International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 7, Issue 5, pp 312-316, May-2023

https://doi.org/10.47001/IRJIET/2023.705044

Literature Review: Application of Nano Fly Ash in High Volume Fly Ash Concrete

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***Abstract* - A review of existing research on Nano Fly Ash (NFA) aims to show that using Nano Fly Ash (NFA) on High Volume Fly Ash Concrete is possible. The application can have an impact on durability improving concrete strength. The higher the compressive strength of the concrete, the more Nano Fly Ash (NFA) is utilized as a partial replacement for cement. The goal of this literature review is to determine how the addition of nano fly ash to high volume fly ash can be accelerated during the manufacturing process. The information is gathered by analyzing many articles on Nano Fly Ash (NFA) from 2013 to 2023. A collection of journals gathered from a variety of national and international publications gathered through the sciencedirect database and Google Scholar via the publish or perish application.**

Keywords: Nano Fly Ash, High Volume Fly Ash Concrete, Workability, Strength, Durability.

I. INTRODUCTION

In general, concrete is defined as a material that is made up mostly of coarse aggregate, fine aggregate, water, and portland cement (SP). The usage of Ordinary Portland cement in the cement and construction industries contributes to high production costs as well as high embodied energy of concrete. One ton of Portland cement clinker produces around one ton of CO_2 [9].

Conventional concretes frequently fail to sufficiently prevent the entrance of moisture and hostile ions. It has been claimed that the use of blended cements or supplemental cementing elements reduces permeability, enhancing the resistance of concrete against deterioration by hostile chemicals such as chlorides. As a result, combining Portland cement with pozzolanic materials is becoming a more common method in structure construction [12]. Manufacturing of high volume fly ash concrete mixtures has received a lot of attention in recent years as a way to minimize the carbon footprint of the building industry [10].

The most commonly used mineral aggregates in concrete mixtures are fly ash and silica fumes [6]. Fly ash is a naturally occurring byproduct of coal burning and volcanic ash emissions. When coal is burned at high temperatures near 2800F in a Hitech power plant, noncombustible minerals form from bottom ash, which is classed as fly Ash. Fly Ash is the substance that is carried away with flue gases and collected by an electric precipitator, depending on the technique of burning the fly Ash [5].

Since the 1930s, fly ash, a pozzolanic substance, has been used in concrete as a partial replacement for portland cement to increase the material's strength and longevity while reducing the amount of early heat generation. From an environmental standpoint, substituting fly ash for cement lowers the overall carbon footprint of concrete and diverts an industrial by-product from the solid waste stream (today, roughly 40% of fly ash is recovered for beneficial usage and 60% is disposed of in landfills) [3].

According to the [1] 1.9 million tons of fly ash were produced at the end of 2019. The vast majority of this sum (83.1%) was recovered. However, the problem of waste disposal persists; around 25 million tons of fly ash was stacked at a landfill in Poland at the end of 2019. This shows how waste management is in high demand.

Storage of coal combustion products involves enormous places which results in energy and heat production expenses. Waste or by-products can be a source of profitable and low-cost construction materials. Another way to prevent fly ash from polluting the environment is to use it as a raw material to replace some or all Portland cement during the concrete making process.

The qualities of fly ash determine how it is used. Several studies have been conducted over the last decade to better understand the possible environmental and health implications of fly ash disposal by land filling [2].

According to ASTM Standars, fly ash with less than 10% calcium concentration is classified as class F, while fly ash with more than 10% calcium content is classified as class C. CaO concentrations are significantly lower than in Class C fly ash because Class F fly ashes are mostly pozzolanic and have little or no cementitious properties of their own [4].

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Several researchers studied the use of nanomaterials in concrete performance, workability, and setting time. A high energy ball experiment was used to convert micro-sized fly ash into nano-structured fly ash. The inclusion of SiO_2 and Al_2O_3 in fly ash improves concrete performance in terms of density and strength [8].

The majority of fly ash particles are spherical in shape and range in size from 0.5 to 100 nanometers. Mullite ($3Al_2O_3$. $2SiO_2$), quartz (SiO_2), aluminium oxide (Al_2O_3), hematite (Fe_2O_3), lime (CaO), and gypsum ($CaSO_4$. $2H_2O$) make up the majority of them. As a result, depending on the mineralogical composition of the used coal and the combustion process, it has a variety of physical, chemical, and mineralogical properties [11].

Nano Fly Ash (NFA) particles have a huge surface area and high reactivity as compared to fresh fly ash particles. This can happen because the particles are generated by the nucleation of volatile components or through chemical processes. Nano Fly Ash (NFA) has been shown to absorb more ions and bind more strongly than larger particles, which can reduce the fraction of adsorbed ions [7].

The purpose and goal of holding this journal review is to find out the results of several research journals in advance to find out the application to durability, workability, and strength in concrete that is increasing, a comparison of the methods used for making Nano Fly Ash (NFA) in several journals, as well as describe the application of Nano Fly Ash (NFA) in civil engineering work that is usually used as an additive in making mortar abrasive. This journal review is provided as a resource for determining how much Nano Fly ash (NFA) is utilized in concrete work.

II. METHOD

The research method used is systematic literature review, which is a systematic way of collecting, evaluating, integrating, and presenting findings from various research studies on questions or topics of interest.

The approach utilized in evaluating journals is classified as a literature review. This journal analysis establishes prior research journals and is related to the topic used, namely research on Nano Fly Ash (NFA). Some of the journals used were research journals published between 2010 and 2023. The information collected pertains to the process of producing Nano Fly Ash (NFA) and the outcomes of incorporating Nano Fly Ash (NFA) into concrete, specifically its durability and workability. Additionally, each finding was re-examined to gather details on the methodology employed in generating Nano Fly Ash (NFA), the proportion of Nano Fly Ash (NFA) utilized as a substitute for cement in mortar or concrete, and the effects on the durability and workability of mortar or concrete containing Nano Fly Ash (NFA).

The information source utilized in this assessment publication involves information retrieved from online publications ranging from national to international scale, facilitated by publish and perish software that utilizes Google Scholar data. The process of handling this research data entails gathering data associated with the research title, followed by scrutinizing the data in terms of the execution approach for producing Nano Fly Ash (NFA), and juxtaposing the outcomes of the resilience and feasibility of supplementing concrete with Nano Fly Ash (NFA), as documented in related publications. This analysis will yield the findings of the examination, which will then be discussed and conclusions will be drawn based on the outcomes of the discussion.

Table 1: Literature Review Topics

Topics	Authors
Performance of High Volume Fly Ash Concrete in Structural Applications	[9] Harihanandh, Viswanathan and Krishnaraja, 2021
Compressibilty of Fly Ash and Fly Ash – Bentonite	[1] Mariola Wasil, 2021
Effect of Nano–Fly Ash on Strength of Concrete	[2] Prince and Jemimah, 2011
Preparation and Characterization of Nano structured Materials from Fly Ash: A Waste from Thermal Power Stations, by High Energy Ball Milling	[11] Thomas Pauletal., 2007
Comparative Study of Compressive Strength of Concrete With Fly Ash Replacement by Cement	[5] Abushad and Sabri, 2017
Effect of Fly Ash and Nano Titanium Dioxide on Compressive Strength of Concrete	[6] Sharma, Kaur and Gupta, 2019
Comparative study on strength and durability of concrete upon partial substitution of fly ash and bagasse ash in conventional concrete	[4] Siddharta, 2021
Metal Adsorption by Coal Fly Ash: the Role of Nano-Sized Material	[13] Etale, Tavengwa and Pakade, 2018

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Comparative study on chemical and morphology properties of nano fly ash in concrete	[8] Harihanandh, Viswanathan and Khrisnaraja, 2019
Development and Evaluation of High-Volume Fly Ash (HFVA) Concrete Mixes	[3] Jeffery, John and David, 2013
Characteristics study of high volume fly ash concrete	[12] Patoliya and Dr. Anurag Misra, 2015

III. RESULTS AND DISCUSSIONS

The outcomes of the journal discuss revealed that there were variations in the tools and methods used for the Literature review, which were sourced from different publications. The tool operates on the same concept, grinding fresh fly ash samples that are micro-sized and then changing to nano-size after a few hours of grinding.

Fly ash is classified into three types: class C, class F, and class N. The surface of the particles is then analyzed using scanning electron microscopy (SEM) to obtain changes in shape and elemental analysis of the phases observed in nano structured fly ash powder particles. Furthermore, nano-sized fly ash samples will be introduced to the test item to determine the compressive, tensile, and flexural strength.

Table 2: Percentage of Added Material Nano Fly Ash and Strength

Research Reviewer	NFA Percentage	Strength (28 days)	Unit
[13] (Naresh, Lavanya and Kumar, 2021)	0%; 25%; 50%	6,3; 7,25; 5,45	N/mm^2
[5] (Abushad and Danish, 2017)	0%; 10%; 20%; 30%; 40%; 50%	40,2; 41,9; 43,23; 45,28; 42,0; 39,15	N/mm^2
[4] (Siddharta, 2021)	0%; 5%; 10%; 15%; 20%; 25%; 30%; 35%; 40%	48,3; 51,4; 52,4; 53,5; 55,7; 56,4; 58,7; 55,9; 53,4	N/mm^2
[14] (Antoni, 2017)	0%; 10%; 20%; 30%; 40%; 50%; 60%	63,9; 64,3; 58,1; 59,8; 52,4; 43,0; 42,6	N/mm^2
[6] (Sharma, Kaurand Gupta, 2019)	10%; 20%; 30%	41,6; 42,7; 40,7	N/mm^2
[9] (Harihanandh, Viswanathan, And Krishnaraja, 2021)	0%; 30%; 35%; 40%; 50%	42,1; 35,2; 41,6; 32,4; 31,3	N/mm^2
[15] Lokesh, Umesh and Chittaranjan	5%; 10%; 15%; 20%	40,32; 39,53; 38,02; 36,94	N/mm^2
[2] (Prince and Jemimah, 2011)	10%; 20%; 30%	39,78; 44,67; 47,02	N/mm^2
[16] (Arie Wardhono, 2021)	0%; 50%; 53%; 55%	30,7; 32,4; 27,2; 26,1	N/mm^2
[17] (Charith, Chamila, David and Sujeeva, 2021)	65%; 80%	41,1; 32,8	N/mm^2
[18] (Sukanya, Golok, Ahin And Raju, 2013)	0%; 5%; 10%; 20%	24,2; 20,8; 19,7; 17,3	N/mm^2
[19] (Dhiaa, Abdulhadi and Kareem, 2021)	0%; 5%; 10%; 15%	31,6; 28,2; 26,5; 23,0	N/mm^2
[20] (Harihanandh and Sivaraja, 2016)	Conventional Concrete (0%); Raw Fly Ash Concrete (23%); Nano Fly Ash Concrete (23%)	25,76; 27,38; 34,50	N/mm^2
[21] (Chenetal., 2021)	38%; 40%; 58%; 60%	69,32; 59,70; 48,68; 43,76	N/mm^2

The addition of a different percentage of Nano Fly Ash (NFA) to the test object causes study differences, which can boost the accuracy in determining the durability value that occurs in the test object. This change is also related to differences in the function of the test during the test object's production.

Strength Results for the Addition of NFA

It was found from the researchers that the testing in several journals had different levels of Strength. This can occur as a result of the application in the manufacture of different test specimens, namely by making test specimens for concrete, so that the composition of the materials used is also

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different, and then adding the same Nano Fly Ash (NFA) content to the manufacture of the test object, the maximum value of durability will be different. Because it was stated on the test object that increasing Nano Fly Ash (NFA) making the concrete stronger, the values of compressive strength in concrete did not reach a linear function in this study. The value of compressive strength decreases.

IV. CONCLUSION

The mechanical and durability properties of HVFA concrete were examined when cement was substituted by fly ash with/without a variety of micro/nano additions. The following conclusions can be drawn from the overall review of this work.

1) Combining Portland cement with pozzolanic materials is becoming a more common method in structure construction [12].
2) The usage of Nano Fly Ash become essential variables in increasing the compressive strength of large volume fly ash concrete [23].
3) An increase in the amount of fly ash substitution reduces the mechanical qualities of HVFA concrete, particularly compressive strength [22].
4) The nano fly ash particles completely fill the pores of the concrete, making it more denser [20].
5) High-volume fly ash concrete is a cost-effective, long-lasting, and ecologically friendly concrete.

This concrete, on the other hand, replaces cement with a substantial proportion of fly ash. During production, a high-range water reducer with trial mixing testing is required. Because high-volume fly ash concrete may have a long setting time, the demolding time of the concrete should be considered [24].

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Citation of this Article:

Suhendro Trinugroho, Ammar Abyan Alkatiry, “Literature Review: Application of Nano Fly Ash in High Volume Fly Ash Concrete” Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 7, Issue 5, pp 312-316, May 2023. https://doi.org/10.47001/IRJIET/2023.705044

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