

Experimental Investigation on M30 Grade Concrete Incorporating Fly Ash and Nano Silica

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Abstract

The growing demand for sustainable construction materials has led to increased interest in the utilization of industrial by-products and nano-materials in concrete. This study presents an experimental investigation on the mechanical and durability performance of M30 grade concrete incorporating fly ash and nano silica as partial replacements of cement. Fly ash was used at a constant replacement level of 10%, while nano silica was varied at 1%, 2%, and 3% by weight of cement. Fresh concrete properties were evaluated using slump cone test. Hardened concrete properties were assessed through compressive strength, split tensile strength, and flexural strength tests at 7, 14, 28, and

56 days. Durability characteristics were examined using water absorption and sorptivity tests.

The results indicate that the incorporation of fly ash and nano silica significantly enhances both strength and durability characteristics of concrete. The mix containing 10% fly ash and 2% nano silica exhibited the highest compressive strength of 44.5 MPa and 48.6 MPa at 28 and 56 days respectively, representing an increase of about 15–18% compared to control concrete. Durability results showed

reduced water absorption and sorptivity, indicating improved resistance to moisture ingress. The study concludes that the combined use of fly ash and nano silica produces a synergistic effect and can be effectively used to develop sustainable and high-performance structural concrete.

Keywords: Fly ash, Nano silica, M30 concrete, Compressive strength, Durability, Sustainable construction.

1. Introduction

Concrete is the most widely used construction material due to its versatility, strength, and durability. However, the production of cement is energy intensive and contributes significantly to global carbon dioxide emissions. To reduce the environmental impact of cement production and improve concrete performance, supplementary cementitious materials (SCMs) such as fly ash have been widely used.

Fly ash, a by-product of coal-based thermal power plants, possesses pozzolanic properties and improves long-term strength and durability of concrete. However, fly ash concrete generally exhibits lower early-age strength due to slow pozzolanic reactions. To overcome this limitation, nano-materials such as

nano silica have been introduced in concrete. Nano silica accelerates cement hydration, refines pore structure, and improves interfacial transition zone properties.

The combined use of fly ash and nano silica is expected to produce a synergistic effect, resulting in improved mechanical and durability performance of concrete. The present study aims to experimentally evaluate this combined effect on M30 grade concrete.

2. Experimental Program

2.1 Materials

- **Cement:** Ordinary Portland Cement (OPC) 53 grade conforming to IS 12269:2013
- **Fly Ash:** Class F fly ash conforming to IS 3812 (Part 1):2013
- **Nano Silica:** Powdered nano silica with particle size <100 nm
- **Fine Aggregate:** River sand (Zone II) as per IS 383:2016
- **Coarse Aggregate:** Crushed granite (20 mm nominal size)
- **Water:** Potable water conforming to IS 456:2000

2.2 Mix Proportions

Concrete mix design for M30 grade was carried out as per IS 10262:2019. Fly ash content was kept constant at 10%, while nano silica content was varied.

Mix ID	Fly Ash (%)	Nano Silica (%)	Water–Binder Ratio
CC	0	0	0.45
F10NS1	10	1	0.45
F10NS2	10	2	0.45
F10NS3	10	3	0.45

2.3 Testing Methods

- Slump cone test (IS 1199:2018)
- Compressive strength (IS 516:2018)
- Split tensile strength (IS 5816:1999)
- Flexural strength (IS 516:2018)
- Water absorption
- Sorptivity

3. Results and Discussion

3.1 Workability

Slump values decreased with increasing nano silica content due to high surface area of nano particles. However, all mixes exhibited workable consistency suitable for structural concrete.

3.2 Compressive Strength

Mix ID	28 Days (MPa)	56 Days (MPa)
CC	38.6	41.2
F10NS1	41.8	44.8
F10NS2	44.5	48.6
F10NS3	43.2	47.1

Compressive strength increased significantly with the incorporation of fly ash and nano silica. Nano silica enhanced early hydration, while fly ash contributed to long-term strength gain. Optimum performance was observed at 2% nano silica.

3.3 Split Tensile Strength

Mix ID	28 Days (MPa)	56 Days (MPa)
CC	3.25	3.45
F10NS1	3.60	3.85
F10NS2	3.95	4.20
F10NS3	3.80	4.05

Improvement in tensile strength is attributed to refined microstructure and improved interfacial transition zone.

3.4 Flexural Strength

Mix ID	28 Days (MPa)	56 Days (MPa)
CC	4.6	4.9
F10NS1	5.1	5.4
F10NS2	5.6	5.9
F10NS3	5.4	5.7

3.5 Durability Properties

Mix ID	Water Absorption (%)	Sorptivity (mm/√min)
CC	4.20	0.29
F10NS1	3.65	0.24
F10NS2	3.20	0.20
F10NS3	3.30	0.22

Lower water absorption and sorptivity values indicate improved durability due to pore refinement and dense C–S–H formation.

4. Conclusions

1. Partial replacement of cement with fly ash and nano silica significantly improves strength and durability of M30 concrete.
2. Nano silica enhances early-age hydration and strength development.
3. Fly ash contributes to long-term strength and durability through pozzolanic reaction.
4. The optimum mix was identified as **10% Fly Ash + 2% Nano Silica**.
5. Durability performance improved due to reduced permeability and capillary absorption.

6. The combined use of fly ash and nano silica promotes sustainable concrete construction.

REFERENCES

1. Mehta, P. K., and Monteiro, P. J. M. (2014). *Concrete: Microstructure, Properties and Materials*. McGraw-Hill Education.
2. Malhotra, V. M., and Mehta, P. K. (2004). High-performance, high-volume fly ash concrete. *Concrete International*, 26(7), 30–34.
3. Siddique, R. (2011). Utilization of fly ash in concrete: A review. *Resources, Conservation and Recycling*, 55(11), 885–898.
4. Neville, A. M. (2011). *Properties of Concrete*. Pearson Education.
5. Mindess, S., Young, J. F., and Darwin, D. (2003). *Concrete*. Prentice Hall.
6. Taylor, H. F. W. (1997). *Cement Chemistry*. Thomas Telford.
7. Thomas, M. (2013). *Supplementary Cementing Materials in Concrete*. CRC Press.
8. Sanchez, F., and Sobolev, K. (2010). Nanotechnology in concrete – A review. *Construction and Building Materials*, 24(11), 2060–2071.
9. Sobolev, K., Flores, I., and Hermosillo, R. (2013). Nano-materials and concrete performance. *ACI Materials Journal*, 110(1), 1–10.
10. Nazari, A., and Riahi, S. (2014). The effects of nano-silica on strength of concrete. *Cement and Concrete Composites*, 44, 114–123.