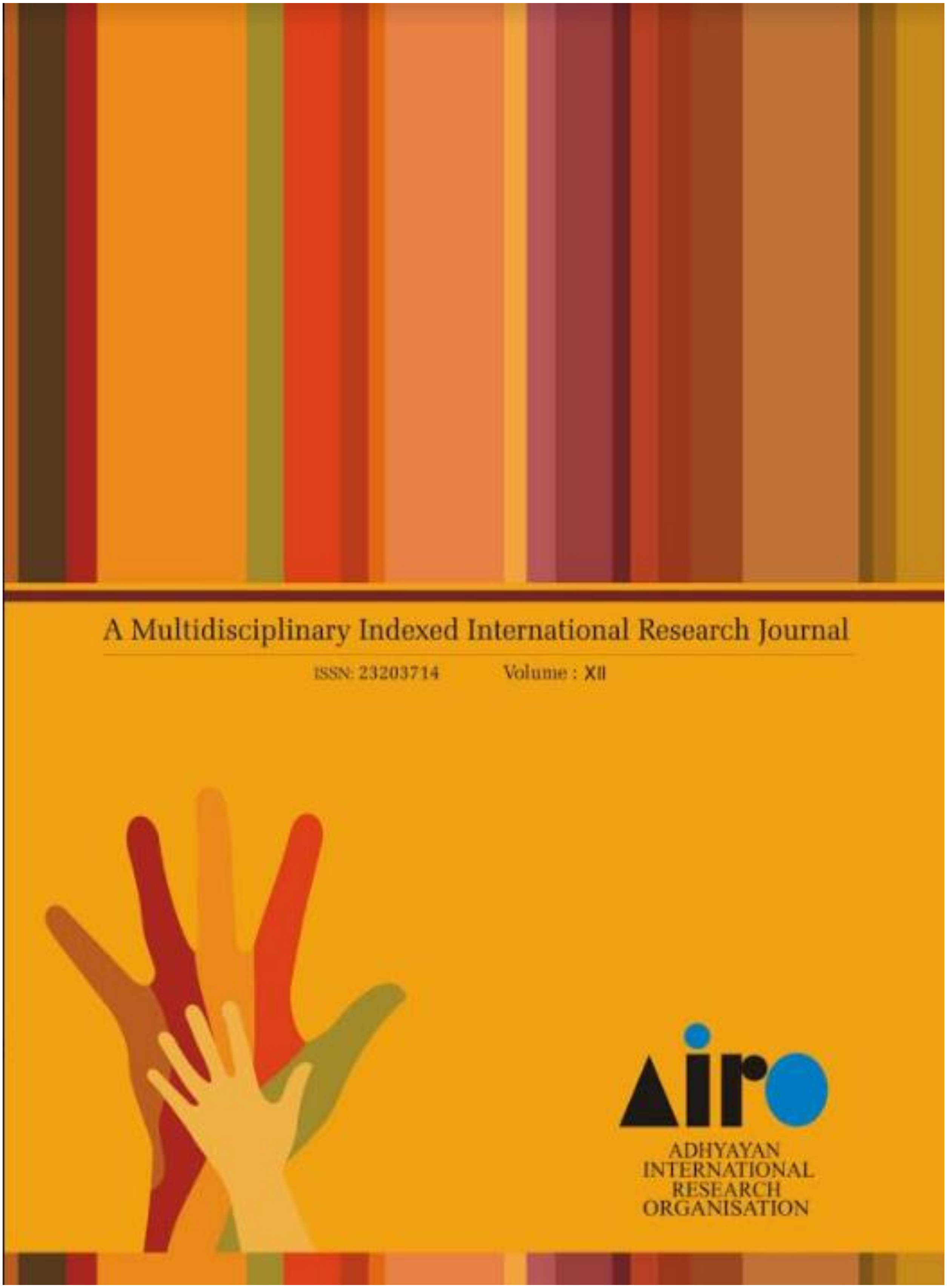
A Multidisciplinary Indexed International Research Journal
ISSN: 23203714
Volume : XII
ADHYAYAN INTERNATIONAL RESEARCH ORGANISATION

REVIEW STUDY ON CONCRETE FLY ASH USE OF HIGH CAPACITY

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ABSTRACT

The use of concrete containing high Capacity of fly ash (HCFA) has as of late picked up fame as an asset proficient, tough, and manageable choice for a variety of concrete applications. In this paper, two HCFA blends, one containing Class C fly ash the other Class F fly ash, were contrasted and TDOT Class A general use blends utilizing the same class of fly ash at a littler substitution rate. The HCFA blends achieved like higher long haul compressive qualities, due to the pozzolanic properties of the fly ash and the lower w/cm proportions. Likewise, the water permeable void contents and absorptions were bringing down for the HCFA mixtures at all ages, showing that the toughness of the HCFA is much better than that of the TDOT mixtures. The setting times for the HCFA mixtures were around two-hour longer than those of the TDOT Class A mixtures at laboratory conditions. Additionally, the costs of the HCFA mixtures were slightly higher. Be that as it may, for field placements at warmer temperatures, the time of set and cost of the HCFA mixtures would diminish while the cost of the TDOT Class A mixtures would increase, due to the requirement for chemical admixtures. In general, the utilization of HCFA mixtures would be perfect for warm weather placements; when contrasted and the TDOT Class

A mixtures, the HCFA mixtures exhibit similar costs, expanded compressive qualities, and upgraded durability properties.

KEYWORDS: Concrete, Fly Ash, High Capacity, temperatures, increase, decrease, sustainable.

INTRODUCTION: Fly ash is one of the side-effects of the combustion of coal in electric power generating plants. For more than 75 years, fly ash has been broadly utilized as a supplementary cementations material for the production of concrete in the United States and other countries. Ordinarily, fly ash replacement levels for the production of concrete have been constrained to around 35% by weight of the aggregate cementations materials because of worries about set up execution and constructability.

Concrete, which is the most broadly utilized construction material on the planet, is a composite of coarse and fine aggregates, Portland cement, and potable water. Nonetheless, Portland cement generation postures challenges of unreasonable vitality use and consumption of natural resources. Additional to this, there is a plenitude of coal combustion products (CCPs, for example, fly ash that are discarded in landfills that could rather be used decidedly in the production of concrete. Portland cement is chemically manufactured from calcium, silicates, and aluminates in a procedure that discharges carbon dioxide as a result into the atmosphere and reduces the mineral assets of our planet. In 2007, the world production of cement was roughly 2.6 billion metric tons, with 127 million created and consumed within the United States. In any case, when a huge amount of fly ash is utilized as a part of place of Portland cement, 55 gallons of oil required to deliver the Portland cement is spared and an equivalent measure of carbon dioxide that would be created by the manufacturing process is kept from entering the Earth’s atmosphere, henceforth having a huge beneficial outcome on the earth and conservation of natural resources (ACAA, 2009).

Portland cement is the most costly material used in the creation of concrete. The cost of one ton of fly ash is normally a large portion of the cost of one ton of Portland cement. In this way, the generation cost for concrete can likewise be decreased by replacing a bit of the cement with more affordable cementations materials. High-Capacity fly ash (HCFA) concrete may be created with significant cost funds when contrasted with conventional Portland-cement concrete.

In an attempt to improve the condition and upgrade the concrete industry, it is basic to give more sustainable and green options as solutions and better contrasting options to existing items. Extensive research has been done trying to make concrete products more sustainable and cost-effective, and HCFA concrete is one potential option.

In addition to the economic and environmental advantages introduced above, HCFA concrete has shown better execution attributes when contrasted with conventional Portland-cement concrete. Fly ash is presently utilized in concrete for some reasons, including: enhancements in workability of fresh concrete, decrease in temperature rise amid starting hydration, improved imperviousness to sulfates, diminished development because of soluble base silica response, and expanded toughness and quality of hardened concrete.

The two most common classes of fly ash utilized as a part of concrete are Class C and Class F as characterized by (ASTM C618 2008) "Standard Specification for Coal Fly Ash and Raw or Claimed Natural Pozzolan for Use in Concrete". Both classes are pozzolanic, which means they respond with overabundance calcium hydroxide (CH) in concrete, framed from cement hydration, to form calcium silicate hydrate (CSH), but Class C fly ash likewise contains higher levels of calcium which makes it more attractive for higher replacement percentages.

All in all, HCFA concrete could offer a solution to the problem of meeting the increasing demands for concrete in the future in a sustainable manner and at lessened or no extra cost, and in the meantime decreasing the natural effect of two industries that are fundamental to economic development, the Portland cement industry and the coal-fired power industry. The utilization of high Capacity of fly ash in concrete generates an immediate connection amongst strength and asset efficiency, thus increasing the utilization of HCFA concrete will enhance the sustainability of the concrete industry.

The main problem with utilizing HCFA concrete in construction is the expanded setting time. Impeded set time defers frame evacuation, which increases time of construction (Marotta et al., 2011). Since labor is the primary cost contributing factor in construction, the setting time of high-Capacity fly ash concrete must be quickened. Previous research has demonstrated that the expansion of chemical admixtures or activators, for example, calcium hydroxide and gypsum, help with starting the hydration process taking into consideration a shorter curing period, while as yet picking up sufficient strength.

REVIEW OF LITERATURE: Fly ash is utilized as a supplementary cementations material (SCM) in the production of Portland cement concrete. A supplementary cementitious material, when utilized as a part of conjunction with Portland cement, adds to the properties of the hardened concrete through water driven or pozzolanic action, or both. All things considered, SCM's incorporate both Pozzolan and hydraulic materials. A Pozzolanic characterized as a siliceous or siliceous and aluminous material that in itself has almost no cementitious value, however that will, in finely separated shape and within the sight of dampness, chemically reacts with calcium hydroxide at standard temperatures to frame mixes having cementitious properties. Pozzolan that are usually utilized as a part of concrete include fly ash, silica rage and an assortment of natural Pozzolan, for example, claimed mud and shale, and volcanic ash SCM's that are hydraulic in conduct incorporate ground granulated impact furnace slag and fly ashes with high calcium contents (such fly ashes show both pozzolanic and hydraulic behavior). The potential for utilizing fly ash as a supplementary cementitious material in concrete has been known practically since the begin of the last century, in spite of the fact that it wasn't until the mid-1900s that huge usage of fly powder in concrete started following the spearheading research directed at the University of California, Berkeley. The last 50 years has seen the utilization of fly ash in concrete grow drastically with near 15 million tons utilized as a part of concrete, concrete products and grouts in the U.S. in 2005. Historically, fly ash has been utilized as a part of concrete at levels running from 15% to 25% by mass of the cementitious material component. The real sum utilized differs generally relying upon the application, the properties of the fly ash, particular breaking points, and the geographic location and climate. Higher levels (30% to half) have been utilized as a part of massive structures (for example, foundations and dams) to control temperature rise. In recent decades, inquire about has exhibited that high dosage levels (40% to 60%) can be utilized as a part of structural applications, producing concrete with good mechanical properties and durability.

Figure 1. Fly ash, powder resembling cement, has been used in concrete

USE OF FLY ASH AS SUPPLEMENTARY CEMENTITIOUS MATERIAL: The Indian consumes more than 108 million tons of Portland cement each year, approximately 25% of which is foreign made (Butalia and Bargaheiser, 2004). The utilization of Portland cement is relied upon to keep on grow throughout the world. Shockingly, the challenge is that for each ton of cement produced, roughly one ton of carbon dioxide is discharged into the atmosphere, and carbon dioxide is the primary greenhouse gas (GHG) ascribed to a worldwide temperature alteration and climate change. Be that as it may, concrete, of which Portland cement is the dynamic fixing, is an amazingly adaptable construction material and is, indeed, the second most consumed product on the planet, just below water. Current U.S. generation of Portland cement contributes over 75 million tons of to the earth's atmosphere yearly Governmental regulations and growing concerns over GHG emanations are invigorating the cement industry to analyze the expanded utilization of supplementary cover materials in request to decrease outflows. Fly ash is the very fine material conveyed in the flue gas, commonly gathered by a bughouse, and put away in storehouses as demonstrated in Figure 2. Bottom ash is the bigger/heavier particles that tumble to the base of the heater after ignition. The 720 coal-terminated power plants produce roughly 63 million tons of fly ash every year About 31 million tons are discarded in landfills. Only approximately 12 million tons are reused and put to helpful reuse in the concrete industry. The rest of the 20 million tons are utilized for a scope of different applications including soil stabilization, roller compacted concrete, road base stabilization, etc.

Figure 2- Fly Ash Production

General remarks on Portland cement: The manufacture of Portland cement requires crude materials that contain lime, silica, alumina, and iron. After the materials are gained, the limestone is diminished to an around measure in the primary crusher and further lessened to ¾ in. in the secondary crusher. For a superior understanding, Figure 3 presents flowchart of the manufacture of Portland cement. All raw materials are put away in the bins and proportioned preceding conveyance to the granulating plant. There are two processes, the wet process that outcomes in slurry, which is blended and pumped to storage bins, and the dry process that creates a fine ground powder which is likewise put away in bins (Marotta et al., 2011). Both processes encourage the revolving ovens where the chemical changes occur. Once the crude nourish has been ground and blended, it is sustained into the furnace, and as the oven pivots, the material passes gradually from the upper to the lower end at a rate controlled by the slope and speed of turn of the furnace. Four distinct processes occur in the oven: evaporation, calcination, clinkering, and cooling (Mindess et al., 2003). In the dissipation zone, the bolster is warmed to calcination temperatures to expel free water. In the calcination zone, the sustain is transformed into a responsive blend of oxides that can go into new chemical combinations. As the material passes through the oven, its temperatures raised to the point of clinkering. In the clinkering zone, the last chemical combination jumps out at shape the calcium silicates. Contingent upon the raw material, this temperature varies in the vicinity of 2400°F and 2700°F finally, as the material moves past the flame, it quickly drops off in temperature in the cooling zone. Here the fluid phase solidifies to deliver the hard knobs called clinker. Clinker is the last condition of the material as it rises up out of the furnace. The clinker produced is dark or greenish black in shading and harsh in surface. The material is then transported to final grinding where gypsum is added to control the setting time of the Portland cement when it is blended with water. On the off chance that gypsum is not included, flash setting of the clinker could occur.

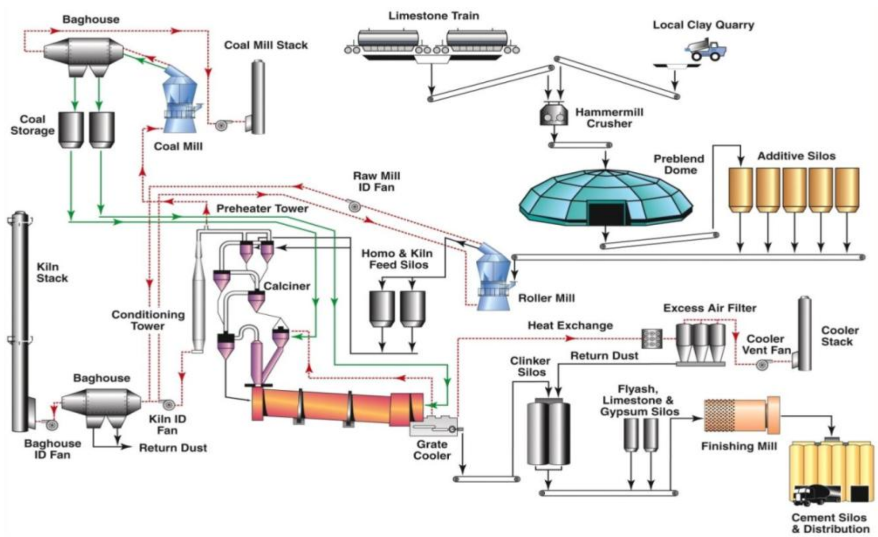

Figure 3- Flow Chart of Manufacture of Portland cement

Portland cements are regularly composed of four fundamental chemical compounds outlined in Table 1 with their names, chemical formulas and abbreviations, and rough weight percent for a normal Portland cement. Each of these mixes displays a specific conduct. The tricalcium silicate solidifies quickly and is to a great extent in charge of introductory set and early quality. The declaim silicate hardens gradually and its impact on strength increases happens at ages past one week. The tricalcium aluminate contributes to quality advancement in the initial couple of days since it is the main compound to hydrate However, the tricalcium aluminate is the minimum attractive compound because of its high warmth era and responsiveness with soils and water with direct to-high sulfate concentration.

Table 1- Typical Composition of Ordinary Portland cement

Chemical name	Chemical formula	Abbreviation	Weight (%)
Tricalcium silicate	$3CaO \cdot SiO_2$	C_3S	55
Dicalcium silicate	$2CaO \cdot SiO_2$	C_2S	18
Tricalcium aluminate	$3CaO \cdot Al_2O_3$	C_3A	10
Tetracalcium aluminoferrite	$3CaO \cdot Al_2O_3 \cdot Fe_2O_3$	C_4AF	8
Calcium sulfate dihydrate (gypsum)	$CaSO_4 \cdot 2H_2O$	$C\bar{S}H_2$	6

General remarks on fly ash: Fly ash is a coal ash recuperated in an electrostatic precipitator (ESP) at coal-fired thermal power plants and contains little measures of iron, magnesium, and calcium and also the fundamental elements of silica and aluminum. Most warm power plants utilize heaters let go with pulverized coal. As the coal travels through the high-temperature zone in the heater, the volatile matter and carbon are consumed off though a large portion of the mineral impurities are diverted by the flue gas in the shape of ash (Malhotra and Mehta, 2008). These fiery remains particles wind up plainly melded in the combustion zone of the heater yet once they leave the combustion zone, the molten ash is cooled quickly and hardens as spherical, glassy particles. Table 2 outlines the normal mass synthesis of both class C and F fly ashes in view of 97 and 45 analyses, respectively, created by (Scheetz et al. 1997). Flyash looks fundamentally the same as to cement in appearance. Be that as it may, when amplified, fly ash will show up as round particles, like ball bearings, whereas cement seems rakish, more like crushed rock as demonstrated in Figure 4. The small size of the fly ash particles is the way to delivering smooth cement paste, permitting better holding amongst total and cement, and bringing about a more durable concrete. The round state of the particles builds the concrete workability without including extra water.

Table 2- Average Bulk Composition of Class C and F Fly Ashes

Oxide	Weight % / STD	
	Class C	Class F
SiO_2	36.9 ± 4.7	52.5 ± 9.6
Al_2O_3	17.6 ± 2.7	22.8 ± 5.4
Fe_2O_3	6.2 ± 1.1	7.5 ± 4.3
CaO	25.2 ± 2.8	4.9 ± 2.9
MgO	5.1 ± 1.0	1.3 ± 0.7
Na_2O	1.7 ± 1.2	1.0 ± 1.0
K_2O	0.6 ± 0.6	1.3 ± 0.8
SO_3	2.9 ± 1.8	0.6 ± 0.5
Moisture	0.06 ± 0.06	0.11 ± 0.14
LOI	0.33 ± 0.35	2.6 ± 2.4

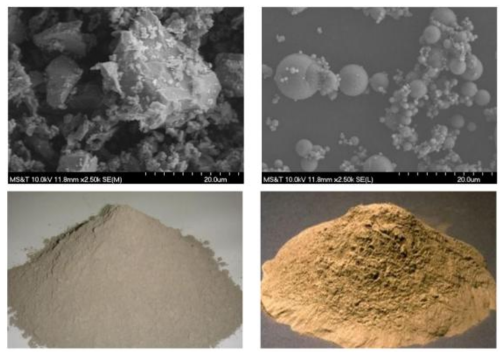

Figure 4- Comparison between Portland cement (left) and Fly Ash (right) Shapes

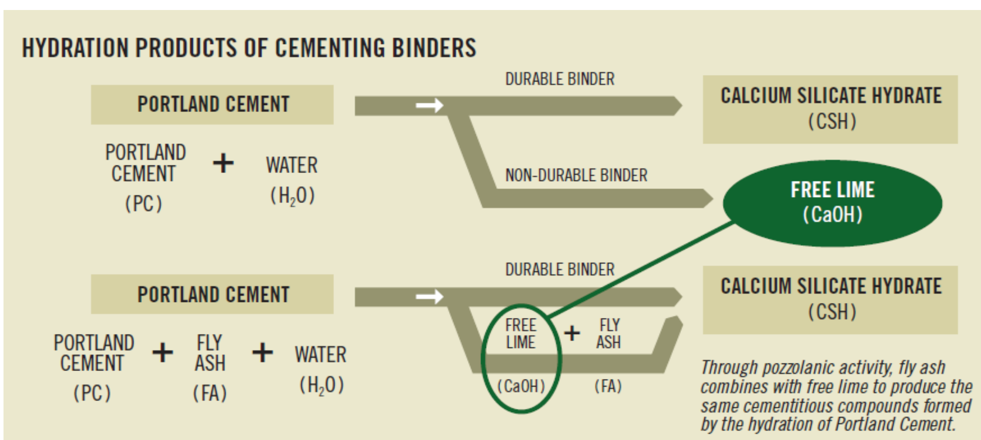

Figure 5- Pozzolanic Reaction

The pozzolanic creation regularly happens more gradually than cement hydration responses and subsequently concrete containing fly ash requires all the more curing amid early ages. Figure 5 displays a graphic description of the pozzolanic creation (Headwaters Resources Tech Bulletin, 2008).

HIGH-CAPACITY FLY ASH (HCFA) CONCRETE: Currently in the India, conventional determinations constrain the measure of fly ash to 25 to 35% replacement by weight of the Portland cement in the concrete. Recent ponders have demonstrated that higher cement replacement percentages (up to 70%) can bring about excellent concrete as far as both quality and strength. Alluded to as high-Capacity fly ash (HCFA) concrete, this sort of concrete offers a practical contrasting option to customary Portland-cement concrete (alluded to as conventional concrete) and is altogether more feasible. HCFA concrete is commonly characterized as concrete having a fly ash substance of half or more noteworthy by weight of cementitious materials. As maintainability concerns keep on increasing in both the construction industry and society as an entire, more prominent accentuation is being set on creating concrete mixtures with expanded Capacity divisions of supplementary cementitious materials, such as fly ash.

Notwithstanding, HCFA concrete can be defenseless to long postponements in completing and may once in a while need vital early age strength development. At all substitution rates, fly ash for the most part slows down the setting time and solidifying rates ofconcrete at early ages Powder increments analyzed in previous research (Bentz, 2010) demonstrated that the expansion of 5% calcium hydroxide by mass of the aggregate solids provides a noteworthy decrease in the hindrance measured in blends in view of either class of fly ash.

MATERIAL & METHOD: The material proportions for the four mixtures are shown in Table 3. The fine aggregate used for all mixtures was Ohio River sand, while the coarse aggregate was a #57 limestone obtained from a local quarry. Both aggregates met the requirements of ASTM C 33.13 Type Portland cement, in accordance with ASTM C 150, was obtained from a local PCC producer from bulk storage. Local tap water was used for all mixtures. Both the Class C and Class F fly ashes were obtained from regional fly ash producers and met the requirements of ASTM C 618.15 One type of Class F fly ash was used in both mixtures, while a different type of Class C fly ash was used in each of the C Ash mixtures; the chemical analyses are shown in Table 4.

Table 3- Mixture Proportions

Component	C Ash		F Ash	
	TDOT A	*HVFA*	*TDOT A*	*HVFA*
Coarse aggregate, lb/yd^3 (kg/m^3)	1835 (1089)	1910 (1133)	1790 (1062)	1836 (1089)
Fine Aggregate, lb/yd^3 (kg/m^3)	1259 (747)	1273 (755)	1221 (724)	1224 (726)
Type 1 PC, lb/yd^3 (kg/m^3)	423 (251)	276 (164)	451 (268)	299 (177)
Class C Fly Ash, lb/yd^3 (kg/m^3)	141 (84)	277 (164)	0	0
Class F Fly Ash, lb/yd^3 (kg/m^3)	0	0	113 (67)	300 (178)
Total Cementious, lb/yd^3 (kg/m^3)	564 (335)	553 (328)	564 (335)	599 (355)
Fly ash, % of Total Cementious	25.0	50.1	20.0	50.1
Water, lb/yd^3 (kg/m^3)	225.5 (134)	187 (111)	254 (151)	209 (124)
w/cm	0.40	0.34	0.45	0.35
Air Entrainer, oz/cwt (mL/100kg)	1.125 (73)	2.625 (171)	1.125 (73)	3.75 (245)
Type E Admixture, oz/cwt (mL/100kg)	0	16 (1043)	0	16 (1043)
Type A Admixture, oz/cwt (mL/100kg)	3 (196)	6 (391)	3 (196)	8 (522)

Table 4- Chemical Analyses of Fly Ashes

Component	F Ash	C Ash (TDOT)	C Ash (HVFA)
Silicon Dioxide (%)	49.82	34.72	29.65
Aluminum Oxide (%)	19.24	17.34	15.02
Iron Oxide (%)	19.09	7.93	10.69
Calcium Oxide (%)	4.94	27.78	30.41
Magnesium Oxide (%)	0.97	4.52	5.29
Sulfur Trioxide (%)	1.15	1.99	1.89
Sodium Oxide (%)	0.64	1.43	2.86
Loss on Ignition (%)	0.56	0.90	0.29

ASTM Type A and E admixtures were used, along with an air-entrainer. Type E admixtures are both accelerating and water-reducing; this was added to the HCFA mixtures in an attempt to reduce the delay in setting time associated with high amounts of fly ash. The HCFA mixtures contained higher dosages of air-entrainer than the TDOT Class A mixtures. As stated in the literature, this was necessary due to the reduced effectiveness of air-entrainer that results from high Capacity of fly ash.6 The HCFA mixture containing F Ash also required a greater dosage of air-entrainer than the C Ash mixture due to the higher carbon content.

RESULT AND DISCUTION: The plastic properties for the batches used for compressive strength testing are given in Table 5. The slump and air content for the Class C ash mixtures were similar, as were those for the Class F ash mixtures. As shown in Figure 6, the HCFA mixture containing Class C ash obtained greater compressive strengths than the TDOT Class

A mixture with 25 percent C ash replacement. The strength of the HCFA mixture was greater than that of the TDOT Class A mixture at all ages. It would seem that the HCFA mixture would have lower strengths at early ages, due to the decreased cement available for reactions. However, it appears that the low w/cm ratio and the increased Type an admixture overcome the adverse effect of increased fly ash. Class C fly ash also has some cementitious properties which contribute slightly to the compressive strengths at early ages. As expected, the long term strengths were greater for HCFA due to the pozzolanic properties of the Class C ash and the lower w/cm ratios. The rate of strength gain for the two mixtures appears to be similar.

Table 5- Plastic Properties

Component	C Ash		F Ash	
	TDOT A	*HVFA*	*TDOT A*	*HVFA*
Slump, in. (cm)	4.5 (11.4)	4 (10.2)	5.75 (14.6)	5.5 (14.0)
Unit Weight, lb/ft^3 (kg/m^3)	145.2 (86.2)	146.94 (87.2)	142.92 (84.8)	141.56 (84.0)
Air content, %	6	6	7	7.75

The long term compressive strengths for the HCFA mixture containing Class F ash were similar to those of the TDOT Class A mixture with 20 percent F ash replacement, as illustrated in Figure 7. Unlike the C ash mixture, the strengths of the HCFA mixture containing F ash were slightly lower than those of the TDOT Class A mixture at early ages. This was the expected behavior due to the large amount of Class F fly ash, which possesses pozzolanic properties but no cementitious properties. Even though the early strength of the HCFA mixture was lower, it still exceeded 750 psi (5.2 MPa) at one day, which has been suggested as an acceptable limit for formwork removal. After approximately three weeks, the compressive strength of the HCFA mixture surpassed that of the TDOT Class A mixture, due to the pozzolanic properties of the F ash. However, at later ages, the compressive strength of the HCFA mixture dropped slightly below that of the TDOT Class A mixture; an explanation for the drop in strength is unclear. It appears from the graph that the rate of strength gain for the HCFA mixture was equal to that of the TDOT Class A mixture, due to the pozzolanic properties.

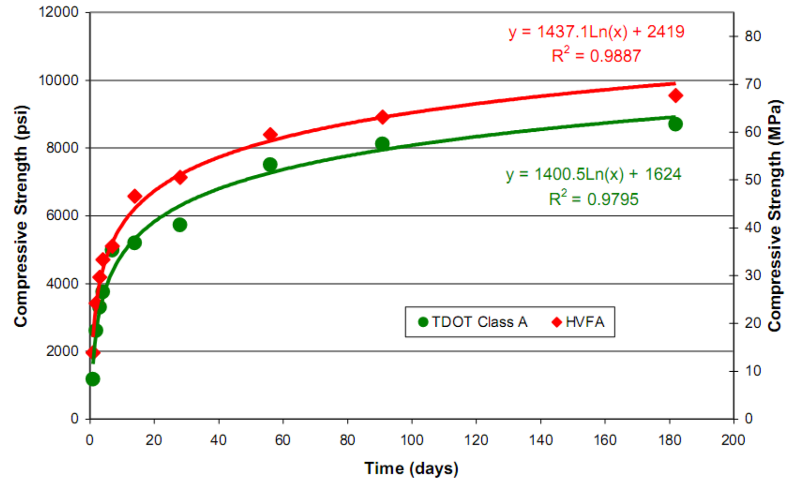

Figure 6- Compressive Strength vs. Time – C Ash Mixtures

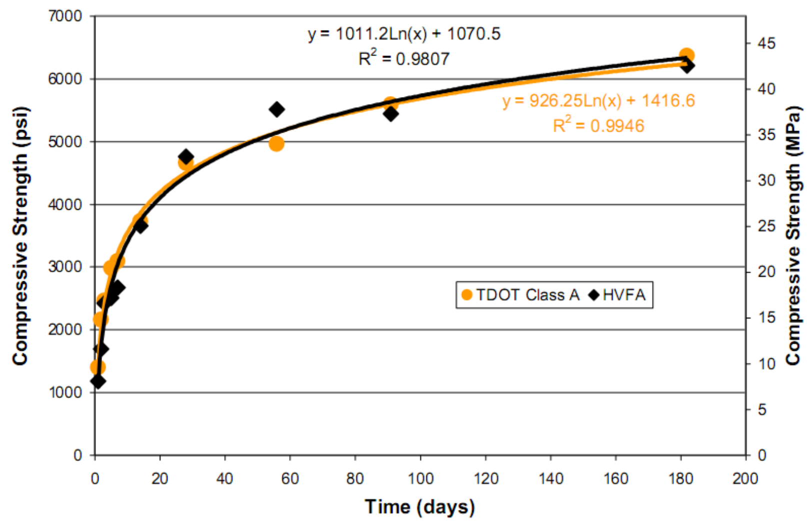

Figure 7- Compressive Strength vs. Time – F Ash Mixtures

Durability Properties: The water absorption and permeable void contents were determined as per ASTM C 642. The water absorption for each of the four mixtures is shown in Figure 8. Both of the HCFA mixtures had significantly less absorption than the TDOT Class A mixtures. Also, Figure 9 illustrates the water permeable void content for each of the mixtures. The HCFA mixtures also had a lower percentage of water permeable voids than the TDOT Class A mixtures. This indicates that the HCFA mixtures will probably exhibit better durability than the TDOT Class A general use mixtures. This is consistent with the literature, which states that the durability of concrete containing large amounts of fly ash is superior to that of normal PCC. The high Capacity of fly ash provides a denser microstructure that is less permeable, resulting in enhanced durability.

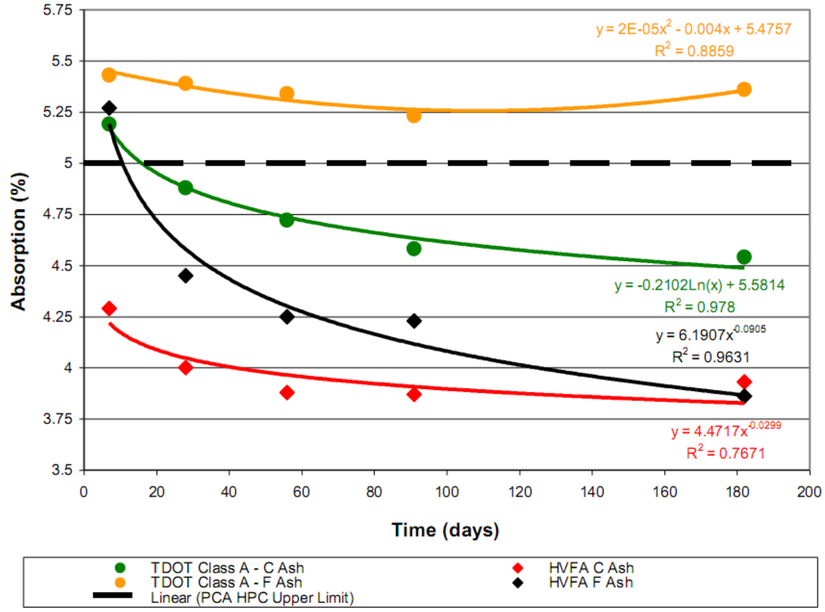

Figure 8- Water Absorption vs. Time

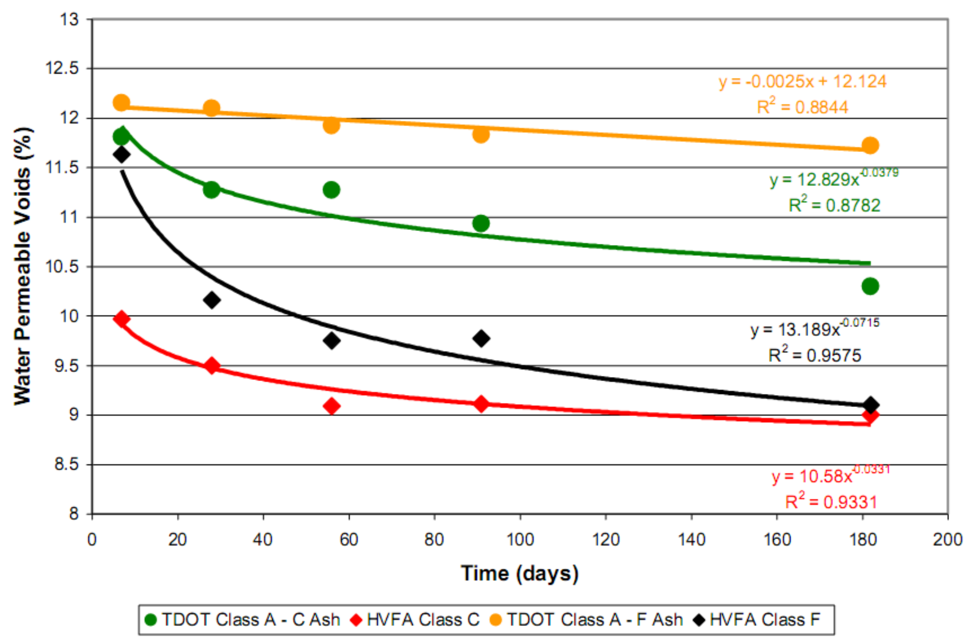

Figure 9- Water Permeable Void Content vs. Time

Time of Set: The plastic properties for both mixtures containing C ash were similar, as were those for the mixtures containing F ash. A comparison of the time of set for the C ash and F ash mixtures is shown in Figures 10 and 11, respectively. The HCFA mixtures had delays in setting times ranging from 1 hour 47 minutes to 2 hours 9 minutes. This is consistent with the literature, which stated that HCFA mixtures have delays in setting times around two hours. The laboratory was maintained at approximately 72°F (22°C) for the duration of testing. When placing in the field at temperatures greater than this, the time required for setting would decrease for the HCFA mixtures. Therefore, it appears that the HCFA mixtures would be ideal for warm weather placements.

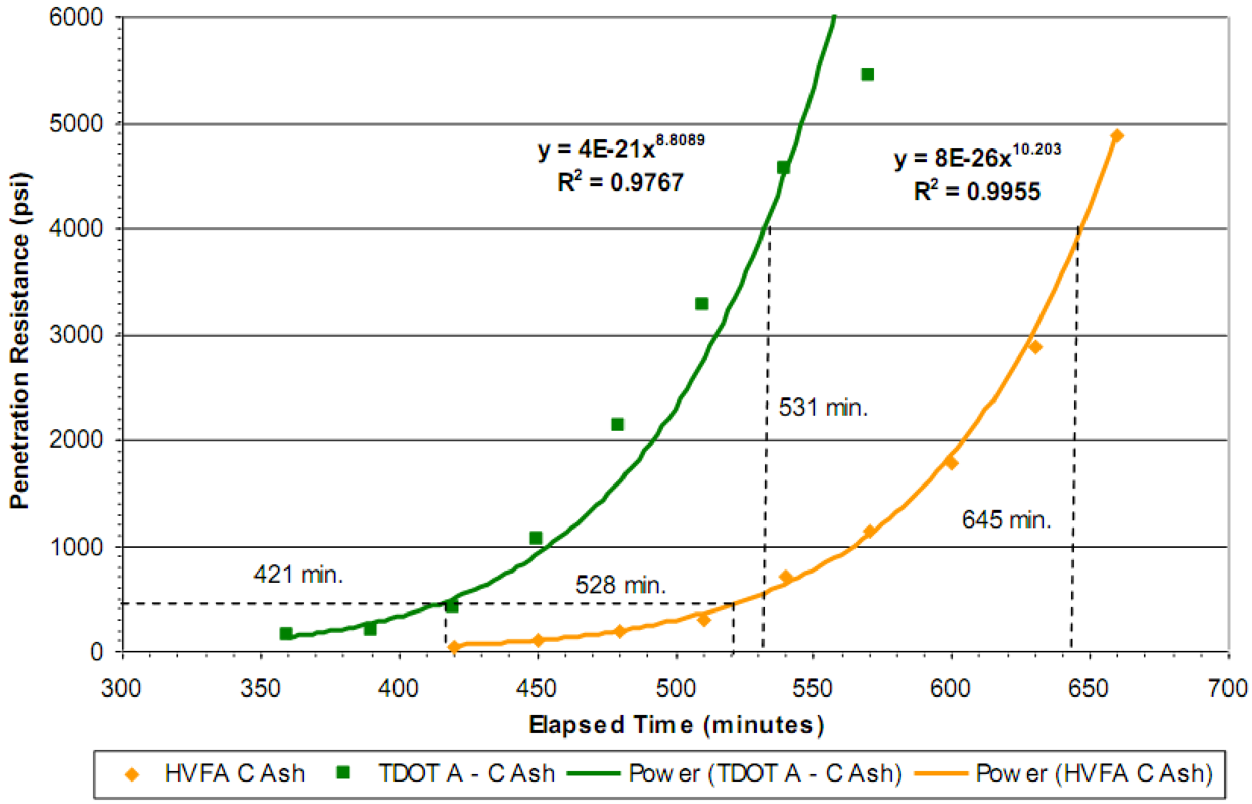

Figure 10- Time of Set Comparison – C Ash

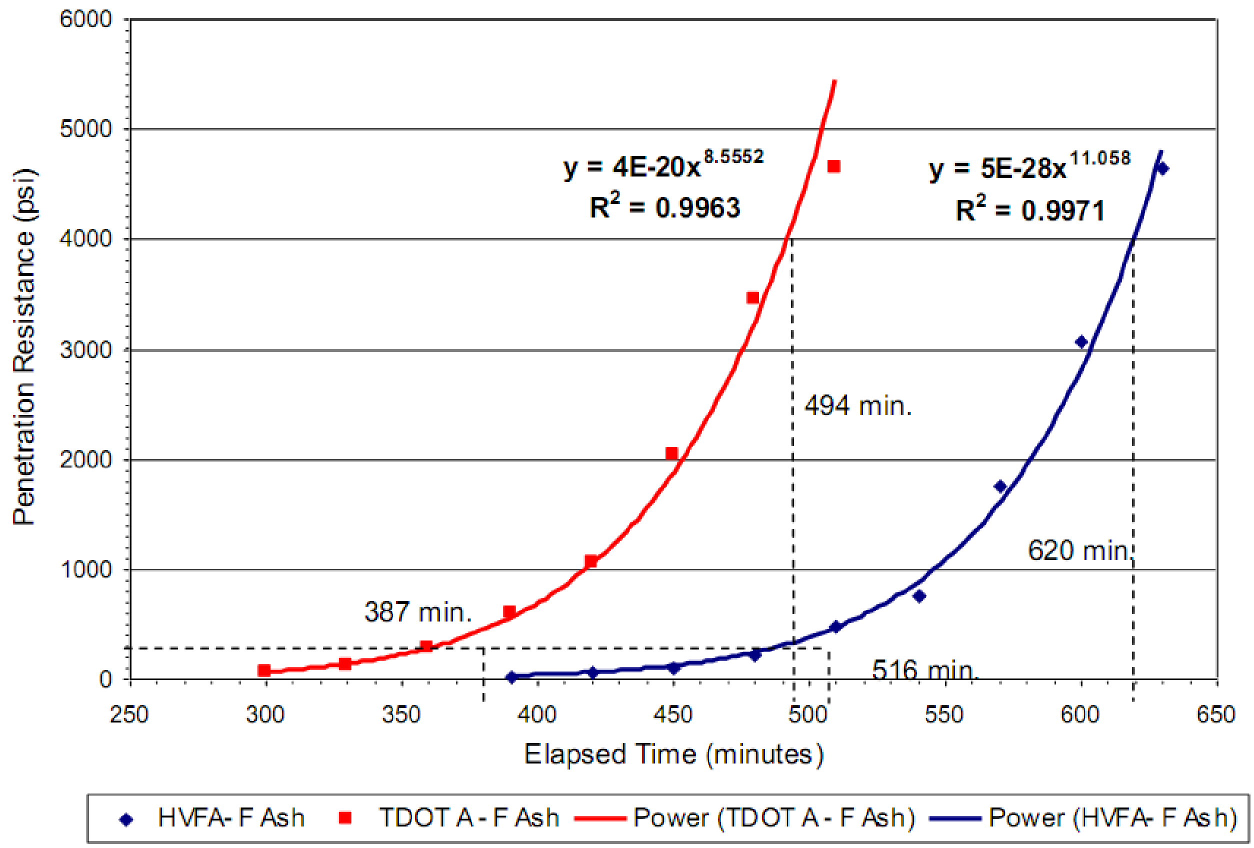

Figure 11- Time of Set Comparison – F Ash

CONCLUSION: The use of high-Capacity fly ash (HCFA) concretes has as of late picked up fame as an asset proficient, durable, cost-effective, sustainable alternative for some sorts of Portland cement concrete (PCC) applications. Any concrete containing a fly ash content that is more prominent than 50 percent by mass of the aggregate cementitious materials is viewed as HCFA PCC. The creation of port land cement is not only costly and vitality escalated, but rather it likewise delivers a lot of carbon dioxide. With large quantities of fly ash accessible around the globe at low costs, the utilization of HCFA appears to offer the best here and now answer for rising cement demands. Fly fiery remains is a side-effect and in this manner more affordable than port land cement; it is additionally known to improve workability and lessen internal temperatures. The improved workability is a consequence of the "ball bearing" activity of the circular fly ash particles. Fly ash enhances the evaluating in the blend by smoothing out the fine molecule estimate conveyance. Likewise, fly ash has been appeared to diminish the measure of water required. Fly ash from present day power plants utilized as a part of huge Capacity can lessen the water content by 15 to 20 percent. However, research has demonstrated that the properties of HCFA concrete are unequivocally reliant on the qualities of the cement and fly ash utilized.

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