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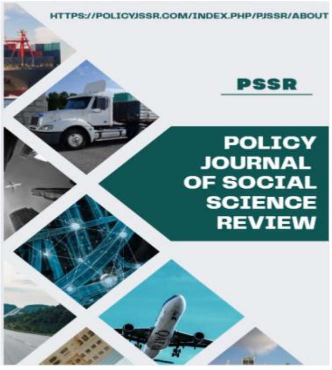

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EFFECT OF NANO-METAKAOLIN ON THE FRESH AND HARDENED PROPERTIES OF CONCRETE

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ABSTRACT

The increasing worldwide need for sustainable, high-performance concrete has prompted significant study into the uses of nanotechnology in cementitious materials. This study seeks to evaluate the properties of fresh and cured concrete with nano-metakaolin (NMK) as a nanoscale additive. This study involved NMK at weight ratios of 0%, 3%, 6%, 9%, and 12% relative to cement. A total of 30 concrete specimens was made adopting a mix proportion of 1:1:2. Total of 30 concrete samples were assessed for water absorption (WA) and compressive strength (CS). The ideal outcome shown that the CS reached 36.5 MPa with the incorporation of 6% NMK in concrete. The workability and WA of concrete declined as NMK content increased.

Keywords: *Concrete, nano-metakaolin, slump test, water absorption, Compressive Strength.*

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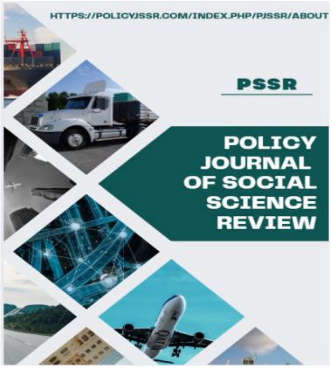

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Introduction

The worldwide construction sector has a major issue: satisfying the increasing demand for resilient infrastructure whereas reducing the significant environmental impact of cement manufacturing [1-3]. The production of Ordinary Portland Cement (OPC) contributes around 7–8% of global anthropogenic CO_2 emissions, with each tonne of cement emitting almost one tonne of CO_2 into the environment [4-6]. The advancement of sustainable, high-performance concrete has emerged as a crucial research objective [7, 8]. Among the several methodologies examined, nanotechnology has surfaced as a revolutionary method, allowing the alteration of material characteristics at the molecular and atomic levels to attain unparalleled improvements in concrete performance [9, 10].

Nano metakaolin (NMK) is among the most scientifically potential nanoparticles in this field. Nano metakaolin is produced through the controlled calcination of kaolin clay at temperatures ranging from 600°C to 850°C, accompanied by ultrafine grinding to achieve nanoparticle dimensions [11, 12]. It merges the recognised pozzolanic properties of traditional metakaolin with the distinct benefits of nanoscale particle size. As the construction sector frequently searches for alternatives to conventional supplementary cementitious materials (SCMs) [13-15] like fly ash [16-18], millet husk ash [19-22] and slag, rice husk ash (RHA) [23-26] whose accessibility is diminishing owing to industrial transitions, nano metakaolin presents a manufactured, continuously high-quality substitute, with remarkable reactivity and performance attributes. Therefore, this study is conducted to determine the impact of nano-metakaolin on the fresh and hardened concrete.

Materials and Methods

Materials

Nano-metakaolin (NMK) was used as nanoparticles in this study. Besides, cement functioned as a binding ingredient in combination. Fine and coarse aggregates were used in this research having 4.75 mm and 20 mm in size respectively. The aggregates were procured locally from the marketplace. The superplasticizer used as a chemical admixture in this study. Drinking water was used for the manufacturing process and curing of concrete.

Mix Proportion

The investigative research seeks to assess the properties of concrete by using 0%, 3%, 6%, 9%, and 12% of NMK as a nanoparticle in mixture. Total of 30 samples of concrete made with 1:1:2 mix proportion, employing a w/c ratio of 0.50, and underwent curing for 28 days. The proportions of this mixture are specified in Table 1. Furthermore, the samples (100 mm x 100 mm x 100 mm) were assessed for CS and WA. Three concrete examples were produced for each percentage, and their average was considered the final result.

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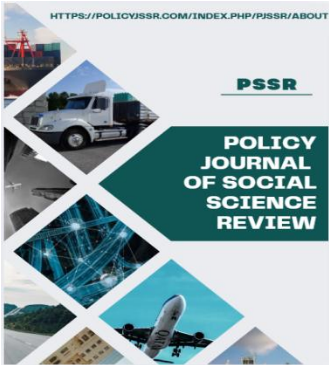

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Table 1:

Mix Design of NMK Concrete

Mix Design	Quantity of Concrete Constituents (%)				
	Cement	NMK	CA	FA	Superplasticizer
NMK0	100	0	100	100	1%
NMK3	100	3	100	100	1.1%
NMK6	100	6	100	100	1.15%
NMK9	100	9	100	100	1.20%
NMK12	100	12	100	100	1.25%

RESULTS AND DISCUSSION

Workability

Figure 1 depicts the assessment conducted to evaluate the homogeneity of concrete using NMK as a nanoscale component. The maximum workability for a control mix is 58 mm, whereas the smallest workability observed is 24 mm with the incorporation of 12% NMK as a nanoscale component. The use of NMK in the combination seems to reduce the slump. The decline in performance is attributed to elevated surface area of NMK nanoparticles relative to cement, which consumes high amount of water as compared to NMK proportion in mixture increases.

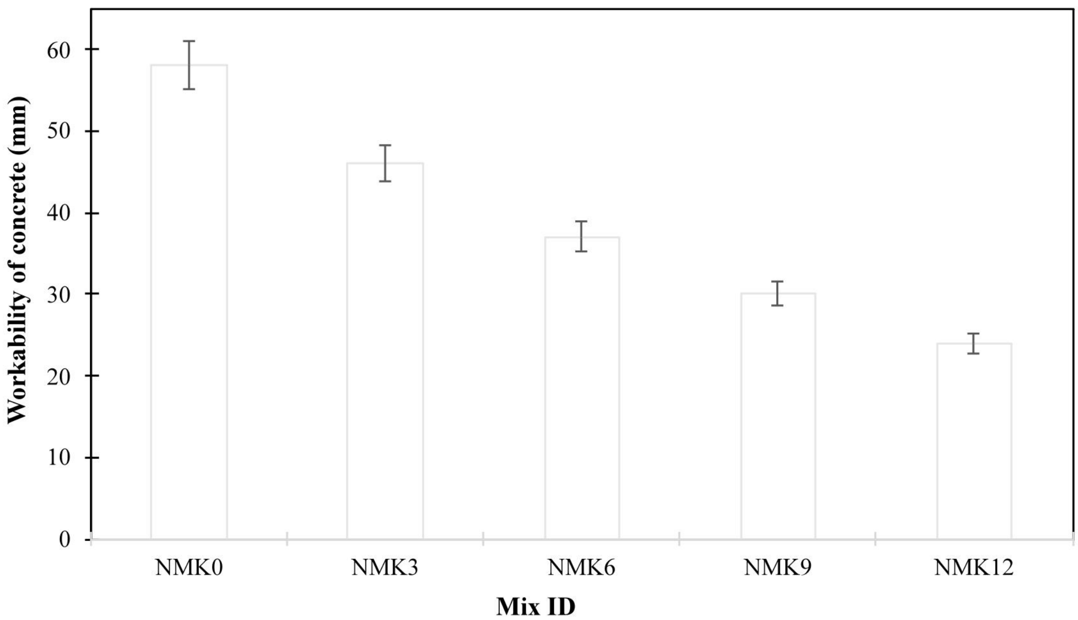

Fig. 1: Slump value of NMK Concrete

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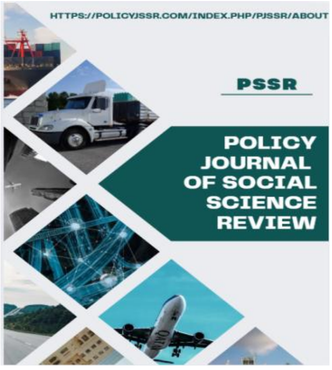

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Water Absorption (WA)

Figure 1 depicts the assessment conducted to evaluate the water absorption of concrete using NMK as a nanoscale component. The maximum WA value for a control mix is 3.8%, whereas the smallest WA value observed is 1.60% with the incorporation of 12% NMK as a nanoscale component. The use of NMK in the combination seems to reduce the WA. The decline in WA is attributed to NMK fills the micropores in concrete.

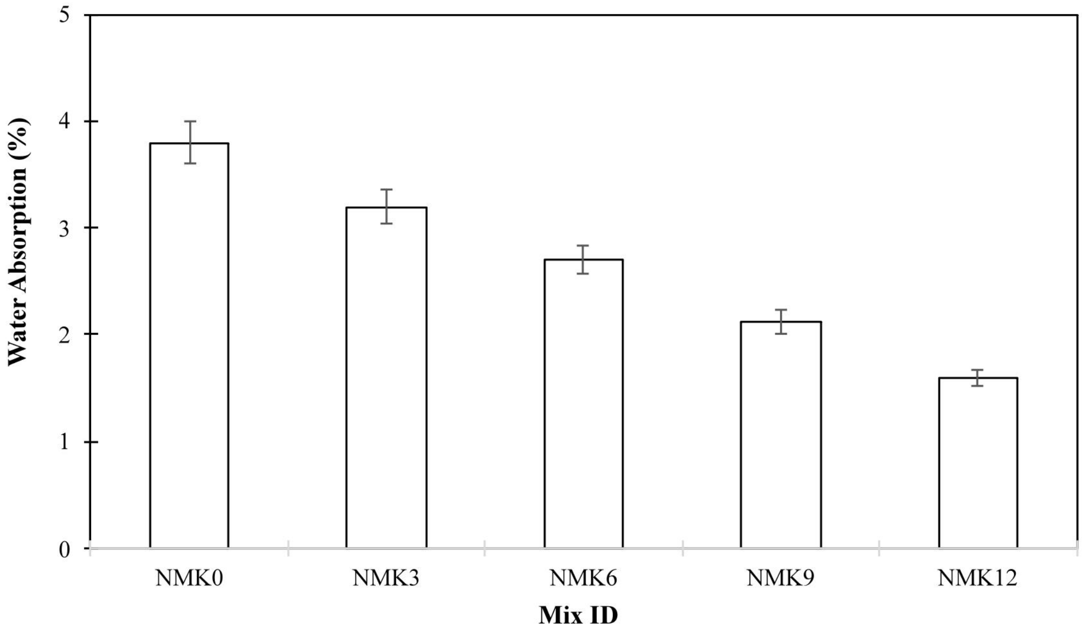

Fig. 2: WA of NMK Concrete

Compressive Strength (CS)

The evaluation was conducted on cubic specimens composed of concrete including NMK as a nanoscale element, as seen in Figure 3. The maximum compressive strength is measured at 36.5 MPa with 6% NMK, while the minimum strength is observed at 27.5 MPa with 12% NMK in mixture at 28 days. The experimental results indicated that the CS of concrete augmented with the incorporation of up to 6% NMK, attributable to nanoscale size of NMK occupying the voids formed by the various concrete constituents. On the other hand, the boost in strength is ascribed to the synergistic effects of augmented C-S-H production via pozzolanic processes, enhanced particle packing density, and expedited hydration kinetics.

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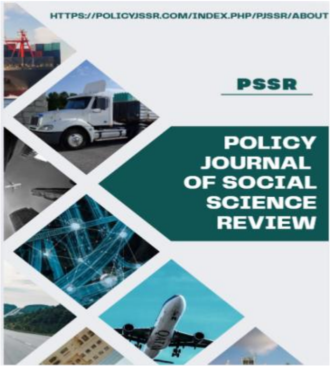

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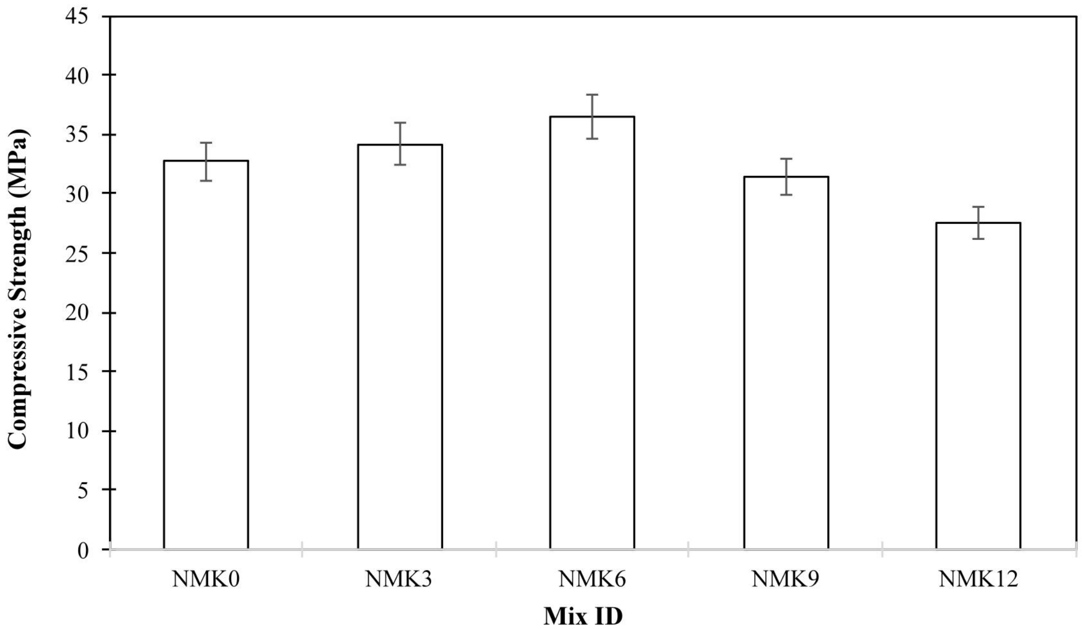

Fig. 3: CS of NMK mixture

Conclusions

The following important opinions are taken from key results:

1. The use of NMK in the combination seems to reduce the slump. The decline in performance is attributed to the elevated surface area of NMK nanoparticles relative to cement, which consumes high water as compared to NMK proportion in mixture increases.
2. The maximum WA value for a control mix is 3.8%, whereas the smallest WA value observed is 1.60% with the incorporation of 12% NMK as a nanoscale component.
3. The experimental results indicated CS of concrete augmented with incorporation of up to 6% NMK, attributable to nanoscale size of NMK occupying the voids formed by various concrete constituents.
4. The assessment findings indicate the 6% NMK provides the maximum strength, therefore, it is suggested for construction use.

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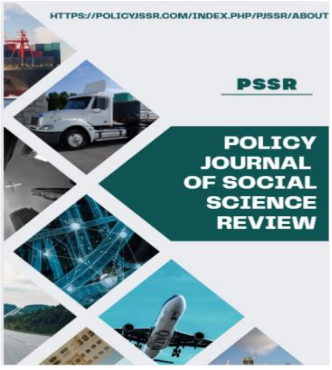

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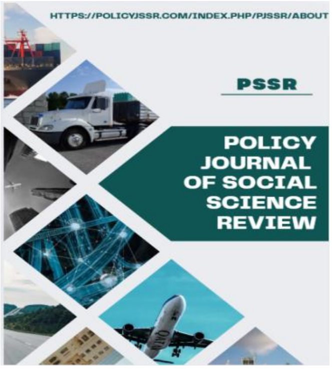

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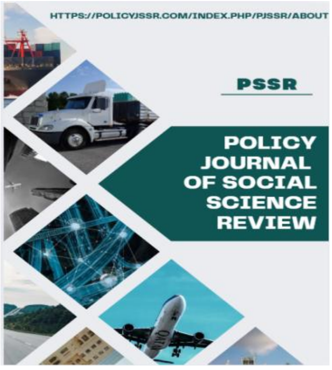

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