

Experimental Investigation on Strength and Durability Characteristics of HPC with Polypropylene Fibre and Silica Fume

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ABSTRACT: Cementitious materials have been in existence for a long time and it is a well known fact that their use in construction activity dates back to the time of Babylonians, Romans and Egyptians. These materials had undergone several changes over the ages and during the past four decades, changes both in the process and concrete composites to be the most economical construction materials of today, in this paper presented the study of compression strength test and durability properties of HPC using polypropylene fibre adding with quarry dust as a partial replacement of fine aggregate with silica fume as the mineral admixture. And find the optimum percentage of Quarry dust replacement and cast a beam with the same mix and to study the flexural behavior of beam and to compare the studies with nominal mix also carry out finite element and modeling analysis using ANSYS and compare the flexural behavior of beam with the experimental results.

KEYWORDS: durability, polypropylene, quarry dust, silica fume, ANSYS.

I. INTRODUCTION

Concrete, despite its inherent deficiencies, is the most extensively used material world-wide for the construction of large infrastructural facilities. In the recent past, there has been considerable attention for improving the properties of concrete with respect to strength and durability, especially in aggressive environments. In the foreseeable future, there seems to be no alternative to concrete as a construction material. There has been substantial advancement during the last 90 years in the science and practice of concrete technology, out of which the 30 years have seen phenomenal progress. Although the compression strength of the concrete has been historically and steadily increasing, the commercial potential of high strength concrete (HSC) became evident for the columns high rise buildings in the 1970s in the United States. The use of HSC for high rise building is now being made world-wide.

During the last two decades, it has been realised that besides strength, there are other equally important criteria for the characterisation of concrete such as durability, workability and toughness. For example, in pre stressed concrete bridges, the concrete should have not only high strength but also reduced shrinkage and creep. For bridges, offshore structures highway and airport pavements and machine foundations, concrete should possess high fatigue strength. For nuclear containers exposed to very high temperatures, the concrete must have a high resistance to thermal cracking. Therefore, considerable attention has been paid to the research and development of high performance concrete (HPC) with a view to enhance the potential of the material to build for the service life of about 100years, instead of customary 40 to 50 years and to provide satisfactory performance under different aggressive environments. All these needs made the engineer think seriously to find out the appropriate technology for improving of concrete.

The technologies developed during the last two decades have led to the improved importance of concrete construction industry; others aimed at improving the performance of concrete as an engineering material. To improve the performance of concrete, numerous new technologies and products have been developed. Notable among them are high strength concrete containing super plasticizer, fibre reinforced concrete, latex-modified concrete, chemically bonded ceramics, macro defect-free cement products and epoxy coated reinforcing steel. Due to high cost and special

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 1, Januray 2016

problems, many researchers believe that the total volume of concrete made by the application of these technologies is too likely to be large. Due to their relevance to durability, the HSC and HPC technologies need to be studied in detail.

Also, it was realized that the high strength alone will not be an effective method for achieving high performance and that the durability of these materials in various environments needs a better understanding to achieve an appropriate solution. These necessitated the utilisation of industrial wastes having pozzolonic property in concrete and showed the possibility of obtaining improvements in durability, besides attaining HSC composites. The improvement milestone of these works is probably the introduction of silica fume. With the use of both pozzolonic materials and super plasticizer, it is now possible to incorporate both high strength and high performance in concrete composites.

II. REVIEW OF LITERATURE

Several researchers from worldwide have investigated the properties of the concrete using quarry dust as a replacement of natural fine aggregate. The present study is about the properties of fibre reinforced HPC using quarry dust. Hence an attempt is made in this chapter to review briefly the recent studies on quarry dust used in concrete structures

Babu K.K., Radhakrishnan R. (1997) "Compressive Strength of Brick Masonry with Alternative- Aggregate Mortar" reported that physical and chemical properties of quarry dust is satisfied the requirements of code provision of IS 4032 in properties studies. Natural river sand, if replaced by 100% quarry dust may sometimes give equal or better strength than the reference concrete made with natural sand in terms of compressive and flexural strength studies.

Ilangovan R. and Nagamani K. (2006) reported that 100% replacement of natural sand with quarry dust is possible with proper treatment of quarry dust. Quarry waste fine aggregate was used in presence of silica fume. The overall results revealed that quarry dust can be utilized in concrete as a good substitute of natural sand. It is found that the compressive, flexural strength and durability studies of concrete made of quarry dust nearly 10% more than the conventional concrete

Indira P.V. (2009) reported that the standard mix design methods cannot be directly applied to HPC since various additional parameters are to be considered simultaneously. ACI 211 was a recommended code to make a mix proportioning of HPC.

Norazila (2010) reported that sand can be replaced by quarry dust up to 40%.

Raman S.N. and M.F.M. Zain (2007) "Non destructive Evaluation of Flowing Concretes Incorporating Quarry Waste" indicated that quarry waste did not significantly affect the non destructive properties of the concrete except initial surface absorption, Dynamic modulus of elasticity, ultra pulse velocity and initial surface varied linearly with compressive strength.

Rajkumar B. et al (2005) reported that one could not use I.S. method as it leads to harsh mixes with low slump for recycled aggregate concrete and they suggested DOE method can be adopted for design.

Sahu A.K., Sunil Kumar (2003) "Quarry Stone Waste as Fine Aggregate for concrete" reported that significant increase in compressive strength, modulus of rupture and split tensile strength when 40% of sand is replaced by Quarry Dust in concrete.

From the research works, it is noticed that there is not much literature available on the study of quarry dust and recycled fine aggregate influencing the durability properties of fibre reinforced high performance concrete. Taking note of the above gap in existing knowledge, an attempt is made in the present study for in the point of durability characteristics.

III. MATERIAL PROPERTIES AND MIX PROPORTIONING

In developing the concrete mix for high performance concrete (HPC), it is important to select proper ingredients, evaluate their properties and understand the interaction among different materials for optimum usage. The ingredients used for this investigation were the same as that used for normal strength as cement, coarse aggregate(CA), fine aggregate(FA) and chemical admixture except silica fume which is generally not used in conventional concrete. The performance requirements of concrete may involve enhancement of the following:

- Ease of placement and compaction without segregation
- Long term mechanical properties
- Early strength

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 1, Januray 2016

- Toughness
- Volume stability
- Long term durability properties
- Long service life

Effective production of HPC is achieved by carefully selecting, controlling and proportioning all ingredients. In order to achieve HPC, proportions must be selected, considering the characteristics of cementitious materials, aggregate quality, paste proportion, aggregate past interaction, admixture type, dosage and meticulous care in mixing and handling.

Cement: The present investigation, 'ACC' (brand name) 53 grade OPC conforming to BIS: 12269-1987 was used. The cement sample was tested as per the procedure given in BIS: 4031-1987 and BIS: 4032-1985.

Quarry Dust: Crushed sand less than 4.75 mm is produced from hard granite rock using state of the art JAW, CONE, VSI Crushing plants. Production of quarry fines is a consequence of extraction & processing in a quarry

Fine aggregates: locally available Karur river sand was used as fine aggregate. The sand was washed and screened at site to remove deleterious materials and tested as per the procedure given in BIS: 2386-1968

Coarse aggregate: The coarse aggregate meeting the requirement of BIS: 383-1970 is suitable for making HPC. Considering all the above aspects, blue granite crushed stone aggregates of 12.5 mm maximum size and of typical particle shape "average and cubic" were used as the coarse aggregate for this present investigation. The aggregates were tested as per the procedure given in BIS: 2386-1963

Superplasticizer: CONPLAST SP 430 is to be used for obtaining workable concrete at low w/b ratio. CONPLAST SP 430 complies with BIS: 9103-1999 and BS: 5075 part 3 and ASTM C 494, Type 'B' as a HRWRA. CONPLAST SP430 is based upon NSF condensates.

Methods of Mix Design

Design of HPC mixes involves determination of the proportion of constituents, cementitious materials (cement and silica fume), coarse and fine aggregates, water and chemical admixture (superplasticizer), so that resultant composition produces a mix which will possess specified properties in fresh and hardened state. Mix design of HPC is more critical process than the design of normal strength concrete (NSC), due to the presence of mineral and chemical admixtures and attainment of low water-binder materials ratio.

The mix design procedure of NSC as presently prevailing in India was found not suitable for mix design of HPC using mineral admixtures. The American Concrete Institute (ACI) methods are available for both NSC and HSC. The ACI method of mix design for HSC considers only the use of fly ash and superplasticizer.

Since there is no specific method of mix design found suitable for HPC, a simplified mix design procedure is formulated by combining the BIS method, ACI method of mix design for HSC and the available published literatures on HPC, using silica fume. The procedure itself is very simple. It follows the same approach as ACI does. It is the combination of empirical results and mathematical calculations based on the absolute volume method.

Required material for 1 cum. of concrete:

Cement	=497.17 kg/m ³
Fine aggregate	=602.91 kg/m ³
Coarse aggregate	=1193.24 kg/m ³
Water	=139.2 litres/m ³
Super-plasticizer	=9.94 litres/m ³

The obtained Mix design ratio for the M60 grade concrete is 1: 1.21: 2.4 and the water-cement ratio amounts to 0.27

Various proportion of Mixes

Mix – 1: (85% C+15% SF): (10% QD+90% FA): (CA): (0.1% PpF)

Mix – 2: (85% C+15% SF): (20% QD+80% FA): (CA): (0.1% PpF)

Mix – 3: (85% C+15% SF): (30% QD+70% FA): (CA): (0.1% PpF)

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 1, Januray 2016

Mix – 4: (85% C+15% SF): (40% QD+60% FA): (CA): (0.1% PpF)

Mix – 5: (85% C+15% SF): (50% QD+50% FA): (CA): (0.1% PpF)

Mix – 6: (85% C+15% SF): (60% QD+40% FA): (CA): (0.1% PpF)

IV. EXPERIMENTAL INVESTIGATION ON CUBE SPECIMENS

Concrete structural components exist in buildings and bridges in different forms. Understanding the response of these components during loading is crucial to the development of an overall efficient and safe structure. Different methods have been utilized to study the response of structural components. Experimental based testing has been widely used as a means to analyze individual elements and the effects of concrete strength under loading. While this is a method that produces real life response, it is extremely time consuming and the use of materials can be quite costly. The use of finite element analysis to study these components has also been used.

Experimental based analysis has been widely used as a means to find out the response of individual elements of structure. To study these components finite element analyses are now widely used & become the choice of modern engineering tools for the researcher. In the present study, destructive test on simply supported beam was performed in the laboratory & load-deflection data of that under-reinforced concrete beams was recorded. After that finite element analysis was carried out by ANSYS by using the same material properties. Finally results from both the computer modeling and experimental data were compared. The observation was mainly focused on reinforced concrete beam behavior at different points of interest which were then tabulated and compared.

Based on the compression strength results indicated in chapter 4, a concrete beam of size 100mm x 150 mm x 1500 mm was cast using mix 5 for concrete grade M60. The results were compared with the control beam made out of the nominal mix.

Flexural Strength Test of Reinforced Concrete Beams:

In this test, a reinforced concrete beam was subjected to flexure using symmetrical two point loading until failure occurs. As the load point was placed at 1/3rd of the span, the test was also called as third point loading test. The theoretical maximum tensile stress reached in the bottom fiber of the test beam is called modulus of rupture. The bearing surfaces of the supporting and loading rollers were wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they were to make contact with the rollers. The specimen was then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould. The axis of the specimen is carefully aligned with the axis of the loading device. The load is applied without shock and increasing continuously at a rate such that the extreme fiber stress increases at approximately 0.7kg/cm²/min. the load was increased until the specimen fails, and the maximum load applied to the specimen during the test was recorded.

Table 1 Flexural Test Results for Beam - B1

S. No.	Load (kN)	Deflection (in mm)			Observations
		Left	Middle	Right	
1	0	-	-	-	
2	2	0.054	0.075	0.056	
3	4	0.196	0.230	0.205	
4	6	0.290	0.380	0.300	
5	8	0.314	0.535	0.328	
6	10	0.415	0.685	0.435	
7	12	0.575	0.855	0.598	

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 1, Januray 2016

8	14	0.620	0.995	0.645	First Crack
9	16	0.775	1.180	0.788	
10	18	0.945	1.350	0.955	Secondary Cracks
11	20	1.035	1.515	1.060	
12	22	1.220	1.895	1.245	
13	24	1.485	2.080	1.515	
14	26	1.600	2.270	1.750	Ultimate Load

Table 2 Flexural Test Results for Beam – B2

S. No.	Load (kN)	Deflection (in mm)			Observations
		Left	Middle	Right	
1	0	-	-	-	
2	2	0.035	0.056	0.040	
3	4	0.050	0.079	0.055	
4	6	0.095	0.125	0.105	
5	8	0.145	0.235	0.154	
6	10	0.210	0.400	0.235	
7	12	0.290	0.550	0.300	
8	14	0.395	0.715	0.405	
9	16	0.515	0.875	0.520	
10	18	0.635	1.030	0.650	
11	20	0.785	1.190	0.795	
12	22	0.935	1.350	0.960	First Crack
13	24	1.155	1.460	1.190	
14	26	1.260	1.585	1.275	Secondary Cracks
15	28	1.375	1.705	1.395	
16	30	1.530	1.915	1.560	
17	32	1.695	2.270	1.750	
18	34	1.850	2.405	1.900	
19	36	2.015	2.600	2.050	Ultimate Load

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 1, Januray 2016

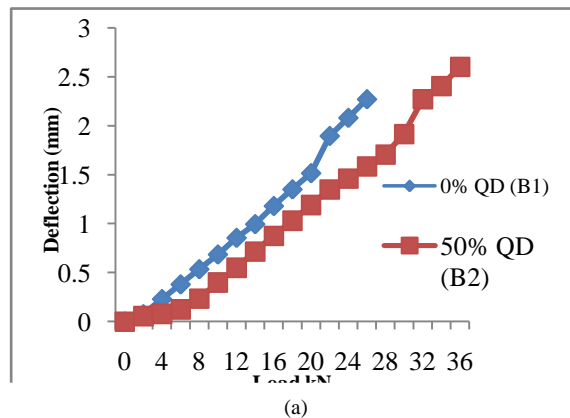


Fig. 1 (a). Load vs Deflection curve for the test beams

From the test results it is seen that the beam with 50 % Quarry dust replacement performs well when compared with the beam made out of nominal mix.

Finite Element Modeling and analysis of Beam:

In recent years, however, the use of finite element analysis has increased due to progressing knowledge and capabilities of computer software and hardware. It has now become the choice method to analyze concrete structural components. The use of computer software to model these elements is much faster, and extremely cost-effective. Experimental based testing has been widely used as a means to analyze individual elements and the effects of concrete strength under loading. While this is a method that produces real life response, it is extremely time consuming and the use of materials can be quite costly. The use of finite element analysis to study these components has been used commonly. The use of FEA has been the preferred method to study the behavior of concrete (for economic reasons).

The objective is to investigate and evaluate the use of the finite element method for the analysis of reinforced concrete beams. A calibration model using a commercial finite element analysis package (ANSYS) was set up and evaluated using laboratory data. A mild-steel reinforced concrete beam with flexural reinforcement was analyzed to failure and compared to experimental results to calibrate the parameters in ANSYS for later analyses. The observation was focused on reinforced concrete beam behaviour, load-deformation response.

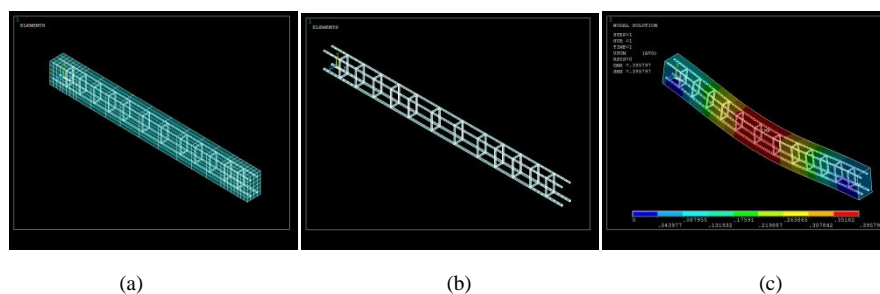


Fig. 2 (a) Modeling and Meshing of beam (b) Reinforcement in beam (c) Finite element Analyses of beam

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 1, Januray 2016

V.RESULTS AND DISCUSSIONS

The beam is studied for different parameters i.e. Maximum principle stress, Minimum principle stress and Displacement on the application of load.

Table 3 Results for beam type B1

Load in KN	Displacement in mm	Mini. Stress in N/mm ²	Maxi. Stress in N/mm ²
5	0.035	-0.6090	0.8418
10	0.435	-10.0995	10.8004
15	0.895	-12.8092	12.9675
20	1.115	-15.1587	15.3482
25	1.846	-19.4434	18.5649

Table 4 Results for beam type B2

Load in KN	Displacement in mm	Mini. Stress in N/mm ²	Maxi. Stress in N/mm ²
5	0.055	-0.4570	0.6698
10	0.537	-7.6752	9.8345
15	0.915	-10.4369	12.1583
20	1.285	-15.4728	17.8565
25	1.659	-22.3576	24.8876
30	2.146	-26.5793	28.8974

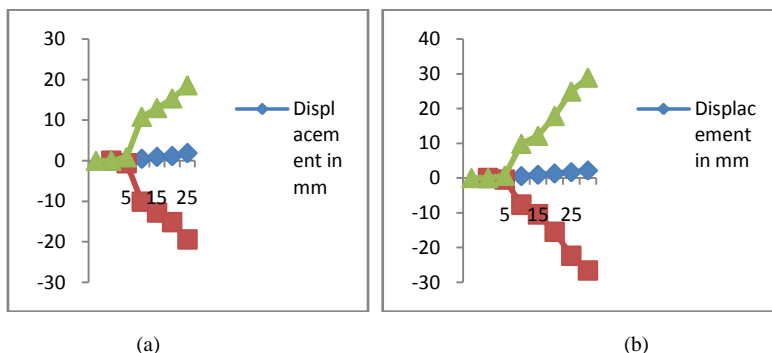


Fig. 3 (a) Load vs Maximum Deformation, Minimum Stress, Maximum Stress Graph for Beams B1 (b) Load vs Maximum Deformation, Minimum Stress, Maximum Stress Graph for Beams B2

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 1, Januray 2016

Tables 3 and 4 shows a comparison between the analysis of beams B1 and B2. The results show that the performance of B2 is better than B1. As load increases displacement, minimum stress and maximum stress also increases. One can also study different loading conditions on beam i. e. cyclic loading, random loading etc.

VI.CONCLUSION

Compression strength and various durability properties of various trials of concrete mix prepared with varying quarry dust proportions were measured and compared with nominal mix of M60. Based on the tests carried out studies the following conclusions were made.

1. Water absorption and porosity of quarry dust aggregates is found to be lesser than that of ordinary fine aggregates.
2. Mix with 0.1% of polypropylene fibre and 50% quarry dust gives a maximum compressive strength of 77.6 MPa when compared with nominal mix and also achieved good results in water absorption, porosity, sorptivity, acid resistance, sea water resistance.
3. Concrete with polypropylene fibre gives smooth finish.
4. Nominal mix gave better finish than concrete with quarry dust.
5. In porosity test Mix 5 and Mix 4 gives a better results comparing to the other trials. Up to 10% of reduction is achieved in Mix 5 and mix 1.
6. In Sorptivity test Mix 4 and Mix 5 gives a better results comparing to the other trials. Sorptivity value is reduced up to 70 to 75 % in both the mixes.
7. Acid resistance test shows Mix 5 gives an excellent result with the reduction of 35% in weight loss compared to the nominal mix.
8. Beam with 50% Quarry dust and 0.1% fibre shows 33% increase in flexural strength when compared to the control beam.
9. From the two point loading experimental test results and the finite element analysis on beam, it is seen that the beam with 50% Quarry dust replacement performs well when compared with the control beam.

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