www.ijiarec.com

ISSN:2348-2079

Volume-8 Issue-3

International Journal of Intellectual Advancements and Research in Engineering Computations

Experimental analysis on concrete using recycled concrete aggregate silica fume and glass fiber

Anil Kumar.K[1], S. Hariharan[2]

[1]Master of Engineering Student, Civil Engineering Department, Easa College of Engineering and Technology, Coimbatore

[2]Assistant Professor, Civil Engineering Department, Easa College of Engineering and Technology, Coimbatore

ABSTRACT

For long it had been debated on the utilization of recycled concrete aggregates in structural concrete as a viable resolution to the extreme pressure that indiscriminate mining imparts on the natural resources. It also has sought a way out of the negative impact the construction as well as Demolition waste can cause on the environment. An attempt is made to study the bevavior of concrete on its compressive and Flexural properties using Recycled or Processed aggregate concrete (RAC) and ordinary concrete (OC) blended with Microsilica and iron fibers or Glass fiber (GFs). The modifying effect Microsilica and fibers can bring on the compressive strength, fracture toughness, modulus of elasticity, and failure mode of the RAC and OC were examined by means of a series of axial compression and three-point bending tests. It has been noticed that the use of thick iron fiber caused a negative effect on the inter- facial bonding with the cement paste, where as the use of Glass fiber fared better. Microsilica when added in small percentages improved the interfacial bonds, thereby bringing about substantial increase in the compressive and flexural properties of the RAC and OC. It was also found that the blending effect of Microsilica and iron fiber was better than that of the Microsilica and GF. Various percentage of individual components was used to cast samples taking into account the cost and all the criteria governing the performance improvement. It was decided to use 12% Microsilica content by the equal quantity substitution of cement method and eventually proved better than substitution by weight of cement method on the compressive and flexural strength of iron-fiber reinforced RAC.

Keyword: Microsilica, Glass fiber, Strength

INTRODUCTION

Concrete is only second to water in terms of anything that is consumed anywhere in the world. That means a huge quantity of waste is going to incur not only during the construction stage but also of the demolition of the structures once the design life of the buildings has surpassed. It is not possible to find a substitute for concrete that does not cause a massive buildup of debris and the unthinkable impact that it can cause on the environment. The recent statics given out by the Government of India based on the research undertaken by environmental agencies gave a whopping 8 billion tons of Demolition waste (DW) in the year 2018 alone. Most often the DWs are disposed off in low lying areas where filling is required. But storage of these waste until a suitable filling area is found is a difficult proposition. Disposal in in-fills have increased the carbon content of the area by a remarkable extend. Hence a lot of thought has gone into the possibility of using the broken building aggregate or D.W as a replacement for natural aggregates like 6mm, 20 mm, 40 mm or greater sized aggregates. In short the idea was to recycle

Author for correspondence:
Civil Engineering Department, Easa College of Engineering and Technology, Coimbatore

DWs, and the possibility of the same has been explored in this study. Recycled or Processed aggregate can be produced by grinding the large sized concrete blocks by heavy machinery, sieving with mechanical Sieve, and cleaning with water jets. This study holds a lot of importance in the backdrop of the hazard the DW's can bring out in terms of climate change by way of increased levels of Carbon emissions and global warming. It will be great to see that the success of using recycled aggregate can reduce the pressure on Quarries that mine deep into earth's Crust in an effort to reach more of her resources. Earlier ground granulated blast furnace slag were regularly used as mineral additives to enhance the mechanical properties of RAC. Micro Silica or Silica flume is an amorphous polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. New Studies have suggested that Microsilica is better than fly ash or ground granulated blast furnace slag when it comes to the compressive strength of concrete. A time will come, hopefully, when Microsilica will be used in place of them and thus is being researched worldwide. Microsilica is now an important additive in the realization of high strength concrete worldwide. In many areas Micro silica which is a byproduct of silicon and ferrosilicon alloy production is an environment pollutant and needs to be recycled just as D.W's. The increase in compressive strength of Recycled concrete can be attributed to the increase in density of recycled concrete that addition of Microsilica can provide. Microsilica can bring about greater level of compactness to RAC probably because of high porosity in recycled aggregate and thus was found to improve the mechanical properties of RAC more than that of NRC. Microsilica can also improve the chloride resistance of concrete. Incorporation of a combination of iron fiber and Microsilica to concrete has also been reported in recent studies. The impact of Microsilica on iron fiber bond properties in reactive powder concrete has also been studied, elsewhere. Microsilica was found to effectively improve the fiber–matrix interfacial properties, especially in fiber pull-out energy. Addition of Microsilica in high strength concrete improved the split tensile and flexural strengths concrete where iron fiber to the extent of 1.5% was used. Further studies showed a significant improvement in the impact performance of concrete when microsilica was used alongside iron fiber.

AIMS AND OBJECTIVES

There has been a lot of research on the possibility of using Recycled Aggregates with the properties of concrete alongside quality improving components like Microsilica and Fibers in optimal quantities. But all of them invariably have studied the independent effects of Microsilica or fibers on the improvement of mechanical properties of Recycled aggregate concrete. The author has no knowledge if any work has been done on the blending effects of Microsilica and fibers on the mechanical properties of RAC. RAC with Microsilica and fibers is generally considered an innovative type of high strength concrete. [1] RAC and Microsilica are recycled because of the aforesaid negative impact on the Environment and also because it can bring about cost reduction. [2] the fibers such as Iron and Glass are added to improve the flexural properties of concrete, such as the flexural strength and fracture toughness; and [3] Microsilica can improve the bonding between the aggregate and paste, resulting in the improved mechanical properties of Recycled aggregate concrete. Therefore, the Author of this article found it extremely important to study the combined use of Micro silica and Fibers alongside recycled aggregate and highlight the mechanism it can bring about to improve the mechanical properties of RAC.

This study effectively probes the blending effects of Microsilica and iron fiber/GF on the compressive and flexural properties of RAC and NRC. A number of cylindrical and prism sample were made and tested under compressive testing machines and three-point bending machines. The test parameters used were the Microsilica integration method with various amounts of Microsilica and different fiber types. In order to see that maximum quantities of Recycled Aggregates can be used the natural coarse aggregate (NA) in the concrete components was replaced by processed or Recycled coarse aggregate (RA) in totality. Iron fiber with a low aspect ratio was also used in the study with an eye on the production cost. The compressive strength, stress–strain relationship, elastic modulus, toughness resistance to fracture, and failure mode were investigated to identify the quantities of Microsilica that gave best results

MIX PROPORTIONS OF SPECIMEN

Group	Sample	Mix Ratio (kg/m^3)								
		Water	Cement	Sand	NA	RA	Microsilica	Additional water	F or P	Super plasticizer
NRC	1	165	340.4	790	1043	–	–	–	–	1.1
NRC-P	2	165	340.4	790	1043	–	–	–	1.3	1.1
	5	165	323.4	790	1043	–	17.2	–	1.3	1.1
	8	165	323.4	790	1043	–	35.6	–	1.3	1.1
	11	165	340.4	790	1043	–	10.6	–	1.3	1.1
NRC-F	3	165	340.4	790	1043	–	–	–	79	1.1
	6	165	306.4	790	1043	–	17.2	–	79	1.1
	10	165	306.4	790	1043	–	35.6	–	79	1.1
	12	165	340.4	790	1043	–	10.6	–	79	1.1
RC-F	4	165	340.4	790	–	968	–	18.3	79	1.1
	7	165	323.4	790	–	968	17.2	18.3	79	1.1
	10	165	306.4	790	–	968	35.6	18.3	79	1.1
	13	165	340.4	790	–	968	10.6	18.3	79	1.1

Note

NRC and RC denote normal concrete and processed concrete, respectively; F and P denote iron fiber and Glass fiber, respectively; S0, S6, and S12 denote the Microsilica substitution ratios of 0%, 6%, and 12%, respectively; S3 denotes the addition of Microsilica (3% wt of the cement).

Group	**Compressive strength (N/mm2)**			
	Microsilica by QS			**Microsilica by AD**
	0%	6%	12%	3%
NRC	41.08	–	–	–
NRC-P	42.11	51.17	53.19	50.5
NRC-F	36.63	39.97	52.9	47.93
RC-F	32.51	36.37	43.08	37.44

The cylinder samples were subjected to axial compression using a compression testing machine with a 4500-kN capacity. The test procedure was performed according to the ASTM Standard. Two linear variable displacement transducers (LVDTs) were employed to measure the axial displacement. Two strain gauges were installed at the half way height of the cylinder samples to measure the hoop-strains under compression. The Axial loads were applied to the cylinders at a displacement rate of 0.2 mm/min. The test was stopped when the load reached 10% of the peak stress of the sample.

FLEXURAL STRENGTH RESULTS

Group	Flexural strength (kN)			
	Microsilica by QS		Microsilica by AD	
	0%	6%	12%	3%
NRC	4.35	–	–	–
NRC-F	5.95	6.6	6.2	6.40
NRC-P	4.91	4.90	4.88	5.32
RC-F	*	*	5.88	5.56

Flexural tests

Three-point bending tests were performed on the prisms using universal testing machine with a 450-kN capacity. Plywood was used to level the surfaces of sample so as to ensure uniform loading. Load was applied at a displacement rate of 0.2 mm/min, Two LVDTs which were placed symmetrically from the mid-span of the prism ascertained mid span deflections. Two LVDT's were placed at each supports. The deflection was determined from the four values. Strain gauges measured the cracking load of the prism, while the crack mouth opening displacement (CMOD) was measured with an extensometer with an accuracy of 0.001m

DISCUSSION ON COMPRESSIVE TEST RESULTS

Failure mode

The Cracks were first noticed at the centre of the sample and a clear sound could be heard. On further loading, the cracks on the middle propagated towards the ends and joined together to form a large crack. This main crack reached the surface of the sample and the sample failed**.**

Compressive failure modes of the samples with microsilica contents of 0%, 6%, and 12% by QS and 3% by AD, respectively were analysed compared with the non-fiber NC, the samples containing iron fiber or G.F after failure remained more intact and had more cracks. But the cracks were narrow. This is in conformity with the tests carried out in the yesterdays. It is proved beyond doubt that incorporation of fiber can arrest the spread of cracking. The fibers played a bridging role between cracks in the concrete. The Fiber which was indiscriminately distributed in the concrete, resisted the formation of cracks. The cracks that formed in the GF concrete were smaller and finer when compared to Iron Fiber. Since Glass fiber is smaller and thinner when compared to iron Fiber, it offered greater bonding surface and therefore bonding between glass Fiber and concrete was stronger. With increasing Microsilica content, the pattern of the samples after failure was substantially different, the crack width increased, and the number of cracks gradually decreased. Major macro-cracks formed along the lengths of the concrete cylinders with 10% IF, whereas many small longitudinal cracks was observed in the concrete without IF. This points to the fact that an increase in Microsilica changed the microstructure the calcium silicate hydrate (C-S-H) gel and created a denser interface between the cement matrix and the GF or iron fiber. This improved the bonding and prevented crack propagation, while at the same time increasing the brittleness of the concrete. Fig. 4 and (d), it is apparent that the failure mode of the sample containing 6% Microsilica by QS was similar to that of the sample containing 3% Microsilica by AD; this is because the mix proportions of these two groups were similar, as shown in Table. In addition, the failure surface of Group RC-F appeared looser than that of Group NRC-F. This result may be mainly attributed to the lower strength and elastic modulus of RA, as well as the higher porosity of RA

Compressive strength

The Sample was tested using a compressive Testing machine. The cited values are the average of the three samples coming under respective categories. The GF helped the sample to increase the compressive strength by 2.2, Iron fiber on the other hand brought the compressive strength down by 11%. Thus the inclusion of GF improved the compressive property of concrete when the inclusion of the shear-wave-type iron fiber had a negative effect. The strength of concrete very much depends on the strength of the aggregates/fiber, the cement matrix and the interfacial transition zone (ITZ) between the matrix and the aggregates/fiber. In the case of Iron Fiber , Iron Fiber with low aspect ratios had their bonding with the cement matrix weak. This resulted in the reduction of compressive strength. Thus this study has confirmed the reports of earlier research, where in fibers with a low aspect ratio could lower the compressive strength of concrete. The GF used is finer, and the aspect ratio of the GF used in the study is over 268, while the aspect ratio of iron fiber is only 42. The iron fiber did not freely mix with the concrete causing an uneven dispersion within the medium of concrete. This was another reason for the loss of compressive strength. GF is finer and thus easily mixed and integrated into a three-dimensional fiber network in concrete, arresting the transverse buckling of concrete. This property of GF improved the compressive strength.

The Table proves beyond doubt that Microsilica increased the compressive strength of Concrete. The addition of 6% and 12% Microsilica by QS method improved the compressive strength of GF concrete by 22% and 26%, respectively. On the contrary, addition of 6% and 12% Microsilica by QS method improved the compressive strength of iron-fiber concrete by 9% and 44%, respectively. The incorporation of iron fiber (without Micro silica) alone brought the compressive strength of sample drastically. But the addition of Microsilica reduced or counteracted the negative effect of iron fiber. The thick iron fibers reduced the density of concrete; when at the same time the filling effect of Microsilica significantly modified the bonding property of iron fiber and paste. The table shows that for Sample NRC-F and NRC-P, which contained Microsilica to the extent of (12%), had significant compressive strength. This result was better than those sample with less percentage of Microsilica in them namely 6% Microsilica by QS or 3% Microsilica by AD. Thus the addition of 12 % Microsilica by QS is the best way to improve the compressive strength of concrete containing GF or iron fiber.

The compressive strength of the iron-fiber concrete without Microsilica was reduced by 11.2% when NA was completely replaced by RA, for RAC. As the case with NRC, the incorporation of Microsilica improved the compressive strength of the iron fiberRAC, and the compressive strength increased with increasing Microsilica content. When 12% Microsilica was added by QS, the compressive strength of the RAC containing iron fiber increased by 32% and was 5% higher than that of Sample NRC. The reaction between Microsilica and $Ca(OH)_2$ produced by the hydration of cement created a new material—C–H–S gel, namely, the pozzolanic effect. This new material filled the hydration products, making the structure of concrete denser. To investigate the effects of the Microsilica content on the compressive strength of RAC with fiber, a comparison of the results of the present study with those of previous investigations concerning non-fiber RAC .It suggests that for the RAC without fibers, the strength improvement rate ranged from 3% to 7% and from 1% to 10% when adding 5% and 10% Microsilica, respectively. A comparison of these previous results with the present findings indicates that the modification effect of Microsilica on the RAC with iron fiber and GF was significantly better than that on the non-fiber RAC. That is, Microsilica and iron fiber have an excellent blending effect. In addition, the effect of adding 3% Microsilica by AD was similar to that of adding 6% Microsilica by QS. Based on the consideration of the compressive strength improvement and economic cost, 6% Microsilica by QS is a better choice than 3% Microsilica by AD.

DISCUSSION ON FLEXURAL TEST RESULTS

Failure mode

The prism samples invariably exhibited same failure patterns. The sample surface was much the same before the load reached the peak. When the peak load was reached, propagation of the pre-crack tip occurred, and a vertical crack was visible. With additional loading, the main crack quickly extended from end of the sample to the other. The failure modes of the fractured surfaces of Samples NRC, NRC-S0P, and RC-S12F were analysed. If we compare the sample NRC with Sample RC-S12F , the fracture surface of Sample RC-S12F was more uneven, which indicates that the iron fiber provided an anti-crack effect in the concrete. But the addition of GF did not cause any change in the failure mode of the sample. For Sample NRC, the main crack mainly propagated along the bonded surface between the NA and paste. For Sample NRC-S0P, the main crack also predominantly passed through the bonded surface between the NA and paste; however, a small amount of splitting occurred in the coarse aggregate, and the GFs were broken at the fractured surface. For Sample RC-S12F, more coarse aggregates (RA) were split, and the pulled-out iron fibers were distributed throughout the fractured surface. These observation show that the bond strength between the concrete and iron fiber was lower than the strength of iron fiber. The cracks must overcome the cohesive force between iron fiber and concrete and lead to pull-out and not breakage of the iron fibers to propagate. From the energetic viewpoint, a crack always propagates along the path with minimum energy consumption. Because the ITZ between the matrix and the processed aggregates was enhanced by the Microsilica, the weakest point, being in these RACs, may be the RA itself. Therefore, the main crack commonly passed through the processed aggregates, as established at a macroscopic scale.

Load–deflection curves

Mid-span deflection of the prism samples were taken from three-point bending test as shown in Fig. 10. A graph is drawn between Load and deflection. The peak loads (i.e., flexural strength) of the samples were determined from the load–deflection curves, and the results are tabulated in Table. GF slightly influenced the load–deflection curve of concrete. On the contrary, the addition of iron fiber significantly increased the peak load of the concrete, and the descending stage of the load–deflection curve became noticeably flatter. Thus, the flexural performance of the iron-fiber concrete is found to be better than that of the GF concrete. It can be seen that the addition of Microsilica had a minimal effect on the flexural strength and stiffness of the GF concrete; But the addition of Microsilica not only clearly improved the flexural strength of the iron-fiber concrete but also flattened the load–deflection curve after the peak load. This finding indicates that compared with the use of iron fiber alone, the combined use of Microsilica and iron fiber can provide additional benefits for the concrete’s flexural properties, which in turn can be attributed to the improvement of the bond strength between the iron fiber and paste. For the RAC, 100% RA replacement not only had an adverse effect on the flexural strength of the concrete but also led to the deterioration of the flexural stiffness. But the combination of iron fiber and Microsilica balanced the defects of RAC. As observed in Table, RAC sample containing iron fiber and Microsilica was found to have its flexural strength significantly higher than that of the NRC. Microsilica and iron fiber exhibited superior blending effect giving, the iron-fiber RAC with Microsilica good flexural strength.

CONCLUSION

The possibility of using Microsilica and iron or Glass fiber in Recycled or Processed aggregate (RAC) and Normal concrete (NRC) was extensively studied. Since compressive and flexural strengths play a crucial part in the design of elements, importance was given in securing the data pertaining to those properties.

The following remarks are based on the results obtained. Glass Fiber was found to be far better than that of shear-wave-type iron fiber on the compressive strength of concrete. The addition of iron fiber alone (without Microsilca) with a low aspect ratio lowered the compressive strength of concrete due to weak bonding interface. However, adding Microsilica compensated for this defect. Microsilica exhibited better modification effect on the compressive properties of the iron-fiber RAC when compared to non-fiber RAC. The improvement in strength of non-fiber RAC ranged from 3% to 10% when 6–12% Microsilica was added. But the compressive strength of RAC containing iron fiber was over 30% after adding 12% Microsilica. The blending effect of Microsilica and iron fiber improved the compressive and flexural properties of RAC. The flexural resistance of concrete using iron fiber was far better than Glass fiber. For enhancing the compressive and flexural properties, RAC incorporating iron fiber and Microsilica is a good alternative than normal concrete for use in concrete structures. 12% Microsilica by the equal quantity substitution of cement is the best option for enhancing the compressive and flexural strength of the iron-fiber RAC when compared to 3% by weight of cement substitution. From the perspective of performance improvement and economic cost, 12% Microsilica content by the equal quantity substitution of cement is optimal for the iron-fiber RA

REFERENCES

[1]. J. Tai, M. An, X.D. Wang, Annual Research Report on the Development of Urban Environmental and Sanitation Industry in India: 2015–2016, Shanghai JiaoTong University Press, Shanghai, India, 2017.

[2]. C. Shi, Y. Li, J. Zhang, W. Li, L. Chong, Z. Xie, Performance enhancement of processed concrete aggregate–a review, J. Cleaner Prod. 112(1), 2016, 466–472. Eng., 14(3), 42–49.