Chapter 2

Literature review

2.1 HIGH PERFORMANCE CONCRETE

Concrete has some advantages as main material for construction in comparison to the other construction materials. It is the most readily available material everywhere and it possesses excellent resistance to water in comparison to wood and steel. Therefore, concrete has become a more durable material. In addition, the plastic consistency of fresh concrete makes it easier to be formed into a variety of shapes and sizes using prefabricated formwork. In discussing the meaning of HPC, Aitcin and Neville (1993) stated that "in practical application of this type of concrete, the emphasis has in many cases gradually shifted from the compressive strength to other properties of the material, such as a high modulus of elasticity, high density, low permeability, and resistance to some forms of attack." The process of selecting suitable ingredients of concrete like materials and mixtures, and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible is termed as concrete mix design. High Performance Concrete is a concrete designed to exceed the properties of ordinary concrete. HPC is used for concrete mixture which possesses high workability, high strength, high modulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack. HPC can be obtained by reducing the water content, varying the ingredients used for concreting, using special admixtures, additives etc. Depending upon the conditions required different types of HPC can be made. The materials which are used as cement replacements in the mix are known as Supplementary Cementitious Materials (SCM’s). Commonly used SCM’s are fly ash, silica fume, ground granulated blast furnace slag, metakaolin etc. Khadiranaikar and Awati (2012) studied the effect of concrete stress distribution factors for high performance concrete. They studied for concrete having compressive strength in between 40MPa to 140MPa, developed a moment interaction curve and proposed stress distribution factors; a new model is proposed to evaluate the Equivalent Stress Block Parameters (ESRB) parameters α & β for HPC. Tafraoui et al (2009) studied the effects of metakaolin in the formulation of ultra-high performance cement. A comparative study was carried out by taking silica fume and
metakaolin. Four mixes were casted with steel fibres, without steel fibres, with crushed quartz and with crushed quartz and fibres. All the mixes were prepared with silica fume and with metakaolin. Moulds of size 40×40×160mm are used. Some of them was water cured for 28 days and one part underwent thermal treatment (90°C-150°C) after 4 days of water curing. Flexural strength was significantly increased for mix with fibres, when they were heat treated. Compressive strength was found to be more or less same for silica fume and metakaolin mixes. Also, compressive strength was increased due to heat treatment. Replacement of silica fume by metakaolin leads to a slight decrease in compressive strength and slight increase in flexural strength. Crushed quartz is not reactive with metakaolin but gives larger compressive strength value. Study of microstructure and durability presents a future study of this paper. Vaishali and Rao (2011) produced HPC with locally available aggregates and metakaolin as the mineral admixture. Various mixes based on different percentage of metakaolin were formed. Chloride ion permeability test and compressive test were conducted to study the durability characteristics. Cylinder and cube moulds were used for casting. It was found that with a 10% replacement of metakaolin for a w/c ratio of 0.3, 95.4MPa compressive strength is obtained without any special curing condition. Also compressive strength was found to decrease beyond 10% replacement level. Durability test conducted shows that HPC mixes were low to medium permeable compared to normal mix. The permeability increased with increase in w/c ratio and decreased with increase in replacement level of metakaolin. So, it was advisable to use lower w/c ratio for HPC’s. Vaishali and Rao (2012) studied the Fibre reinforced high performance concrete containing metakaolin based on its compressive strength, split tensile strength, flexural strength and chloride ion permeability. Different fibres were tried out namely steel fibres, polypropylene fibres and glass fibres in the percentage varying from 0.5%-1.25%. Steel fibre reinforced HPC showed higher compressive strength compared to Polymer fibre reinforced HPC and Glass fibre reinforced HPC. Also, tensile strength was maximum for Steel fibre reinforced HPC for 1% of fibre addition and thereafter a slight decrease was noted due to balling effect. Flexural strength and chloride ion permeability of Steel fibre reinforced HPC was also satisfactory compared to other two mixes. Indrajit et al (2012) was a part of a comprehensive research on implementation of HPC for bridge decks in a shrinkage prone area. Using three different SCM combinations: slag + silica fume, fly ash + silica fume, and metakaolin; three different w/c: 0.4, 0.35, and 0.3; two types of
coarse aggregates: crushed limestone and river gravel, a total of 18 different mixtures were investigated. The slump obtained for all of them were between 150 and 220 mm and the air content 5.8–7.6%. These slump values were reasonable for pouring the decks. With the decrease in w/c ratio, the rate of increase of compressive strength of metakaolin HPC was found to be highest among all HPC mixtures. The compressive strength of mixture with limestone was slightly higher than mixtures with gravel. Mixtures with limestone had 10–15% higher modulus of elasticity (28-day) than mixtures with gravel. It was observed that the mixtures with gravel usually had a higher free shrinkage strain than the mixtures with limestone. HPC with gravel generally cracked 2–8 days later compared to HPC with limestone whereas for HPC with lower w/c ratio, the crack occurred earlier which confirmed that for any acceptable mix design of HPC made with gravel or limestone, the concrete must have cracking onset more than 25 ± 4.4 days or to be on the conservative side more than 29.4 or 30 days. Abid et al (2013) carried out a research to evaluate high performance concrete made with fly ash and metakaolin with replacement level of 20 percent by weight of cement after elevated temperatures exposure (200°C, 400°C, 600°C and 800°C). Ordinary Portland cement complying with low-calcium pulverized fuel ash and metakaolin were used as cementitious materials. Coarse aggregates employed were crushed granites of two sizes 20 mm and 10 mm with specific gravity of 2.62 and 24 h absorption value of 0.6% while fine aggregate used was river sand with particles having specific gravity of 2.61, 24 h water absorption 0.7% and fineness modulus of 2.4. Three HPC mixes made with water cement ratio of 0.3 were investigated which included control mix (PC), metakaolin (MK20) and fly ash (FA20) mix. Metakaolin and fly ash mixes were used in replacement level of 20%. A sulphonated naphthalene formaldehyde condensate was used in the mixes to achieve desired slump of 100 mm and above. The superplasticiser content in percent by weight of binder content varied from 0.4 to 0.8. From the study it was observed that the post-elevated temperature compressive strength of MK20 mix continuously decreased with the increase of temperature. The loss in compressive strength of up to 9%, 22%, 37% and 72% was observed after exposure level of 200°C, 400°C, 600°C and 800°C respectively. The fly ash mix showed loss in post-elevated temperature compressive strength as temperature increased from 27°C to 800°C. The loss in compressive strength after exposure of 200°C, 400°C, 600°C and 800°C was up to 10%, 15%, 41%, 72% respectively whereas the FA20 mix showed gain in post-
elevated temperature compressive strength of 14% when concrete was subjected to 200°C while after 400°C exposure, a very small reduction of 4% was observed.

2.2 FIBRE REINFORCED CONCRETE

Fibre Reinforced Concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres; each of which lends varying properties to the concrete. Fibres are usually used in concrete to control cracking due to plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion, and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete and therefore cannot replace moment resisting or structural steel reinforcement. The weak matrix in concrete, when reinforced with steel fibres, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete. Because of the vast improvements achieved by the addition of fibres to concrete, there are several applications where FRC can be used. These fibres are widely used in the construction of industrial floors, pavements, highway-overlays, tunnelling etc. FRC is defined by ACI Committee 544 as a concrete made of hydraulic cements containing fine and coarse aggregates and discontinuous discrete fibres. FRC is concrete containing fibrous material which increases its structural integrity. So we can define fibre reinforced concrete as a composite material of cement concrete or mortar and discontinuous discrete and uniformly dispersed fibre. Fibre is discrete material having some characteristic properties. The fibre material can be anything. But not all will be effective and economical. Drago Saje et al (2011) studied shrinkage of polypropylene fibre-reinforced high Performance concrete. The volumetric content of polypropylene fibre varied from 0 to 0.75%. He found that the autogenous shrinkage of high performance concrete containing previously moistened polypropylene fibres is lower than that of non-previously moistened fibre. The workability of high performance fibre-reinforced concrete was decreased, when the optimum volumetric content of polypropylene fibres changes from 0.25 to 0.5%. Ding et al (2012) analyzed the effect of different fibres on Fibre Reinforced Self Compacting High Performance Concrete
The mix design of FRSCHPC was cement of grade CEM I 42.5 500 kg/m$^3$, fly ash 100 kg/m$^3$; fine aggregate 1 to 4 mm, aggregate crushed limestone with particle size between 5 and 12 mm, water/binder ratio 0.37, PP fibres and steel fibres. The experiments showed that the hybrid combinations of 55 kg/m$^3$ steel fibres and 2 kg/m$^3$ PP fibres as well as 40 kg/m$^3$ steel fibres and 3 kg/m$^3$ PP fibres could be the upper boundary of the fibre content regarding the workability required by Self Compacting High Performance Concrete (SCHPC) and that the addition of steel fibres aided in converting the brittle properties of concrete into a ductile material, but no significant trend of improving compressive strength was observed. FRSCHPC with hybrid fibres exhibited superior flexural toughness and fracture energy compared to the mono fibre reinforced SCHPC beams. After heating at different high temperatures, the flexural strength, the ultimate load, flexural toughness, fracture energy of all mixes dropped clearly with the increasing of the temperatures, and the load bearing capacity decreased monotonic with the increasing of the deflection. It was also concluded that the use of fibre cocktail reinforced SCHPC material could be very effective in reducing thermal stress and in improving composite effect of hybrid fibres on the postcrack behaviours during heating process at high temperature. Holschemacher et al (2010) studied the role of steel fibres having different configuration in combination with steel bar reinforcement. It reports on results of an experimental research program that was focused on the influence of steel fibre types and amounts on flexural tensile strength, fracture behaviour and workability of steel bar reinforced high-strength concrete beams. In the frame of the research 2 type of bar reinforcements one with 2 numbers of 6 mm and second with 2 numbers of 12 mm and three types of fibres configurations two type of straight with end hooks fibre by varying ultimate tensile strength and another one was corrugated type were used. Experiments show that for all selected fibre contents a more ductile behaviour and higher load levels in the post-cracking range were obtained. Strength and geometry of fibres have a direct influence on the load bearing capacity of high strength steel fibre reinforced concrete beams without bar reinforcement. Using high-strength fibres resulted in a clearly better ductile behaviour and higher load levels in the post-cracking range, compared to normal strength ones. Ziad and Henning (2001) have conducted studies on the cracking behaviour of steel fibre reinforced concrete. Concrete mixtures containing steel fibres in volume fractions of 0, 0.5, 1, 1.5 and 2 per cent were investigated. Three beam specimens in each volume fractions were
subjected to four point loading, utilizing linear variable differential transducers to measure deflections. Test results indicate that the incorporation of steel fibres significantly enhanced the cracking behaviour of concrete. It was also found that flexural stress increased with an increase of fibre content which improved material tolerance. Talukdar and Baruah (2007) conducted studies to determine the compressive strength, modulus of rupture, split tensile and shear strength of concrete made using fibres of five different origins. The fibres were steel fibre of two different sizes and added with volume fraction ranging from 0.5% to 2%. This research concluded that increase in flexural strength was as high as 48.38% in case of steel fibrous concrete and compressive strength of around 20% relative to plain concrete. Song and Hwang (2004) studied the mechanical properties of high strength steel fibre reinforced concrete. From the study it was concluded that the low tensile strength concrete can be increased by addition of steel fibres this paper deals with the mechanical properties like compressive, splitting tensile strength, modulus of rupture and toughness index of high strength steel fibre reinforced concrete. Steel fibres having different percentage variation of 0.5%, 1, 1.5%, 2% of volume of concrete are added. Maximum compressive strength is obtained at 1.5% volume fraction having 15.3% improvement over high strength concrete. Splitting tensile strength and modulus of rupture of fibre reinforced concrete improved with increasing the volume fraction having 98.3% and 126.6% improvements at 2% volume fraction. Jyotsna and Rao (2014) studied about flexural and split tensile strength of steel fibre reinforced concrete at high temperature. By adding 1% of steel fibres fracture resistance of concrete can be increased. High temperature induces high temperature gradients which in turn induces high tensile stresses. Fibres present in the concrete act as a bridge and helps in arresting cracks. The main application of steel fibre is its post cracking behaviour and toughness. It was observed that at later ages for fibre reinforced high strength concrete the flexural strengths are increasing with temperature whereas for normal strength fibre reinforced concrete the values were decreasing with temperature. Also steel fibres helps in decreasing the internal pressures and also helps in improved flexural and split strengths. The geometry of steel fibres helps in better bonding of concrete, it also helps the fibre to act more efficiently as a bridge in reducing fracture of concrete.
Ahmed et al (2014) studied about the factors affecting flexural tensile strength of concrete. The deflection and cracking behaviour of concrete structure depend on the flexural tensile strength of concrete. Many factors which influence the flexural tensile strength of concrete are level of stress, size, age and confinement to concrete flexure member etc. The concrete members having confining reinforcement increases ductility and large deflections in structures provide a good warning of failure prior to complete failure of the flexure member and also for efficient use of constructional material. It was concluded that the factors like confinement conditions and age of concrete should be given due consideration in deriving the flexural tensile strength and compressive strength proportionality equations. The flexural tensile strength increases with increase of age and strength of concrete and proportional increase in the flexural tensile strength at same age of concrete goes on decreasing with increase of level of concrete strength. The flexural tensile strength increases many folds under confinement confining condition of concrete.

2.2.1 STEEL FIBRE REINFORCED CONCRETE

Steel fibre reinforced concrete (SFRC) is concrete made of hydraulic cements containing fine or fine and coarse aggregate and discontinuous discrete steel fibres. In tension, SFRC fails only after the steel fibre breaks or pulled out of the cement matrix shows a typical fractured surface of SFRC. Properties of SFRC in both the freshly mixed and hardened state, including durability, are a consequence of its composite nature. The mechanics of how the fibre reinforcement strengthens concrete or mortar, extending from the elastic precrack state to the partially plastic post-cracked state, is a continuing research topic. One approach to the mechanics of SFRC is to consider it a composite material whose properties can be related to the fibre properties (volume percentage, strength, elastic modulus, and a fibre bonding parameter of the fibres), the concrete properties (strength, volume percentage, and elastic modulus), and the properties of the interface between the fibre and the matrix. A more general and current approach to the mechanics of fibre reinforcing assumes a crack arrest mechanism based on fracture mechanics. In this model, the energy to extend a crack and debond the fibres in the matrix relates to the properties of the composite.

2.2.2 POLYPROPYLENE FIBRES

The main disadvantage of Polypropylene (PP) fibre is their non-polar nature, which inhibits adhesion to concrete. Several methodologies use shrinkage reducing
admixtures to increase compatibility of PP fibres and to limit crack width. The key factor to obtain good mechanical properties for concrete is the interfacial adhesion between the concrete matrix and the fibre. To this regard, mechanical modifications as fibrillations and indentation increase the bonding with cement matrix. Surface treatments are able to modify the fibre/concrete interface by roughening the fibre surface, altering surface polarity. The modification of the surface chemistry and morphology of polymers increase the interfacial strength compared to untreated PP fibres. Polypropylene fibres are chemically inert and hence, any chemical that will not attack the concrete constituents will not have any effect on the fibre also. When more aggressive chemicals come in contact, the concrete will always deteriorate first before fibres. Polypropylene is hydrophobic, meaning it does not absorb water. Polypropylene fibres are not expected to bond chemically in a concrete matrix, but bonding has been shown to occur by mechanical interaction. Polypropylene fibres are produced from homo polymer polypropylene resin. The melting point and elastic modulus, which are low relative to many other fibre types, may be limitations in certain processes such as autoclaving. Test data have been compiled for composites containing polypropylene fibres at volume percentages ranging from 0.1 to 10.0 percent. The material properties of these composites vary greatly and are affected by the fibre volume, fibre geometry, method of production and composition of the matrix. This is true for all synthetic fibre types.

2.3 UTILISATION OF GGBS IN CONCRETE

Mahesh et al (2013) studied strength of high performance concrete with GGBS and crusher sand. Workability of concrete decreased with increase in crusher sand. 10.04% and 16.54% were the percentage increase in the compressive strength at 7 and 28 days obtained by the replacement of 40% cement with GGBS and 20% of sand with crusher sand. Babu and Kumar (2000) assessed the efficiency of GGBS on concrete. Taken an effort to quantify the 28-day cementitious efficiency of ground granulated blast furnace slag (GGBS) in concrete at the various replacement levels. The evaluations had shown that at 28 days, the overall strength efficiency factor varied from 1.29 to 0.70 for percentage replacement levels varying from 10% to 80%. Barnett et al (2001) studied the fast track construction with high-strength concrete mixes containing GGBS. Very fine sand as fine aggregate with 81% of particle finer than 600μm was used for this study. Half of the total amount of
specimen was used for 28 days compressive strength testing and other half or the specimens were placed in humidity controlled chamber (adiabatic temperature). After 5 days they wrapped in polythene sheet and tested. The early age strength of concretes with 28-days cured at 200°C were adversely affected by the increased levels of cement replacement with GGBS. By high curing temperatures early age strength contribution of GGBS was improved. Arivalagan (2014) takes an effort to quantify the strength of GGBS at various replacement levels and evaluate its efficiencies in concrete. From this study, it can be concluded that, since the grain size of GGBS is less than that of ordinary Portland cement, its strength at early ages is low, but it continues to gain strength over a long period. The optimum GGBS replacement as cementation material is characterized by high compressive strength, low heat of hydration, resistance to chemical attack, better workability, good durability and cost-effectiveness.

2.4 UTILISATION OF ALCCOFINE 1203 IN CONCRETE

Alccofine 1203 is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. Due to its unique chemistry and ultra-fine particle size, Alccofine 1203 provides reduced water demand for a given workability, even up to 70% replacement level as per requirement of concrete performance. Alccofine 1203 can also be used as a high range water reducer to improve compressive strength or as a super workability aid to improve flow. Alccofine 1203 is known to produce a high-strength concrete and is used in two different ways: as a cement replacement, in order to reduce the cement content (usually for economic reasons); and as an additive to improve concrete properties (in both fresh and hardened states). Therefore, utilisation of Alccofine 1203 together with Fly Ash provides an interesting alternative and can be termed as high strength and high performance concrete (www.alccofine.com). Siddique and Deepinderkaur (2012) studied the behaviour of concrete with elevated temperature. Also 53 grade OPC with 4.75mm sized fine aggregate and coarse aggregate with 10mm nominal size were used. Sulphonated Naphthalene Polymer with a dosage of 1.1% by weight of cement was used as water reducing superplasticiser. One control mixture was designed M-0, to have a 28 days compressive strength of 34Mpa. By replacing 20%, 40% and 60% of cement by weight, other mixtures namely M-1, M-2, M-3 were made. Cylindrical moulds of size 150mm × 300mm were prepared and
heated up to 100, 200, 350°C in an electric oven. Tests for compressive strength and splitting tensile strength were conducted. Mass loss increased with increase in temperature. Compressive strength of concrete containing 20%, 40% and 60% of GGBS were 16.8%, 24% and 28.5% respectively at room temperature. Splitting tensile strength of concrete containing 20% replacement of cement with GGBS at 100, 200 and 350°C was 17.68%, 21.0%, and 28.9% respectively. Similar results were observed with 40% and 60% replacement. Modulus of elasticity at 28 days decreased with increase in GGBS content. Durai et al. (2013) investigated the characteristics of M75 concrete by replacing cement with Ground Granulated Blast furnace Slag (GGBS) and glass fibre in different levels by using super plasticizer CONPLAST SP-430. Four mixes were examined with GGBS & Glass Fibre with a W/C ratio of 0.26. Standard sizes of cubes, cylinders and prisms as per Indian standards were casted for each mix and compressive strength, split tensile strength and flexural strength were conducted. Among the mixes the mix with replacement level as 7.5% GGBFS and 0.3% glass fibre showed the optimum result. Further increase of GGBS decreased the strength of concrete.

2.5 UTILISATION OF METAKAOLINE IN CONCRETE

Gruber et al. (2001) studied the resistance of HPC containing metakaolin against chloride ion permeability and reduction in expansion due to alkali-silica reactivity. Bulk diffusion method showed that metakaolin mix have greater resistance to chloride ion ingestion. The diffusion coefficients were reduced by 50% to 60% for mixes with 8% and 12% of metakaolin compared to a control mix. Experiments showed that mix with 15% of metakaolin showed less expansion due to alkali-silica reactivity. Pore solution studies shows that a replacement level of cement by metakaolin at 20% reduced the pore solution alkalinity significantly. Thus 8-12% replacement level of metakaolin improved the durability performance of HPC while 15- 20% replacement level was necessary for reduction in expansion due to alkali silica reactivity (ASR). Khatib (2008) studied the performance of concrete containing metakaolin at low water-binder ratios. Six mixes were prepared: one control and other containing metakaolin in percentages of 5%, 7.5%, 12.5%, 15% and 20%. Superplasticizer dosage adopted is 1.36% by mass of binder.15 cubes for each mix as well as 4 prisms were casted for each mix, out of which 2 prisms are water cured and two are air cured. Workability was low for all the mixes, almost less than 20mm.
Relative strength (RS) was found to be higher for metakaolin mix beyond 1 day of curing. Maximum relative strength is obtained at 14 days of curing where RS > 1.35. Thus for a low water-binder ratio maximum strength is obtained at 15% replacement level of metakaolin. For dynamic modulus of elasticity, the maximum value is obtained at 12.5%-15% replacement level of metakaolin. Water cured specimens showed higher elasticity values compared to air-cured specimens. 20% replacement level of metakaolin showed reduction in long term shrinkage compared to control mix. Paiva et al. (2012) studied the effect of metakaolin in fresh and hardened properties of concrete. Workability was adjusted with water or with High range water reducing admixture (HRWRA). After mixing of concrete, the concrete rheology was tested using a concrete rheometre, which allows determination of stress and viscosity from momentum and angular velocity measurements. Thermal analysis was carried out to study the amount of Ca(OH)₂ consumed due to metakaolin inclusion. Rheological studies showed that increase in viscosity and yield stress denotes a decrease in slump as the mix becomes more rigid. It was also found out that as the metakaolin percentage increased there was a greater tendency to form agglomerates, when HRWRA is not used which subsequently leads to reduction in compressive strength. For mixes with no HRWRA, where sufficient workability is obtained by increasing the water content, decrease in mechanical properties and increase in porosity was found out due to presence of agglomerates. Guneyisi et al. (2012) studied the effects of metakaolin and silica fume in high performance concrete. He replaced cement by 5% and 15% with metakaolin and silica fume. Compressive and split tensile strength tests were done to study mechanical properties and water sorptivity and gas permeability tests to study the permeability features. It was found out that compressive and tensile strengths for all the mixes were higher compared to a control mix. Also, shrinkage characteristic was found to be decreasing as we increase the percentage of metakaolin and silica fume. Weight loss was found to be less for metakaolin mix than the control mix. Even if the initial crack formation was on the same day (8th day), the final crack width was found to be less in metakaolin mix. Dhinakaran et al. (2012) studied the compressive strength and chloride ion permeability of different mixes at varying water-cement ratios 0.32, 0.35, 0.4, 0.5. Metakaolin percentage was varied from 5%-15% with an increment of 5%. Compressive strength at 3, 7, 14, 28 and 90 days were tested. 100mm size cubes and 100mm×50mm size specimens for chloride ion permeability test were casted. The
mix ratios for different watercement ratios of 0.3, 0.32, 0.4, 0.5 are 1:0.69:1.61, 1:0.9:2.1, 1:0.99:2.31, 1:1.2:2.8 respectively. Increasing the metakaolin percentage leads to decrease in workability because of high chemical reactivity and high specific surface of metakaolin particles. Highest increase in compressive strength was observed at higher watercement ratios. Among all, the optimum is found as 0.4 w/c ratio and 10% replacement level of metakaolin. Due to filler effect, pozzolanic reaction and accelerated cement hydration, resistance to chloride ion permeability was greater for metakaolin mix.

2.6 DURABILITY CHARACTERISTICS OF CONCRETE

Khan (2003) studied the permeation-related properties of high performance concrete utilizing fly ash and micro silica as cement replacing materials. They found that the incorporation of fly ash resulted in a marginal reduction in the oxygen permeability, porosity and sorptivity values, especially at later ages. The inclusion of microsilica up to 10% effectively reduced the oxygen permeability, porosity and sorptivity of concrete for all fly ash replacement levels but above 12% incorporation, the reductions were marginal only. Elahi et al (2010) studied the mechanical properties using compressive strength and durability properties from chloride diffusion, electrical resistivity, air permeability and water absorption. Ordinary Portland Cement(OPC) was replaced with silica fume, Fly ash and GGBS by 40%, 50% and 70% replacement levels. Silica fume is found to have better performance compared to other Cement Replacing Materials. Fly ash mix shows better permeation results. The results are compared against a control mix with OPC only. Mix design was done as per ACI 211.1:91. Also early age compressive strength was found to be decreasing for all type of mixes, but later age strengths are considerably high. Decrease in air permeability as well as sorptivity was obtained for all mixes with age. All the mixes with cement replacement materials showed at least three times greater resistance to chloride diffusion than the control mix. Patil and Kumbhar (2012) studied the workability, compressive strength and durability of M60 grade HPC mixes for different percentages of metakaolin. The mix proportion arrived at after several trial mixes is 0.31:1:1.63:2.33. Compressive strength test result showed that maximum value at 7.5% replacement level of metakaolin. Also, resistance of HPC against chloride attack and sulphate attack were evaluated by curing the specimens in 3.5% NaCl and 5% MgSO₄ solution for a period of 180 days and testing their
compressive strength. Results showed that they have better resistance to these attacks compared to control mix. Sheng et al (2001) studied the influence of mineral admixtures on compressive strength and carbonation of high performance concrete. River sand was used as fine aggregate. Replacement levels of Fly Ash (FA) and GGBS were 15%, 30%, 45% and 60% by weight. HPC showed higher compressive strength for low w/c ratio. FA with replacement up to 30% resulted an increase in compressive strength, carbonation depth and gas permeability. Alavi et al (2013) assessed the strength and durability characteristics of GGBS on self-compacting concrete (SCC). OPC grade cement with 43 grade was used. Fine aggregate corresponding to grading zone II was adopted. The Specific gravity of coarse aggregate was 2.77 and that for cement and sand was 3.15 and 2.65 respectively. Five SCC mixes were made with replacement levels of 20%, 30%, 40% and 50% of cement content. Water-powder mass ratio was taken as 0.45. In water absorption and porosity test conducted, the percentage of water absorption and percentage of effective porosity increased with increase in GGBS content. With the increase in superplasticizer dosage, the workability is increased. For 30% GGBS replacement, the fresh properties obtained were fine as compared to 10%, 20%, 40% and 50% GGBS replacement. With increase in the GGBS replacement a better workable concrete was obtained.