

# Experimental Investigation on the Effect of Nano- Alumina on Mechanical Properties and Microstructure of Concrete

CHANDRAGIRI NAVEEN KUMAR<sup>1</sup>, P GURU PRATHAP<sup>2</sup>

<sup>1</sup>M. Tech Student, Department of Civil engineering, Bharath Educational Society Group of Institutions Golden Valley Intergrated Campus,Angallu, Madanapalli Dist, AP, India,

<sup>2</sup>Assistant Professor, Department of Civil engineering, Bharath Educational Society Group of Institutions Golden Valley Intergrated Campus,Angallu, Madanapalli Dist, AP, India,

## Abstract

The application of nanotechnology in concrete has emerged as an effective approach to enhance mechanical and microstructural properties. This experimental study investigates the influence of nano-alumina ( $Al_2O_3$ ) as a partial replacement of cement on the mechanical properties and microstructure of M30 grade concrete. Nano-alumina was incorporated at 1%, 2%, and 3% by weight of cement. Compressive strength, split tensile strength, and flexural strength tests were conducted at curing ages of 14, 28, and 56 days. Microstructural analysis was carried out using SEM and XRD. The results indicated that concrete containing 2% nano-alumina exhibited optimum performance, showing significant improvement in strength and a denser microstructure compared to control concrete.

**Keywords:** Nano-alumina, Concrete, Compressive strength, Flexural strength, SEM, XRD

## 1. Introduction

Concrete is the most widely used construction material; however, conventional concrete suffers from limitations such as low tensile strength,

microcracking, and permeability. Recent advancements in nanotechnology have introduced nano-sized materials capable of modifying the cement matrix at the micro and nano scale. Among these materials, nano-alumina has shown promising potential in accelerating cement hydration, refining pore structure, and enhancing mechanical performance. This study focuses on evaluating the effect of nano- alumina on the strength and microstructure of concrete.

## 2. Experimental Program

### 2.1 Materials

- OPC 53 Grade cement
- Natural river sand (Zone II)
- Crushed granite coarse aggregate (20 mm)
- Nano-alumina ( $Al_2O_3$ )
- Potable water

### 2.2 Mix Proportions

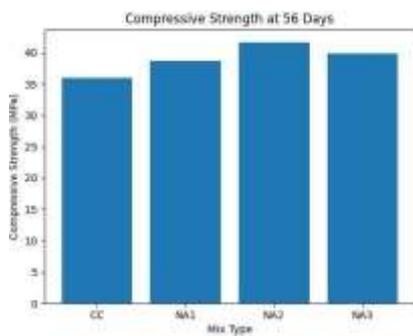
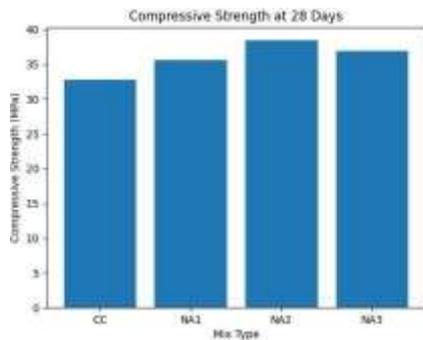
M30 grade concrete was designed as per IS 10262:2019. Nano-alumina was used as partial replacement of cement.

Mix ID	Nano-Al <sub>2</sub> O <sub>3</sub> (%)	Cement (kg/m <sup>3</sup> )	Nano-Al <sub>2</sub> O <sub>3</sub> (kg/m <sup>3</sup> )
CC	0	413	0
NA1	1	408.9	4.13
NA2	2	404.7	8.26
NA3	3	400.6	12.39

### 3. Test Results and Discussion

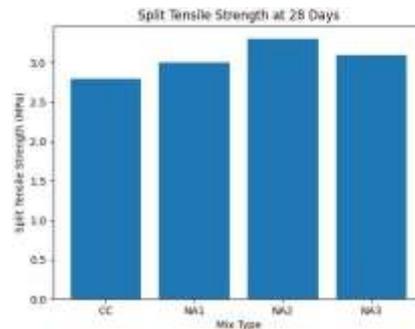
#### 3.1 Compressive Strength

Mix	14 Days (MPa)	28 Days (MPa)	56 Days (MPa)
CC	26.5	32.8	35.9
NA1	28.2	35.6	38.7
NA2	30.1	38.4	41.6
NA3	29.0	36.9	39.8



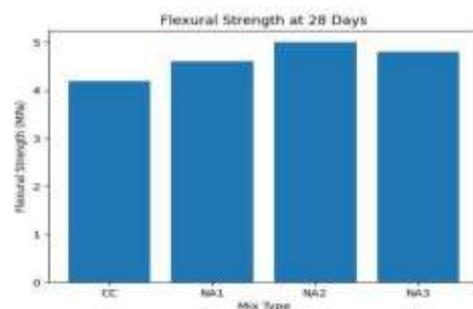
#### 3.2 Split Tensile Strength (28 Days)

Mix	Split Tensile Strength (MPa)
CC	2.8
NA1	3.0
NA2	3.3
NA3	3.1



#### 3.3 Flexural Strength (28 Days)

Mix	Flexural Strength (MPa)
CC	4.2
NA1	4.6
NA2	5.0
NA3	4.8



#### 3.4 Microstructural Analysis

SEM images of nano-alumina concrete revealed a dense and compact microstructure with reduced pore size and improved interfacial transition zone. XRD analysis indicated enhanced formation of calcium silicate hydrate (C-S-H) and

reduced calcium hydroxide content in nano-alumina mixes, particularly for the 2% replacement level.

#### 4. Conclusions

- Nano-alumina significantly improves compressive, split tensile, and flexural strength of concrete.
- Strength enhancement increases with curing age.
- Optimum performance was achieved at **2% nano-alumina replacement**.
- SEM and XRD confirmed microstructural densification and improved hydration.

#### 5. Future Scope

Further studies may focus on durability performance, combined use of nano- materials, field-scale application, and life- cycle cost analysis of nano-modified concrete.

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