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Research Paper



Investigation on Mechanical and Durability Properties of Rapid Strength Gaining Concrete

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Abstract

The strength of cement paste and aggregate components helps to decide the strength of the concrete, their properties of deformation, and the binding properties among the aggregate surface and cement paste. It is conceivable with many of the aggregates to form high strength concrete by increasing the cement paste strength, which can be controlled by choosing of water-content ratio and type of admixture dosage. The current scenario in the concrete technology and the accessibility of many kind of mineral and chemical admixtures, and special super plasticizer to gain the targeted compressive strength of a concrete. In this study MYK Remicrete PC30 and BASF Master Glennium ACE 30 were utilized as the admixtures as Add 1 and Add 2 which acts as high rate water reducing agents. These developments have led to increase uses of Rapid strength concrete. To compare the mechanical and durability properties of concrete using Fly ash and Admixtures the following tests were conducted on concrete tests specimens. Mechanical tests are to be conducted such as compressive strength tests, and tensile strength tests, durability tests like water absorption test, acid test by HCL, H_2SO_4 and HNO_3. The result indicates that rate of development of compressive strength and tensile strength are higher for the concrete design mix which has HRWR admixture of 1% and FA of 20%.

Keywords: *Rapid strength concrete, Fly ash, Compressive strength, acid curing, Durability studies, Admixtures.*

1. Introduction

The Concrete is a composite material comprising of aggregate which encloses of cement with possible pozzolans and it has two main segments - cement paste and aggregates. With most characteristic aggregates, it is conceivable to make high quality cement by enhancing the strength of the cement mortar, which is controlled through the selection of water-cement ratio, type and dosage of admixtures[1, 2]. The cost of construction has been reduced by using chemical admixtures which also helps to change the properties of hardened concrete. High-range water reducers (HRWR) were commonly referred as super plasticizers, are admixtures of chemical that can be added to ready-mix concrete which improves its plastic and hardened properties. They are also known as super fluidizers, super fluidifiers and super water reducers [3].

High-range water reducers are capable of decreasing the slump by 30% as the decrease of water requirement, which helps to produces good quality concrete having more strength and less permeable. They are more advantageous as compare to conventional water reducers which helps for the reduction of water requirement up to 15%.By adding super plasticizer the workability of the concrete increases [4, 5]. However, high dosages for super Plasticizer have a tendency will disable those cohesiveness of cement. By using the chemical type admixtures slump loss might be reduced. The compressive strength of concrete is improved by addition of SP compared with control concrete, even its ultimate strength is more than the desired compressive strength concluded by Salahaldein Alsadey (2012) [6].The permeability and strength of concrete containing fly ash, silica fumes and high slag cement can be beneficial in the utilize of these waste materials in concrete work, mostly in the terms of durability concluded by Elsayed (2012) [7]. To overcome this gap, this study aims to use of HRWR for the decrease in the water content and increase in the compressive strength of the concrete cube and which with stands to the acid resistance with HNO_3, HCL, H_2SO_4.

2. Materials and Methods

2.1. Materials Used

The cement use in preparing the test specimens was Ordinary Portland cement 53 gradecomplying with IS 269:2015 and was packed in 50 Kg bags.The Fly ash used in preparing the test specimens was collected from Ennore thermal power station confirming to IS 3812 -1:2003 as reported by [8-10].The fine aggregates used was natural River sand confirming to Zone II. The sand was air dried prior to use.The coarse aggregate used was a 20mm and 12.5mm downgraded aggregated. Portable water is used for mixing and curing of the test specimens. High range water reducing admixtures from two different companies were used in preparing the test specimens. As per the product specification the dosage of

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admixture is added as 1% of the cementitious materials in concrete.As per the product specification the dosage of admixture is added as 1% of the cementitious materials in concrete.The admixtures will be MYK Remicrete PC30 (Add1) and BASF Master Glennium ACE 30 (Add 2) used in this investigation.

2.2 Mix Proportions Details

Many trial batches were performed in the laboratory andseveral adjustments were carried out in order to identifythe optimum proportions as reported by [11]. The concrete ingredientsselected for use in this study are representative ofmaterials typically used in Chennai. IS10262:2009 method is used for Mix design. The final Mix proportionobtained for M30 grade control concrete is 1: 2.4: 3.36 (W/C is 0.45) with fixed cement content, aggregate system, and water cement ratio was for consistency. FA replacement ranged 20% and 40%, and HRWR admixture 1% on the total cementitious material.

2.3 Specimen Preparation and Testing

Cube mould of size 150 x 150 x 150mm is used for making specimen using 20% and 40% of Flyash with control and admixture concrete. Oil is applied inside the cube mould and concrete is filled in three layer up to the mould height and compacted by tapping rod of 25 blows in each layer.Cube Specimens are used for testing acid resistance, water absorption, and compressive strength.Cylinder of size 100mm diameter and 300mm long is used for making specimen using 20% and 40% of Flyash with control and admixture concrete. Oil is applied inside the cube mould and concrete is filled in three layer up to the mould height and compacted by tapping rod of 25 blows in each layer.Cylinder specimen is used for Splitting tensile test.
Compaction factor and slump cone test was performed on fresh concrete to know the effect of adding HRWR admixture and pozzolanic materials on workability of concrete.Casted concrete cubes are tested at 7 days , 14 days , 28 days as per the IS 516-1959. The average test result of three specimens was taken for comparison.Casted cylinders are tested at age 7 days, 14 days , 28 days as per the IS 5816 (1999), Reaffirmed (2004),The average test result of three specimens was taken for comparison.Casted cube specimens were tested after 28 days of curing as per ASTM C 642-97. The average test result of three specimens was taken for comparison.Casted cube specimens were tested after 28 days of curing as per ASTM C 267. The cube specimens were tested with three acids HCL, H_2SO_4, and HNO_3. The average test result of three specimens was taken for comparison.The casting and testing of concrete specimens shown in Figure-1.

3. Results and Discussion

3.1 Physical Properties Of Cement

The basic properties of the cement used are tested as per IS 4031 and confirms the requirement of IS 8112: 1989. The normal consistency is to be found as 27.5% by using the v-cat apparatus. The specific gravity is to be found as 3.15. The initial setting time is 125 minutes and the final setting time is 240 minutes. The fineness and the soundness of the cement is 292 m^2/Kg and 1.0 mm respectively. The compressive strength at 1 day of curing is 30.4 MPa. The compressive strength ay 3 days is 44.8 MPa. The compressive strength at 7 and 28 days is 54.4 MPa,60.14MPa respectively.

3.2 Physical Properties Of Fine And Coarse Aggregate

The Tests were conducted to know the physical properties of fine and coarse aggregate as reported by [12]. The test details are given in Table 3.1.The below Table 3.1 represents the river sand and the coarse aggregate used for this research satisfies the IS requirements. The specific gravity of the fine aggregate is to be found out using the pycnometer test which was found to be 2.63. For the coarse aggregate of 20 mm and 12.5 mm the specific gravity is to be found as 2.7 and 2.71. Different tests were conducted as bulk density, water absorption for both fine aggregate and coarse aggregate. Flakiness index, Elongation Index, Impact Value, Crushing value tests for coarse aggregate of both 20 mm and 12.5 mm sizes.



Fig.1: Casting and testing of specimens

Table 3.1 Physical properties of fine and coarse aggregate

Test Conducted	Fine aggregate	Coarse aggregate	
	sand	20mm	12.5 mm
Specific gravity	2.63	2.70	2.71
Bulk density – Loose	1.54 kg/ltr	1.572 kg/ltr	1.581 kg/ltr
Bulk density – Rodded	1.67 kg/ltr	1.712 kg/ltr	1.734 kg/ltr
Water absorption	1.25 %	0.45 %	0.40 %
Flakiness Index	-	14.0 %	24.2 %
Elongation Index	-	14.2 %	21.0 %
Impact Value	-	16.8%	15.15 %
Crushing Value	-	24.6%	22.60 %

3.3 Fresh Concrete Behavior

The test results of slump value at initial on fresh concrete is shown in Figure-2. Slump test was performed on fresh concrete to know the effect of adding HRWR integral admixture and pozzolanic materials on workability of concrete as reported by [13-14]. The slump value is more for the mix OPC + 40% FA+ Add-1 which is 90 mm while compared to the remaining mixes and the slump value is less for both mixes of OPC + 40% FA which is 25 mm. The test results of compaction factor on fresh concrete is shown in Figure-3. Compaction factor was performed on fresh concrete to know the effect of adding HRWR integral admixture and pozzolanic materials on workability of concrete as reported by [15]. The compaction factor value is more for the mix OPC + 40% FA+ Add-1 which is 0.89 while compared to the remaining mixes and the compaction factor value is less for both mixes of OPC + 40% FA and OPC + 20% FA + Add-2 which is 0.855.

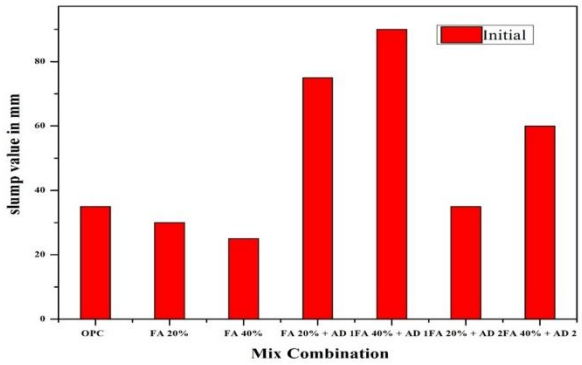


Fig.2: Slump values of fresh concrete

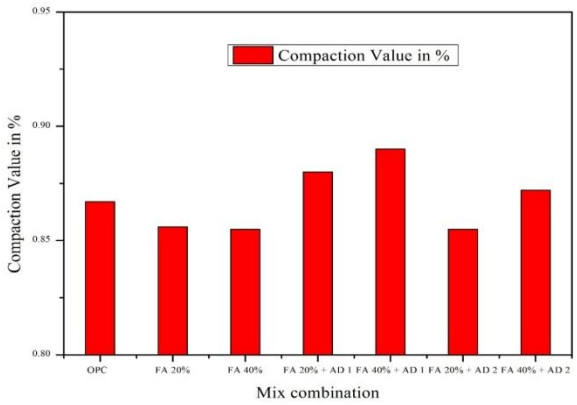


Fig. 3: Compaction Factor values of fresh concrete

3.4 Compressive strength of concrete

The compressive strength of concrete with different mix proportions are shown in Figure-4 and 5. The compressive strength test results shows that concrete made with of 20% FA and 1% HRWR admixture -1 has high compressive strength at the age of 3 days, 7 days, 28 days than all other mixes as reported by [16-17]. For the 3 days of curing the strength is increased by 18.18 %, for the 7 days curing the strength is increased by 21.22% and for 28 days of curing the strength is increased by 0.2% as compared to OPC.

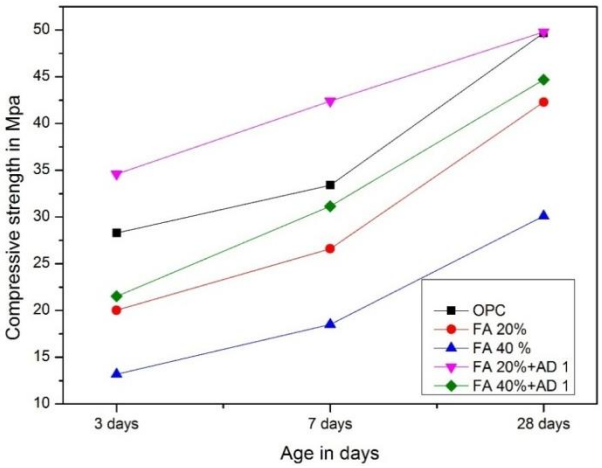


Fig. 4: Compressive strength of concrete with Admixture 1

From the Figure-5, the test results show that the maximum compressive strength achieved is 54.7 MPa at 20% of FA replacement addition with 1% HRWR admixture 2 and those achieved for 40% with 1% admixture 1. For the 3 days of curing the compressive strength increases by 3.4% , for 7 days of curing the compressive strength increased by 18.05% , for 28 days of curing the compressive strength increased by 9.14% as compared to OPC.

3.5 Splitting tensile Strength of concrete

The different mix proportions of concrete specimen tested the split tensile strength shown in Figure-6 and 7. Split Tensile strength test results shows that concrete made with of 20% FA and 1% HRWR admixture -1 has high Tensile strength at 3,7 and 28 days than all other mixes as reported by [18]. For 3 days curing the tensile strength increases by 19.776%, for 7days curing the tensile strength increases by 11.76% and for 28 days curing the tensile strength increases by 16.8% while compared to OPC. From the Figure-7, Split Tensile strength test results shows that concrete made with of 20% FA and 1% HRWR admixture -2 has high Tensile strength at 3,7 and 28 days than all other mixes. For 3 days curing the tensile strength increased by 7.32%, for 7 days curing the tensile strength increased by 1.8% and for the 28 days curing the tensile strength decreased by 0.28% while compared to OPC.

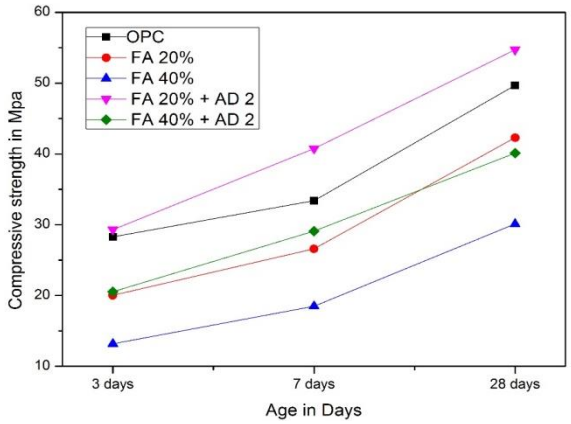


Fig.5: Compressive strength of concrete with Admixture 2

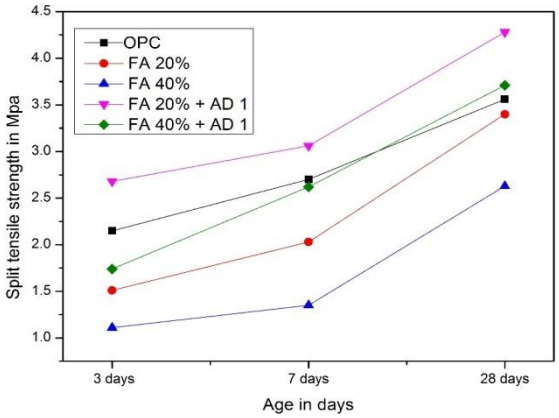


Fig.6: Split tensile strength of concrete with Admixture 1

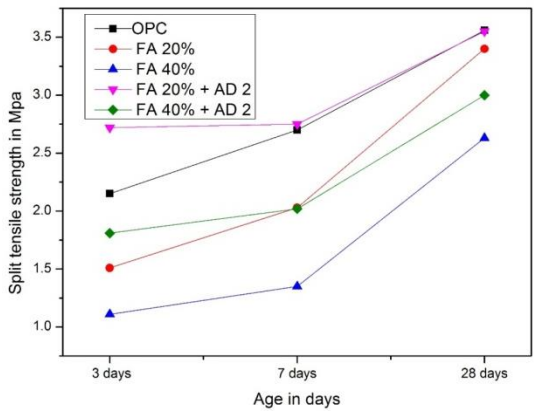


Fig.7: Split tensile strength of concrete with Admixture 2

3.6 Comparison of Normal and Different Acid Curing Compressive Strength Of Concrete

The compressive strength of concrete normal curing and HCL, $HNO_3$and H_2SO_4 curing acid curing at the age of 60 days results shown in Figure-8. The acid resistance test result shows that concrete made with 20% FA with Admixture 2 has higher compressive strength at 28 days of HNO_3 acid curing. It reaches the compressive strength up to 65.51 MPa while compared to the normal curing of 54.7 MPa the increase in the compressive strength is 16.50%.

The compressive strength of concrete normal curing and HCL curing acid curing at the age of 60 days acid resistance test result shows that concrete made with 20% FA with Admixture 1 has higher compressive strength at 28 days of HCL acid curing as reported in [19-21]. The increase in the compressive strength for the acid curing is represented as 67.22 MPa compared to the normal curing of 49.8 MPa and the varying the compressive strength shown as 25.91%.The compressive strength of concrete normal curing and H_2SO_4 curing acid curing at the age of 60 days acid resistance test result shows that concrete made with 20% FA with Admixture 2 has higher compressive strength at 28 days of H_2SO_4 acid curing. The compressive strength for the acid curing shown as 63.3 MPa and for the normal curing is shown as 54.7MPa then the varying of compressive strength is shown as 13.5%.

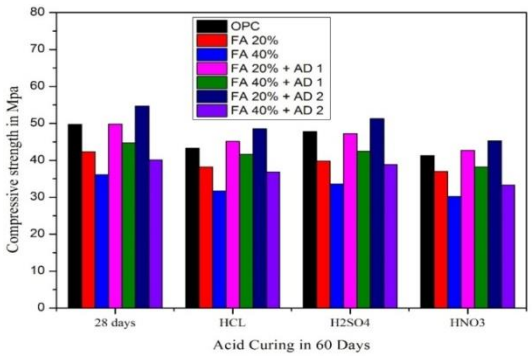
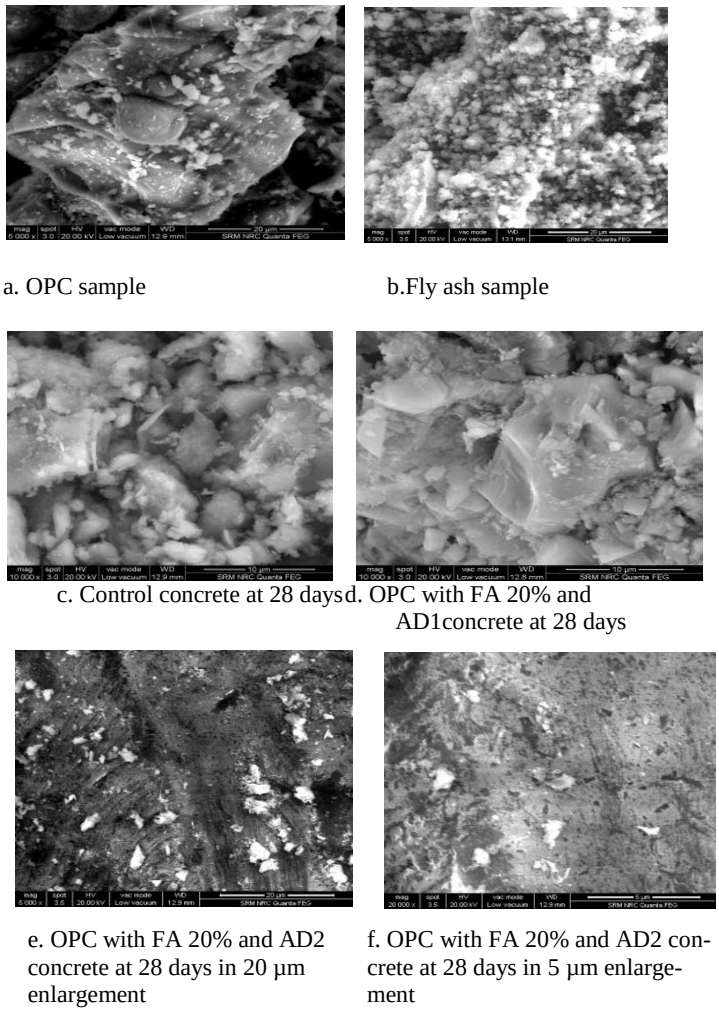


Fig.8: Comparison of compressive strength between normal curing and acid curing

3.7 Scanning Electron Microscope Analysis

The micro structure of the test specimens from the scanning microscope analysis are done for materials such as Cement and fly ash and concrete specimens at the age of 28 days. The samples from the concrete specimens are collected after the crushing of cubes for compressive strength at the age of 28 days curing as reported by [22-24]. The collected samples are further grind to powder form for scanning electron microscope image and is shown in Figure-9.



a. OPC sample b.Fly ash sample

c. Control concrete at 28 days d. OPC with FA 20% and AD1concrete at 28 days

e. OPC with FA 20% and AD2 concrete at 28 days in 20 µm enlargement f. OPC with FA 20% and AD2 concrete at 28 days in 5 µm enlargement

Fig.9: SEM image analysis for cement and fly ash blended concrete

From the Figure 9, the SEM image shows that the Fly Ash having denser and less voids in its micro structure than control concrete. This is because of the reason that the Fly Ash is finer than cement. The grinding process of Fly Ash from the source is effectively done. The SEM image evident that the cement particles are angular in shape which may be the reason of cement got grounded with the help of vertical roller mill technology as reported by [25-26]. From the SEM analysis, it is evident that the concrete mix with FA and admixture is having more density and good cohesive between cement and aggregates. Also it is evident from the SEM images that the control mix is having more porous than the concrete made with admixture.

4. Conclusion

From the analysis of the results of the experimental work following conclusions are to be made with respect to the utilization of FA and HRWR admixture.

- Result indicates that the rate of development of compressive strength and tensile strength are higher for the concrete design mix which has HRWR admixture of 1% and FA of 20%.
- From the experimental work, the compressive strength was found to be higher than that of the other mixes in the initial and later stages for the design mix with 20% FA and with 1% HRWR admixture. Also, found that the development of tensile strength was higher than the other mixes for the design mix with 20% FA and with 1% HRWR admixture.

- The early strength is comparatively less in FA where as it is very high in HRWR admixture concretes than control concrete.
- Significant strength increase is observed in FA concretes when replaced with 20% than control concrete. The results indicate that the strength benefits are increased as the age of FA concrete increases.
- Results evident that the admixtures added in the concrete stimulate which resulted in high compressive strength and better resistance to different acids.
- The use HRWR admixture in the range of 1% and to replace cement by 20% with FA for better results subject to further tests and investigation with longer curing ages such as 180 and 360 days.

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