Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 10, October-2023

Enhancement of Interfacial Transition Zone (Itz) by using Chemical Additives

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Abstract— Interfacial Transition Zone (ITZ) enhancement is a vital process aimed at augmenting the mechanical and physical attributes of composite materials through targeted modifications of the ITZ. Various techniques, including the utilization of additives, surface coatings, specialized treatments, and refined mixing procedures, are employed to fortify the ITZ. The objective is to facilitate superior bonding among the components of concrete.

Furthermore, comprehensive tests are conducted to furnish essential data pertaining to the concrete's strength, stiffness, and toughness. This data plays a pivotal role in the design and evaluation of structural enhancements for the concrete. Analyzing the behavior of concrete under diverse loading conditions is imperative for comprehending the failure process in concrete. It also aids in devising strategies to forestall failure. Moreover, a range of tests is utilized to monitor the quality of concrete production, ensuring it adheres to required specifications.

The use of Scanning Electron Microscopy (SEM) stands out as an exceptionally potent tool for scrutinizing the microstructure, particularly in the context of ITZ post-failure. SEM allows for the high-resolution visualization of the internal structure of concrete, magnifying details up to 60µ. This technique furnishes invaluable insights, enriching our understanding of concrete at a profound level.

In conclusion, the Interfacial Transition Zone represents a critical region characterized by a gradual shift in material properties. A thorough comprehension of ITZ holds paramount importance in advancing the durability and performance of concrete structures. It also serves as a cornerstone for the development of innovative materials and construction methodologies.

I. INTRODUCTION

Concrete, hailed as the bedrock of modern construction, stands as humanity's unparalleled and versatile building material. Its peak performance relies on the artful balance of meticulous proportions, thorough mixing for seamless cohesion, precise placement, and efficient compaction. Furthermore, concrete attains its desired properties through proper curing, maintaining an enduring internal moisture level for continuous hydration. Early-stage curing involves not only the application of water but also the creation of conditions conducive to sustained hydration within the matrix. It's noteworthy that the standard water content in concrete mixes typically suffices for complete cement hydration.

The Interfacial-Transition-Zone (ITZ) in concrete designates the pivotal realm between aggregate particles and the cement paste. This zone fundamentally shapes the efficacy and longevity of concrete structures. Concrete, a fusion of coarse aggregates like gravel or crushed stone, and a cementitious paste composed of cement, water, and additives, gives rise to the ITZ where the cement paste interfaces with the aggregate material. It stands distinct due to its unique composition and properties, setting it apart from both the aggregate and cement adhesive. This region is characterized by a higher water-to-cement ratio, augmented porosity, and diminished strength compared to the bulk cement paste. These distinctions arise from factors such as incomplete hydration of cement particles, the presence of air voids, and the absence of direct bonding between paste and aggregates. To counteract the detrimental effects of the ITZ, an array of measures can be deployed. These encompass refining concrete mix design, integrating mineral additives, incorporating chemical admixtures, and ensuring thorough consolidation during construction. These strategies aim to fortify the bond strength between aggregate and cement paste, reduce porosity, and elevate the overall quality of the ITZ.

The fatigue strength of concrete emerges as a pivotal parameter dictating its ability to withstand repeated cyclic loading without incurring substantial damage or failure. This consideration assumes paramount importance in the design and assessment of concrete structures subjected to dynamic or fluctuating loads over time. Concrete's inherently brittle nature renders it prone to developing microcracks under cyclic loading, which can progress into more substantial macrocracks. In this study, a groundbreaking approach has been adopted, introducing glass fibers into the material matrix of concrete to augment its fatigue strength. This innovation seeks to bolster the material against the rigors of cyclic loading, ultimately enhancing the longevity and reliability of the concrete structure. This pioneering advancement holds immense promise for applications in high-stress environments such as bridges, highways, and industrial structures, heralding a new era in concrete technology and the construction industry as a whole.

II. OBJECTIVES

The significant objectives of the work are:

- Strengthen ITZ in concrete through the application of Epoxy and SBR compounds.
- Reduce ITZ porosity to enhance aggregate bonding and structural integrity.
- Incorporate SBR and Epoxy with fibers to augment fatigue resistance.
- Improve ITZ's resistance against cracking and damage for extended structure lifespan.
- Utilize SEM for in-depth microscopic analysis of the Interfacial-Transition-Zone.
- Assess long-term durability and performance under varying environmental conditions.
- Evaluate economic and environmental feasibility of composite additives in concrete mix design.

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III. METHODOLOGY

The general block diagram of the Experiment fig(1).

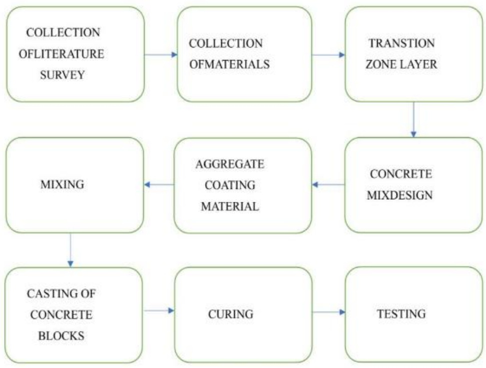

Fig .1: Methodology of Experiment

The flowchart you have described outlines the process of making a concrete block. Below is a detailed description of each step for your report:

1. Collection of Literature Survey:

- This is the initial step in the process, where a comprehensive review of existing literature is conducted. It involves studying research papers, industry standards, and best practices related to concrete block production. This step helps in understanding the latest advancements and ensuring that the concrete block production process adheres to relevant standards.

2. Collection of Materials:

- After gathering information from the literature survey, the next step is to collect the necessary materials for making concrete blocks. This includes cement, aggregates, water, and any additional materials required for specific block types.

3. Transition Zone Layer:

- The transition zone layer is a critical part of concrete production. It refers to the region where the aggregate particles come into contact with the cement paste. Ensuring a proper transition zone is essential for the structural integrity and durability of the concrete block.

4.Mixing:

- In this stage, the collected materials are combined in specific proportions. The mixing process involves blending cement, aggregates, and water to form a homogenous mixture. The quality of mixing impacts the strength and consistency of the concrete.

5. Aggregate Coating Material:

- Certain types of concrete blocks may require the application of aggregate coating materials to enhance their appearance or provide specific functional properties. This step involves the addition of coatings as needed.

6. Concrete Mix Design:

- Concrete mix design is a crucial step where the exact proportions of each material are determined. It's essential to achieve the desired strength, workability, and durability of the concrete block. The mix design takes into account factors like aggregate size, water-cement ratio, and any additives.

7. Casting of Concrete:

- Once the mix design is finalized, the concrete is cast into molds. The molds are typically in the shape and size of the desired concrete blocks. During this step, it's important to ensure proper compaction to eliminate air voids and achieve structural integrity.

8. Curing:

- After casting, the concrete blocks need to undergo a curing process. Curing involves providing the right conditions of temperature and humidity to ensure proper hydration of the cement. This step is crucial for the development of strength and durability in the blocks.

9. Testing:

- Quality control is paramount in concrete block production. Testing involves assessing the properties of the concrete blocks, such as compressive strength, density, and moisture content. This step ensures that the blocks meet the required standards and specifications.

10.Block:

- The final step in the process is the production of the concrete block itself. This is the result of all the preceding stages, and the quality and characteristics of the block are determined by the precision and care taken in each of the earlier steps

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The tests are carried on concrete specimens with a (water-cement) WC ratio of 0.45. The tests were conducted as per the standard specifications. The tests outputs are presented in this lesson and discussed with suitable graphical representation. Experimental results on concrete have shown that the compressive strength, tensile strength, flexural strength, and durability of concrete could be affected by a number of factors, including the design mix, in the curing time, and the age of the concrete.

COMPRESSIVE STRESS VALUES

Table(1): Compression test values

MIX	3 DAYS	7 DAYS	28 DAYS
CONVENTIONAL	20	31	44.5
	21	31.6	45.2
	20.5	32.2	44.9
EPOXY	14.6	27.9	49.2
	14.4	28.2	50.3
	14.8	27	49.8
SBR	15.2	24.5	37.5
	16.5	24.5	38
	15.8	30	37
EPOXY WITH FIBER	14.25	26	47.5
	14.0	26.5	47
	15.4	26.8	48
SBR WITH FIBER	14.2	28.8	35.5
	14.0	29.4	36.3
	15.5	28.2	34.4

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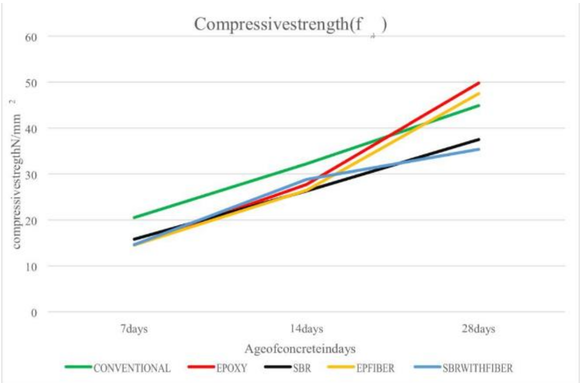

Fig .2: Compressive strength of concrete graph

LOAD	DIV	STRAIN	STRESS
50000	2	1.33E-05	2.829423
100000	5	3.33E-05	5.658845
150000	9	6.00E-05	8.488268
200000	14	9.33E-05	11.31769
250000	18	1.20E-04	14.14711
300000	24	1.60E-04	16.97654
350000	30	2.00E-04	19.80596
400000	36	2.40E-04	22.63538
450000	43	2.87E-04	25.4648
500000	50	3.33E-04	28.29423
550000	58	3.87E-04	31.12365
556000	65	4.33E-04	31.46318

Table (2): Stress vs Strain curve values(conventional)

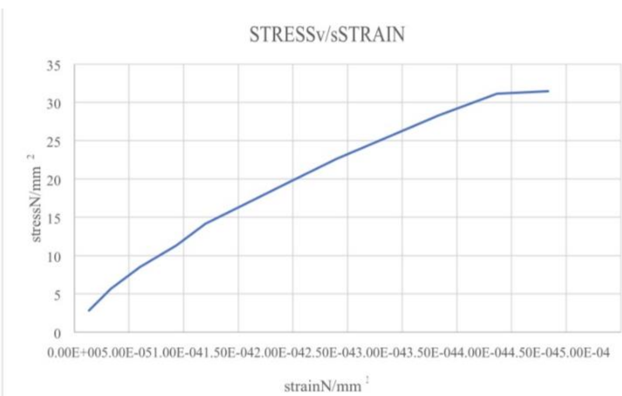

Fig .3: Compressive strength of concrete graph

SL NO	LOAD	DIV	STRAIN	STRESS
1	50000	0.15	0.00000	2.83
2	100000	5	0.00003	5.66
3	150000	9.5	0.00006	8.49
4	200000	15.5	0.00010	11.32
5	250000	21	0.00014	14.15
6	300000	26	0.00017	16.98
7	350000	31	0.00021	19.81
8	400000	36	0.00024	22.64
9	450000	43	0.00029	25.46
10	500000	49	0.00033	28.29
11	550000	57	0.00038	31.12
12	590000	125	0.00083	33.39

Table (3): Stress vs Strain curve values (epoxy)

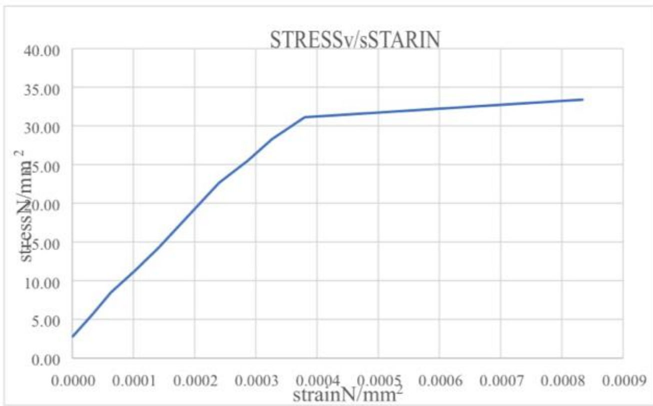

Fig .4: stress vs strain curve

LOAD	DIV	STRAIN	STRESS
50000	1	6.67E-06	2.829423
100000	3	2.00E-05	5.658845
150000	6	4.00E-05	8.488268
200000	11	7.33E-05	11.31769
250000	17	1.13E-04	14.14711
300000	26	1.73E-04	16.97654
350000	30	2.00E-04	19.80596
400000	39	2.60E-04	22.63538

Table (4): Stress vs Strain curve values (SBR)

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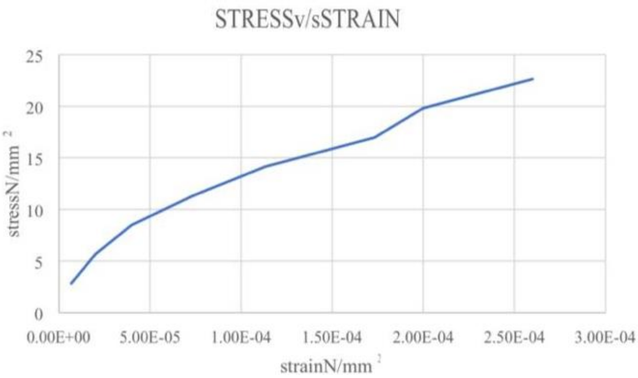

Fig .5: stress vs strain curve (SBR)

SPLIT TENSILE TEST

Mix	Split tensile strength (N/mm)
	28days
CONVENTIONAL	3.5
EPOXY	3.95
SBR	3.26

Table (5): Split tensile Strength of cylinders.

FLEXURE TEST

Mix	Flexural strength (N/mm)
Conventional	7
Epoxy	9
SBR	7.8
Epoxy with Fiber	8.3
SBR with Fiber	6

Table (6): Flexure test of beams at 28 days

NO. of Cycles	Load	V1	V2	Stress
0	511.2	0.053	-0.002	0.05112
2000	280.8	0.144	0.062	0.02808
4000	278.8	0.2	0.077	0.02788
6000	275.7	0.241	0.067	0.02757
8000	274.7	0.282	0.087	0.02747
10000	52.4	0.287	0.067	0.02737
12000	276.7	0.297	0.077	0.02767
14000	277.8	0.323	0.092	0.02778
16000	272.7	0.307	0.097	0.02727
18000	274.7	0.313	0.087	0.02747
20000	269.6	0.302	0.072	0.02696
22000	281.8	0.313	0.072	0.02818
22000	281.8	0.313	0.072	0.02818
24000	266.5	0.307	0.067	0.02665
26000	271.6	0.343	0.067	0.02716
28000	271.6	0.338	0.087	0.02716
30000	273.7	0.353	0.087	0.02737
32000	271.6	0.338	0.077	0.02716
34000	272.7	0.348	0.092	0.02727
36000	271.6	0.338	0.082	0.02716
38000	269.6	0.343	0.077	0.02696
40000	273.7	0.343	0.092	0.02737
42000	272.7	0.343	0.077	0.02727
44000	270.6	0.323	0.077	0.02706
46000	270.6	0.333	0.072	0.02706
48000	272.7	0.338	0.087	0.02727
50000	270.6	0.333	0.082	0.02706
52000	277.8	0.343	0.087	0.02778
52945	857.9	0.358	0.161	0.08579

Table (7): Fatigue test of beams at 28 days

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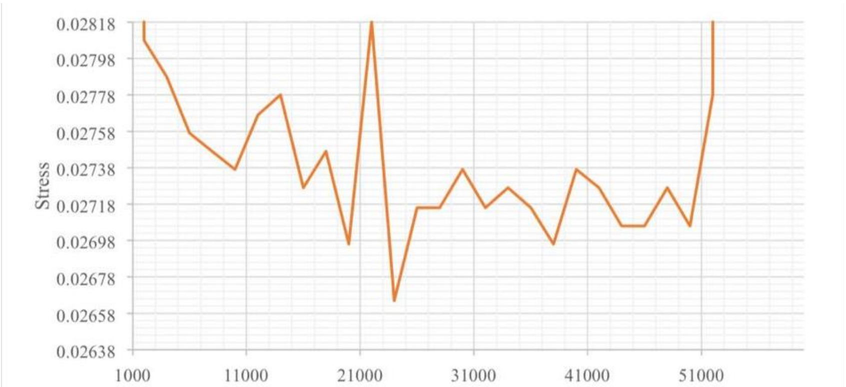

Fig .6: Fatigue test of beams at 28 days

No.cycles	load	v1	v2	load	stress
505	669.3	0	0.077	669300	66.93
4595	668.3	0.015	0.097	668300	66.83
10790	711.1	0.021	0.102	711100	71.11
12890	669.3	0.015	0.097	669300	66.93
19785	796.7	0.015	0.122	796700	79.67
22805	781.4	0.015	0.112	781400	78.14
27295	785.5	0.026	0.132	785500	78.55
28265	760	0.015	0.132	760000	76
32880	809	0.021	0.142	809000	80.9
39230	846.7	-0.005	0.132	846700	84.67
41495	816.1	0.026	0.146	816100	81.61
47505	1006.8	0.01	0.161	1006800	100.68
51190	1019	0.01	0.161	1019000	101.9
51295	641.8	-0.005	2.069	641800	64.18

Table (8): Fatigue test of beams at 28 days

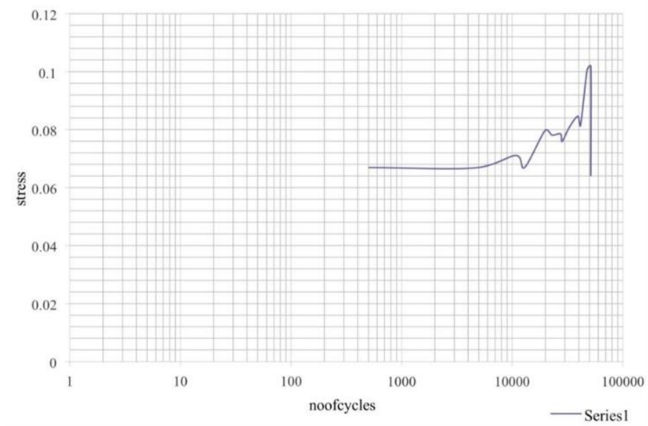

Fig .7: Fatigue test of beams at 28 days

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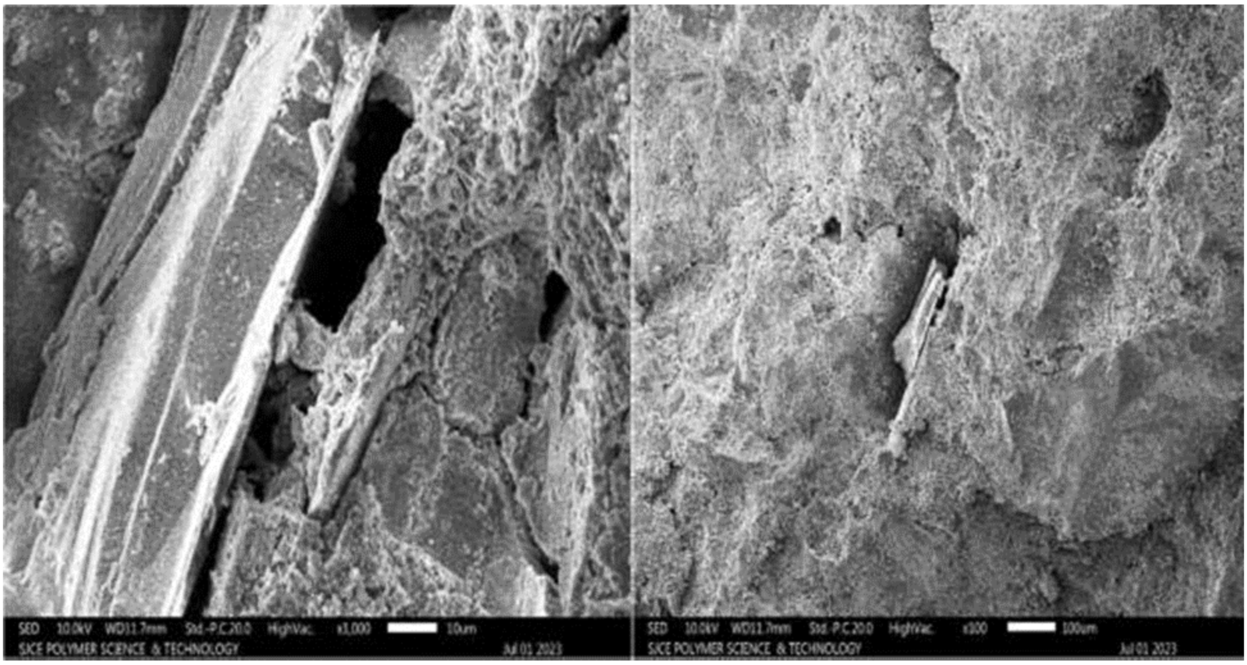
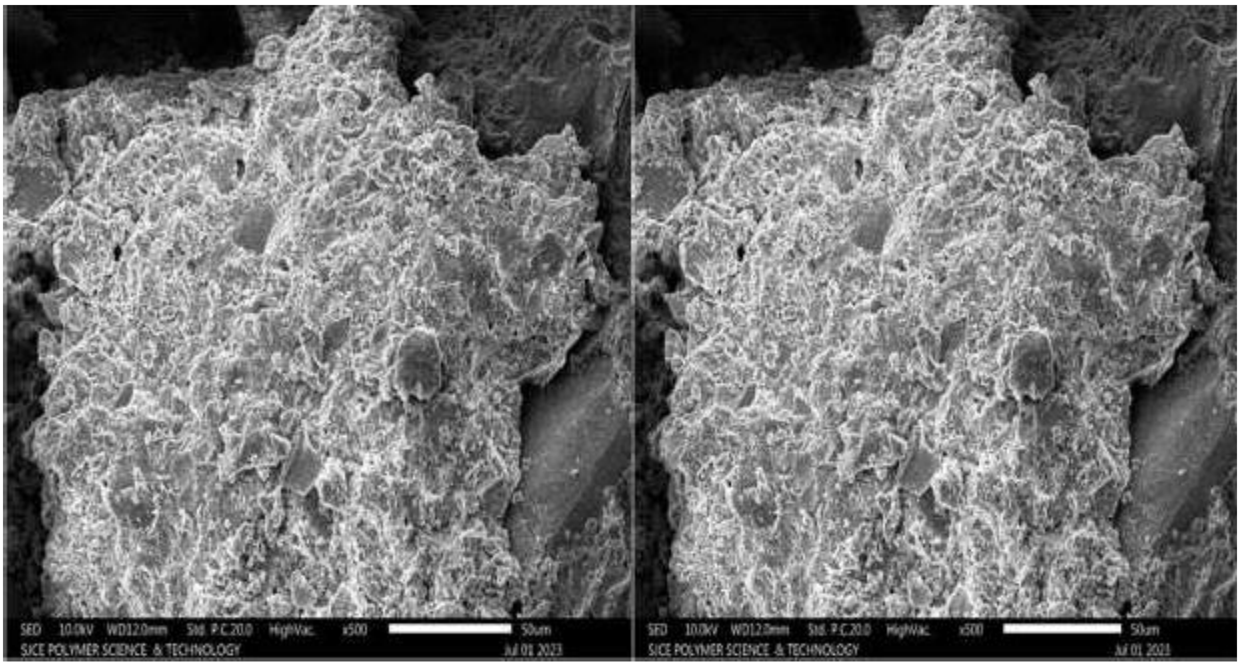
SCANNING ELECRON MICROSCOPE ANALYSIS

Scanning Electron Microscopic images of conventional concrete





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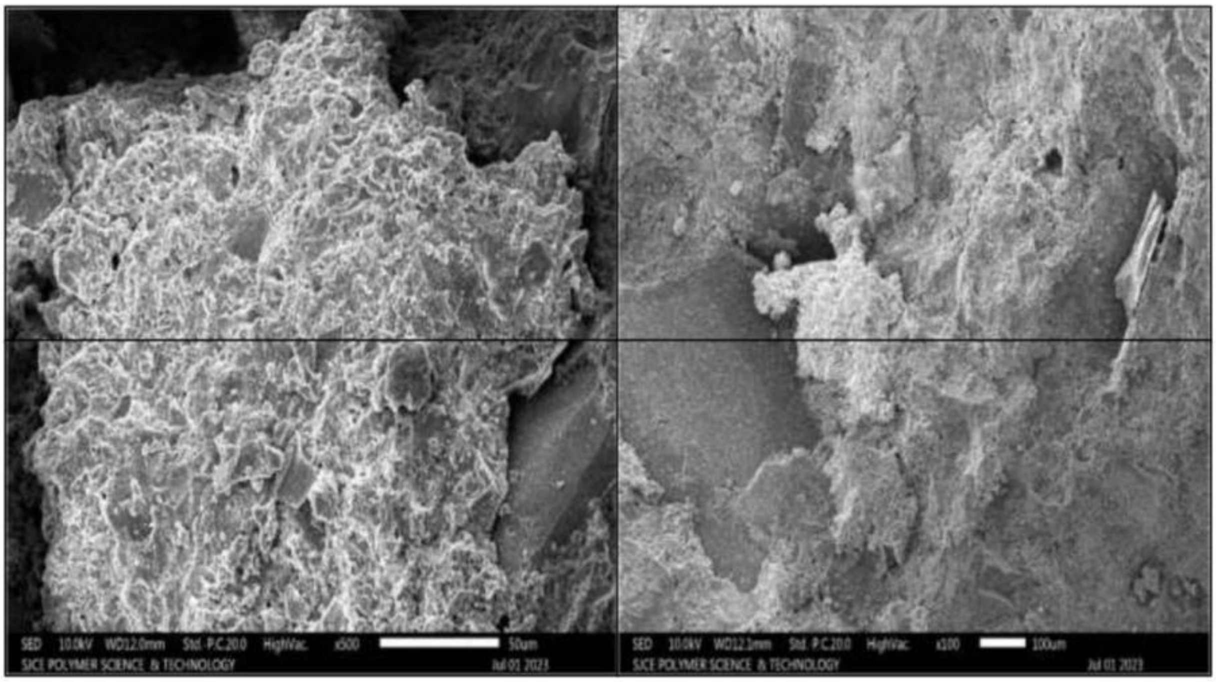
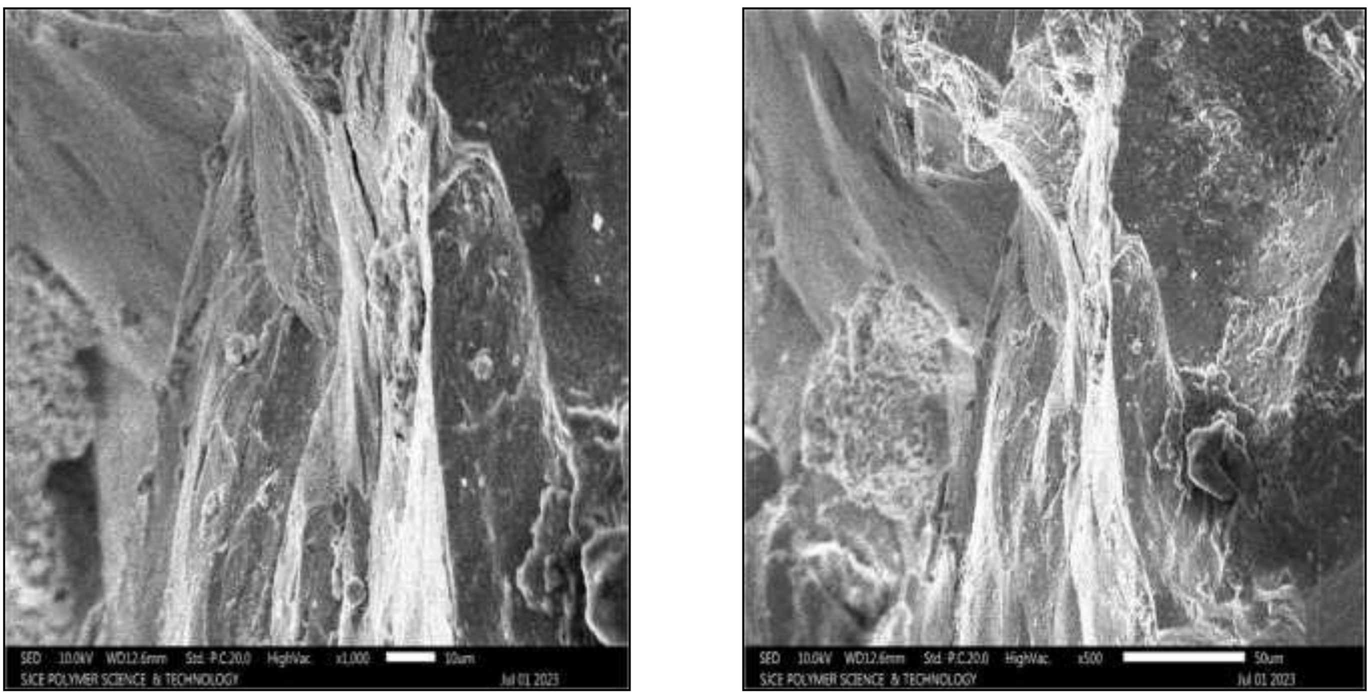


RESULTS

- A typical concrete mixture comprises coarse and fine aggregate, Portland cement, water, and an admixture.
- An examination utilizing scanning electron microscopy (SEM) unveiled the existence of an inconspicuous but weaker zone positioned between the aggregate and the cement paste.
- The microstructural components within the concrete alone do not provide adequate improvement to the Interfacial Transition Zone (ITZ).

Scanning Electron Microscopic images of Epoxy concrete:



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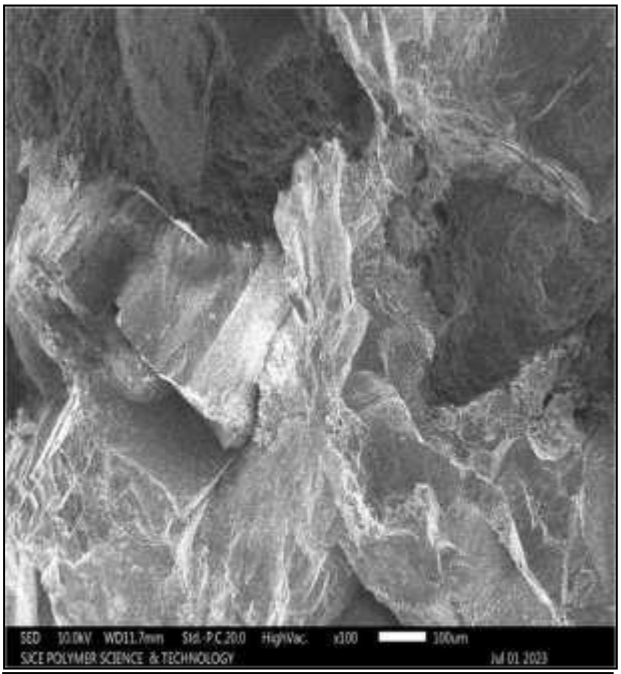

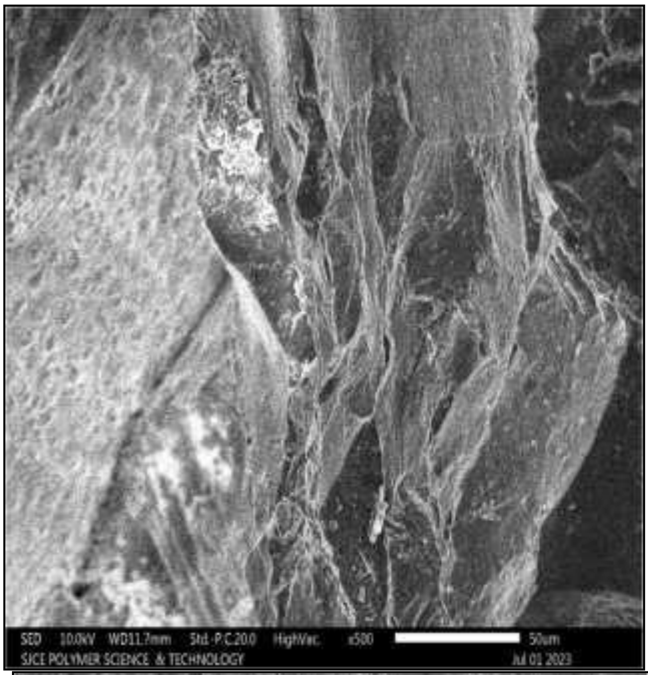

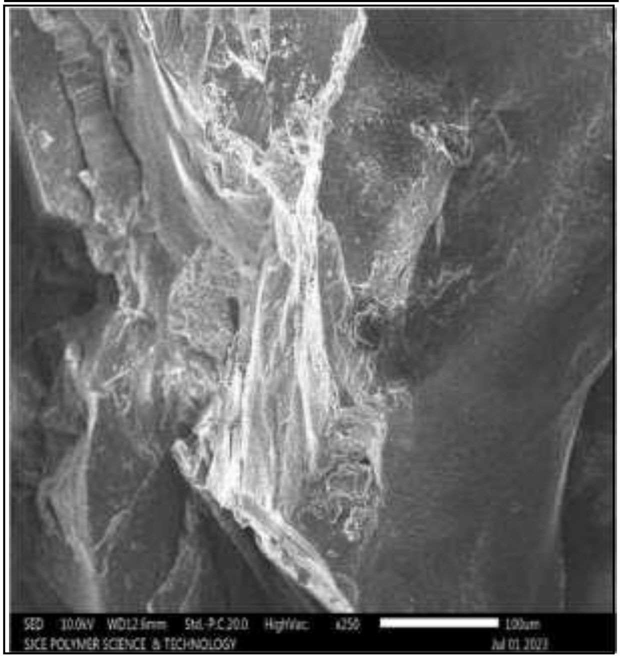

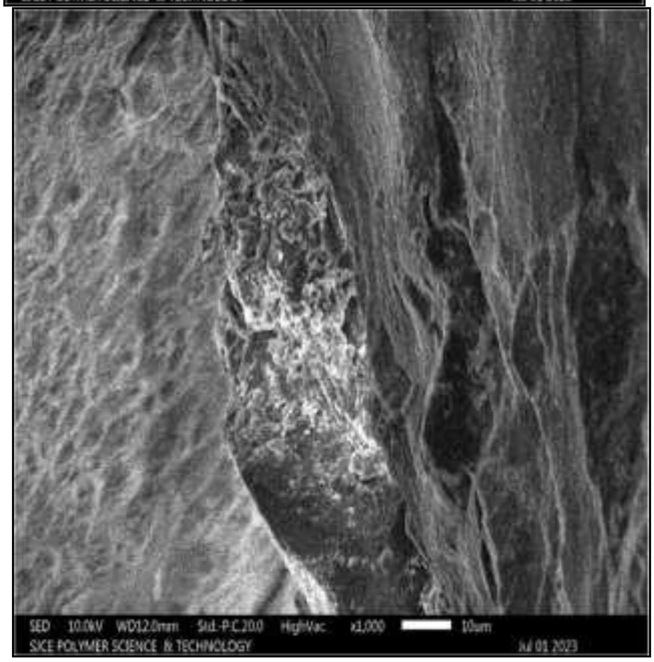

RESULTS

- As per our findings regarding the research on Epoxy adhesives used in this experiment which helps in ITZ enhancement when compared to other adhesives Epoxy reduces voids present in the surface of the aggregate, at the same time this results in less porosity. Hence, it contributes for increase in compressive strength(fck) when compared to our normal design mix(conventional).
- The behaviour of ultra micro structural elements presents in the Epoxy design mixed concrete obtained by SEM analysis. The enhancement of ITZ as taken place with presence of Epoxy adhesives present in between aggregate and cement paste (ITZ Layer),

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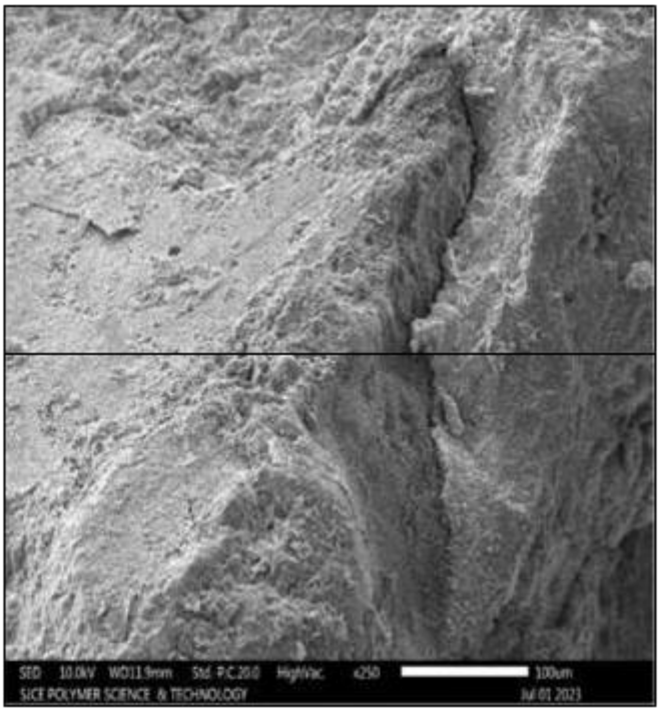
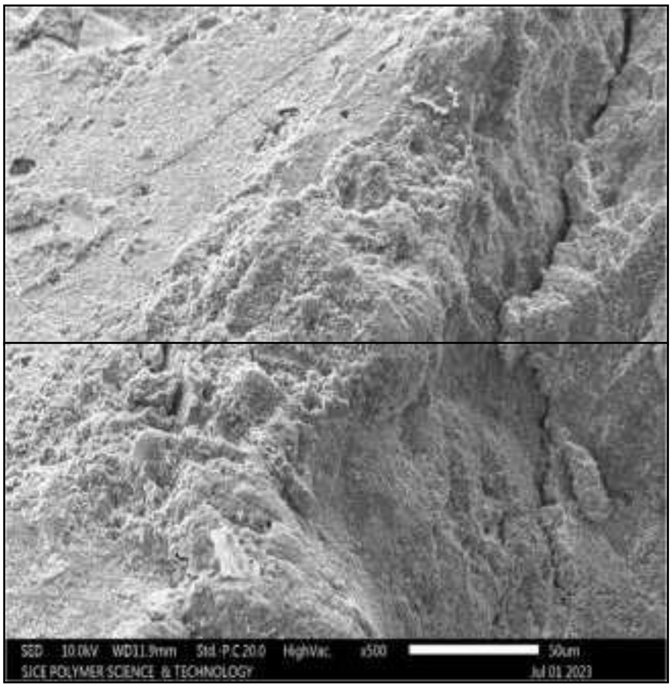
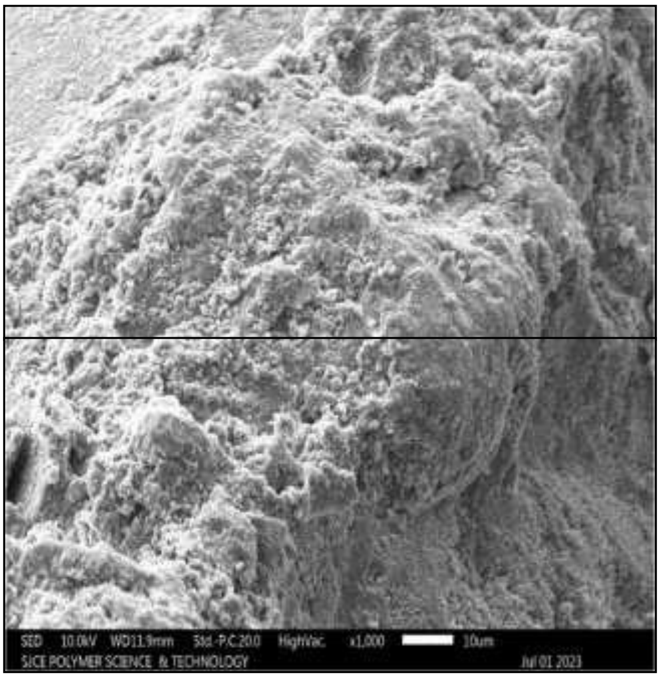
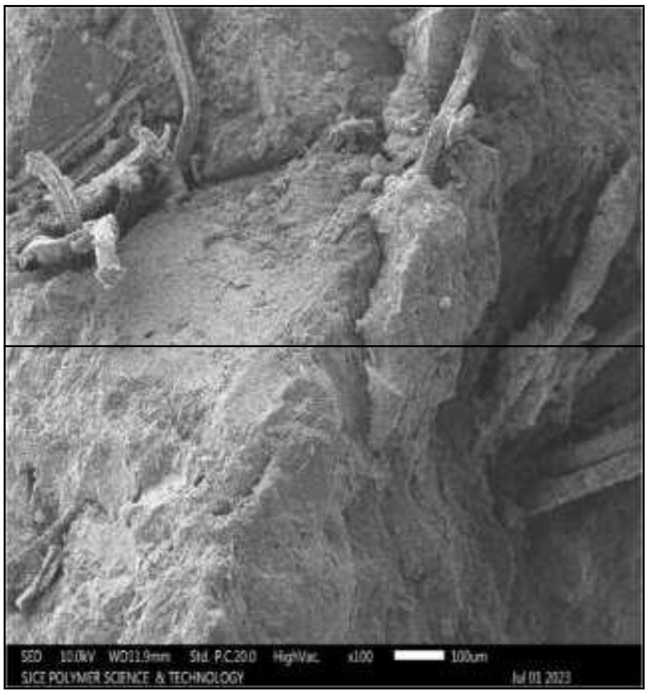
Scanning Electron Microscopic images of Epoxy fibre concrete:









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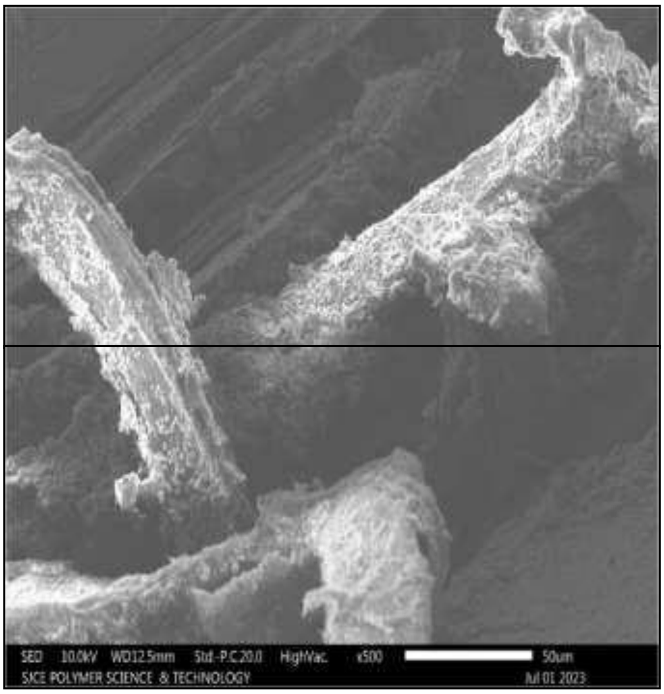

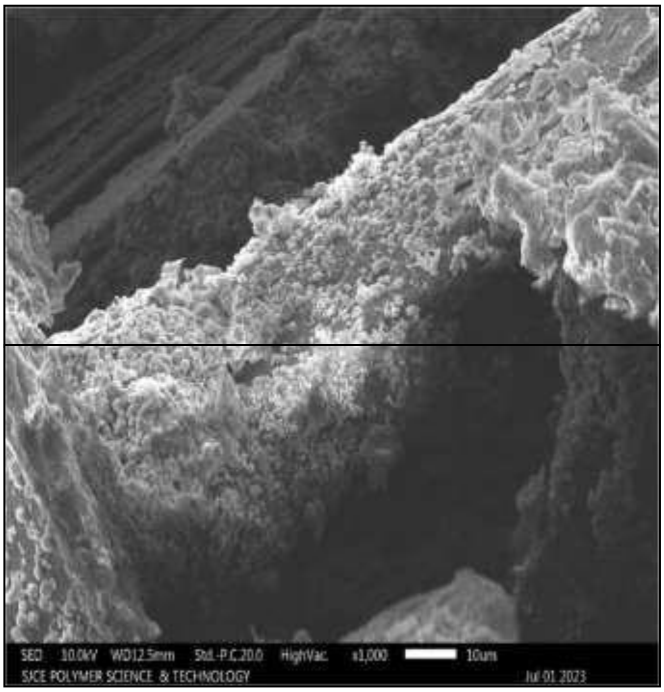

RESULTS

- The specialized design mix of Epoxy with fibers comparatively had better results of compressive strength of concrete and Tensile strength to that of conventional and SBR coated design mix aggregates.
- Epoxy constituting aggregates had a larger strength than that of Epoxy with fiber. Nevertheless, the ITZ layer in case of Epoxy with fiber is quite enhanced with the adhesives, when compared to the conventional and SBR coated aggregate design mix.

International Journal of Engineering Research & Technology (IJERT)
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IV.CONCLUSIONS

Based on the experimental results, the following conclusions can be deduced:

1. Compressive Strength: The compressive strength of concrete increases over time, with epoxy-coated aggregates demonstrating a significant contribution to the enhancement of compressive strength compared to other mix variations.
2. Influence of Factors: The compressive strength of concrete is influenced by various factors, including curing conditions and concrete age. Notably, epoxy-coated aggregates exhibit lower initial compressive strength but experience a rapid increase, surpassing SBR, conventional, and SBR with fiber mixes over time.
3. Tensile Tests: Tensile testing methods, including splitting tensile tests, fatigue tests, and flexural tests, are commonly used. Epoxy-coated aggregates consistently display superior tensile strength when compared to other mixtures.
4. Stress-Strain Behavior: The stress-strain curve for epoxy-coated aggregates appears to be more linear when compared to the curves of other materials with different coatings.
5. ITZ Enhancement: Our primary objective of enhancing the Interfacial Transition Zone (ITZ) through adhesives like Epoxy and SBR was successfully achieved. This conclusion is substantiated by the analysis of SEM (Scanning Electron Microscope) data, which provided key findings supporting the desired ITZ enhancement.

These conclusions underscore the efficacy of epoxy-coated aggregates in enhancing the mechanical properties of concrete, specifically in terms of compressive and tensile strength, as well as the desirable linear behavior in stress-strain curves. Furthermore, the SEM analysis confirmed the successful improvement of the Interfacial Transition Zone as a result of the adhesives used in the study.

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