A REVIEW PAPER ON NUMERICAL ANALYSIS OF CONCRETE BEAM WITH NANO SILICA AND POLYVINYL ALCOHOL FIBER

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Abstract-This mini project investigates the structural performance of concrete beams enhanced with Nano silica and Polyvinyl Alcohol (PVA) Fibers using ANSYS software. The aim is to analyze and compare the deformation behavior of modified and conventional concrete beams. A beam model with dimensions 150 mm × 150 mm × 1000 mm was developed and subjected to load in a finite element environment. Two beam variants were considered: one with traditional concrete and another incorporating nano silica and PVA fibers. The simulation results revealed that the modified beam experienced less deformation under loading, demonstrating improved mechanical strength. The study concludes that nano silica and PVA fiber can effectively enhance the structural behavior of concrete, promoting their use in high-performance construction application.

1.INTRODUCTION

1.1 General

Environmental preservation and responsible usage of resources are currently the main challenges facing sustainability. Cement manufacture is precise, and are crucial factor for the maximum CO2-formation. It is reliable for approximately 5%–8% of the carbon produced worldwide. Many by-products were assessed as a substitution for cement . The better the pozzolanic properties possessed by the material, the higher the opportunity to effectively replaced the cement. In response to growing environmental concerns and the global push toward sustainable development, there is an increasing focus on identifying and incorporating alternative materials that can partially or wholly replace conventional cement in construction. Sustainable construction practices are guided by three primary pillars: environmental sustainability, economic feasibility, and social responsibility. Within this context, the present study investigates the *partial replacement of cement with* nano silica, a high purity amorphous silica powder, and the incorporation of polyvinyl alcohol fiber as a reinforcing agent in concrete.

The objective of this research is to evaluate the mechanical and durability characteristics of concrete modified with *nano silica* and polyvinyl alcohol fiber, with the aim of promoting innovative and sustainable practices in civil engineering materials.

1.2 Nano Silica

Nano silica, (nanosilica or SiO_2 nanoparticles) refers to silica particles with a nanometer-scale size, typically ranging from 1 to 100 nanometers. Due to its high surface area, excellent mechanical properties, and ability to interact at the molecular level, nano silica is widely used in various engineering and scientific applications. In the field of civil engineering, it is especially valued for its potential to enhance mechanical strength, durability, and other performance characteristics of composites and materials. One of the key characteristics of nano silica is its high reactivity and pozzolanic behavior, especially when used in cement-based or composite materials. It can fill microvoids in matrices, leading to a denser microstructure, and it actively reacts with calcium hydroxide in cementitious systems to form additional calcium silicate hydrate (C-S-H), thereby improving strength and durability.

Nano silica is widely used in various fields including:

1.3 Polyvinyl Alcohol Fiber

PVA fiber is a synthetic, high-strength fiber known for its excellent chemical stability, strong adhesion to cement matrices, and superior resistance to alkali environments. Unlike other synthetic fibers, PVA provides both mechanical and chemical bonding within a composite system. Compared to steel fibers, PVA fibers offer corrosion resistance, finer crack control, and enhanced ductility. Their hydrophilic surface also allows better interaction with cementitious matrices, making them ideal for Engineered Cementitious Composites (ECC).

1.4 Literature Review

"Experimental Investigation on the Mechanical Characteristics of Cement-Based Mortar Containing Nano-Silica, Micro-Silica, and PVA Fiber" Hossein, Nematian Jelodar, Rahmat Mandandoust (8 September 2022)

This study investigates the mechanical properties of cement-based repair mortar enhanced with nano-silica (NS), micro-silica (SF), and polyvinyl alcohol (PVA) fibers, used individually (single), in pairs (binary), and all together (ternary). A total of 28 mix designs and 112 specimens were tested for compressive and flexural strengths using standard methods (ACI

318 and BS EN 1015-11). Results showed that the optimal single-mode mix was 10% silica fume (SF10), improving flexural and compressive strength by 27% and 48%, respectively. In binary mode, the best performance was achieved with 2% NS and 8% SF (NS2SF8), showing a 24% increase in flexural and 49% in compressive strength. For the ternary mode, a mix with 0.75% PVA and 10% SF (PVA0.75SF10) was most effective, though the improvements were lower—3.5% in flexural and 4.6% in compressive strength. Overall, binary combinations offered the most significant enhancements.

"Investigation of mechanical properties of PVA fiber-reinforced cementitious composites under the coupling effect of wet-thermal and chloride salt environment" Peng Zhang , Shiyao Wei (19 July 2022)

This study examined the mechanical properties of polyvinyl alcohol fiber-reinforced cementitious composites (PVA-FRCC) exposed to a harsh environment combining high temperature, humidity, and chloride salt. Experiments assessed compressive strength, flexural performance, elastic modulus, fracture behavior, and microstructure. The environment simulated was 50 °C, 100% RH, 5% NaCl solution for 30 days. PVA fiber content ranged from 0 to 1.5%. Results showed that while the harsh environment degraded composite performance, adding PVA fibers significantly improved mechanical properties. Optimal performance occurred at 0.6–0.9% fiber content. Notably, fracture properties saw the greatest enhancement at 1.5% fiber, with fracture energy increasing by over 2600%.

"Influence of steel fiber and polyvinyl alcohol fiber on properties of high performance concrete" Yanzhong Ju, Meitong Zhu(28 March 2022)

To investigate influence of the single steel fibers, single polyvinyl alcohol fiber (PVA) and hybrid fibers on the properties of high performance concrete (HPC), the tests of the fresh properties, compressive strength, flexural strength and toughness of HPC reinforced with steel fiber and PVA fiber were conducted. The toughness of hybrid fiber HPC was evaluated through several flexural performance analysis methods and improved flexural toughness evaluation methods. In order to analyze the fiber toughening principle and the effect of different fiber content on flexural strength, the four-point bending test was simulated by finite element modeling. And the calculation formula of hybrid steel-PVA fiber HPC flexural strength was proposed. The results indicate that, steel fibers, PVA fibers and hybrid fibers can both improve HPC strength and toughness, while the content of PVA fiber had a critical value about 1%. If it is greater than this value, the enhancement of toughness will be reduced. Furthermore, the steel fiber and PVA fiber can play a bridging role in different scales to improve the toughness and strength of HPC.

"**Compressive Strength Prediction of PVA Fiber-Reinforced Cementitious Composites Containing Nano-SiO_2 Using BP Neural Network" Ting-Yu Liu , Peng Zhang (22Jan 2020)**

This study presents a method to optimize the mix proportions of polyvinyl alcohol (PVA) fiber-reinforced cementitious composites to improve compressive strength. A three-layer neural network (TLNN) trained using the Levenberg-Marquardt backpropagation (BP) algorithm was developed to model the nonlinear relationship between mix factors and compressive strength. An orthogonal experiment was used to fine-tune the network, and a genetic algorithm was applied to determine the optimal mix proportions. The model accurately predicted compressive strength, and the optimized mix, including nano-SiO_2, showed improved performance. The approach effectively predicts and enhances the strength of PVA-reinforced composites.

2 NUMERICAL ANALYSIS USING ANSYS SOFTWARE

ANSYS is a powerful software suite used for engineering simulation and analysis. It offers a wide range of tools and capabilities for various engineering disciplines, including structural analysis, fluid dynamics, electromagnetic simulations, and more. ANSYS enables engineers to virtual1y prototype and test their designs, helping them optimize performance, reliability, and safety while reducing development costs and time. The model of 1000mm long with a cross section of 150 mm x 150 mm is fabricated.

PROCESSING STAGE

Pre-processing: In this stage the model of the physical problem is defined and an ANSYS input file was created.

Simulation: ANSYS simulation offers complete and powerful solutions for routine and sophisticated engineering problems.

Post processing: The results can be evaluated once the simulation has been completed and the displacements, stresses, or other fundamental variables have been calculated. The evaluation is generally done interactively using the visualization module.

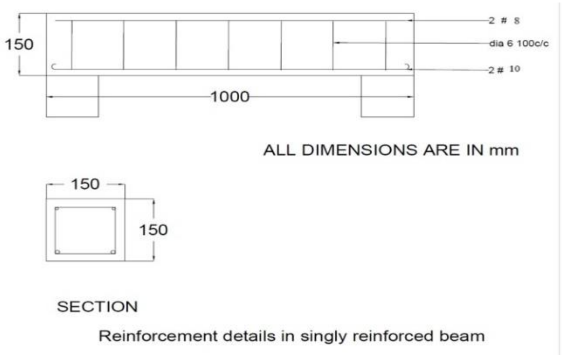

Fig.1 Beam Cross Section

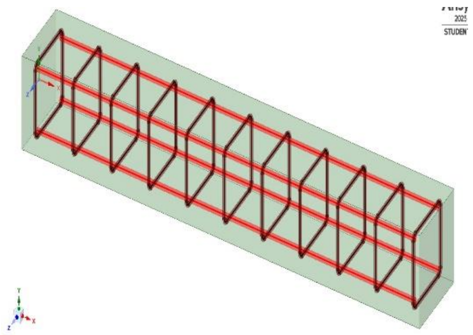

Fig.2 Spaceclaim Model

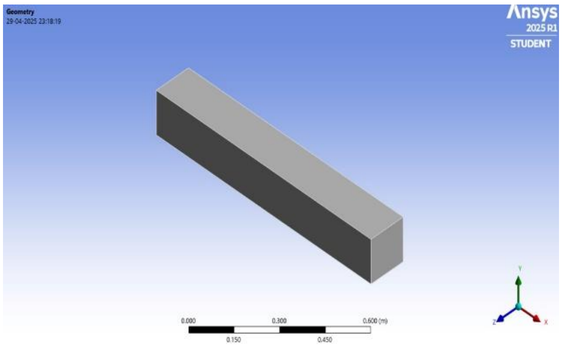

Fig .3 Conventional Beam

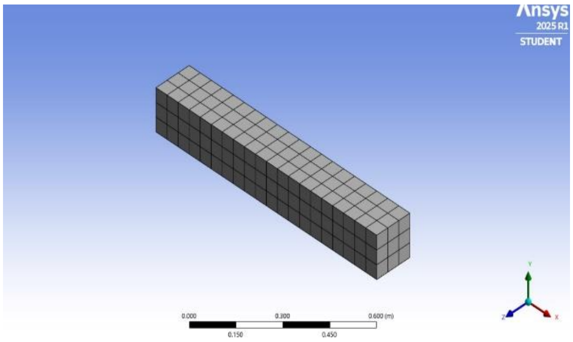

Fig.4 Geometry Meshing Model

3 PROCEDURE FOR ANALYSIS

Analysis procedure:

- The section was created based on the center line dimensions.
- The material properties like Young's modulus, Poisson's ratio, and Yield stress were defined and assigned to the sections.
- Then sections were assembled together using part instance.
- The section was converted into a finite element model by using mesh module.
- The reference points and constraints were created at both the ends.
- Then the boundary conditions were defined at both the ends based on the

support condition.

- Unit loads were applied at reference points.
- Then the Eigen value buckling analysis was performed and deformed mode shape was obtained.
- Geometrical (local) imperfection was considered for this deformed shape and fed as an input for the non-linear analysis.
- Then the non-linear analysis was performed and a graph was plotted between the load-deformation and stress-strain.
- From this graph the ultimate moment capacity (in kN-m) of the section and its corresponding results were obtained.

4. RESULTS AND DISCUSSION

The analysis is based on gradually applying loads on the beam. Load applied on the beam is between 0 to 700 kN and their corresponding deformation, stress and strain values are noted for each of the applied loads.

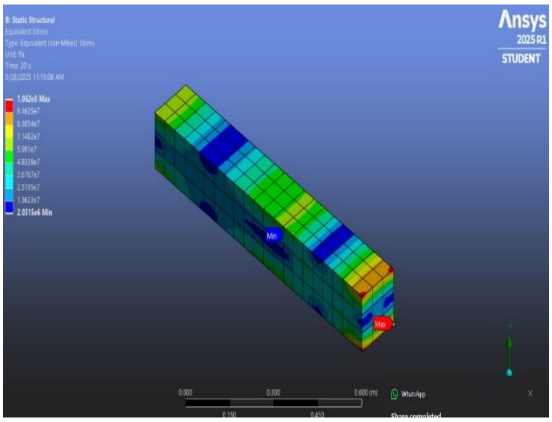

Fig.5 Total deformation

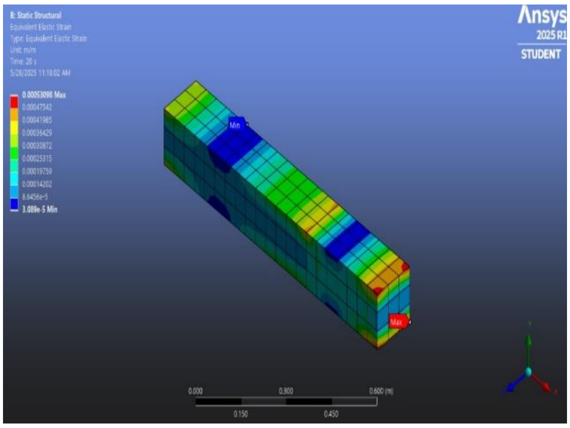

Fig.6 Total Stress

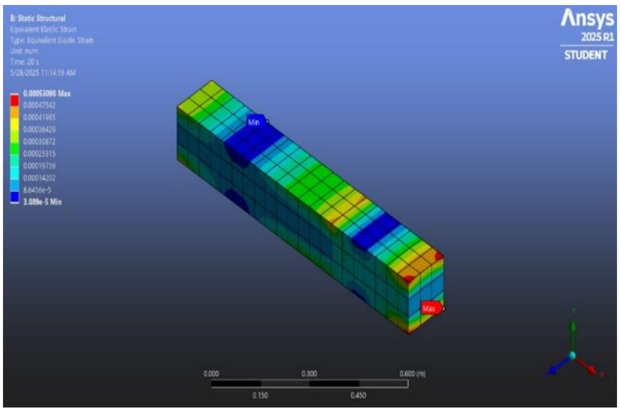

Fig.7 Total strain

Stress,Strain and Deformation Value for PVAfrc With NS

S.NO	LOAD (kN)	DEFORMATION (mm)	STRESS(N/mm2)	STRAIN
1.	0	0	0	0
2.	100	0.87	29.66	0.781
3.	200	1.74	59.32	1.56
4.	300	2.60	88.98	2.34
5.	400	3.47	118.64	3.12
6.	500	4.34	148.30	3.90
7.	600	5.21	177.96	4.68
8.	700	6.08	207.62	5.46

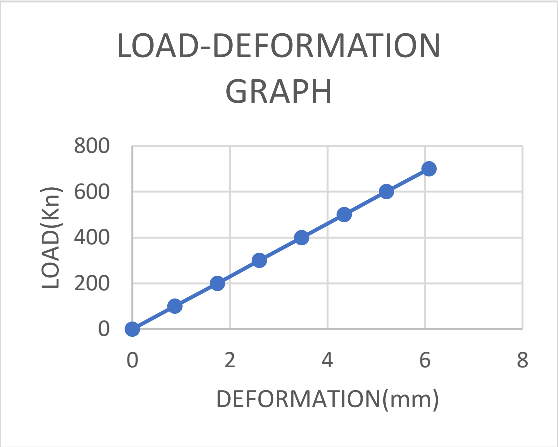

Fig.8 Load-Deformation graph

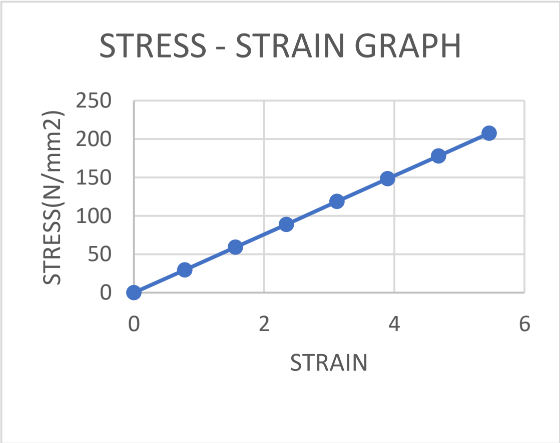

Fig.9 Stress-Strain graph

5.CONCLUSION

The results demonstrated that the beam incorporating Nano-silica and PVA fibres exhibited significantly lower deformation under the same loading conditions compared to the conventional beam. This reduced deformation suggests enhanced stiffness and improved load-carrying capacity, likely due to the pozzolanic activity of Nano-silica, which refines the microstructure, and the bridging effect of PVA fibres, which helps control crack propagation.

These findings indicate that the use of Nano-silica and PVA fibres can lead to structurally superior and more durable concrete elements, making them suitable for high-performance applications such as seismic zones or long-span structures.

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