Effects of Coarse Aggregate and Admixtures in High Performance Concrete

R.V. Sankaranarayanan [1], N. Nalanth [2]

[1,2]Noorul Islam Centre for Higher Education, INDIA

Article Info
Volume 82
Page Number: 16936 - 16940
Publication Issue:
January - February 2020

Article History
***Article Received**: 18 May 2019*
***Revised**: 14 July 2019*
***Accepted**: 22 December 2019*
***Publication**: 29 February 2020*

Abstract

In the construction field, HPC (High Performance Concrete) becomes a leading construction method due to its enhanced structural properties. This investigation analyses various applications of HPC in the construction field and analyse the effects of various constituents of HPC incorporated in concrete mix. The main contribution of this work is to analyse the influence of coarse aggregate, mineral and chemical admixtures in the HPC mix. The effects of each material in HPC are studied by the failure mechanism under uniaxial compression mode. Critical parameters that lead to the failure of the idealized HPC specimen determined by conducting parametric studies.

Keywords; *High performance Concrete, complex structure construction, silica fume, coarse aggregate, Superplasticizer, Ground granulated blast furnace slag.*

I. INTRODUCTION

In India, each year 100 million cubic meters of concrete were utilized in the construction field. [1]. Conventional concrete structures easily affected by aggressive environmental weathering conditions, take much time for construction, less energy absorption ability and do not meet the functional requirements of repairing structures. So, it is necessary to design an advanced concrete that performs far superior to conventional concrete. A special type of concrete developed to achieve superior performance and uniformity requirements that are not able to attain by conventional concrete is named High-Performance Concrete [2]. Recently HPC has used as a construction material in complex structure production [3]. The major typical applications of HPC such as bridges, platforms, high rise buildings, and protective structures. Many trials have been conducted to enhance the mechanical properties of HPC thereby enhance the structural applications. Cement, fine aggregate, coarse aggregate, mineral, and chemical admixtures are the main constituents of HPC. The effects of these constituents play a major role in the placement and compaction of concrete without segregation, early age strength, mechanical properties, the stability of volume or life time and performance in aggressive circumstances. Table 1 listed out the requirements of HPC when it is utilized in the Strategic Highway Research Program. In this research, the effects of constituents of HPC were investigated by reviewing various research works conducted on HPC. In the following sections, the effects of admixtures and coarse aggregates are elaborately explained to attain an optimum mix design of HPC.

II. OVERVIEW

Conventional concrete is a normal construction material that contains coarse aggregate, fine aggregate, water, chemical, and mineral; admixtures. In concrete structure, coarse aggregate is implanted in the cement paste. Elastic modulus of the coarse aggregate contributes the main role in its strength properties. Normally mortar matrix elastic modulus is lower than that of elastic modulus of Coarse aggregate. This mismatch reflects their stress when the concrete structure is getting loaded. These issues are eradicated in HPC concrete by reducing water content, incorporation of mineral and chemical admixtures thereby strengthening the ITZ. The role of admixtures and coarse aggregate is elaborated in the upcoming sections of this work.

Table 1 Requirements of High-Performance Concrete

Characteristics	Time Duration	Required Values
Compressive strength	4 hours	≥17.5 N/mm^2
	24 hours	≥35 N/mm^2
	28 days	≥70 N/mm^2
W/C ratio		≤0.35
Durability factor		>80 after 300 cycles of freezing and thawing

III.EFFECTS OF COARSE AGGREGATE AND STEEL FIBRES IN HPC

Several previous works have analyzed the effects of CA type, particle size, shape, stiffness, strength and mineralogical composition play an important role in the mechanical properties of HPC. HPC blocks cast using stronger aggregates exhibited increased their strength properties in fresh and hardened stages H. [4], [5] explained the performance of CA in HPC at ambient temperatures. Different dosages of aggregate volume and steel fibers were incorporated into this study. Bulk material dosages are 0%, 16%, 28% and 38%. And steel fibre dosage in HPC is 0%, 1%, 2% and 3%. Mechanical properties and parametric studies have conducted and the outcomes proved that the strength properties increased in CA level from 0% to 28% and decreased from 29% to 38%. The increased amount of CA in HPC reduced the flexural properties such as maximum deflection, peak load, toughness, and ductility. At the same time, incorporation of steel fibre increased the split tensile strength and flexural properties but it has limited influence on compressive strength properties. The following figure explains the effects of CA in HPC. Synergistic effects are created in HPC specimens due to the inclusion of CA and steel fibres. Incorporation of steel fibre improved the tensile strength, restrain crack extension and bridge cracks [9] at the same time CA in HPC form a rigid skeleton thereby enhanced the stiffness as well as compressive strength of the concrete [10]

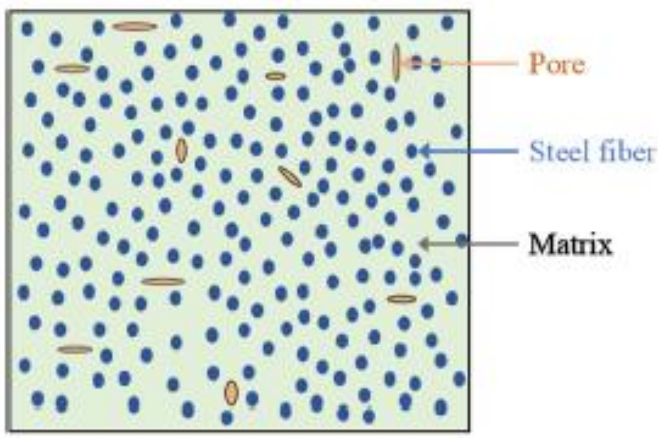

Figure 1 Effect of HPC without CA (LihuaXu et al , 2019)

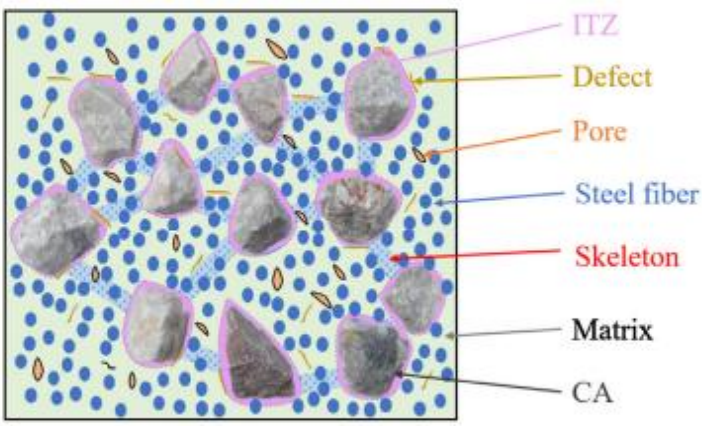

Figure 2 Effect of HPC with CA (LihuaXu et al , 2019)

Aggregate -Mortar link exhibits the weakest link in cement paste system. [11]. CA in the HPC mix creates many microcracks and defects this leads to strength reduction [12]. From the results, it can be

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193-4120 Page No. 16936 - 16940

concluded that the placement of CA inappropriate amounts satisfies the mechanical properties and reduced the manufacturing costs. Figure 1 exhibits the pattern of HPC mix without Coarse aggregate and steel fibre reinforcement. Figure 2 explains the steel fibre and CA effects in HPC specimens. Even the distribution of steel fibres in HPC specimens without using CA is observed in figure 1 and Figure 2 exhibited denser dispersion of steel fibres around the CA in HPC which enabled multiple cracking behaviour as well as strain hardening of specimens [13]. The skeleton mentioned in figure 2 enhanced the stiffness thereby increasing compressive strength [14].

IV.EFFECTS OF ADMIXTURES IN HPC

An essential part of HPC is occupied by admixtures. Based on the applications the usage of admixture may vary. Particle properties of mineral admixture are listed in Table 1. Determination of the chemical composition of mineral admixtures used to enhance the HPC properties. Materials such as Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBS), Metakaolin, Rice Husk Ash (RHA), Silica fume (SF), Copper Slag, Ceramics have been commonly substituted as SCMs in HPC. Normally SCMs are the industrial waste and by-products which pollute the environment. So, the application of SCMs in HPC is encouraged and reduced the threats to the environmental effects. Chemical admixtures with low W/C ratio are preferred in the production of HPC and their functions are tabulated in Table 2.

Table 1 Mineral admixtures with their properties

Admixture Type		**Categorization**	**Particle properties**
Primary	Fly ash	SCM	Particles size: <45 µm Particle shape: Sphere and smooth surface
	Silica fume	Active pozzolan	Particle size: 0.1 µm diameter Particle shape: Solid spheres
Secondary	Ground granulated blast furnace slag	SCM	Particle size: <45 µm particles Particle shape: Solid spheres with rough texture
	Rice husk ash	Active pozzolana	Particle size: <45µm particles Particle shape: Cellular and porous structure

Table 2 Chemical admixture and their usages

Chemical admixtures	**Usage of the admixture**
Superplasticizer	Without compromising the workability water content is reduced by 15%
Water reducing admixture	For achieving the required workability with low water to cement ratio.
Retarder	For high temperature concrete methods retarder is used to increase the setting time
Accelerator	In Cold weather concrete methods, accelerator was used to reduce setting time
Air entraining admixture	Creating air bubbles to improve the workability and enhance cushioning effect

TEST Engineering & Management

January - February 2020
ISSN: 0193-4120 Page No. 16936 - 16940

V. EXPERIMENTAL RESULTS ON HPC BY VARIOUS RESEARCHERS

Effects of silica fume and SP

Shannag et al examined the benefits of silica fume and naphthalene formaldehyde sulfonatedsuperplasticizer. For this experiment, HPC mixes are prepared by replacing 0 % to 15%cement weight by silica fume and adding 0 to 60 kg/m3 of naphthalene formaldehyde sulfonatedsuperplasticizer. The test specimens are kept in aggressive sulphate environments and seawater. From the results, it was evident that the HPC mix contains 15% of silica fume exhibited better performance than other mixes and it retained 65% of compressive strength after one year of the lifetime.

Effect of metakaolin in HPC

Effects of metakaolin in HPC was observed by conducting mechanical and durability tests on HPC specimens contain various proportions of metakaolin. The time duration for the is about 180 days[15]. From the results, it was evident that the addition of metakaolin in HPC specimens provides high resistance to sulphate and chloride attacks.

Effect of GGBS in HPC

Compressive and tensile strength of the HPC specimens of M30 grade was investigated by Specimens which contains 0% t0 60% of ground granulated blast furnace slag, crusher dust of proportions ranges from 0% to 30% and 1.5% SAVEMIX SP111 admixture was tested. The results of this investigation suggested that the usage of 50% GGBS and 25% of crusher dust improved 11.06% of the compressive strength.

Effect of copper slag fine aggregate in HPC

Fine aggregate partially replaced by copper slag at 20 % to 100% replacement levels and 30% cement was replaced by GGBS in HPC specimens and durability tests are conducted by [16]. The results proved that water absorption level and chloride penetration was decreased by 4.58% and 29.90 % with 30% CGBS in the place of fine aggregate.

Effects of Rice husk ash in HPC

Performance of HPC specimens prepared partially replace cement by RHA with the proportions of 0% to 20% were investigated by [17] Compressive strength of each specimen was determined and the results exhibited 3% to 10% increased value in compressive strength and 0.6% to 8% increased value in flexural strength with 10% of rice husk ash in HPC specimens.

CONCLUSIONS

Various studies are analysed in this research to determine the appropriate proportion of each constituents in HPC thereby producing an idealised HPC mix. Addition of silica fume at the range of 15% enhanced the compressive strength by 65%. Highest proportion of metakaolin in HPC enhanced the durability properties of the HPC. Incorporation of GGBS in the place of cement enhanced the compressive strength by 11.06%. RHA in the place of cement enhanced the flexural strength by 8%. From the analysis in this work it is concluded that the addition of GGBS, RHA and silica fume used in cement replacement significantly improved the compressive strength properties and incorporation of SP in HPC mixes enhanced the strength properties of HPC.

REFERENCES

1. Vatsal Patel, Niraj Shah "A Survey of High-Performance Concrete Developments in Civil Engineering Field" Open Journal of Civil Engineering, 2013, 3, 69-79
2. M. J. Shannag and H. A. Shaia, "Sulfate Resistance of High-Performance Concrete", Cement & Concrete Com- posites, Vol. 25, No. 3, 2003, pp. 363-369
3. Kmita, "A New Generation of Concrete in Civil Engi- neering," Journal of Materials Processing Technology, Vol. 106, No. 1-3, 2000, pp.80-86.

January - February 2020
ISSN: 0193-4120 Page No. 16936 - 16940

4. H. Beshr, A.A. Almusallam, M. Maslehuddin, Effect of coarse aggregate quality on the mechanical properties of high strength concrete, Constr. Build. Mater. 17 (2003) 97–103.
5. T. Akçaogˇlu, M. Tokyay, T. Çelik, Effect of coarse aggregate size and matrix quality on ITZ and failure behavior of concrete under uniaxial compression, Cement Concrete Comp. 26 (2004) 633–638.
6. M. Uysal, The influence of coarse aggregate type on mechanical properties of fly ash additive self-compacting concrete, Constr. Build. Mater.37 (2012) 533– 540.
7. M.H.A. Beygi, M.T. Kazemi, I.M. Nikbin, J. VaseghiAmiri, S. Rabbanifar, E. Rahmani, The influence of coarse aggregate size and volume on the fracture behavior and brittleness of self-compacting concrete, Cement Concrete Res. 66 (2014) 75–90
8. H. Beushausen, T. Dittmer, The influence of aggregate type on the strength and elastic modulus of high strength concrete, Constr. Build. Mater.74 (2015) 132– 139.
9. L.F. Maya, B. Graybeal, Experimental study of strand splice connections in UHPC for continuous precast prestressed concrete bridges, Eng. Struct. 133 (2017) 81–90
10. R. Yu, P. Spiesz, H.J.H. Brouwers, Development of ultra-high performance fiber reinforced concrete (UHPFRC): towards an efficient utilization of binders and fibers, Constr. Build. Mater. 79 (2015) 273–282.
11. M.S. Meddah, S. Zitouni, S. Belâabes, Effect of content and particle size distribution of coarse aggregate on the compressive strength of concrete, Constr. Build. Mater. 24 (2010) 505–512.
12. P.P. Li, Q.L. Yu, H.J.H. Brouwers, Effect of coarse basalt aggregates on the properties of ultra-high performance concrete (UHPC), Constr. Build. Mater. 170 (2018) 649–659.
13. J. Liu, F. Han, G. Cui, Q. Zhang, J. Lv, L. Zhang, Z. Yang, Combined effect of coarse aggregate and fiber on tensile behavior of ultra-high performance concrete, Constr. Build. Mater. 121 (2016) 310–318
14. M. J. Shannag and H. A. Shaia, "Sulfate Resistance of High-Performance Concrete", Cement & Concrete Com- posites, Vol. 25, No. 3, 2003, pp. 363-369.
15. B. B. Patil and P. D. Kumbhar, "Strength and Durability Properties of High Performance Concrete Incorporating High Reactivity Metakaolin," International Journal of Modern Engineering Research, Vol. 2, No. 3, 2012, pp. 1099-1104.
16. K. Pazhani and R. Jeyaraj, "Study on Durability of High Performance Concrete with Industrial Wastes," Applied Technologies & Innovations, Vol. 2, No. 2, 2011, pp. 19- 28.
17. A. Shukla, C. K. Singh and A. Sharma, "Study of the Properties of Concrete by Partial Replacement of Ordi- nary Portland Cement by Rice Husk Ash," International Journal of Earth Sciences and Engineering, Vol. 4, No. 6, 2011, pp. 965-968.