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An Investigation of the Effects of a High Volume of Fly Ash in Concrete

Dhipanaravind Singaravel [a], Nandhagopal Boopathi [b], Divya Thirugnanam [c], Silpa Nayaruveettil[d]

[a,b,c,d] *Assistant Professor, Civil Engineering, Annapoorana Engineering College, Salem, Tamil Nadu, India*

A B S T R A C T

India's power production is projected to grow from 876.89 BU in 2011-12 to 1624.158 BU in 2022-23, with coal being the country's principal energy generator. Production of fly ash in India's thermal power plants has skyrocketed, from 150 million tons in 2008 to an anticipated 300 million tons in 2022. It is now projected that global production of coal ash is over 600,000,000 tons per year. If the amount of fly ash generated increases from its present levels, there will be a greater environmental issue over its disposal. Cement manufacturing, meanwhile, is on the rise, adding to the problem of climate change. To put it another way, the production of one metric ton of cement results in the emission of one metric ton of carbon dioxide. One of the most potential uses has been in the concrete production business, and experts from across the world have been hard at work developing novel methods to recycle this undesired waste.

Keywords: Coal, Fly ash, Concrete, Climate change, waste

1. Introduction

Aside from exceptionally high resource and energy consumption, cement manufacturing is a substantial source of CO2 emissions, accounting for roughly 4.4% of worldwide CO2 emissions from industry [1]. Another negative environmental consequence of Portland cement manufacture is its high energy usage [2]. However, owing to its great adaptability, availability, and cheap cost, concrete is the most used synthetic material on the globe [3]. Fly ash (FA) is a byproduct of pulverized coal combustion in electric power plants that is recovered from fuel gases by mechanical and electrostatic separators [4]. The benefits of employing fly ash in concrete businesses include environmental, economic, energy saving, and ecological benefits.

Power generation in India is expected to rise from 876.89 BU in 2011-12 to 1624.158 BU in 2022-23, with coal serving as the primary energy source. Fly ash production in India's thermal power plants has increased dramatically, from 150 million tons in 2008 to an estimated 300 million tons in 2022. The worldwide output of coal ash is currently expected to exceed 600,000,000 tons per year [5]. If the amount of fly ash generated increases from its present levels, there will be a greater environmental issue over its disposal. Cement manufacturing, meanwhile, is on the rise, adding to the problem of climate change. To put it another way, the production of one metric ton of cement results in the emission of one metric ton of carbon dioxide [6-7]. One of the most potential uses has been in the concrete production business, and experts from across the world have been hard at work developing novel methods to recycle this undesired waste [8-10].

Alternatives to clinker and Portland cement that exhibit these qualities include slag, fly ash, silica fume, and minerals found in rock. Natural materials like pozzolans, calcined clays, and so on that need little processing might partly replace synthetic counterparts, reducing both energy usage and greenhouse gas emissions. Cement production is much outpaced by the output of byproducts that might be substituted for it (slags, fly ashes, silica fumes, rice husk ash, etc [11-12]. Recyclables like these may be used into aggregates or fillers for concrete. They may also be processed into clinker or used in cementing systems. The most recent developments in crushing and blending machinery will make it considerably simpler to reuse these waste products. More accurate control over production processes and the actualization of the concrete's desired attributes are made possible by advancements in chemical admixtures such super plasticizers, air entraining agents, etc.

1.1 Fly ash

Byproducts of power production, such as nitrogen oxides and sulfur oxides from the burning of solid fuels like coal, peat, and slate, and fly and bottom ashes from the combustion of gas or oil, provide a significant challenge for today's thermal power plants (TPPs). Fortunately, Portland cement may be largely replaced by supplemental cementing materials (SCMs) such as fly ash, a byproduct of coal-burning in thermal power plants. Both the concrete batch plant and the blending of mixed cements are viable options for making the adjustment.[14-17]

Fly ash is abundant in India, hence it is essential that every effort be made to make extensive use of it to meet current construction demands and reduce environmental impact. There's a limit on how much cement may be replaced. The 20% mark is a popular and feasible goal. Maltos, found that ASTM Class F fly ash may be used in lieu of up to 60% cement [18]. The use of fly ash that has been chemically self-activated as a full cement substitute has been shown in recent experiments. Although a few activators have been proposed, their use either requires too much or is too pricey. An important problem with fly-ash concretes is their slow strength development [19-21].

In reality however, only a small percentage of construction projects need for really robust beginnings. Since slow strength development results in lower heat and hydration rates, it may be useful in many different contexts, including ones calling for mass concrete. Because the exact properties of the fly ash may vary from batch to batch depending on the source material, quality control is another area of concern [22]. So, projects with high aesthetic criteria are less likely to utilize concrete with a lot of fly ash in it. Fly ash has been proven to lessen the potency of the alkali-silica interaction in several tests.

Fly ash, a finely divided waste formed after burning ground or powdered coal, is released into the atmosphere along with the exhaust gases from coal-fired power plants. It possesses some cementitious property because to the presence of siliceous and aluminous elements, but only a very minor quantity [23-27]. In addition to the glassy and crystalline phases, fly ashes also include a wide variety of other minerals and chemicals.

Classification of fly ash

They are classified as either Class C or Class F by the American Society for Testing and Materials. The main components are ferric oxide (Fe_2O_3), alumina (Al_2O_3) and silica (SiO_2) (Fe_2O_3). In addition to sulfur trioxide and alkali, they also contain calcium and magnesium oxides.

Class C materials must include between 50 and 70 percent total SiO_2, Al_2O_3, and Fe_2O_3. This is according to ASTM regulations. Most items in this category have a calcium oxide content of 15%-30%, much over the typical 10% content. Particles less than 10 micrometers in size make up a significant fraction of the total.

For a material to be classified as ASTM Class F, it must include at least 70% SiO_2, Al_2O_3, and Fe_2O_3. Silica glass, quartz, mullite, and low-reactivity magnetite all fall into this group since they contain a negligible amount of calcium oxide (less than 10%). A higher concentration of calcium in fly ash allows for faster development of maximum potency. Particles of solid fly ash generally range in size from 1 micrometer to 1 millimeter or bigger, and their specific gravity is between 2.2 and 2.8.

2. Experimental studies on fly ash concrete

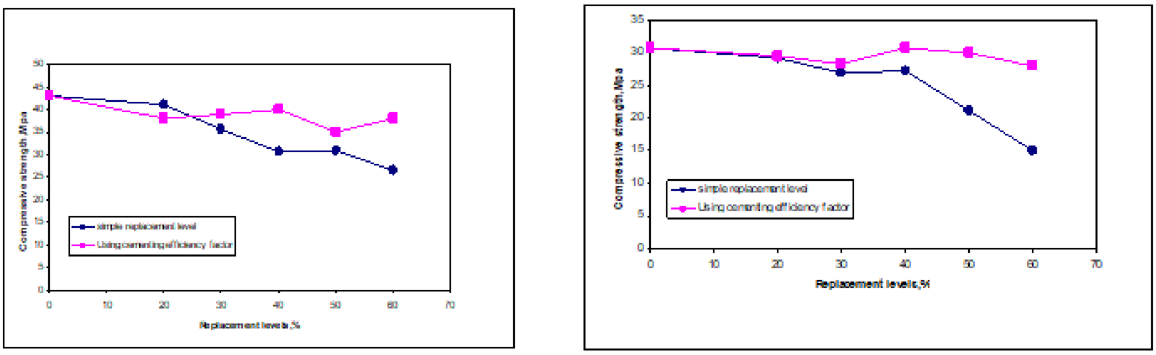
The goal of the experiments was to compare the durability of conventional concrete to that of concrete augmented with fly ash. The corrosion rates (mmpy) of the implanted steel reinforcements were used to calculate the durability factor. What kind of concrete was utilized has a major role in how long it will last. The studies in this research were conducted using M20 and M35 grade concrete.

These goals were studied in the following ways. Concrete parameters

1. Mix design.
2. Slump test.
3. Compressive strength.
4. Splitting tensile strength.
5. Flexural strength & Flexural Elastic modulus.
6. Permeable voids and water absorption.
7. Chloride diffusion test.
8. Steel parameters (Durability tests):
9. Time to cracking.
10. Open circuit potential measurement.

Mix design modifications, such as a low w/c ratio, may provide a strong composite at either the 50% or 60% replacement levels.

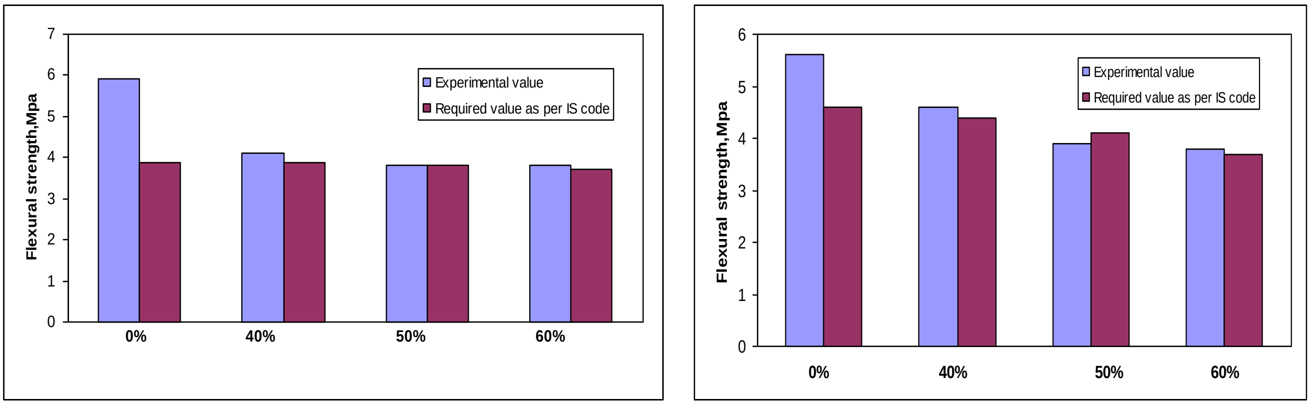
According to the CEP-FIP model code, the tensile strength of fly-ash concrete is much higher than that of conventional concrete. In contrast to the control concrete, this concrete has been demonstrated to be less durable.



(a) (b)

Fig. 1 - (a) (b) Compressive strength for M20 and M35 grade concrete at the end of 28th day curing.

Weakening of the early and 28-day compressive strengths is expected if more than 20% of the fly ash is replaced during the design phase.With the cement efficiency factor, the early and 28-day compressive strengths of the replacement concrete are comparable to those of the control concrete up to a 40% replacement level, while a reduction is seen between the 50% and 60% replacement levels.



(a) **(b)**

Fig. 2 - (a) (b) Flexural strength of M20 and M35 Grade concrete

There is a greater amount of deflection under flexural loads in fly-ash concrete compared to control concrete. In this way, the flexural elastic modulus of fly-ash concrete is less than that of control concrete.

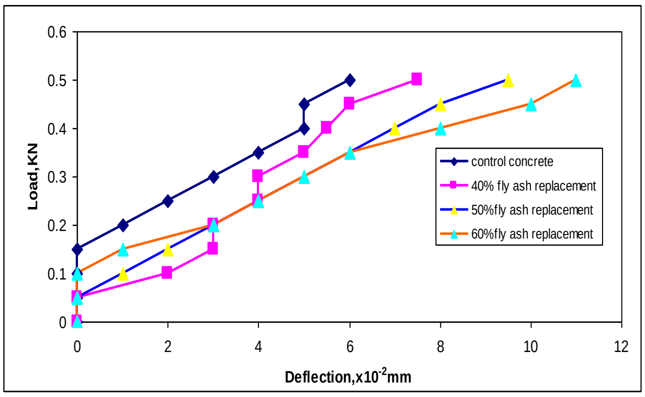
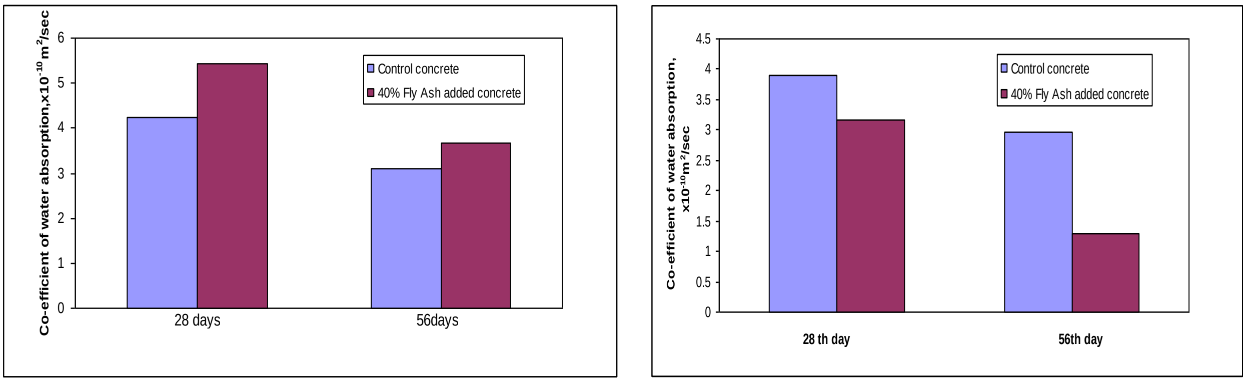


Fig. 3 - Flexural Elastic Modulus of M20 and M35 Grade concrete



(a) (b)

Fig. 4 - (a) (b) Water absorbtion of M20 and M35 Grade concrete

The percentage of water absorption is less in fly ash concrete in M35 grade than control concrete at both the curing periods' studied. But this is not observed in M20 grade concrete.

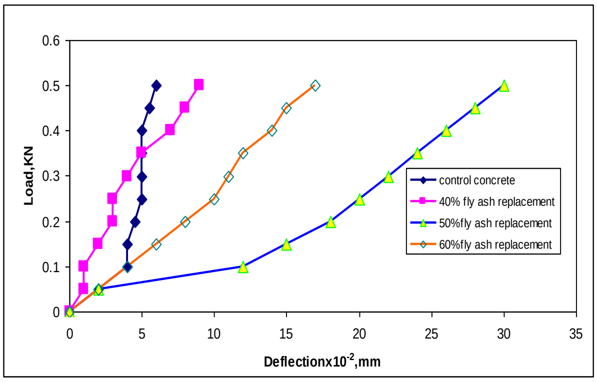
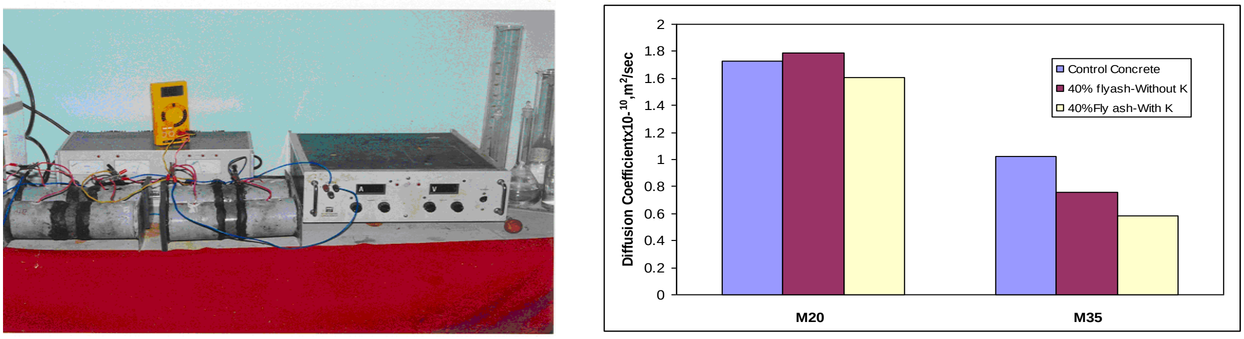


Fig. 5 - Co-efficient of water absorption for M20 and M35 Grade concrete



(a) (b)

Fig. 6 - (a) Chloride Diffusion Coefficient - Apparatus Fig: 6 (b) Chloride Diffusion Coefficient

The chloride diffusion co-efficient of fly ash concrete is less in both the grades of concrete studied than control concrete.

Concrete that has fly ash added has a smaller negative score in the time to cracking test, suggesting less corrosion when exposed to chlorides. The fact that exposed rebar appears in the final photograph supports this idea.

Using the RCC corrosion monitor, it was found that the corrosion rate of fly-ash concrete was reduced in the ponding test for 90 days. So, the reduced corrosion rate and chloride diffusion may be attributed mostly to the poredensification of fly ash concrete brought about by the pozzolanic process. Superior Quality Concrete of the M20 Grade M35 Concrete Grade.

(a)

(b)

Fig. 7 - 7-90 days Ponding Results for M20 and M35 grade concrete

3. Conclusion

Producing concrete has a major negative impact on the environment and depletes natural resources. As such, it is more obligated than most to provide significant support for long-term growth and prosperity. To achieve this goal, it must prioritize the following four factors:

1. Looking at other cement-making methods that emit fewer pollutants and require less energy.
2. The most realistic option until these technologies become generally available is to increase the usage of cementitious materials, especially waste materials, to cut down on the need for portland cement.
3. Second, by making careful addition selections and using a well-planned concrete mix,
4. Reduce the frequency with which buildings must be rebuilt by increasing their longevity.

Below are some particularly productive instances of this. The connecting thread is that everyone makes the most of inherent characteristics to create value. Taking use of fly ash's pozzolanic characteristics, for instance, may turn a waste product of the coal-burning power industry into a valuable commodity with a market value on par with the cement it displaces. The value of this once-discarded semiconductor industry byproduct has skyrocketed thanks to its discovery as a crucial component of high-performance concrete. Because of the additional decorative and architectural applications that are made possible by color-sorting waste glass, the market value of this material has increased to that of premium aggregates used in the production of speciality items. Oftentimes, political issues in addition to strictly economic ones play a part in deciding which resources are more valued on the market.

References

[1] Ignjatović, I., Z. Sas, J. Dragaš, J. Somlai, and T. Kovács. 2017. "Radiological and Material Characterization of High Volume Fly Ash Concrete." Journal of Environmental Radioactivity 168(December 2017):38–45. doi: 10.1016/j.jenvrad.2016.06.021.

[2] Camoes, Aires. 2014. "Durability of High-Volume Fly Ash Concrete."

[3] Arezoumandi, Mahdi, Jeffery S. Volz, Carlos A. Ortega, and John J. Myers. 2015. "Shear Behavior of High-Volume Fly Ash Concrete versus Conventional Concrete: Experimental Study." Journal of Structural Engineering (United States) 141(3). doi: 10.1061/(ASCE)ST.1943-541X.0001003.

[4] Sun, Jinfeng, Yu Zhang, Xiaodong Shen, Gang Tan, and Jennifer Tanner. 2019. "Water Absorption of High Volume Fly Ash Concrete Prepared by Local Fly Ash." 15th International Congress on the Chemistry of Cement (16-20 September).

[5] Bhatt, A.; Priyadarshini, S.; Mohanakrishnan, A.A.; Abri, A.; Sattler, M.; Techapaphawit, S. Physical, chemical, and geotechnical properties of coal fly ash: A global review. Case Stud. Constr. Mater. 2019, 11, e00263.

[6] Ahmaruzzaman, M. A review on the utilization of fly ash. Prog. Energy Combust. Sci. 2010, 36, 327–363.

[7] Huseien, G.F.; Joudah, Z.H.; Khalid, N.H.A.; Sam, A.R.M.; Tahir, M.M.; Lim, N.H.A.S.; Alyousef, R.; Mirza, J. Durability performance of modified concrete incorporating fly ash and effective microorganism. Constr. Build. Mater. 2021, 267, 120947.

[8] Nath, S.; Kumar, S. Role of particle fineness on engineering properties and microstructure of fly ash derived geopolymer. Constr. Build. Mater. 2020, 233, 117294.

[9] Huseien, G.F.; Shah, K.W.; Sam, A.R.M. Sustainability of nanomaterials based self-healing concrete: An all-inclusive insight. J. Build. Eng. 2019, 23, 155–171.

[10] Ng, D.S.; Paul, S.C.; Anggraini, V.; Kong, S.Y.; Qureshi, T.S.; Rodriguez, C.R.; Liu, Q.-F.; Šavija, B. Influence of SiO2, TiO2 and Fe2O3 nanoparticles on the properties of fly ash blended cement mortars. Constr. Build. Mater. 2020, 258, 119627.

[11] Liu, M.; Tan, H.; He, X. Effects of nano-SiO2 on early strength and microstructure of steam-cured high volume fly ash cement system. Constr. Build. Mater. 2019, 194, 350–359.

[12] Rashad, A.M. Effects of ZnO2, ZrO2, Cu2O3, CuO, CaCO3, SF, FA, cement and geothermal silica waste nanoparticles on properties of cementitious materials–A short guide for Civil Engineer. Constr. Build. Mater. 2013, 48, 1120–1133.

[13] Zhang, R.; Cheng, X.; Hou, P.; Ye, Z. Influences of nano-TiO2 on the properties of cement-based materials: Hydration and drying shrinkage. Constr. Build. Mater. 2015, 81, 35–41.

[14] Samadi, M.; Shah, K.W.; Huseien, G.F.; Lim, N.H.A.S. Influence of glass silica waste nano powder on the mechanical and microstructure properties of alkali-activated mortars. Nanomaterials 2020, 10, 324.

[15] Khan, N.N.; Saha, A.K.; Sarker, P.K. Reuse of waste glass as a supplementary binder and aggregate for sustainable cement-based construction materials: A review. J. Build. Eng. 2020, 28, 101052.

[16] Bueno, E.T.; Paris, J.M.; Clavier, K.A.; Spreadbury, C.; Ferraro, C.C.; Townsend, T.G. A review of ground waste glass as a supplementary cementitious material: A focus on alkali-silica reaction. J. Clean. Prod. 2020, 257, 120180.

[17] Hamzah, H.K.; Joudah, Z.H.; Georgescu, D.P.; Khalid, N.H.A.; Huseien, G.F. Laboratory evaluation of alkali-activated mortars modified with nanosilica from glass bottle wastes. Mater. Today Proc. 2021, 46, 2098–2104.

[18] Matos, A.M.; Sousa-Coutinho, J. Durability of mortar using waste glass powder as cement replacement. Constr. Build. Mater. 2012, 36, 205–215.

[19] Larsen, A.W.; Merrild, H.; Christensen, T.H. Recycling of glass: Accounting of greenhouse gases and global warming contributions. Waste Manag. Res. 2009, 27, 754–762.

[20] Mehta, A.; Siddique, R.; Ozbakkaloglu, T.; Shaikh, F.; Belarbi, R. Fly ash and ground granulated blast furnace slag-based alkali-activated concrete: Mechanical, transport and microstructural properties. Constr. Build. Mater. 2020, 257, 119548.

[21] Thomas, B.S. Green concrete partially comprised of rice husk ash as a supplementary cementitious material—A comprehensive review. Renew. Sustain. Energy Rev. 2018, 82, 3913–3923.

[22] Nasr, M.; Hussain, T.; Kubba, H.; Shubbar, A. Influence of using high volume fraction of silica fume on mechanical and durability properties of cement mortar. J. Eng. Sci. Technol. 2020, 15, 2494–2506.

[23] De Maeijer, P.K.; Craeye, B.; Snellings, R.; Kazemi-Kamyab, H.; Loots, M.; Janssens, K.; Nuyts, G. Effect of ultra-fine fly ash on concrete performance and durability. Constr. Build. Mater. 2020, 263, 120493.

[24] Siad, H.; Lachemi, M.; Sahmaran, M.; Mesbah, H.A.; Hossain, K.M.A. Use of recycled glass powder to improve the performance properties of high volume fly ash-engineered cementitious composites. Constr. Build. Mater. 2018, 163, 53–62Schwarz, N.; Cam, H.; Neithalath, N. Influence of a fine glass powder on the durability characteristics of concrete and its comparison to fly ash. Cem. Concr. Compos. 2008, 30, 486–496.

[25] Aliabdo, A.A.; Abd Elmoaty, A.E.M.; Aboshama, A.Y. Utilization of waste glass powder in the production of cement and concrete. Constr. Build. Mater. 2016, 124, 866–877.