values increase as the crumb rubber content increase from 0% to 30%. Crumb rubber mixture is more workable compare to normal concrete. Inclusion crumb rubber in concrete reduced the static modulus elasticity. The deformability of crumb rubber concrete is increased compared to normal cement concrete. Wesam Amer Aules 2 did a study on utilization of crumb rubber as partial replacement in sand for cement mortar. Use of rubber waste as partial replacement of fine aggregate (5, 10 , 15, 20 , 25 and 30 %) Rubberize cement mortar. Tests were done for compressive, flexural strength, stress-strain behavior and length change. The result revealed that a reduction in strength modulus of elasticity reduce as the waste rubber content increase. Deformability rubber concrete decreasing compared to conventional concrete. The addition of crumb rubber could be beneficial for reducing shrinkage in mortar. Mohammad Reza sohrabi3 did an study on crushing strength of concrete containing crumb rubber experimentally. Addition of rubber to concrete resulted in the improvement of energy adsorption, better ductility, and better crack resistance.

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The compressive strength of concretes containing crumb rubber; silica fume and Nano silica was studied. The 7- day and 28- day compressive strength was found to be increased by addition of silica fume. This is because of the filling capability of silica fume as well as good adhesion between the rubber and the cement paste. Addition of 2 and 3% nano silica to rubber-containing specimens results in the increase of 7- day and 28- day compressive strength in comparison with those which only contain crumb rubber. The reason of this increase is that nano materials can fill the nano voids and provide a denser structure. Addition of silica fume and nano silica had no significant effect on the 7- day strength, while the 28- day strength increased relatively. Compressive strength increment of rubber-containing concrete in the presence of silica fume was higher than nano silica and their mixtures. C. E. Pierce.,et.al.,4 did a study to find out the potential of scrap tire rubber as lightweight aggregate in flowable fill. This is done by replacing sand with crumb rubber in flowable fill to produce a lightweight material. Mixture proportions were varied to investigate the effects of water-to-cement ratio and crumb rubber content on fill properties. The focus of the experimental program was to investigate the performance of flowable fill when mixed exclusively with crumb rubber as aggregate. No sand was added to the mixtures. Experimental results indicate that crumb rubber can be successfully used to produce a lightweight flowable fill with excavatable 28-day compressive strengths ranging from 269 to 1194 kPa. Using a lightweight fill reduces the applied stress on underlying soils, thereby reducing the potential for bearing capacity failure and minimizing soil settlement. Hui Li.,et.al., (2006)5did a study on abrasion resistance with nanao particles in concrete. Both nano-SiO2 and nano-TiO2 were used as additives.The abrasion resistance of PCC and concrete containing polypropylene fibres were experimentally studied. The test results showed that the abrasion resistance of concrete containing nano-particles was much higher than polypropylene fibres. The concrete containing nano-TiO2 was better than nano-SiO2.Finally, it was indicated that the abrasion resistance of concrete increases with increasing compressive strength. An attempt has been made to study the properties of concrete with cement replaced with nano silica fume and fine aggregate replaced with crumb rubber.

II. MATERIALS USED IN THIS INVESTIGATION

OPC of 53 grade conforming to IS 12269-2013 and procured from a single source is used for this investigation. The specific surface area is 303m^2/kg. The initial setting time was 70 minutes and final setting time 510 minutes. M sand free from debris is used for fine aggregate and good quality hard broken stones conforming with IS383-1970 are used for coarse aggregate. The potable water drawn from siruvani water resources is used. Silica fume obtained from a single source is converted to nano size by grinding the micro silica for 30 minutes in high energy ball grinding milling machine. Scanning electron microscope(SEM) was used to determine the particle size and shown in Figure 1. Crumb rubber shredded from automobile tyre is used, In this study, an attempt was made to partially replace cement with nano silica fume and fine aggregate with crumb rubber powder. The basic properties of fine aggregate and crumb rubber was found using pycnometer, sieve analysis and water absorption. From the pycnometer test, the specific gravity of fine aggregate was found to be 2.79 and for crumb rubber it was 1.15.

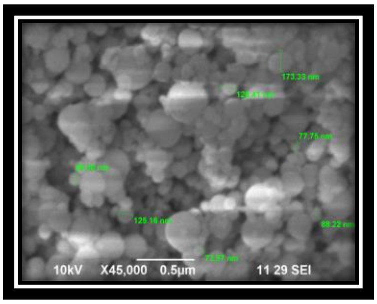

Figure 1 Sem image of NSF

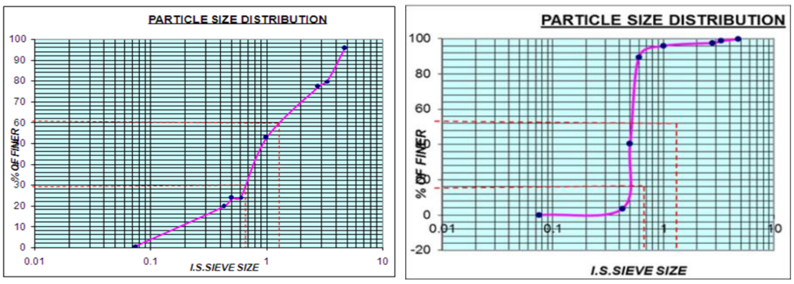

Figure 2 Particle size distribution of crumb rubber and M sand

From the particle size distribution graph in Figure 2, it is seen that a uniform grading was attained. Further the fineness modulus was found to be 2.74 for fine aggregate and 4.27 for crumb rubber. Fine aggregate and crumb rubber falls under zone II. The average water absorption percentage was found to be 2.2% for fine aggregate whereas the value was 1.05% for crumb rubber powder. The nano silica fume was Hence an attempt has been made to partially replace cement with nano silica fume and fine aggregate with crumb rubber.

III. EXPERIMENTAL INVESTIGATION & RESULTS

The mix design of concrete was calculated using IS10262 and the mix ratio is 1:1.12:2.93 at a water/cement ratio of 0.44. The compressive strength and split tensile strength of hardened concrete with partially replacing cement with nano silica fume and fine aggregate with crumb rubber was found using a compression testing machine of capacity 2000kN. The compressive strength and the flexural strength was performed as per IS516 – 1959 and the split tensile test was conducted as per IS 5816-1999. The specimens used for compressive strength were standard cubes of size 150 x 150 x 150mm, for split tensile test standard cylinder specimen of diameter 150mm and height 300mm and for flexural strength 500mm x 10mm x 100mm beam specimen.

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Figure 3. Compressive strength, split tensile strength and Flexural strength test

IV. RESULTS AND DISCUSSION

An attempt is made to study the strength of concrete replacing cement with nano silica fume(NSF) and crumb rubber(CR) replaces fine aggregate.

Compressive strength of concrete

The strength of concrete under compression with cement replaced with nano silica fume and crumb rubber replaced fine aggregate was given in Table 1. PRCNSF represent the percentage replacement of cement with nano silica fume and PRFACR represent the percentage replacement of fine aggregate with CR.

Table 1 Strength of concrete under compression with nano silica fume and crumb rubber

Compressive strength of concrete N/mm²						
PRCNSF	PRFACR					
	0	20	40	60	80	100
0	29.44	30.20	23.12	19.48	17.32	14.20
10	31.39	31.42	32.98	21.42	20.12	18.80
20	32.22	32.33	33.43	23.44	21.34	19.41
30	33.46	33.56	35.62	24.08	22.46	20.45
40	35.48	35.66	37.96	25.78	24.12	21.34
50	32.26	32.68	34.32	23.82	22.32	20.12

Graph are drawn for concrete between compression strength and percentage replacement of cement with nano silica fume for percentage replacement of fine aggregate with crumb rubber and given in Figure 4.

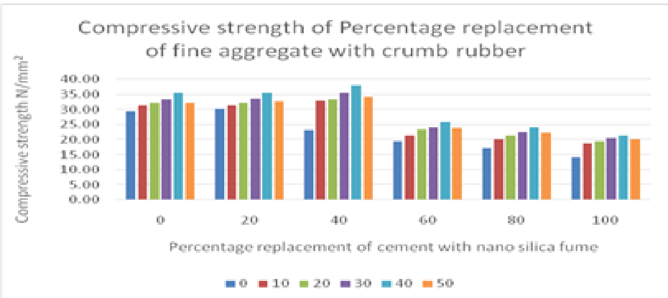


Figure 4. Strength of concrete under compression with NSF and CR

From the Table 1 and Figure 4 it can be seen that the strength under compression increases up to 40% replacement of cement with NSF. It was also found that the optimum replacement of fine aggregate with CR was 20% without admixture. When NSF was added, the strength was found to increase and the optimum percentage replacement of concrete with CR was found to be 40%.

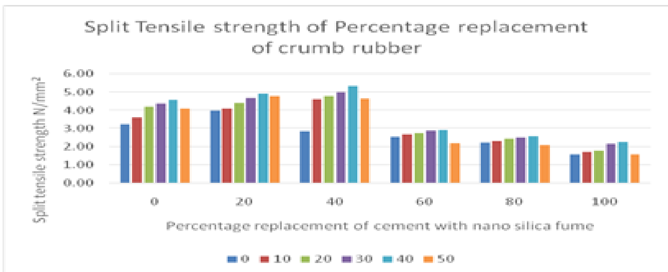
Split tensile strength of concrete

The concrete under tension with cement replaced with NSF and fine aggregate replaced with CR is given in Table 2. PRCNSF represent the percentage replacement of cement with nano silica fume and PRFACR represent the percentage replacement of fine aggregate with crumb rubber.

Table 2 Strength of concrete under tension with nano silica fume and crumb rubber

Split tensile strength of concrete N/mm²						
PRCNSF	PRFACR					
	0	20	40	60	80	100
0	3.26	3.98	2.86	2.56	2.21	1.60
10	3.62	4.12	4.62	2.68	2.32	1.72
20	4.22	4.42	4.79	2.76	2.44	1.80
30	4.38	4.68	5.01	2.88	2.52	2.14
40	4.56	4.90	5.33	2.92	2.58	2.26
50	4.12	4.78	4.64	2.18	2.08	1.60

Graph are drawn for concrete between strength under tension and percentage replacement of cement with nano silica fume for various percentage replacement of fine aggregate with crumb rubber and given in Figure 5.



From the Table 2 and Figure 5 it can be seen that the split tensile strength increases up to 40% replacement of cement with nano silica fume. It was also found that the

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optimum replacement of fine aggregate with crumb rubber was 20% without admixture. When nano silica fume was added the split tensile strength was found to increase and the optimum percentage replacement of crumb rubber was found to be 40%.

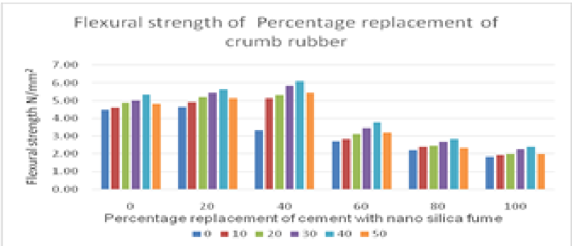
Flexural strength of concrete

The flexural strength of concrete with cement replaced with nano silica fume and fine aggregate replaced with crumb rubber is given in Table 3. PRCNSF represent the percentage replacement of cement with nano silica fume and PRFACR represent the percentage replacement of fine aggregate with crumb rubber.

Table 3 Strength under Flexure with nano silica fume and crumb rubber

Flexural strength of concrete N/mm^2						
PRCNSF	PRFACR					
	0	20	40	60	80	100
0	4.48	4.64	3.34	2.72	2.22	1.84
10	4.62	4.92	5.12	2.84	2.38	1.92
20	4.88	5.20	5.32	3.12	2.46	2.00
30	5.00	5.44	5.85	3.46	2.68	2.26
40	5.34	5.62	6.10	3.76	2.82	2.38
50	4.82	5.12	5.44	3.22	2.34	1.98

Graph are drawn for concrete between flexural strength and percentage replacement of cement with nano silica fume for percentage replacement of fine aggregate with crumb rubber and given in Figure 6.



From the Table 3 and Figure 6, it can be seen that the strength under flexure increases up to 40% replacement of cement with nano silica fume. It was also found that the optimum replacement of fine aggregate with crumb rubber was 20% without admixture. When nano silica fume was added the strength was found to increase and the optimum percentage replacement of crumb rubber was found to be 40%.

V. CONCLUSION:

An attempt has been made to find out the strength of concrete with cement replaced with NSF and fine aggregate replaced with CR. The strength characteristics were found at 28th for M30 grade of concrete and the results were compared with the conventional concrete. The optimum replacement of fine aggregate with CRwas found to be 20% which is enhanced to 40% on addition of NSF.

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