International Journal of Civil
Engineering (IJCE)
ISSN(P): 2278-9987; ISSN(E): 2278-9995
Vol. 5, Issue 1, Dec – Jan 2016, 27-36

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

AN ART OF THE STATE OF LITERATURE ON HIGH PERFORMANCE CONCRETE

T. SUBBULAKSHMI[1] & B. VIDIVELLI[2]

[1]Research Scholar, Department of Structural Engineering, Annamalai University, Chidambaram, India

[2]Professor, Department of Structural Engineering, Annamalai University, Chidambaram, India

ABSTRACT

In recent years, high performance concrete has been used to all types of structural buildings in construction activities. There has been increased use of high performance concrete in bridges, buildings where both strength and durability are important considerations. The primary reasons for selecting HPC are to produce a more economical product, provide a feasible technical solution, or a combination of both. HPC has received increased attention in the development of infrastructures leading to utilization of large quantity of concrete. High performance concrete can be defined as a low w/b ratio concrete with an optimized aggregate binder ratio to control its dimensional stability. Also it is so durable than usual concrete and its increased use will be more often linked to its durability than its high strength. This paper presents the state of the art in High performance concrete with regard to use in Civil Engineering infrastructure. Compiled from forty above papers of references provides a framework for profit a deeper understanding of HPC as well as platform from which to increase the use of this class of advanced cementitious composite materials and industrial by products materials. This paper presents an extensive coverage of High performance concrete developments in Civil Engineering field. It highlights the high performance concrete prominent part and requirements over conventional concrete. Moreover, some recent trends with respect to high performance concrete development in this area are examined. It was concluded from the investigation that what has been done and looks forward to what needs to be done to achieve appropriate applications of HPC in Civil Engineering field.

KEYWORDS: Literature on High Performance Concrete

INTRODUCTION

High performance concrete is one of the types of concrete that meets special performance and uniformity requirements that could not able to carry out with the techniques and materials adopted for the conventional concrete production. The concrete contains one or more cementitious materials of mineral and chemical admixtures are high performance concrete with enhancing properties [1]. The requirements may involve enhancement of placement and compaction without segregation, long term mechanical properties, early age strength, volume stability or service life in severe environments. In general, better durability performance has been achieved by using high strength, low water to cement ratio concrete. Though in this approach the design is based on strength and the result is better durability, it is desirable that the high performance, namely, the durability, is addressed directly by optimizing critical parameters such as the practical size of the required materials. The addition of mineral admixtures also reduces the quantity of cement in concrete, which directly contributes to the reduction of CO_2 emissions [2]. The ingredients generally used in investigations are Cement, Fine aggregate, Coarse aggregate, Water, Mineral Admixtures and Chemical Admixtures [3 to...]. Mineral admixtures used in high performance concrete are fine materials and of two types, reactive and inert fines. Pozzolans such as silica fume, fly ash etc and latent hydraulic material such as ground granulated blast furnace slag are reactive fines. Improved properties of high performance concrete are due to change in the microstructure of concrete composite, particularly due to change in the microstructure of the transition zone reduction of its thickness, associated voids and micro cracks as well as uniform particle distribution [3].

ROLE OF ADMIXTURES IN HIGH PERFORMANCE CONCRETE

Admixtures play an important role in the production of High performance concrete. Mineral admixtures form an essential part of the high performance concrete mix. They are used for various purposes depending upon their properties. Chemical admixtures determine the role of mineral admixtures in enhancing properties of concrete. Some of the different pozzolanic admixture properties such as fly ash, ground granulated blast furnace slag, silica fume, high reactivity metakaolin, rice husk ash, copper slag, fine ground ceramicas have been widely used as supplementary cementitious materials in the production of high performance concrete. Different chemical admixtures are extensively used in development of high performance concrete with very low water cement ration. Such properties are not only help to improve the strength and durability characteristics of high performance concrete but will also help to dispose more of the industrial by products which are major environmental threats[2]. So different combinations of these materials may be used, depending on the application and some of these are described below:

High performance concrete mixes containing different percentages of metakaolin were tested for strength and durability and have shown better resistances to the attacks of chemicals such as chloride and sulphates [4]. Vikan et al reported that the replacement of silica fume with different volume of well graded natural fine aggregate with the same water cement ratio with various proportions of natural pozzolan (0%, 5%, 10%, and 15%) by weight of cement with naphthalene formaldehyde sulfonated super plasticizer in severe suphate environments [5]. Eehab Ahmed Badrelding Khalil et al developed fly ash and silica fume based high performance concrete mixes and found significant improvements in the property of fresh and hardened concrete [6]. Ozgur Cakir et al carried laboratory study on the properties of effects of incorporating silica fume in the concrete mix design to improve the quality of recycled aggregates in concrete and Portland cement was replaced with silica fume at 0%, 5% and 10% [7]. Sumit Kumar et al investigated that the significance of silica fumes in enhancing the quality of concrete and found its effect on concrete after addition of silica fume. An experimental investigation on the flexural behaviour of reinforced high performance concrete was conducted by Paramasivam suresh kumar et al by using crushed stone sand replaced by fine aggregate and coarse aggregates in addition with silica fume and fly ash combination with super plasticizer [8]. A. Talah et al to assess the suitability of using marble powder as a partial substitute for Portland cement to produce high performance concrete having constant water binder ratio of 0.5 [9]. Pazhani et al produced High performance concrete by replacing 20%, 40%, 60%, 80% and 100% of fine aggregate with copper slag and 30% of cement with GGBS and tested to assess the durability parameters such as water absorption and chloride ion penetration [10]. Khalifa S. Al Jabri et al suggested that the effect of copper slag as a replacement of sand on the properties of high performance concrete [11]. A. Elahi et al presented an investigation of mechanical and durability properties of high performance concrete containing w/c ratio 0.3 which has used supplementary cementitious materials such as silica fume, fly ash, ground granulated blast furnace slag in binary and ternary systems. Portland cement was used with fly ash upto 40% and silica fume upto 15% and GGBS was replaced upto 70% performed the best amongst all the mixes to resist the chloride diffusion [12]. High performance concrete made with glass fibre with fly ash as the mineral admixture with the replacement level of 0%, 10%, 20%, 30% and glass fibre of 0%, 0.5%, 1%, 1.5% suggested by Dr. H. Sudarsana Rao et al

[13]. Sung Won Yoo et al expressed autogenous shrinkage in High performance concrete with w/c ratio 0.3 with mineral admixtures fly ash 0%, 10%, 15%, 20% & 30% and silica fume 0%, 5%, 7.5%, 10% & 15% and chemical admixture shrinkage reducing agent and expansion agent. The autogenous shrinkage in high performance concrete with fly ash was decreased continuously with larger fly ash replacement and silica fume has increased when compared to that in OPC concrete and they explained both of these admixtures in adequate amount can provide decrease in autogenous shrinkage as well as improvement of the strength [14].

SUMMARY OF MATERIAL ADMIXTURES IN HIGH PERFORMANCE CONCRETE

The constituent materials of High performance concrete generally consists of Portland cement, fine aggregate, fine sand, ground quartz, high reactivity water reducing agent, accelerating admixtures, steel fibres, silica fume, GGBS, metakaolin, fly ash, bottom ash, copper slag, marble powder, marble chips, steel slag aggregate, water etc. As a class, High performance concrete has high cementitious material contents and very low water cementitious material ratios. HPC can be mixed in conventional mixers but the HPC mixing time is longer than the conventional concrete. To enhance some measured properties with the help of application of heat for several days with delaying, although it may not be compatible with the rapid production in precasting operations.

Table 1: Role of Mineral Admixtures in HPC [2]

Sl. No.	Mineral Admixtures	Classification	Particle Characterization
1	Fly Ash	Cementitious, Pozzolanic	Solid particles, Smooth, Size of the particles <45µm
2	Silica Fume	Highly active pozzolana	Solid spheres fine powder, size of the particles 0.1µm
3	GGBS	Cementitious, Pozzolanic	Rough texture, Size of the particles <45µm
4	Rice Husk ash	Highly active pozzolana	Cellular type particles, size of the particles <45µm
5	Metakaolin	Highly active pozzolana	Whitish fine powder, size of the particles.........
6	Natural materials	Natural pozzolans	Crystalline silicate materials, Size of the particles <45µm
7	Bottom ash	Weak pozzolans	Rough texture of fine powder & ground materials

Table 2: Role of Chemical Admixtures in HPC [2]

Sl. No.	Mineral Admixtures	Function
1	Super plasticizer	To reduce the water requirement by 15% to 20% without affecting the workability leading to a high strength & dense concrete
2	Accelerator	To reduce the setting time of concrete
3	Retarder	To increase the setting time by slowing down the hydration of cement
4	Water Reducing Admixture	To achieve certain workability at low water cement ratio for a specified strength
5	Air entraining admixture	To entrain small air bubbles in concrete which act as rollers?

FRESH CONCRETE PROPERTIES ON HIGH PERFORMANCE CONCRETE

The mixing time of the high performance concrete can be reduced by increasing the relative solid concentration by optimising the particle size distribution, replacement of cement by silica fume, matching the type of super plasticizer and cement in the mix and increasing the speed of mixing [15]. K. Perumal et al observed that the workability of concrete decreased as the percentage of Silica fume content was increased and the optimum replacement of cement replacement by silica fume is 10% for strength related test for M110 grade of concrete [16]. C. Mathiraja investigated that the mechanical properties of concrete using bottom ash manufactured sand and metallic fibres for production of high performance concrete and dealt about the workability of high performance concrete made with fibre showed reduction in workability [17]. Rafat Siddique studied the effect of waste foundry sand on the slump of high performance concrete and observed that the waste foundry sand decreased the fluidity and the slump value of the fresh concrete. Due to the presence of clayey type fine materials in the waste foundry sand, which are effective in decreasing the fluidity of the fresh concrete [18,19,20]. Kasemchaisiri et al reported that the total porosity of concrete was increased with higher contents of bottom ash mixes in self compacting concrete and total porosity of SCC concrete also increased when the replacement level of bottom ash is increasing [21]. Naik et al has investigated the physical properties of SCC with different morphology and grain size distribution and the findings showed that when incorporation of one or more mineral additives or powder materials, can improve particle packing density and reduce inter particle friction and viscosity of SCC [22]. Yogesh Aggarwal et al investigated that the microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates and the presence of above mentioned materials in concrete lead to the increase in the water demand as compared to the regular sand particles. Thus to maintain the workability within specified range, the water content was gradually increased with increase in replacement of sand with waste foundry sand and bottom ash, which gave an idea about the increase in water demand due to increase in replacement of sand with waste foundry sand and bottom ash [23]. Colangelo and Cioffi suggested that the sustainable production of artificial aggregates using three different samples of solid industrial wastes such as cement kiln dust, granulated blast furnace slag and marble sludge by a cold bonding pelletization process by determining physical and mechanical properties of two selected size fractions of the granules for each studied mixture [24]. Rheological properties of high performance concrete mixes produced by rice husk ash and fly ash were studied and found that for low yield stress and moderate plastic viscosity, blending of equal masses of silica fume and rice husk ash seems to be a suitable admixture [25].

HARDENED CONCRETE PROPERTIES ON HIGH PERFORMANCE CONCRETE

The experimental analysis have shown that all high performance concrete achieved sufficient compressive and bending strengths and a limit of 80 MPa in compression was safely differences in mechanical properties due to the application of supplementary cementing materials were low, similarly as the bulk density of hardened mixtures. SCM of fly ash as partial replacement of Portland cement led to a slight decrease of strength and higher mass loss in testing the resistance against chemical de icing substances [26]. Flexural and splitting tensile strengths of high performance fiber reinforced concrete were determined with variable fiber volume fraction 0%, 0.5%, 1%, 1.5% with an aspect of 80, silica fume replaced for Portland cement. The addition of steel fibres upto 1.5% resulted in increase of 38% in the flexural & tensile strength and an increase of 56% in the splitting tensile strength compared with a conventional concrete matrix [27]. The experimental investigation carried out the mechanical behaviour of the concrete with waste foundry sand and bottom ash showed strengths comparable to that of conventional concrete except for FB60 mix at the age of 365 days. The mixes can be developed by varying the water content at constant rate as specified till 30% and thereafter till 50% replacement of fine aggregates and this is not recommended as the water content of this mix is high which also reflects on various strength. The splitting tensile strength of this mix was observed to be more than the control mix at all ages [23]. The research was conducted to obtain the optimum replacement level of cement upto 10% with silica ume in M110 grade of HPC and obtain higher values of compressive strength, split tensile strength, flexural strength and elastic modulus and lower values of saturated water absorption, porosity and sorptivity at the age of 28 days [16]. M. Bastami et al to investigate experimental program on the effects of elevated temperature exposure on the mechanical properties and potential for explosive spalling of high strength concrete and mechanical property strength was reduced if concrete is heated upto 800 ^{0}C. Residual strength of the mixtures was at least 13.77% for mixture of addition of without silica fume concrete and 35.81% for addition of silica fume concrete [28]. K. Chinnaraju et al conducted an Experimental test programme to study the effect of fly ash, GGBS and silica fume on high performance concrete with w/b ratio 0.32. the conventional concrete mixture of grade M60 included only ordinary Portland cement as binder and other mixtures incorporated binary (CC+Fly ash, CC+GGBS, C+SF), ternary (CC+Fly ash+GGBS, C+Fly ash+SF, CC+GGBS+SF) and quaternary (CC+Fly ash+GGBS+SF) cementitious blends were designed. The replacement levels for both fly ash and GGBS were 10%, 20% and 30% while those of SF were 2.5%, 7.5%, 10% and 12.5% by weight of cement as addition. The mix with 20% replacement of cement by 10% of fly ash and 10% of silica fume showed the best compressive strength for 7 days and 28 days with an increase in compressive strength of 15.64% and 13.24% respectively. The increase in splitting tensile strength was moderate for various combinations of fly ash and GGBS with silica fume upto 10%. Beyond that there was no increase in splitting tensile strength [29]. The research evaluated high performance concrete mixes containing fine ground ceramics as Portland cement replacement in an amount to upto 60% of mass were developed by Eva Vejmelkova. The compressive strength decreased very fast for the replacement levels higher than 20% the produced concrete lost its high performance character. For same level water absorption coefficient was relatively low, the frost resistance was excellent and showed good chemical resistance [30]. Graybeal also investigated the effect of cylinder and cube size on the measured compressive strength using different sizes of cylinders and cubes. The cubes had compressive strengths about 5% higher than the cylinders [31 & 32]. Schmidt and Frohlich reported that irregularities in the loaded surface of specimens tested in compression caused a more pronounced decrease in the measured compressive strength in high performance concrete than was evident with conventional concrete and observed that specimens hear cured at 194 ^{0}F (90^0) for 48 hours and tested in flexure had a 15% higher flexural strength than specimens stored continuously at 60 ^{0}F [33]. A study of Wille and Parra Montesinos investigated the effects of beam size, casting methods, and support conditions of HPC flexure test results. The study reported that large discrepancies in results were possible for an individual high performance concrete, depending on the test setup and specimen characteristics [34]. M.M. Lopez et al investigated that evaluation of durability and mechanical properties of the cement mortar added with slag blast furnace and they concluded that the compressive strength increased when the grain size of the slag decreased, obtaining higher values than the control samples. The granulated blast slag furnace concrete mixture with 20% of slag in all cases showed less strength, the control cubes showed higher strength except at the age of 118 days, and without slag had 20% showed less strength than the control cubes except for 118 days where it showed a strength of about 24 MPa increasing a 6% [35]. Diana Bajare et al developed the experimental investigation of coal combustion bottom ash as microfiller with pozzolanic properties for traditional concrete. The grinded bottom ash concrete can effectively replace cement upto 20% of its total amount without reducing compressive strength of concrete and its strength class and by replacing 20% of cement with bottom ash compressive strength class of concrete C30/37 can be ensured, which is equivalent to the reference mix of concrete. Replacing 40$ of cement with grinded bottom ash the compressive strength of concrete reduces significantly [36].

SUMMARY OF MECHANICAL PROPERTIES ON HIGH PERFORMANCE CONCRETE

The application of pozzolanic materials and industrial byproducts has a significant on the mechanical properties of High performance concrete. It increases the compressive strength, tensile cracking strength, and modulus of elasticity. It may decrease creep and virtually eliminates subsequent shrinkage. These beneficial properties can also be achieved without heat curing. However, the effect is reduced, and it takes a longer time to achieve the beneficial properties. Sufficient information has been published about the mechanical properties of High Performance concrete to establish a range of properties to consider in structural design.

DURABILITY PROPERTIES ON HIGH PERFORMANCE CONCRETE

Quantitative assessment of different cement replacement levels with silica fume 0%, 2.5%, 5%, 7.5% 10%, 12.5%, 15% on strength and durability properties for M60 grade of concrete with different w/b ratios of high performance concrete mixes was carried out by K. Perumal et al [16]. B.N. Krishnaswami et al performed experiments to make a comparative study on the durability aspect of high performance concrete with fly ash, silica fume and fumed silica for two different grades of concrete. The incorporation of mineral admixture greatly increases the water absorption of concrete mix with fly ash, silica fume and fumed silica and increases in dosage of fly ash increases the water absorption [37]. Muthupriya et al to assess the strength and durability characteristics of high performance concrete with mineral admixtures such as silica fume, metakaolin and fly ash and strength were investigated to find the optimum replacement of mineral admixtures. Experiments were conducted to study permeability, water absorption, porosity, acid resistance and alkalinity measurement with different percentage replacement of mineral admixtures. The test results values have demonstrated superior durability characteristics of HPC mixes containing admixtures except alkalinity of concrete mixes containing with a little % was less compared with that of the concrete mixes without admixtures [38]. An experimental study on Durability characteristics of High performance concrete was conducted by P. Magudeaswaran et al by using fly ash, silica fume for partially replaced by cement with superplasticizer. The rate of absorption of high performance concrete is reduced by 0.24% and it was acceptable for strength and durability characteristics can be achieved by using a fly ash and silica fume [39].

SUMMARY OF DURABILITY CHARACTERISTICS ON HIGH PERFORMANCE CONCRETE

The use of High performance concrete will increase in order to extend the service life of concrete structures exposed to severe environments. The durability of concrete structures depends on several factors, one of which is the durability of the concrete itself. As the durability of concrete is essentially linked to its permeability, High performance concrete with its dense microstructure and very low permeability, should obviously be more durable than ordinary concrete. High performance concrete with low permeability but without high strength, researchers have to learn to take advantage of the extra strength provided by low w/b ratio concrete. The use of HPC in any infrastructure application requires the high performance concrete to have adequate resistance to deterioration caused by the environment to which it is exposed. Also the dense matrix of HPC prevents deleterious solutions from penetrating into the matrix and so the mechanisms that can cause conventional concrete to deteriorate are not present. Consequently, durability properties, as measured by permeability test, freeze thaw tests, scaling test, abrasion test, resistance to ASR, and carbonation are significantly better than those of conventional concrete.

CONCLUSIONS

- High performance concrete can be prepared to give optimized performance characteristics for every condition along with the requirements of cost, service life, strength and durability.
- The applications of concrete will indispensable the use of High performance concrete incorporating new generation materials such as mineral, chemical and by-product admixtures.
- The success of High performance concrete requires more attention on proper material selection, mix design and curing of concrete. For each of these requirement parameters should be achieved by concrete producer for an environment that a structure has to face.
- The researchers do not know how to make high performance concrete with low permeability but they must know can make without the high strength. And must learn to take advantage of the extra strength provided by low w/c ratio concrete. It will lead to a greater use of HPC in next generation's society s greater interest in ecological concerns.

REFERENCES

1. S.P.Shah and S.H. Ahmad, *High performance concretes and Applications,* First edition, Edward Arnold, Great Britain, 1994.
2. Vatsel Patel and Niraj Shah, *A survey of High performance concrete developments in Civil Engineering Field,* Open Civil Engineering, 2013, 2, 68 to 79.
3. Subhajit Saraswati and Prabir C.Basu, *Durability of High performance concrete: An overvie,* Proceedings of the INCONTEST 2003 on 10 to 11 September 2003 Kumaraguru college of Technology, Coimbatore.
4. 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 to 1104.
5. H. Vikan and H.Justnes, *Influence of Silica fume on the Rheology of Cementitious Paste,* Proceedings of International symposium of fly ash, silica fume, slag and natural pozzolans in concrete, ReSykjabik, Iceland, 17 to 20 August 2003.
6. Ehehab Ahmed Badrelding Khalil and Mohamed Anwar, *Carbonation of ternary cementitious concrete systems containing fly ash and silica fume,* Water science Journal, http://dx.doi.org/10.1016/wsj.2014.12.001.
7. Ozgur Cakir and Omer Ozkan Sofyanli, *Influence of silica fume on mechanical and physical properties of recycled aggregate concrete,* HBRC Journal 2015, 11, pp 157 to 166.
8. P.S. Kumar, M. A. Mannan and K.V. John, *High performance reinforced concrete beams made with sand stone reactive aggregates,* The Open civil Engineering Journal, Vol. 36, No. 5, 2008, pp. 41 to 50.
9. A. Talah, F. Kharchi & R. Chaid, *Influence of Marble powder on High performance concrete behaviour,* 1st International conference on Structural Integrity, Institute of Science and Innovation in Mechanical and Industrial

Engineering, Science direct journal, http://doi: 10.1016/j.proeng.2015.08.010.

10. K. Pazhani and R. Jeyaraj, *Study on Durability of High performance concrete with Industrial wastes*, Applied Technologies & Innovations, Vol. 2, No. 10, 2010, pp. 5107 to 5113.
11. K.S. Al. Jabri, M. Hisada, S.K. Al. Oraimi and A.H. Al.Saidy, *Copper slag as Sand replacement for High performance concrete,* Cement and concrete composites, Vol. 31, No. 7, 2009, pp.484 to 488.
12. A. Elahi, A.M. Basheer, S.V. Nanukuttan and Q.U.Z. Khan, *Mechanical and Durability properties of High performance concretes containing supplementary cementitious materials,* Construction and Building Materials, Vol. 24, No. 3, 2010, pp. 292 to 299.
13. H.S. Rao, H.M. Somasekharaiah and V.G. Ghorpade, *Strength and workability characteristics of fly ash based glass fibre reinforced high performance concrete*, International Journal of Engineering sciences and Technology, Vol. 3, No.8, 2011, pp. 6266 to 6277.
14. S.W. Yoo, S.J. Kwon and S.H. Jung, *Analysis Technique for Autogenous shrinkage in High performance concrete with Mineral and chemical admixtures,* Construction and Building materials, Vol. 34, 2012, pp. 1 to 10. Doi:10.1016/j.conbuildmat.2012.02.2005.
15. O. Mazanec, D. Lowke and P. Schie, *Mixing of High performance concrete: Effect of concrete composition and mixing intensity on mixing time,* Materials and structures, Vol. 43, No. 7, 2009, pp.983 to 992.
16. K. Perumal and R. Sundararajan, *Affect of Partial replacement of cement with silica fume on the strength and durability characteristics of M110 grade high performance concrete*, Proceedings of the International conference on Advances in concrete composites and structures, Jan 6 to Jan 8, 2005, SERC, pp. 141 to 148.
17. C. Mathiraja, *Mechanical Properties of concrete using Bottom ash manufacturing sand and metallic fibres*, International Journal of Innovations in Engineering and Technology, Vol. 3, Issue 2, December 2013, ISSN: 2319:1058.
18. Rafat Siddique, *Utilization of industrial byproducts in concrete*, 2nd International conference on Sustainable Civil Engineering Structures and construction Materials 2014 (SCESCM 2014), Science Direct Journal, dio:10.1016/j.proeng.2014.12.192.
19. Y. Guney, Y.D. Sari, M.Yalcin, M.Tuncan and Donmez.S, *Reusage of waste foundry sand in high strength concrete*, Waste Management, Vol. 30, pp. 1705 to 1713.
20. M. Etxeberria, C. Pacheco, J.M. Meneses and I. Berridi, *Properties of concrete using metallurgical industrial byproducts as aggregates*, Construction Building Materials, Vol 24, pp. 1594 to 1600.
21. R. Kasemchaisiri & S. Tangtermsirikul, *Properties of self compacting concrete in corporating bottom ash as a partial replacement of fine aggregate,* Science Direct Journal, Asia, Vol. 34, pp.87 to 95.
22. T.R. Naik, Y.M. Chun, R. Kumar, B.W. Ramme, *Applications of Self compacting concrete in Japan, Europe and the United states Bridges and Structures,* Access date: 15 Mach 2015, www.fhwa.dot.gov/bridge/scc.cfm.
23. Yogesh Aggarwal and Rafat Siddique, *Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates,* Construction and Building Materials, Vol 54, 2014, pp.

210 to 223.

24. F. Colangelo & R. Cioffi, *Use of cement Kiln Dust, Blast furnace slag and Marble sludge in the Manufacture of Sustainable Artificial Aggregates by means of Cold Bonding Pelletization*, Concrete and Construction materials, Vol. 6, pp. 3139 to 3159.
25. A.I. Laskar & S. Talukdar, *Rheological behaviour of high performance concrete with mineral admixtures and their blending*, Construction and Building Materials, Vol.22, No.12, 2008, pp. 2345 to 2354.
26. E. Vejmelkova, P. Konvalinka & R. Cerny, *Properties of HPC containing supplementary cementing materials,* Concrete under sever conditions, Taylor and Francis Group, London, 2010, ISBN 978:0:415:59316:8.
27. P. Ramadoss & K. Nagamani, *Tensile strength and durability characteristics of high performance fiber reinforced concrete,* The Arabian journal of Science and Engineering, vol.33, No.2, 2008, pp. 307 to 319.
28. M. Bastami, a. Chaboki Khiabani, M. Baghbadrani & M. Kordi, *Performance of high strength concretes at elevated temperature,* Scientia Iranica, Sharif University of Technology, 2011, Vol.11, pp. 1028 to 1036.
29. K. Chinnaraja, K. Subramanian & S.R.R. Senthilkumar, *Strength Properties of HPC using Binary, Ternary and Quaternary Cementitious Blends,* Structural concrete, Vol. 11, No. 4, 2010, pp. 191 to 198.
30. E. Vejmelkova, M. Keppert, P. Rovnanikova, M. Ondracek, Z. Kersner and R. Cerny, *Properties of High performance concretes containing supplementary cementitious materials,* Construction and Building Materials, Vol. 24, No. 3, 2010, pp. 292 to 299.
31. B. Graybeal, *Material Property characterization of Ultra high performance concrete,* FHWA, U.S. Department of Transportaion, Report No. FHWA.HRT.06.103, McLean, VA 2006.
32. B. Graybeal and M. Davis, *Cylinder or cube: Strength testing of 80 to 200 MPa Ultra High performance fiber reinforced concrete,* ACI Materials Journal, Vol. 105, No.6, November December 2008, pp. 603 to 609
33. M. Schmidt & S. Frohlich, *Testing of High performance concrete*, Proceedings of the International workshop on ultra high performance fibre reinforced concrete. Designing and Building with UHPFRC: State of the art development, 17 to 19 November 2009, Marseille, France, AFGC/gib, Paper 5.3.2.
34. K. Wille and G. Parra Montesinor, *Effect of Beam size, casting method and support conditions on flexural behaviour of UHPFRC,* ACI Materials Journal, Vol. 109, No. 3, May June 2012, pp. 379 to 388.
35. M.M. Lopez, Yaneth Pineda & Oscar Gutierrez, *Evaluation of durability and mechanical properties of the cement mortar added with slag blast furnace,* Science direct journal, International congress of science and technology of Metallurgy and materials, SAM CONAMET 2014, doi:1.1016/J.MSPRO.2015.05.006.
36. Diana Bajare, Girts Burmanis & Liga Upeniece, *Coal Combustion bottom ash as Microfiller with pozzolanic properties for traditional concrete,* Science direct Journal, 11th International conference on modern building materials, structures and Techniques, MBMST 2013, doi:10.1016/j.proeng.2013.04.022.
37. B.N. Krishnaswami, J.K. Dattatreya, P. Jeyabalan & M. Neelamegam, *Durability aspect of High performance concrete,* Indian Concrete Institute Journal, January March 2007.

38. P. Muthupriya, K. Subramanian & B.G. Vishnuram, *Strength and Durability characteristics of High performance concrete*, International journal of Earth sciences and Engineering, ISSN 0974 5904, Vol. 03, No. 3, June 2010, pp. 416 to 433.

39. Er. Magudeaswaran & Dr. P. Eswaramoorthi, *Experimental study on Durability Characteristics of High performance Concrete*, International Journal of Emerging Technology and Advanced Engineering, ISSN: 2250 2459, Vol.3, Issue 1, January 2013.

40. Saaid I.Zaki, Ibrahim M.Metwally, and Sameh A. EI Betar, *Flexural Behaviour of Reinforced High performance concrete beams with steel slag coarse aggregate*, International scholarly research network, ISRN Civil Engineering, Vol 2011, Article ID 374807.

41. S.A. Balachandra and Rajesh L. Shirale, *Performance of steel fiber reinforced Metakaolin concrete*, The Indian Concrete Journal, August 2011.

42. K.R. Muthuswamy and G.S. Thirugnanam, *Mechanical Properties of hybrid fibre reinforced high performance concrete*, The Indian Concrete Journal, April 2013.