

## **CAREER EPISODE 2**

### **Application of Nano-materials in Thermal Storage of Concrete**

#### **INTRODUCTION**

##### **CE 2.1**

I undertook this project as a [REDACTED]. The project spanned from [REDACTED], during my 8th semester course "Concrete Technology." The duration of the project was 2 months and this project was focused on the application of nano-materials in the thermal storage of concrete, aiming to explore innovative approaches to enhance the thermal properties and efficiency of concrete structures.

#### **BACKGROUND**

##### **CE 2.2.1**

The project was selected to explore innovative approaches to improving the sustainability and energy efficiency of concrete which is a widely used construction material. As global economic development accelerates, so does the demand for energy, which leads to increased consumption of traditional fossil fuels and a corresponding rise in greenhouse gas emissions. The construction industry, being one of the largest energy consumers, is a significant contributor to these emissions, primarily due to the extensive use of Portland cement and producing one ton of conventional Portland cement releases an equivalent amount of CO<sub>2</sub>, accounting for approximately 5% of global CO<sub>2</sub> emissions and this environmental challenge necessitates the search for alternative materials that can mitigate these adverse effects. So, the project's primary goal was to assess the feasibility of using nano-materials, specifically zeolite and silica fume, as partial substitutes for cement in M40 grade concrete. Hence, by integrating these nano-materials, the project aimed to develop concrete with improved thermal storage capacity, thereby promoting energy efficiency in buildings and reducing reliance on conventional energy sources. The selection of this project was driven by the urgent need to find cost-effective and sustainable alternatives to traditional cement since the increasing cost of cement and its significant environmental impact have led to the exploration of supplementary materials like zeolite and silica fume and this. These materials offer not only a reduction in the usage of conventional cement but also potential improvements in the strength, durability, and thermal efficiency of concrete structures.

##### **CE 2.2.2**

This project had aimed to contribute to the development of sustainable construction practices by promoting the use of nano-materials in concrete and the findings have the potential to influence future construction methodologies, emphasizing the importance of energy-efficient and environmentally friendly building materials and this. So, through this research, I sought to address the dual challenges of enhancing the performance of concrete while reducing its environmental footprint, ultimately contributing to a more sustainable built environment. Here, our project team

consisted of three members other than me, which were

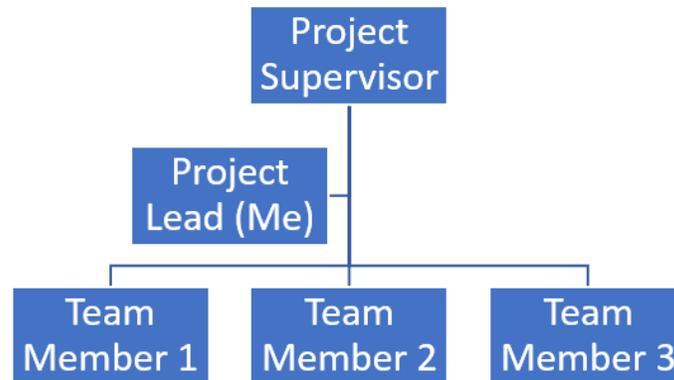


Figure 1: Hierarchy

Each member played a vital role in various aspects of the project, from literature review and material procurement to experimental setup and data analysis and we worked collaboratively to design and execute the experiments, ensuring that all tasks were completed efficiently and effectively.

## PERSONAL ENGINEERING ACTIVITY

### CE 2.3.1

The project had begun with an extensive literature review to understand the existing research on the use of nano-materials in concrete and here I identified the environmental impact of conventional Portland cement and the necessity to find sustainable alternatives due to its high CO<sub>2</sub> emissions. So, my goal was to investigate how replacing cement with zeolite and silica fume could not only reduce these emissions but also improve the thermal storage capacity of concrete. I had selected M40 grade concrete for this study due to its prevalent use in structural applications and the materials used included ordinary Portland cement (OPC), natural zeolite, and silica fume. Zeolite is a hydrated aluminosilicate mineral known for its high silica content and pozzolanic properties, which make it suitable for partially replacing cement. I made a project methodology in the initial stages of the project.

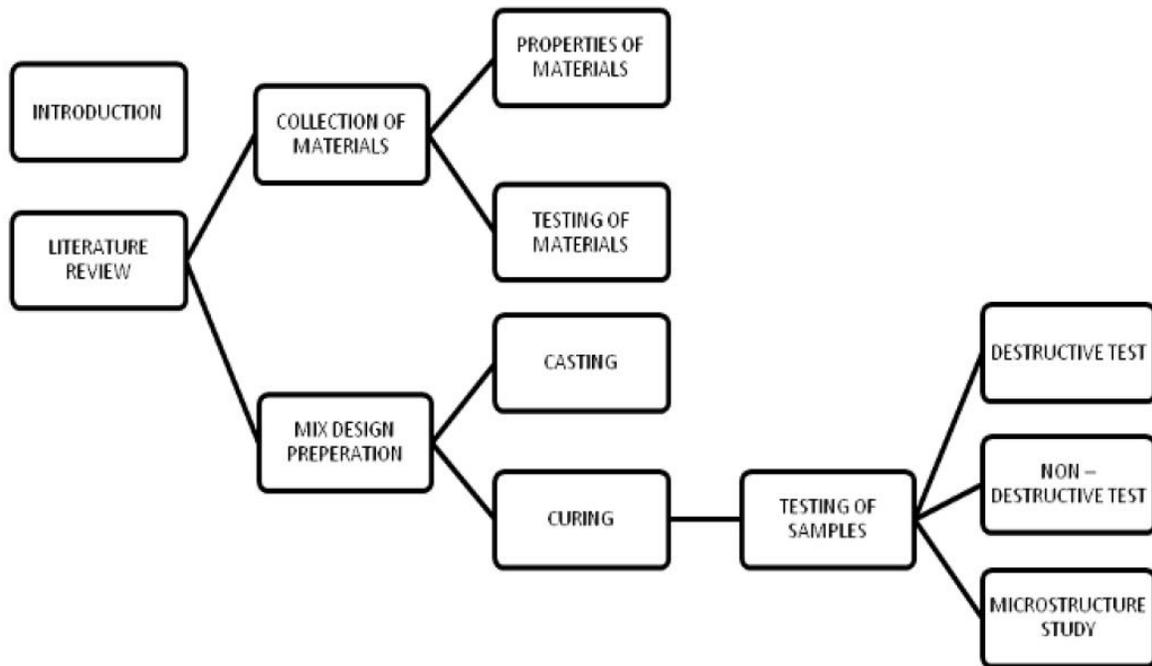


Figure 2: Project Methodology

### CE 2.3.2

The experimental design involved creating two sets of concrete samples: cement replaced with 12% zeolite and cement replaced with 6% silica fume so I prepared these samples following the International Standard IS 10262-2009 mix design method and the concrete mix design was calculated to maintain the workability and strength characteristics required for M40-grade concrete. To prepare the concrete samples, I had first performed sieve analysis on the fine and coarse aggregates to ensure they met the necessary specifications. The specific steps involved were such that, first I gathered all the necessary materials, ensuring they were of high quality and free from impurities which included the OPC, fine and coarse aggregates, zeolite, silica fume, and water. Using IS 10262-2009 guidelines, I had calculated the mix proportions for the concrete. This involved determining the amount of each material required per cubic meter of concrete to achieve the M40 grade specification. The mixing process involved the following steps such that I first mixed the dry components (cement, aggregates, zeolite, and silica fume) thoroughly to ensure uniform distribution.

Table 1: Fine Aggregate – Sieve Analysis

SI No.	IS sieve size	Weight retained in grams	% retained	Cum. % retained	Cum. % passing
1	4.75mm	28	28	2.8	97.2
2	2.36mm	85	4.25	6.30	90.80
3	1.18mm	484	24.20	30.5	72.40
4	600 micron	918	45.90	76.40	33.60
5	300 micron	428	21.40	97.80	3.80
6	150 micron	24	1.20	99	1.7

$$\begin{aligned}\text{Fineness modulus of fine aggregate} &= \Sigma \text{Cumulative weight retained} / 100 \\ &= 400.5 / 100 \\ &= 4.0\end{aligned}$$

Table 2: Coarse Aggregate – Sieve Analysis

SI No.	IS Sieve Size	Weight Retained (g)	Cumulative Weight Retained	Cumulative Weight Retained %	Cumulative % passing
1	20 mm	0	0	0	0
2	12.5 mm	300	300	1.5	98.5
3	10 mm	1600	1900	95	5
4	4.75 mm	65	1965	98.25	1.75
5	2.36mm	35	2000	100	0
6	1.18mm	0	2000	100	0
7	600 micron	0	2000	100	0
8	150 micron	0	2000	100	0

$$\begin{aligned}
 \text{Fineness Modulus} &= \Sigma \text{Cumulative weight retained \%} / 100 \\
 &= 594.75/100 \\
 &= 5.94
 \end{aligned}$$

Fineness modulus of coarse aggregate = 5.94

### CE 2.3.3

Once the concrete was mixed, I cast the samples into molds of specified dimensions for different tests. I knew that curing is a critical process as it allows the concrete to achieve its desired strength and durability. So, the mixed concrete was poured into molds of various shapes and sizes depending on the test requirements. I had ensured that the molds were properly lubricated to

facilitate easy demolding. I even compacted the concrete in the molds using a tamping rod to remove any entrapped air and ensure a dense, uniform structure and this step was crucial to avoid voids that could weaken the concrete. After setting, the samples were immersed in water tanks for curing. Curing was done for periods of 7, 14, and 28 days to study the strength development over time and proper curing is essential for the hydration process, which is necessary for the development of strength and durability in concrete.



*Figure 3: Casting of Specimen*



*Figure 4: Curing of Specimen*

Table 3: Casting of test specimens

S.No	Test	Days	Plain	Zeolite 12%	Silica fume 6%
1	COMPRESSION TEST	7	3	3	3
		14	3	3	3
		28	3	3	3
2	SPLIT TENSILE TEST	7	3	3	3
		14	3	3	3
		28	3	3	3
3	FLEXURAL TEST	7	3	3	3
		14	3	3	3
		28	3	3	3

#### CE 2.3.4

After the curing period, I had conducted several tests to evaluate the mechanical and thermal properties of the concrete samples and this included the compressive strength test performed on cube samples.

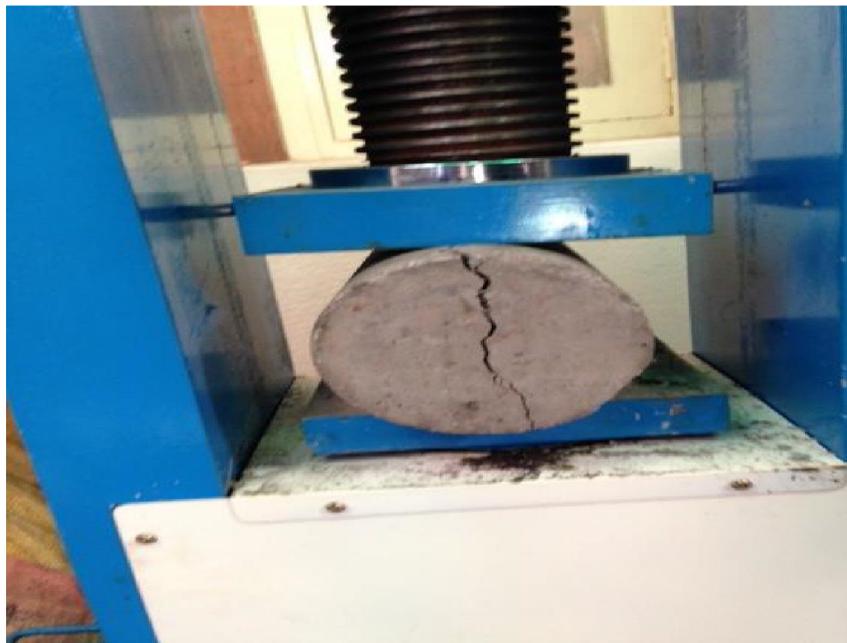


Figure 5: Compression Testing

Table 4: Specific gravity of cement

SI No.	Empty Weight of container (W1)	Weight of container and cement weight(W2)	Weight of container + dry sample and kerosene (W3)	Weight of container and water (W4)	Specific gravity of cement
1	0.023	0.030	0.048	0.042	3.15
2	0.023	0.032	0.050	0.042	3.15

So, the test results revealed that the concrete with 12% zeolite replacement exhibited superior thermal storage capacity and mechanical strength compared to the sample with 6% silica fume and this specifically showed the strength of the zeolite concrete at day 28 was 37.9 N/mm<sup>2</sup>, which was higher than the silica fume-modified concrete's strength of 32.6 N/mm<sup>2</sup>. The split tensile and flexural strength tests also showed better performance for the zeolite-modified concrete and also the results showed a consistent increase in compressive strength with curing time for both zeolite and silica concretes and also the zeolite-modified concrete displayed a higher strength gain compared to the latter, indicating its superior pozzolanic activity and better bonding with the cement matrix. The split tensile strength tests revealed that the zeolite-modified concrete had a higher tensile strength compared to the silica fume-modified concrete and this can be attributed to the better distribution of stress and improved microstructure due to the presence of zeolite particles. The TGA results indicated a significant improvement in the thermal storage capacity of the zeolite-modified concrete and the weight loss due to thermal decomposition was lower in the zeolite samples, indicating better thermal stability, which makes zeolite-modified concrete an excellent candidate for applications in thermal energy storage systems.



*Figure 6: Split tensile strength test specimen*

### **CE 2.3.5**

During the project, I had meticulously recorded observations and data to ensure reliability of results and also used statistical analysis to compare the performance of the two types of modified concrete. I had known that the addition of zeolite and silica fume required careful adjustment of the water-cement ratio to maintain the desired workability. Zeolite-modified concrete exhibited slightly lower workability compared to silica fume-modified concrete, necessitating the use of

superplasticizers to achieve the required consistency. In addition to the standard strength tests, I even did conduct durability tests such as water absorption, permeability, and resistance to sulfate attack and here the zeolite-modified concrete showed lower water absorption and permeability, indicating improved durability and also it exhibited better resistance to sulfate attack, which is crucial for concrete structures exposed to aggressive environments . Although the initial material costs for zeolite and silica fume are higher than conventional cement, the long-term benefits in terms of energy savings and durability justify the investment .

Table 5: Water absorption for fine aggregate

Description	Sample 1	Sample 2	Sample 3
Wt. Of Saturated Surface Dried Sample In Gm(A)	2420	2418	2422
Wt Of Oven Dried Sample In Gm (B)	2406	2404	2407
Water Absorption $[(A-B)/B] \times 100$	0.58	0.58	0.62
Average	0.60		

Table 6: Water absorption for coarse aggregate

Description	Sample 1	Sample 2	Sample 3
Wt. Of Saturated Surface Dried Sample In Gm(A)	2500	2498	2502
Wt Of Oven Dried Sample In Gm (B)	2476	2473	2477
Water Absorption $[(A-B)/B] \times 100$	0.97	1.01	1.01
Average	1.00		

### **CE 2.3.6**

This project contributed to the reduction of greenhouse gas emissions and promotes sustainable construction practices. So, the improved thermal storage capacity and lower thermal conductivity of zeolite-modified concrete enhance the energy efficiency of buildings, which can lead to significant energy savings in heating and cooling . The enhanced mechanical properties and durability of zeolite-modified concrete ensure longer service life and reduced maintenance costs for concrete structures and this is particularly beneficial for infrastructure projects where longevity and durability are critical . The use of supplementary materials like zeolite and silica fume can also provide cost savings by utilizing industrial byproducts . The project successfully demonstrated the feasibility of using partial replacements for cement in concrete and these findings highlighted that zeolite, in particular, could enhance the thermal storage capacity and mechanical strength of concrete, making it a viable option for sustainable construction practices . So, throughout this project, I applied various civil engineering principles, including material science, mix design, and structural analysis, to achieve the desired outcomes and here the hands-on experience and analytical skills gained from this project have been invaluable in my journey as a civil engineer . The detailed observations, analysis, and practical implications of this study have equipped me with a deeper understanding of advanced concrete technology and sustainable construction practices. At the end of this project, I compiled all the results and documented them into one report.

## **SUMMARY**

### **CE 2.4.1**

The project had provided me with a comprehensive understanding of the use of nano-materials in concrete and their potential benefits for sustainable construction and the successful application of these materials in improving the thermal and mechanical properties of concrete highlights their importance in modern civil engineering practices. The knowledge and skills I had acquired through this project will undoubtedly benefit me in my future career as a civil engineer and the ability to conduct detailed research, perform complex experiments, and analyze results are critical skills that will enable me to contribute effectively to the field of civil engineering. Then also, the emphasis on sustainability and innovation aligns with the current trends in the industry, making me well-prepared to address the challenges of future construction projects. In summary, this project had been a valuable learning experience, providing me with practical insights and technical expertise in the field of concrete technology.