Mechanical and microstructure analysis of sustainable concrete using paper waste

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Abstract

This research work carried out the employment of waste, paper as an additive material in concrete. The mixture of waste material like adding waste paper as a partial additive to the weight of the cement required in the concrete mix. This research focuses on the study of microstructure analysis, and mechanical properties. Also develop the correlation between the microstructure analysis, and mechanical properties. The waste paper with the concrete achieves strength due to the presence of hydrogen bonds, in the microstructure of paper. The waste paper has comparatively less in cost with other alternative building materials. The quantity of waste paper used in concrete after the saturated surface dryness test (SSD) is 5%, 10%, 15% and 20%. The optimum percentage of waste paper addition in concrete is 10% and the scanning electron microscope (SEM) image shows that the C-S-H formation for proper bonding in concrete. The X-ray diffraction (XRD) image depicts the crystallographic structure of waste paper with concrete. The waste paper added in concrete compound helps to reduce the waste in the environment.

Introduction

Concrete is a composite of different construction materials like cement, fine aggregate and coarse aggregate[1]. Concrete is most important material consumed in construction site considering it's several of applications in structural engineering. The major problem facing in construction industry is construction materials. The major issue in construction site is use of cement discharged the CO2. The CO2 emission from cement affected the environmental and also causes various health problem to human and animals[1]. On other side to light on the need of green environmental, sustainable development and energy savings in Engineering construction, the waste material used for engineering construction has become a focus of research in recent years. Among these this study is mainly focused to resolve these kinds of issues[2]. Paper waste is a new construction material used in concrete production, this is also known as papercrete. Paper waste concrete developed 50 years ago but it is now rediscovered. The incorporation of paper waste along with concrete to enhance the mechanical behaviour, microstructure analysis and thermal properties[3]. Paper waste used in concrete reduces the quantity of cement and make building as environment friendly. Paper waste concrete has good sound absorption, resistant to fire and fungi, and pests of all kinds with addition of some special mixes[4]. Paper waste incorporated in concrete can reduce the density of construction materials; it has been created the light weight structure and make an efficient low cost building.[5] It has been decided to study the strength characteristics, workability, and other properties of paper waste concrete.

Materials And Methods

Cement

Cement is a binder material used for bind other construction materials together hardens and adheres, OPC grade of 53 as per Indian standard confirming to IS 12269:1987[6] used for preparation of concrete mixes as the binder.

Fine aggregate

Aggregates passes through 4.75mm IS sieve are fine aggregate is conforming to zone III of IS: 383:1997 [7] used for concrete mix. The specific gravity of fine aggregate is 2.6.

Coarse aggregate

Most important constituents in concrete are coarse aggregate. As coarse aggregate, the aggregate was retained on a 4.75 mm IS sieve. It should be angular and graded with a maximum size of 10 mm used for concrete manufacturing. According Indian standard confirming to IS: 2386 - 1963 [8] various properties of coarse aggregate were found in laboratory.

Paper

A variety of common materials like cardboard and newspapers, magazines and books can be added to the mix either dry or pre-soaked, depending on the mixer. This acts as a glue to hold the mixture together and it is used as a crack arrester in concrete, making it more rigid and durable.

Experimental Investigation

As per the IS code standards, the concrete mix design and testing of concrete specimens are done.

Design mix

In this research concrete is made as per the provisions given in the IS10262-2009[9]. In order to produce concrete that is strong and long-lasting, the selection and proportioning of concrete's ingredients and their relative amounts. After the curing of 3 days, 7 days and 28 days, the concrete specimens were tested to find their mechanical strengths.

Compressive strength

The compressive strength of a material refers to its ability to withstand a certain amount of force before failing. The most important concrete test is the compressive strength test, which provides information on the material's properties. Compressive strength is measured using a 100×100×100 mm concrete cube. The cubes are compressed on the compression testing equipment in the accordance with IS 516 (1959) [10].

Split-tensile strength

The characteristic split tensile strength of concrete members is used to discover the maximum load they can bear before splitting. The characteristic split tensile strength of concrete test is essential because it consistently yields reliable results despite being relatively simple to conduct. In order to discover the concrete characteristic split-tensile strength, 100mm diameter and 200mm length of cylinder is used. The

cylinders are tested on the compression testing equipment on the 3rd, 7th, and 28th days in accordance with IS 516 (1959) [10].

Flexural strength

The flexural strength is measured using a concrete specimen with dimensions of 100×100×500 mm. According to IS 516 (1959)[10], the specimen is tested after 3 days, 7 days, and 28 days.

SEM analysis

A scanning electron microscope was used to examine the microstructure of the materials used in this research[11]. For testing, concrete specimens are tested at various intervals over a period of time. For the most accurate analysis, both the concrete and the microscopic broken aggregate should be included in the sample. Samples of paper concrete were examined in this study.

Discussions And Findings

The findings of all of the laboratory tests were discussed and compared to IS standards.

Compressive strength test

The compression testing machine using the characteristic compressive strength of conventional concrete and paper waste concrete was measured as shown in figure 1. The compressive strength of paper waste concrete mixes results are listed in table.1.Figure 2 shows the graphical representation of concrete with paper waste [1].

Table 1

Compressive strength test values.

Materials	Compressive strength N/mm^2		
	3rd day	7th day	28th day
Conventional concrete	16.2	20.2	27.5
Paper waste 5%	17.4	21.8	28.1
Paper waste 10%	18.1	23.9	29.4
Paper waste 15%	17.5	21.6	28.3
Paper waste 20%	16.3	20.8	27.2

Split tensile strength test

The results of the split tensile strength test, which was performed on a compression testing machine as shown in figure 3, were compared to paper waste used concrete as shown in table 2, and the graphical representation is shown in figure 4.

Table 2

Paper waste concrete split-tensile strength test

Materials	Split tensile strength N/mm^2		
	3 day	7 day	28 day
Conventional concrete	2.6	3.6	4.5
Paper waste 5%	2.7	3.4	4.6
Paper waste 10%	2.5	3.5	4.8
Paper waste 15%	2.4	3.4	5.1
Paper waste 20%	2.2	3.1	4.7

Flexural strength test

The flexural strength test were performed using compression testing machines, as shown in figure 5. The flexural strength results of paper waste used concrete are shown in Table 3 and compared to conventional concrete in figure 6.

Table 3

Flexural strength test values.

Materials	Flexural strength N/mm^2		
	3rd day	7th day	28th day
Conventional concrete	4.4	5.5	5.8
Paper waste 5%	4.3	5.4	5.7
Paper waste 10%	3.9	4.8	5.2
Paper waste 15%	3.7	4.6	4.9
Paper waste 20%	3.3	3.9	4.2

SEM analysis

For the purpose of identifying the chemical elements, core samples were collected at the conclusion of various periods and sent to a Nanotechnology laboratory for SEM analysis SEM images, in general, only

show the surface characteristics of the samples being examined as shown in figure 7-11. For the most part, the strength of ordinary portland cement hydrated in calcium silicate hydrate (C-S-H) comes from the nano crystalline phase. Long and cylinder ettringites are transformed into fibre crystals that form calcium hydroxide and small fibre C-S-H are shown in figures.

XRD analysis

Figure 12-16 shows the XRD patterns, and it is clear that paper concrete is an amorphous substance with no discernible crystalline pattern. Both $Ca(OH)_2$ and C-S-H are important constituents. Calcite and Ettringite are minor constituents of crystalline materials. Quartz is the most important crystalline phase.

Conclusion

- The amount of wastepaper in a group of papercrete mixes increased the compressive strength of concrete by 10%.
- The split tensile strength was increased 15% of paper waste.
- According to the SEM observation, adding paper waste to the mix causes the production of more C-S-H gel, which aids in achieving the desired strength.
- The incorporation of paper waste had no discernible effect on the hydration product of $Ca(OH)_2$, C-S-H gel and Ettringite according to XRD pattern.
- Paper waste not only helps the environment by reducing the amount of cement used in construction.

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Figures

Figure 1

Compression test on concrete cube

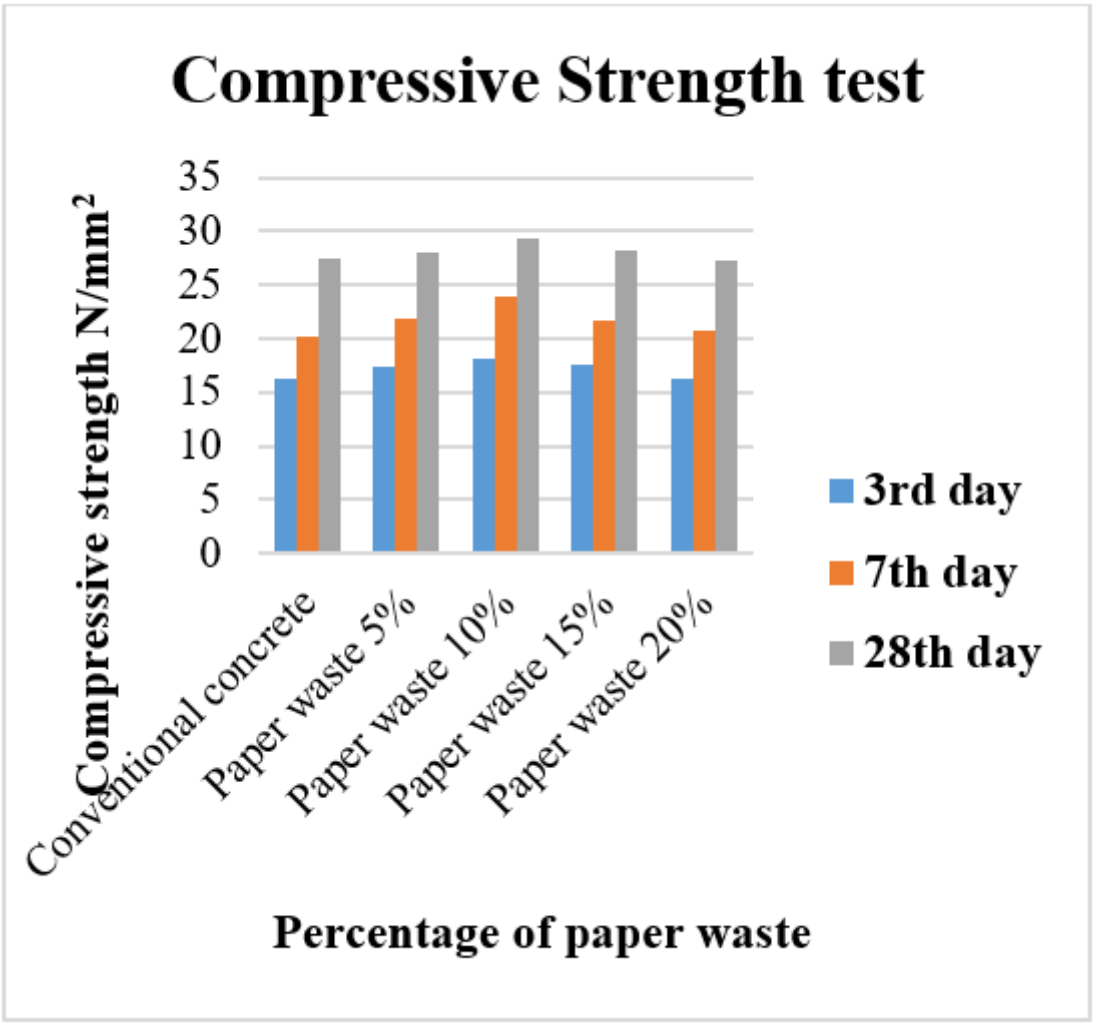

Figure 2

Graphical representation of paper waste concrete

Figure 3

Split tensile test on paper waste concrete

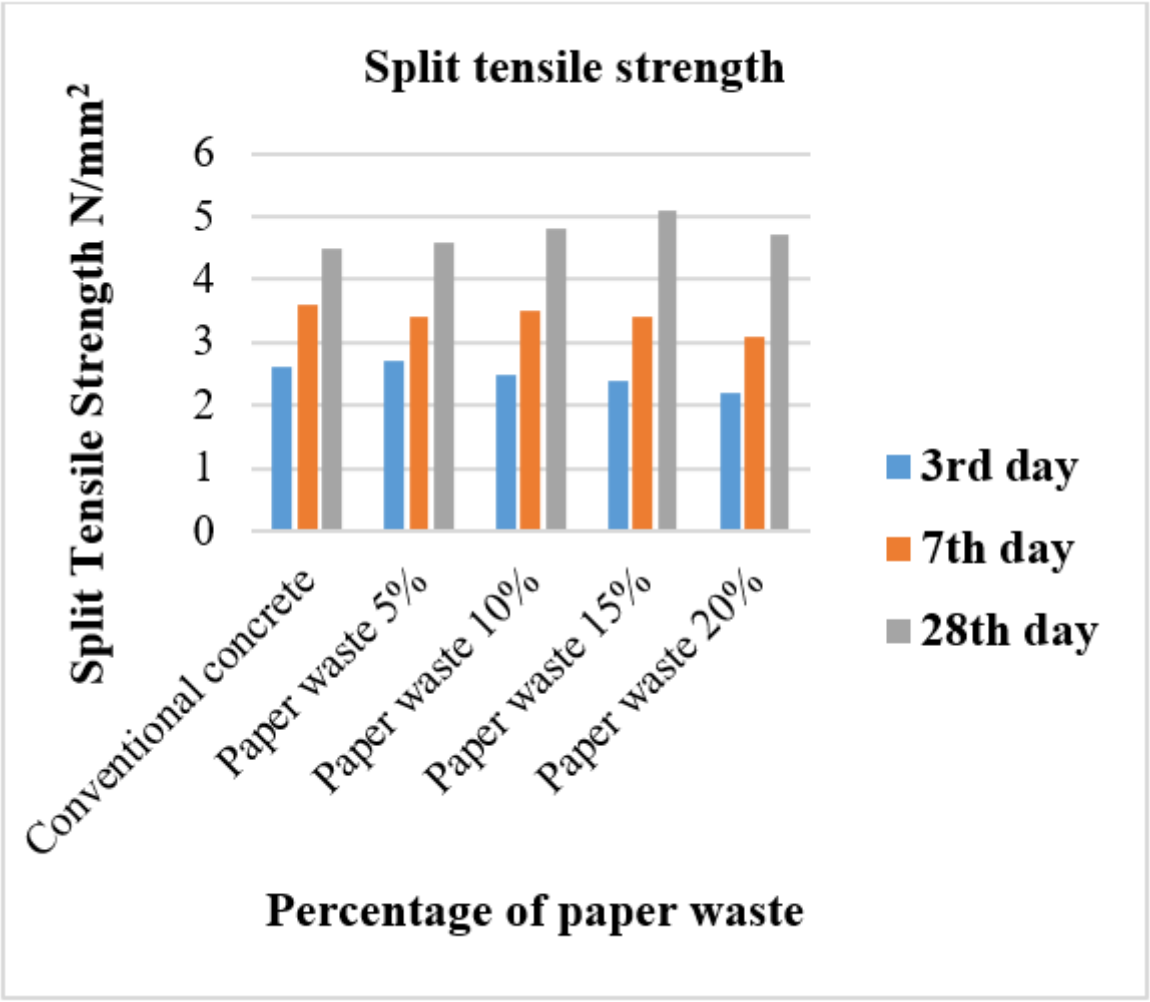

Figure 4

Graphical representation of split tensile strength on paper waste concrete

Figure 5

Flexural strength test on prism

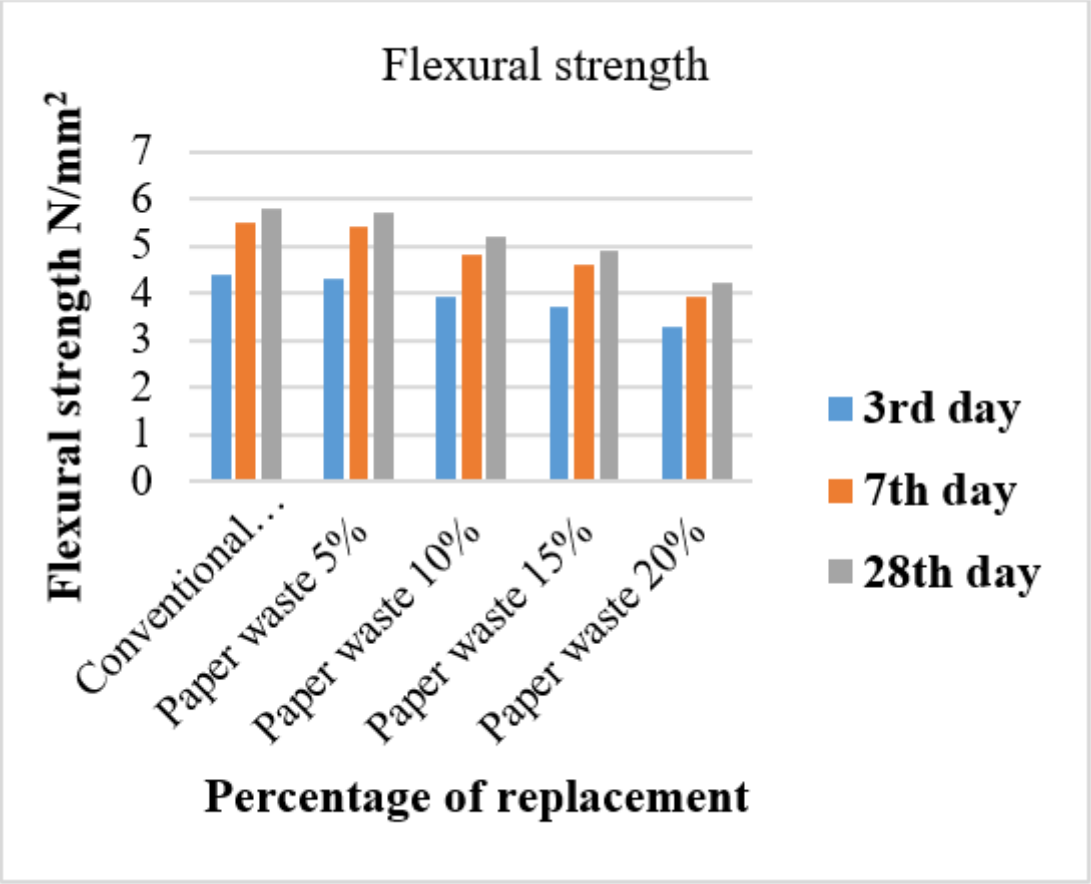

Figure 6

Graphical representation of Flexural strength values

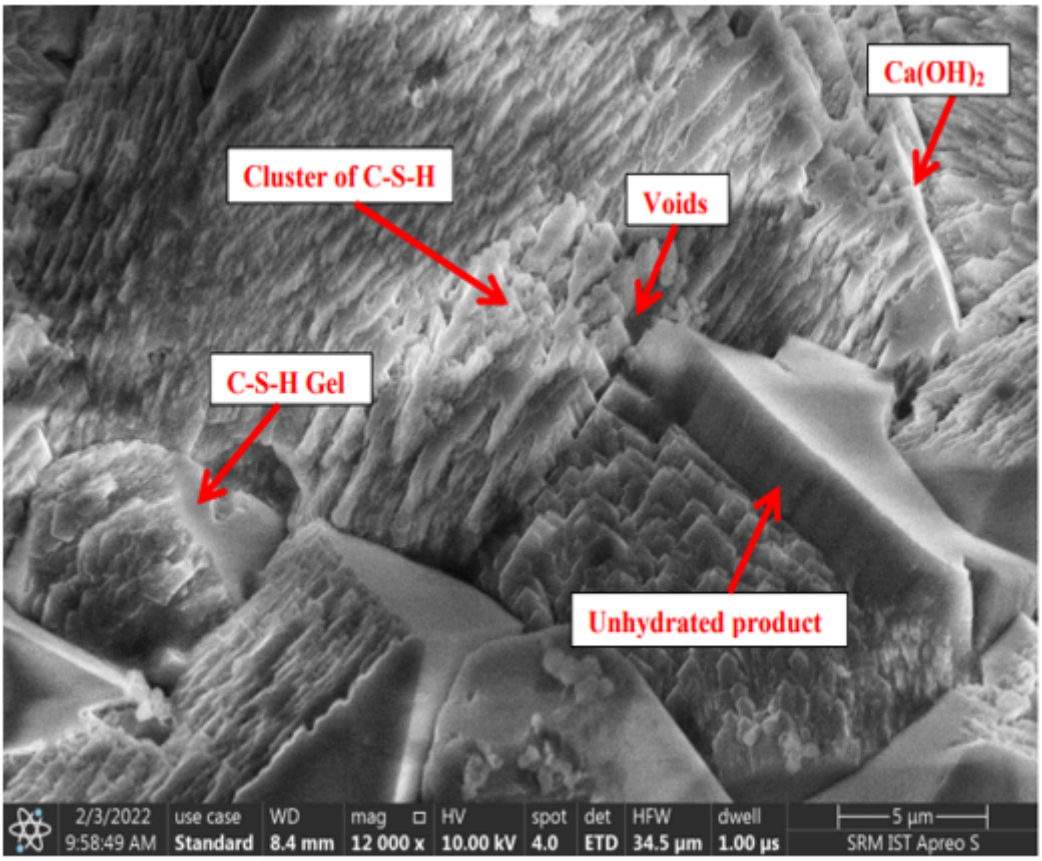

Figure 7

SEM depiction of conventional concrete

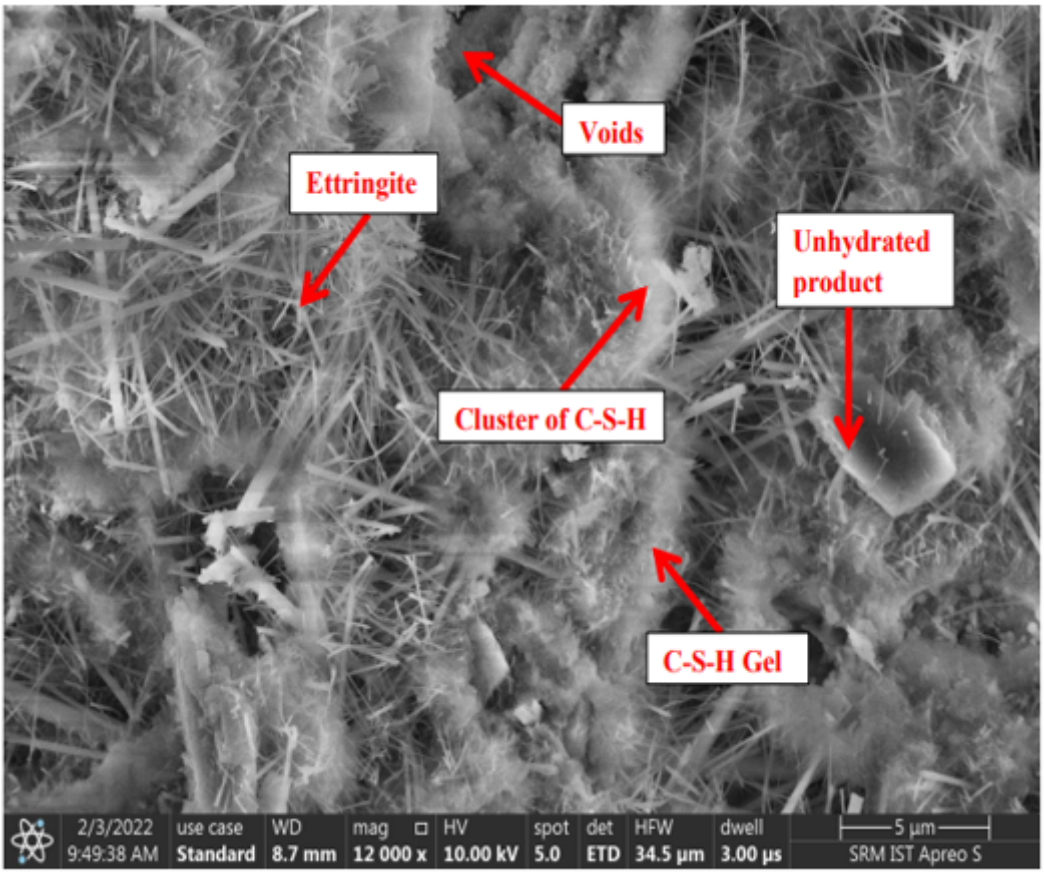

Figure 8

SEM depiction of paper concrete 5%

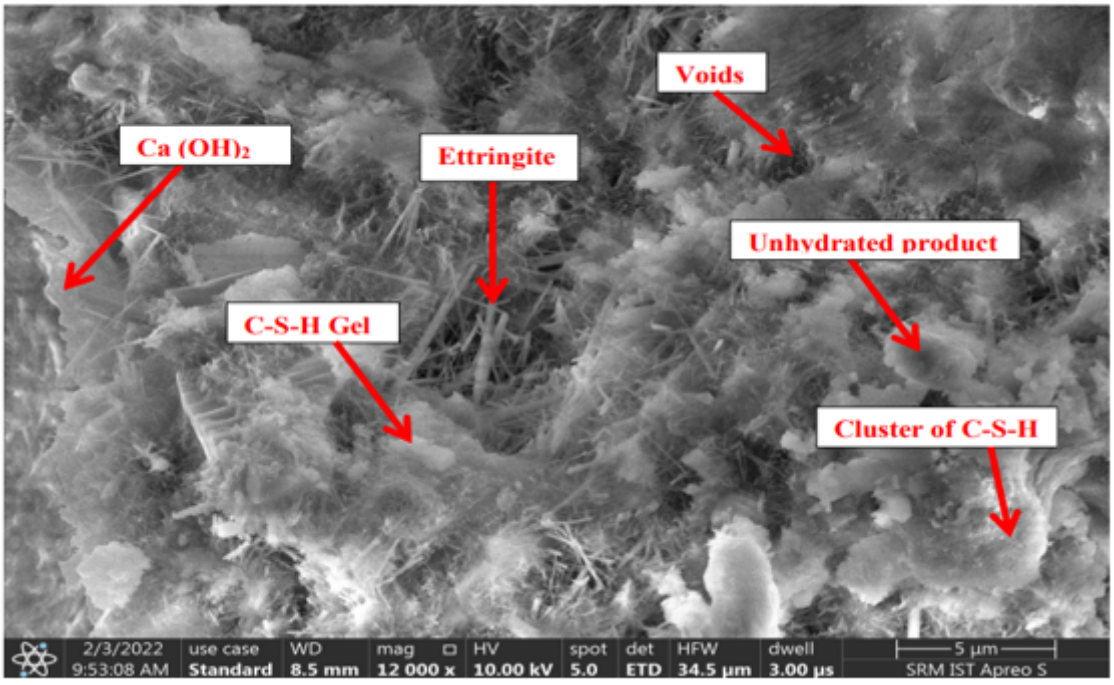

Figure 9

SEM depiction of paper concrete 10%

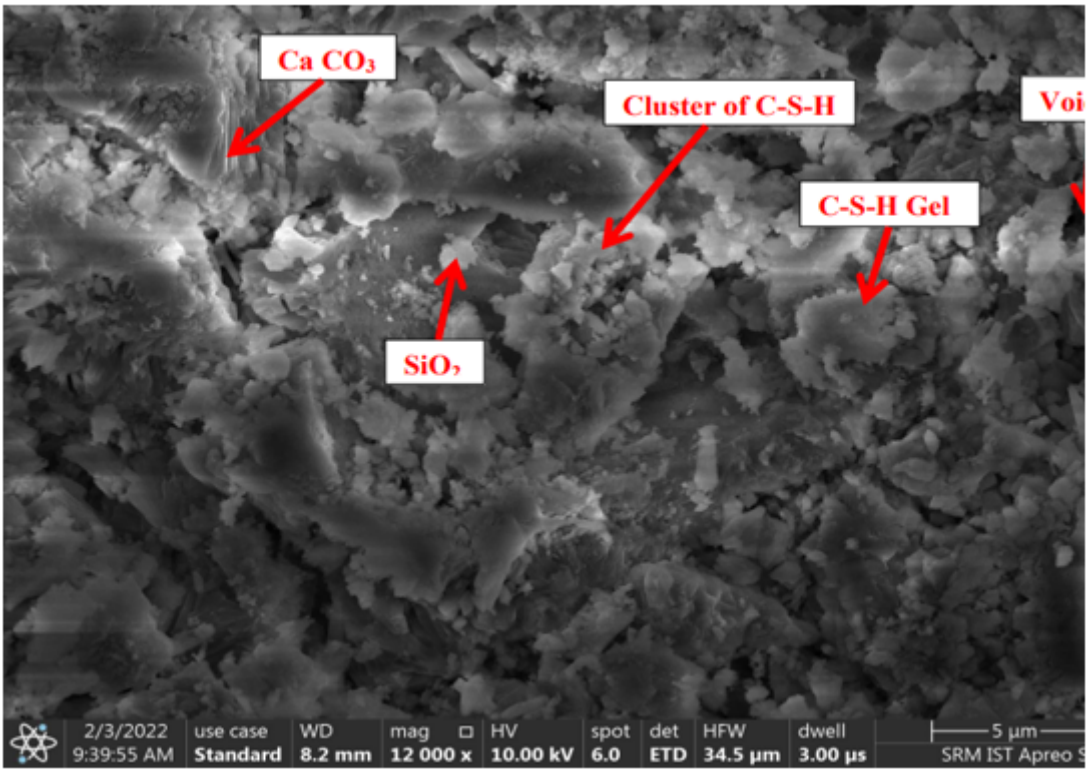

Figure 10

SEM depiction of paper concrete 15%

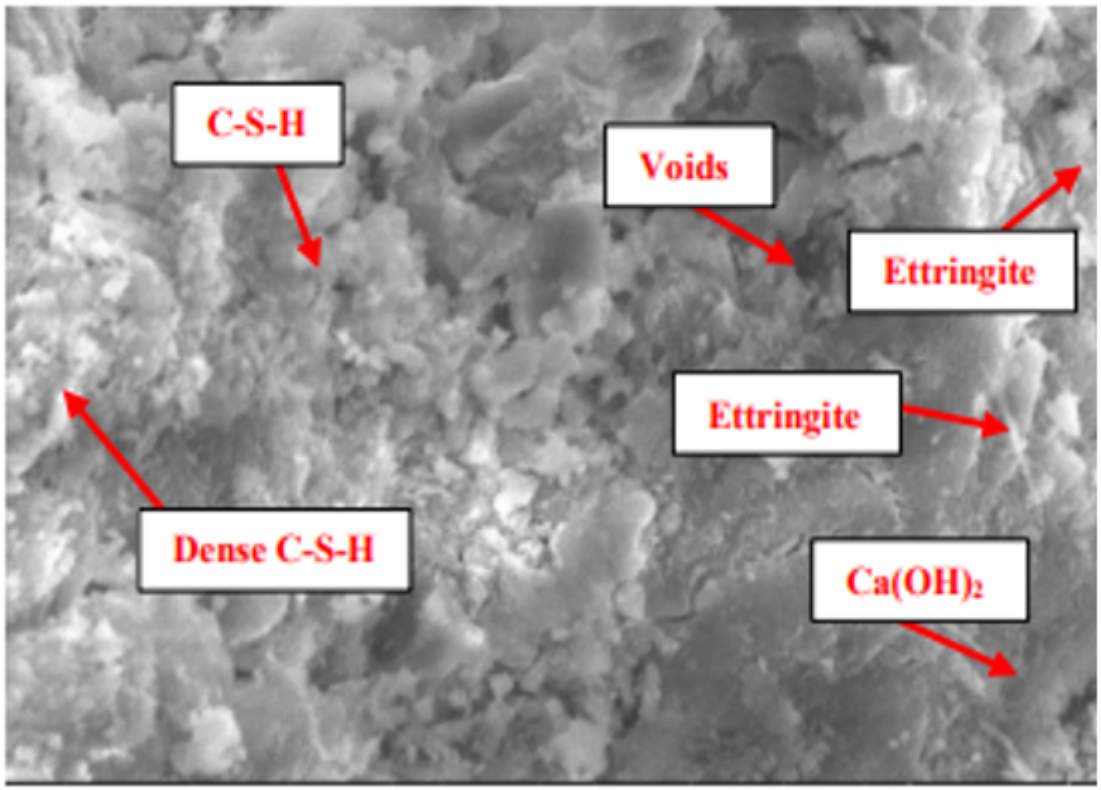

Figure 11

SEM depiction of paper concrete 20%

Figure 12

XRD pattern of conventional concrete

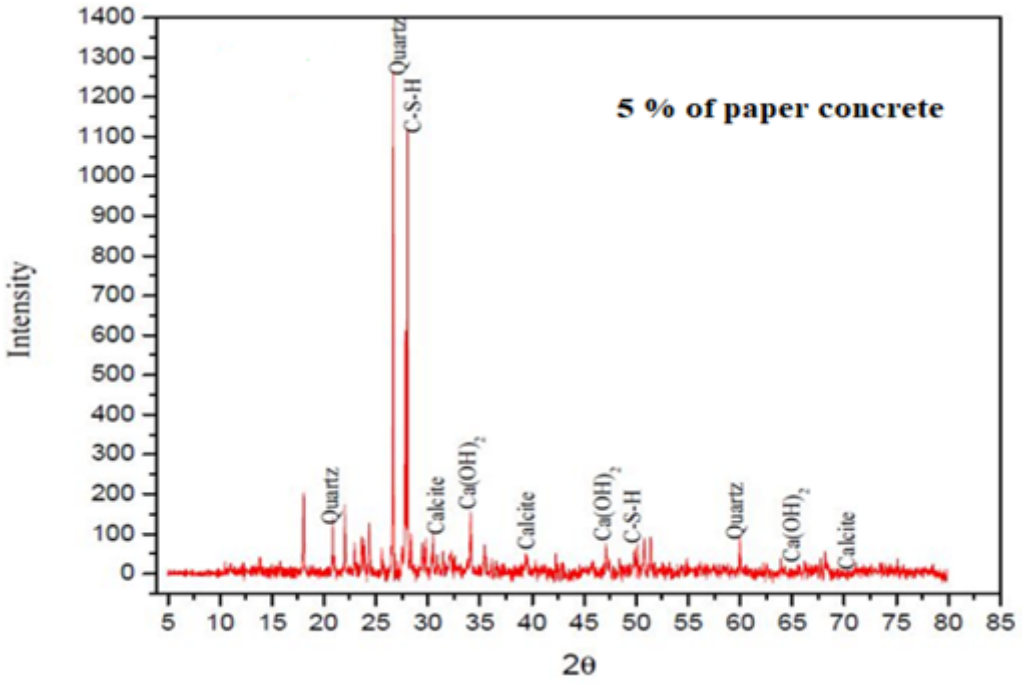

Figure 13

XRD pattern of 5% paper concrete

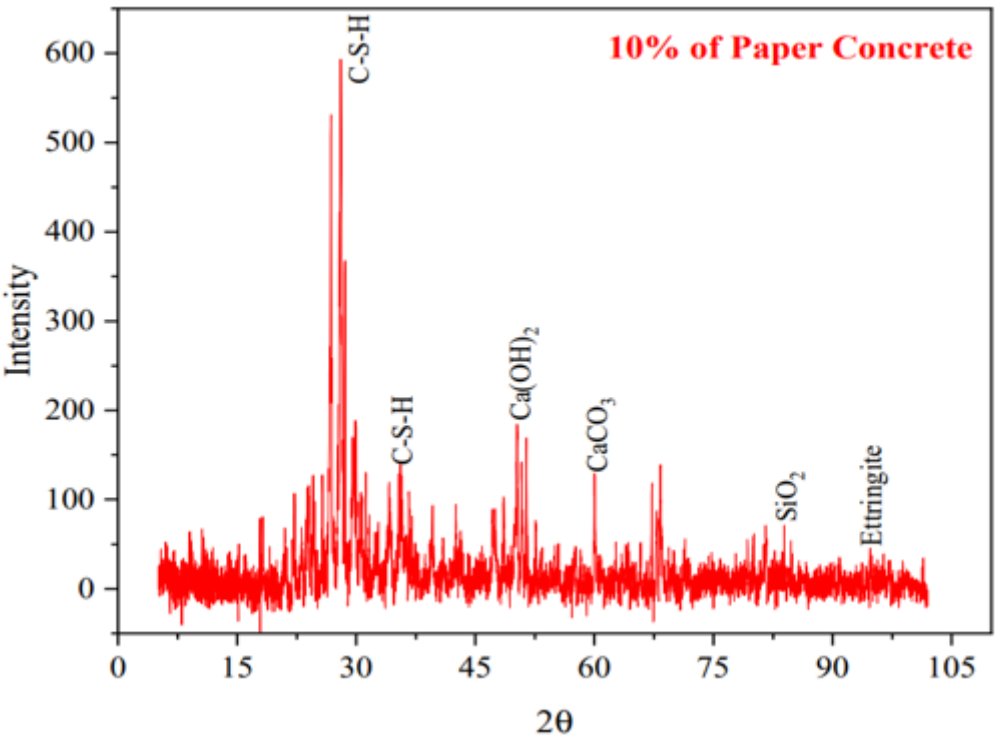

Figure 14

XRD pattern of 10% paper concrete

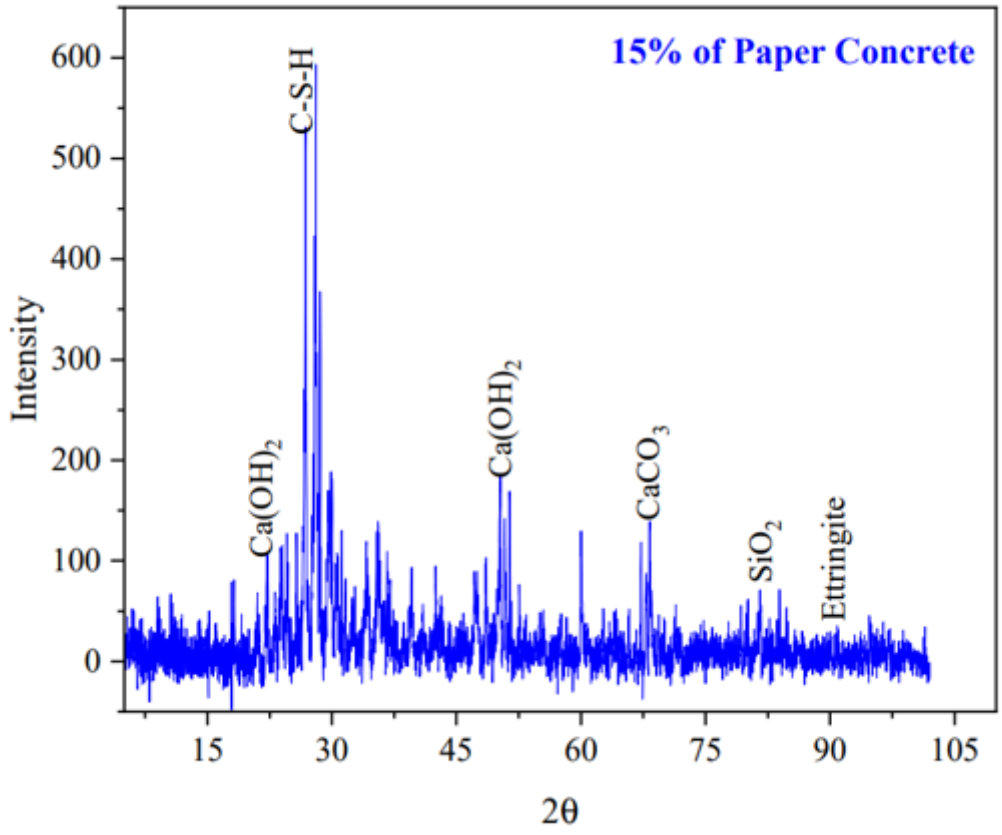

Figure 15

XRD pattern of 15% paper concrete

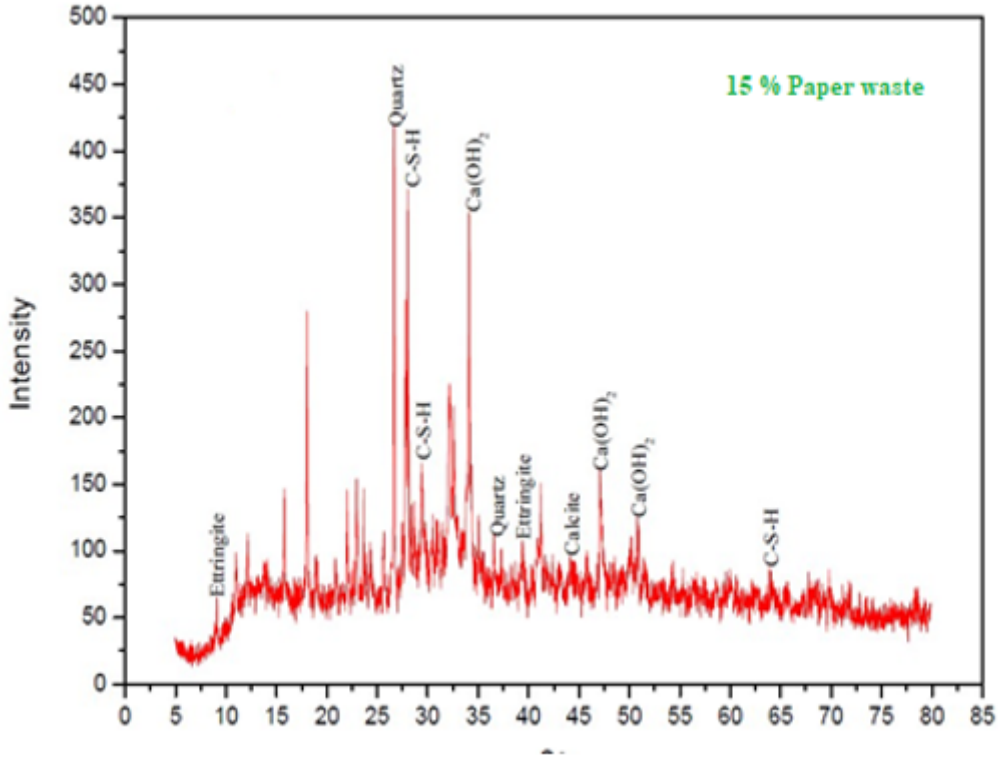

Figure 16

XRD pattern of 20% paper concrete