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RECENT INNOVATIONS IN HIGH VOLUME FLY ASH CONCRETE: A REVIEW

Batham Geeta[1], Akhtar Saleem[2], Rajesh Bhargava[3]

[1]PhD Scholar, UIT-RGPV, Bhopal, India,
[2] Professor, UIT-RGPV, Bhopal, India,
[3] Professor, RGPV, Bhopal, India.

Abstract: In this study, an extensive literature review has been conducted to understand the increased potential of HVFA concrete in recent years. HVFA concrete performance depends on material ingredients and mixture proportioning, which leads to denser and relatively more homogenous particle packing. However, sustained research studies in producing HVFA using various mineral admixture such as ultra-fine fly ash, class C and F fly ash, line stone powder, GGBS, Silica fume, Alccofine under various curing conditions are studies here and a database was compiled from various research and field studies on the fresh and hardened properties of high volume fly ash concrete using mineral admixture. The literature review revealed that the curing time, fly ash content, choice of mineral admixtures and its content are the main factors that control the mechanical and durability properties. Although various research have been conducted on HVFA concrete still there are challenges regarding the selection of mineral admixture and its content in HVFAC. This study helps to better understand the potential and capabilities of HVFA using various mineral admixture in concrete, which will minimize the drawback of HVFA and provide sustainable construction material to the construction industry.

Keywords: high volume fly ash concrete, mineral admixtures, workability, compressive strength, flexural strength, split tensile strength.

I. INTRODUCTION

The term of high volume fly ash (HVFA) concrete is firstly introduced by Malhotra at CANMET in the 1980s. The HVFA concrete is the concrete with at least 50 % of the Portland cement by mass is replaced with ASTM class F or class C fly ash [Mehta and Malhotra, 2005]23. The 15%-20% fly ash by mass of the total cementitious material is good for workability and cost economy of concrete but it may not be enough to sufficiently improve the durability to sulfate attack, alkali-silica expansion, and thermal cracking [Sarath et. al., 2011]9. The definition of HVFA concrete given by [Mehta and Malhotra, 2005]23 are (i) Minimum of 50% of fly ash by mass of the cementitious materials must be maintained (ii) Low water content, generally less than 130 kg/m3 is mandatory (iii) Cement content, generally no more than 200kg/m3 is desirable. The mixture design of HVFA should be economical and sustainable for achieving denser matrix, reduced porosity and improved internal microstructure, leading to superior mechanical and durability properties. The use of High Volume Fly Ash concrete in construction is a solution to environmental degradation being caused by cement industry. The concept very much fits into the era of sustainable development. As cement industry, itself, is responsible for 7% of world's carbon dioxide emissions, responsible for global warming, attention needs to be drawn by construction industry to solve the problem [Vanita Aggrawal et. al., 2010]10.

Sustainability, durability, ecology and economy are the major parameters that make ideal choice for HVFA concrete instead of conventional concrete. To understand most beneficial features of HVFA concrete comparison between HVFA concrete and conventional Portland cement concrete is given here.

High Volume Fly Ash Concrete	**Conventional** Portland cement concrete
Less energy intensive manufacture	Energy intensive manufacture
Higher ultimate strength	Lower ultimate strength
More durable	Less durable
Requires less water	Requires more water

Uses a waste by-product	Uses virgin materials only
Creates fewer global warming gases	Creates more global warming gases

Comparison clearly demonstrates that HVFA concrete is more environmentally friendly and has more desirable technical properties than conventional concrete (Green Resource Center, 2004). HVFAC has excellent workability, low heat of hydration, adequate early-age and high later-age strengths, reduced drying shrinkage, reduced micro cracking, excellent durability characteristics while being more economical and environment-friendly when compared to conventional concrete [T.P. Singh, 2007]8. [Ghafoori et. al., 1997]24 concluded that good strength, stiffness, drying shrinkage and resistance to wear and repeated freezing and thawing cycles could be obtained with concretes containing bottom ash. [Siddique and Kadri, 2012]25 reported reinforcement of high-volume fly ash concrete with natural fibres. Incorporation of high volume fly ash in concrete results in many advantages such as reduced water demand, improved workability, reduction cracks due to thermal and drying shrinkage, enhanced durability to reinforcement corrosion sulphate attack, and alkali-silica expansion [P Kumar Mehta, 2004]26. Some of the benefits of high volume fly ash in concrete reported by many researchers are compiled here.

II EARLIER INVESTGATION & SCOPE OF THE STUDY

The application of concrete in construction is as old as the days of Greek and roman civilization. But for numerous reasons, the concrete construction industry is not sustainable. It consumes a lot of virgin materials and the principal raw material of concrete i.e. cement is responsible for green house gas emissions causing a threat to environment through global warming. Therefore, the industry has seen various types of concrete in search of a solution to sustainable development. Infrastructural growth has witnessed many forms of concrete like High Strength Concrete, High Performance Concrete, Self-Compacting Concrete and the latest in the series is High Volume Fly Ash Concrete (HVFC). The paradigm has shifted from one property to other of concrete with advancement in technology. The construction techniques have been modernized with focus on high strength, dense and uniform surface texture, more reliable quality, improved durability and faster construction [10]. A no. of mineral admixtures are used in HVFA concrete to achieve these desired properties as a partial replacement of cement concrete. Proper selection of mineral admixture and its mix proportion in HVFA concrete is relatively more beneficial it enhances properties like strength, stability, and provide future sustainable material than the cement. However, previous research studies in producing HVFA concrete using various mineral admixture such as ultra-fine fly ash, class C and F fly ash, limestone powder, GGBS, Silica fume, Alccofine under various curing conditions are studied and reviewed here. A database is prepared from various research and field studies on the fresh and hardened properties of high volume fly ash concrete. This study will help in selection of proper mineral admixture, its content and curing conditions to enhance the beneficial features of HVFA concrete.

III SIGNIFICANT CONTRIBUTIONS IN THE FIELD OF HVFA CONCRTE

A no of studies have been conducted on use of mineral admixture in HVFA concrete such as class c fly ash in HVFA concrete [Shrivastava and Bajaj, 2012]1, [Sravana, and Rao, 2006]3, [Soni and Saini, 2014]5, [Krishnaraj and Ravichandran, 2020]14 and in high strength concrete [G. K. Kate et. al., 2013]4, class F fly ash [Alaa M. Rashad et. al., 2014]13, Fly ash in HVFA concrete [Nikhil T. R., 2012]2, [S. Lokesh et. al., 2013]6, [T.P. Singh, 2007]8, [Jeong-Eun Kim et. al., 2016]11, GGBS and silica fume in concrete [Jeong-Eun Kim et. al., 2016]11, [Alaa M. Rashad et. al., 2014]13, limestone powder [Dale P. Bentz, 2012]21, [Dale P. Bentz, 2014]22 and Alccofine in HPC [Indu Lidoo et. al., 2017]12. The brief literature review of the latest studies are as follows.

[Shrivastava and Bajaj, 2012]1 investigated the performance of Fly Ash (FA) in the soil stabilization with replacement it with different soil for 10 to 60%. In this investigation, the engineering properties like compaction of sand, sand + fly ash (SF) @ (10, 20, 30, 40 & 50) and sand + fly ash + soil (SFS) @ (1:1:1, 1:1.5:0.5) had been tested and results are compared. Author produced M20, M50 and M70 with target mean strength of 26.25 MPa, 56.36 MPa and 78.69 MPa. Replacement of cement by fly ash was found to be 20%, 35%, 50% and 70%. The compressive strength was determined by 150 × 150 × 150 mm mould and flexural strength by 600 × 150 × 100 mm prism. Author investigated the fresh and hardened properties like slump, temperature, modulus of elasticity, modulus of rigidity. The results showed that up to 50% replacement of cement can be used for construction with in addition reduces 12% overall cost.

[Nikhil T. R., 2012]2 conducted experimental study in three stages. In the first stage compatibility test is made to select the type of cement. Second stage preliminary investigations such as consistency, specific gravity, initial and final setting time of cement and sieve analysis of fine aggregates and coarse aggregates were carried out on materials used. In the third stage concrete mix proportioning was done as per the draft code (IS: 10262) and cubes, beams and cylinders were casted and tested. The cubes beams and cylinders were tested properly in uniaxial compressive testing machine, flexural testing machine and split tensile testing machine at the age of 7, 14, 28 and 56 days. Author concluded that 55% replacement of cement by fly ash is the optimal percent above which strength decreases.

[Sravana, and Rao, 2006]3 conducted test on M20, M30, M40, and M50 grades of concrete containing OPC and studied the effect of thermal cycle to the concrete produced at different temperatures. The compressive strength of concrete at various thermal cycles i.e. 7, 28, 45 and 90 were evaluated and compared. Author revealed that concrete containing fly ash addition was more effective in resisting the effect of thermal cycles than ordinary and fly ash replace cement concrete.

[G. K. Kate et. al., 2013]4 conducted experimental investigation carried out to evaluate the shrinkage of High Strength Concrete. High Strength Concrete is made by partial replacement of cement by fly ash. The shrinkage of High Strength Concrete has been studied using the different mixes from a minimum of 10% to maximum of 70 %. From the test results of the above investigation it can be concluded that the shrinkage strain of High Strength Concrete increases with increase in fly ash content. The rate of increase in shrinkage with time is uniform for low fly ash content, whereas it generally increases after 28 days for high volume of fly ash and the high volume fly ash concrete yields slow strength development at an early age.

[Soni and Saini, 2014]5 investigated effect of mineral addition in concrete on strength and durability characteristics at high temperatures. Author produced concrete mix proportions of 1:1.45:2.2:1.103 with a water cement ratio of 0.5 by weight. The percentages of replacements were 30, 40 and 50 % by weight of cement. Specimens were prepared and tested in the laboratory. Compressive strength, split tensile strength and modulus of elasticity were performed at room temperature at 80˚C, 100˚C, and 120˚C for all types of fly ash concrete at different curing at the age of 28 days and 56 days. Test results showed that the compressive strength, split tensile strength and modulus of elasticity of concrete having cement replacement up to 30% was comparable to the reference concrete without fly ash. With the increase in temperature, compressive strength of concrete mixes with 30%, 40% and 50 % of fly ash as cement replacement decreases by 11.4%, 30.1%, 28.9%, and 27.5% at 120˚C when compared to room temperature.

[S. Lokesh et. al., 2013]6 uses fly ash as light weight aggregate in concrete. Fly ash as a waste material from thermal power plant was converted into light weight aggregate (i.e., production of fly ash based aggregates either by bonding or sintering technique) for use in concrete as porous light weight in nature. Author produced four trial mixes (C100& NA100, C100& NA60 FA40, C60F40& NA60FA40 and C60F30S10& NA60FA40) M25 grade of concrete and with water cement ratio 0.3. 12 no. of each specimen were produced in the laboratory. Size of cube, beam and cylinder are 150x150x150, 100x100x500, 150 dia. & 300 height respectively. Author found such light weight aggregate concrete with high volume fly ash cement has all the attributes of high performance concrete i.e. excellent mechanical properties, lower permeability, superior durability and environmental friendly nature. Author concluded light weight aggregate concrete made with cement mortar in combined use of fly ash with silica fume, has improved the strength development in initial days

[Coppola et al., 2018]7 used five different types of cement (CEMI, CEMII/A-LL, CEMIII/A, CEMIII/B, and CEM IV according to EN 197-1) with siliceous fly ash (FA) or ultrafine fly ash (UFFA) to produce mortar. Replacement percentage were 5%, 15%, 25%, 35%, and 50% of cement mass. Author conducted research to study the rheological and physical performance of mortars. Results indicate that compressive strength of mortars with UFFA is considerably higher than that of mixtures containing traditional FA, both at early and long ages. Moreover, experimental data reveal that replacement of cement with up to 25% of UFFA determines higher compressive strength at 7, 28, and 84 days than plain mortars (containing cement only), regardless of the type of cement used. Mortars manufactured with 35% or 50% of UFFA show slightly lower or similar compressive strength compared to the reference mortar (containing cement only).

[T.P. Singh, 2007]8 shared Indian experience in field performance of high volume fly ash concrete. Author presents the properties of HVFAC with 50% Fly ash used on two demonstration projects in New Delhi, India. Author prepared three different mixes 30 Mpa Plain concrete, 40 Mpa HVFAC and 30 Mpa HVFAC for the project to construct a 100-m stretch of road pavement - 7m wide at Fatehpur Beri, Mehrauli and New Delhi in HVFAC. The road stretch carries heavy traffic including overloaded trucks during day as well as night. The new concrete pavement was designed as a 270-mm thick slab in 30 Mpa grade concrete, laid on the existing asphalt pavement. The author investigated that HVFAC is indeed an excellent material with later age properties superior to conventional concrete, namely - compressive strength, flexural strength, elastic modulus, abrasion resistance and permeability. From the viewpoint of sustainable development, it is a strongly viable solution as a building material in the years ahead.

[Sarath et. al., 2011]9 prepared a detailed literature review on contribution of fly ash to the properties of Mortar and Concrete. Author studied various research paper and prepared a database on effect of fly ash replacement (by cement) on various fresh and hardened properties of concrete such as workability, setting time, bond strength , compressive strength, split tensile strength and flexural strength etc. Author also provide platform for effect on other properties drying shrinkage, thermal cracking, durability of HVFA concrete. Author reported significant influence of fly ash in improving the properties like water requirement, workability, setting time, compressive strength, durability of mortar and concrete. Investigation clearly demonstrates that fly ash is an effective pozzolan which can contribute the properties of concrete. Fly ash blended concrete can improve the workability of concrete compared to OPC. It can also increase the initial and final setting time of cement pastes. Fly ash replacement of cement is effective for improving the resistance of concrete to sulfate attack expansion. The higher is the compressive strength of concrete, the lower is the ratio of splitting tensile strength to compressive strength.

[Vanita Aggrawal et. al., 2010]10 prepared a review paper on concrete durability of high volume fly ash concrete. The research discusses the development of high volume fly ash concrete for construction with reference to its predecessors like HSC and HPC. Author provide excellent literature on use of fly ash in concrete for getting start further research on use of high volumes of fly ash in concrete pavements. Author reported that incorporating fly ash in concrete reduces the compressive strength at early ages but there is a drastic increase in the compressive strength at later ages. The early strength is reduced further if the percentage of replacement is increased. But, on the other hand when the percentage of replacement is increased the water/ binder ratio gets reduced, thereby, increasing the later age compressive strength. Also, it is observed that the later age strength of concretes having more than 40% replacement of cement by fly ash suffers adversely though water/ binder ratio is gradually reduced. For concretes with less than 40% replacement of cement, the characteristic strength at 28 days is on higher side. Whereas, for concrete with 40% replacement of cement, the 28 days compressive strength is at par with that of plain concrete. The concrete with more than 40% replacement of cement show lesser 28 days strength but gains better strength at 90days or later.

[Jeong-Eun Kim et. al., 2016]11 conducted experimental study to investigate mechanical properties of energy efficient concrete with binary, ternary and quaternary admixture at different curing ages. Author prepared various mix proportion in combination of fly ash, silica, and blast furnace slag replacement percentages for fly ash ranges 15 to 30 whereas silica fume percentage used was 5 to produce energy efficient concrete. Slump test for workability and air content test were performed on fresh concretes. Compressive strength, splitting tensile strength were made on hardened concrete specimens. For each batch, cylindrical molds of size 100 mm X 200 mm (4 X 8 in.) were cast for the determination of compressive strength, splitting tensile strength and modulus of elasticity of energy efficient concrete. Investigation showed use of silica fume increased the compressive strengths, splitting tensile strengths, modulus of elasticity and Poisson's ratios. On the other hand, the compressive strength and splitting tensile strength decreased with increasing fly ash.

[Indu Lidoo et. al., 2017]12 prepared an experimental program to design high performance concrete (M100) using mineral admixture alccofine 1203 and fly ash. The different combinations with Alccofine as the replacement to cement by 8%, 10%, 12% & 14%, along with the incorporation of Fly Ash by 10% were prepared. The workability and compressive strength of the Fly ash mix by varying the different percentages of Alccofine is recorded and the percentage of Alccofine is optimized by researchers. Then for this optimized mix, cube specimens 150 x 150 x 150 mm were casted and tested for Compressive strength. Author prepared a lot of trials of combination of 1:1.3:2.6 of cement, fine Aggregates and Coarse Aggregates with 10% of Fly ash and 10% of Alccofine. Author reported ALCCOFINE 1203 the future generation pozzolona as a substitute for partial replacement of normal cements.

[Alaa M. Rashad et. al., 2014]13 In this study, Author partially replaced portland cement (PC) with a Class F fly ash (FA) at level of 70 % to produce high-volume FA (HVFA) concrete (F70). F70 was modified by replacing FA at levels of 10 and 20 % with silica fume (SF) and ground granulated blast-furnace slag (GGBS) and their equally combinations. All HVFA concrete types were compared to PC concrete. After curing for 7, 28, 90 and 180 days the specimens were tested in compression and abrasion. The various decomposition phases formed were identified using X-ray diffraction. The morphology of the formed hydrates was studied using scanning electron microscopy. The results indicated higher abrasion resistance of HVFA concrete blended with either SF or equally combinations of SF and GGBS, whilst lower abrasion resistance was noted in HVFA blended with GGBS.

[Krishnaraj and Ravichandran, 2020]14 conducted experimental program to understand the strength improvement and microstructural behavior of ultra-fine fly ash particles. They use synthesis and characterization techniques for analyzing the fly ash mortar and masonry prism. It was found that the ultra-fine fly ash masonry block shows higher compressive strength, higher resistance to shear, higher bonding between two bricks compare to conventional masonry blocks. Author investigated process of grinding alters the particle size and specific surface area but not shown any variation in chemical composition. Overall, investigations show that additional use of 45% ultra-fine fly ash in construction applications without compromising the quality.

[S. Abbas et. al., 2016]15 studied various research papers and prepared a database on the material characterization of UHPC and its potential for large-scale field applicability. Author emphasis on Mechanical Performance, Durability, Sustainability and Implementation Challenges in production of ultra-high performance concrete. Research shows that UHPC provides a viable and long-term solution for improved sustainable construction owing to its ultrahigh strength properties, improved fatigue behavior and very low porosity, leading to excellent resistance against aggressive environments. The Author revealed that the curing regimes and fiber dosage are the main factors that control the mechanical and durability properties of UHPC. Author investigated Production of UHPC using locally available materials under normal curing conditions can reduce its material cost.

IV. HVFA COMPOSITION

Supplementary Cementitious Material

Supplementary Cementitious Material (SCM) play important role on strength properties of HVFA concrete and HSC concrete. Physical and chemical properties of SCM affects HVFA and HSC to large extent. Use of SCM such as class c fly ash in HVFA concrete [Shrivastava and Bajaj, 2012]1, [Sravana, and Rao, 2006]3, [Soni and Saini, 2014]5, [Krishnaraj and Ravichandran, 2020]14 and in high strength concrete [G. K. Kate et. al., 2013]4, class F fly ash [Alaa M. Rashad et. al., 2014]13, Fly ash in HVFA concrete [Nikhil T. R., 2012]2, [S. Lokesh et. al., 2013]6, [T.P. Singh, 2007]8, [Jeong-Eun Kim et. al., 2016]11 is very common to provide economical, ecological , green concrete and to minimize environmental problem. Fly ash is most commonly used as a pozzolona in concrete. Pozzolonas are siliceous and aluminous materials, which in a finely divided form and in presence of water, react with calcium hydroxide at ordinary temperatures to produce cementitious compounds [Vanita Aggrawal et. al., 2010]10. A FA particle distribution will typically consists of particle ranging from slightly greater than 150 micrometers to submicron size. Mehta has reported that a majority of the reactive particle in FA are actually less than 10 micrometers in diameter [Mehta P. K., 1985]31. It was observed that increase in fly ash content results in improved workability. [Poon C. S., 2000]46 reported that concrete with a 28 days compressive strength of 80 MPa could be obtained with a low-calcium fly ash content of 45%. The spherical particle shape of fly ash also participates in improving workability of fly ash concrete. Use of fly ash increases the absolute volume of cementitious materials (cement plus fly ash) compared to non-fly-ash concrete; therefore, the paste volume is increased, leading to a reduction in aggregate particle interference and enhancement in concrete workability [Sarath et. al., 2011]9. [Shrivastava and Bajaj, 2012]1, [Nikhil T. R., 2012]2 and [G. K. Kate et. al., 2013]4 reported increase in workability while [Sravana, and Rao, 2006]3 found reduction in workability therefore super plasticizer dosage was used to maintain the workability. Optimum percentage of FA content for workability found 50 % and 55% for [Shrivastava and Bajaj, 2012]1 and [Nikhil T. R., 2012]2.

Water/Binder Ratio

It was observed that lower the water binder ratio higher the performance of HVFA concrete. [Jeong-Eun Kim,]11 found the lower the value of W/B ratio, the higher is the compressive strength of concrete. The fly ashes actually function as a kind of mineral water reducers. UFFA displays a strong tendency to reduce water demand for comparable workability as silica fume concrete, a 10 % reduction in total water content together with as much as 40 % reduction in HRWR, was possible [K. H. Obla et. al., 2003]28. [Jiang and Malhotra, 2000]20 have shown that with HVFA concrete mixtures, depending on the quality of fly ash and the amount of cement replaced, up to 20% reduction in water requirements can be achieved. The phenomenon is attributable to three mechanisms. First, fine particles of fly ash get absorbed on the oppositely charged surfaces of cement particles and prevent them from flocculation. The cement particles are thus effectively dispersed and will trap large amounts of water that means that the system will have a reduced water requirement to achieve a given consistency. Secondly, the spherical shape and the smooth surface of fly ash particles help to reduce the inter particle friction and thus facilitate mobility. Thirdly, the "particle packing effect" is also responsible for the reduced water demand in plasticizing the system [Sarath et. al., 2011]9.

Due to its lower density and higher volume per unit mass, fly ash is a more efficient void-filler than Portland cement [Mehta, 2004]26. Experimental studies by [Li Yijin et al., 2004]29 have shown reduction in water demand when cement is replaced by HVFA. [Copeland et al. 2001]27 and [Obla et al., 2003]28 reported 10 % reduction in water demand when 50% cement replaced by ultra-fine fly ash. [Jiang and Malhotra, 2000]20 reported 20% reduction in water requirements can be achieved. Maximum reduction depends up on quality of fly ash and the amount of cement replaced. [Rafat Siddque, 2013]30 use high volume class F fly ash to replace fine aggregate. Due to increase in cementitious materials in the mixture, continuous reduction in water demand was observed with the increase in replacement %. Some water binder ratio used by various researcher for various grades are 0.4 for HVFA M-60 with FA replacement 40-65 % [Nikhil T. R., 2012]2, 0.3 for low volume fly ash concrete with FA replacement 10-25 % and 0.3 for high volume fly ash concrete with FA replacement 40-70 % [G. K. Kate et. al., 2013]4, 0.5 for FA replacement 30-50 % [Soni and Saini, 2014]5. [Sravana, and Rao, 2006]3 used w/B ratio 0.55, 0.50 0.42 and 0.38 normal concrete and 0.36, 0.33, 0.30 and 0.27 for HVFA concrete.

Super Plasticizers

Fresh concrete with replacement of cement by fly ash required lower super plasticizer as compared to the other concretes and decreased with the increase in percentage replacement of fly ash. This is due to the small size of solid and spherically particle shapes of fly ash which reduces the friction between cement and aggregates and results in an increase of workability of fresh concrete [Namagga and Rebecca, 2009]16. The required SP dosage significantly depends on the compatibility between the mixture ingredients and the type of SP used. Improved compatibility can lead to lower SP dosage [S. Abbas et. al., 2016]15. With super plasticizers, concrete with as low as 0.2 W/C ratio is possible with good workability and a strength as high as 83 Mpa is possible at test age of 28 days [ACI Committee 211, 1993]17. The maximum strength reported with fly ash and super plasticizer is about 60 Mpa, [Swamy, R.N., 1985]18. [Kumar B. et. al., 2007]19 studied the suitability of superplasticized HVFA concrete for pavements. He concluded that HVFA concrete with 50% - 60% fly ash can be designed to meet the strength and workability requirement of concrete pavements.

Aggregates

Use of high volume fly ash is not beneficial to replace cement content only. Incorporation of Higher replacement (for fine and coarse aggregate) of fly ash in concrete also reported improved performance of concrete. High volume fly ash is used in recycled concrete aggregate and light weight aggregate also. [Rafat_Siddque, 2013]30 used high volume class F fly ash to replace fine aggregate. Replacement percentages were 35, 45 and 55. Author reported resistance to all properties (compressive strength, splitting tensile strength, flexural strength, modulus of elasticity and abrasion) continued to increase with the increase in fly ash percentages at all ages. Increase in strength was found mainly due to densification of the paste structure due to pazzolanic action between fly ash and calcium hydroxide liberated as a result of hydration of cement. At 28 days maximum increase in compressive strength, splitting tensile strength, flexural strength and modulus of elasticity were found 41 %, 21 %, 17 % and 23 % respectively. Maximum depth of wear was found at 60 minutes abrasion time for all mixes. [Rafat Siddique, 2003]39 conducted experimental study to replace fine aggregate by fly ash. It was observed that compressive strength of concrete at 10%, 20%, 30%, 40%, and 50% fine aggregate replacement by fly ash, were higher than the control mix at all ages. [Namagga , 2009]16 demonstrated that the compressive strength of the fly ash concrete increased with an increase in the number of days that it was cured. [Lokesh et al., 2013]6 Use fly ash aggregate to replace natural aggregates with combination of cement and silica fume. Three trial mixes were prepared(trial-I,40 % fly ash aggregates +60 natural; trial-II, 40 % fly ash aggregates +60 natural aggregates+ 40 % cement replaced by fly ash; trial-III, 40 % fly ash aggregates +60 natural aggregates+ 40 % cement replaced by (30 % fly ash+ 10 % silica fume)). Compressive strength of all three trial were found more than 25 MPa, Similarly flexural strength and split tensile strength were found satisfactory; author recommended the use of high volume fly ash in light weight aggregate concrete (trial-III) for structural components.

Mineral admixtures

The necessity of high performance concrete is increasing because of the increasing demand of the construction materials in the construction industry. Efforts for improving the performance of concrete over the past few years suggest that cement replacement materials along with Mineral & chemical admixtures can improve the strength and durability characteristics of concrete. Alccofine and Fly ash are pozzolanic materials that can be utilized to produce highly durable and economical concrete composites [Indu Lidoo et. al., 2017]12. [Jeong-Eun Kim et. al, 2016]11 reported use of silica fume results in increased compressive strength, split tensile strength, modulus of elasticity and poissons ratio. The enhancements in strength depend on the content of SF in the HVFA concrete matrix. [Alaa M. Rashad et. al., 2014]13 reported enhancement in strength was 5.8 % at 7 days, related to F70, whilst it reached 40 % at 28 days. Increasing the dosage of SF from 10 to 20 % with combination of 50 % FA led to further increasing in compressive strength values at all ages. The increases in compressive strengths were 107.6, 191.4, 127.4 and 105.1 % at ages of 7, 28, 90 and 180 days, respectively, relative to F70. Author found higher abrasion resistance of HVFA blended concrete found with SF and combination of SF+GGBS with class F fly ash. Lower abrasion resistance in HVFA concrete found GGBS. [S. Lokesh et. al., 2013]6 observed compressive strength increases when silica fume (10 %) is used as mineral admixture in concrete and loss of strengths can be compensated initially.

The Poisson ratio is a basic factor in analyzing, designing and important attribute of the mechanical response of any materials. Poisson's ratio is defined as the ratio of the transverse extension strain to the longitudinal contraction strain in compression [Jeong-Eun Kim et. al, 2016]11. Author performed tests on specimens with strain gauge units and tensile strain gauge units. Poisson's ratio in this study were ranged from 0.101 to 0.236. Author found poisons ratio of silica fume concrete are slightly larger than those of normal concrete. Poisson's ratio of SF5 specimens were larger than those of other specimens. This is attributed to the fact that silica fume particles are very small, compared with fly ash and blast furnace slag particles. The ultra fine silica fume particles enter the relatively coarse cement inter-particle space. Thus components fineness was effected by particle size of silica fume. This trend is similar to that of compressive strength. [Indu Lidoo et. al., 2017]12 reported addition of 10 % silica fume with class c fly ash and alccofine provide better results.

V. CONCLUSIONS

The coal-fired power plants generate considerable solid wastes that included fly ash (FA)—up to 700 million tons per years worldwide—that can be used in cement and concrete production due to its pozzolanic characteristics [Ahmaruzzaman, 2010]41, [Yao, Z.T. et. al., 2015]42, [González, A.et, al, 2009]43. This allows to reduce gross energy requirement (GER), CO2 emissions (Global Warming Potential: GWP), and consumption in natural resources, since FA can partially replace Portland cement in concrete and mortar production [Coppola et al., 2018]7. From the Investigation carried out using ultra-fine fly ash indicates that in the construction industry it can also be considered to use the Eco sustainable material which is relevant to the conventional material. It is also useful for minimising the usage of natural resources which are used for producing the cement material. This will make the low impact on the contamination of land by disposing the waste products. The future studies may conduct the process of ball milling may be concentrated the energy involved in the process and cost analysis [Krishnaraj and Ravichandran, 2020]14. The literature surveyed reported that incorporating fly ash in concrete has positive effect on almost all properties searched and reviewed here. Literature review showed that the properties of concrete are enhanced when HVFA concert is produced using mineral various mineral admixture such as ultra-fine fly ash, GGBS, Silica fume, Alccofine under various curing conditions. Efforts for improving the performance of HVFA concrete over the past few years suggest that cement replacement materials along with mineral & chemical admixtures can improve the strength and durability characteristics of concrete. The technology to create HVFA concrete is economical and environment friendly and thus the technology should be promoted and explored further.

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