

To Study on Behavior of Concrete Containing Polypropylene Granules

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ABSTRACT

This study investigates the behavior of concrete incorporating polypropylene granules as partial replacement of fine aggregate. The percentage of replacement of fine aggregate by polypropylene granules are 0%, 5%, 10%, and 15%. To examine the parameters such as workability compressive strength, flexural strength, and split tensile strength at different curing periods (7, 28, and 56 days). The results indicate that the incorporation of polypropylene granules positively influences the mechanical properties of concrete. Specifically, an optimal percentage of polypropylene granules improves the compressive, flexural strength and split tensile strength. The findings aim to provide insights into the potential benefits and practical applications of using polypropylene granules in concrete construction, highlighting their role in enhancing the material's performance.

Keywords: Polypropylene granules, partial replacement, fine aggregate, concrete behavior, workability, compressive strength, flexural strength, split tensile strength, curing periods, mechanical properties, optimal percentage, and sustainable construction.

INTRODUCTION:

The effect of plastic waste, such as dense debris from plastics, artificial fibers, and E-waste granulates, on the strength of concrete is investigated in this study. It promotes responsible disposal of waste and lowers environmental pollution by highlighting the potential benefits of utilized PET bottles and technology trash in concrete. Because of its resistance to chemicals and biological agents, polypropylene fibers (PPF) are frequently utilized in small amounts (0.1–0.3%) to reduce shrinkage cracking, increase toughness, and improve impact resistance. Although the hydrophobic property of PPF can lessen its bonding with cement, new research indicates that virgin PPF can be effectively replaced with recycled polypropylene fibers (RPF) derived from waste materials, which will encourage sustainable construction practices while keeping equivalent concrete performance.[1,2]

In this work, a reference mortar and mortars including plastic additives then fibers are compared, and the evolution of the hydration degree for different curing temperatures is examined. The significance of compressive strength is emphasized as the study investigates the effects on fly ash with fibers on concrete's resistance to abrasion. According to research, sand does not usually impair abrasion resistance the same way that fly ash does when replacing cement. Abrasion resistance is increased by adding fibers, especially steel fibers. The article also discusses the advantages for the environment of substituting some of the natural aggregates for concrete with ferrous slag, a byproduct of iron production, which lowers prices and promotes sustainability [3,4,5]

Concrete performs good under compression but badly in tension due to its inherent brittleness. In order to withstand tensile forces and stop structural deterioration from inevitable breaking, steel bars or mesh, sometimes known as "re-bar," have traditionally been employed as reinforcement. Fiber reinforcement—which includes steel, glass, and polymeric fibers—has become more popular recently; nonetheless, its main purpose is now crack control as opposed to structural strengthening. Concrete with fibers made of polypropylene, in instance, has fewer cracks when it is still fresh and has improved resistance to cavitation and abrasion. Because of developments in concrete technology and environmental concerns, there is a growing usage of waste materials, especially plastic, in concrete. These materials assist solve the growing problem of plastic waste, save prices, and increase the durability of concrete.[6,7,8,9]

The microstructural temperature as well as water behaviour of cementitious materials are important factors that affect their thermal impacts, especially during the drying process. Elevated temperatures during the curing process improve final compressive strength, whereas they have a negative effect on it when new concrete. Widely used polymer polypropylene (PP) is produced by controlled polymerization using certain catalysts and is generated from propylene gas. Common techniques for analyzing pore properties in cement-based materials include SEM, NMR, NAD, and MIP, and MIP being especially useful for a broad variety of pore sizes. In order to boost fatigue life and prevent rutting as well as thermal cracking under greater wheel loads along with changing climates, bituminous binders—which are crucial to paving—are strengthened with synthetic polymers.[10,11,12,13]

Owing to its affordability, water resistance, and adaptability, plastic is a synthetic material composed of organic polymers that finds widespread application. Among the types are PVC, LDPE, HDPE, PP, and PET. The production of plastic surpassed 359 millions metric tons worldwide in 2018, but there are serious environmental problems due to its non-biodegradability.

It is imperative to reuse plastic garbage in order to mitigate pollution and save resources. Due to their non-magnetic, rust-free, along with alkali-resistant qualities, polypropylene (PP), a significant portion of plastic waste, is abundantly generated and utilized in concrete reinforcement. PP fibers improve the longevity of concrete and work well with any type of chemical admixture, which makes them perfect for a wide range of building uses.[14,15,16,17,18]

To study the mechanical properties of concrete with the incorporation of PP Granules as a partial replacement for fine aggregate and the effect of PP Granules on water absorption of concrete and the chemical composition of concrete with the incorporation of PP Granules and also to find optimum dosage of PP Granules as a fine replacement

EXPERIMENTAL STUDIES:

Materials used:

Pozzolana Portland Cement:

A blended cement known as Pozzolana Portland Cement (PPC) is made of fly ash, volcanic ash, and silica fume combined with regular Portland cement. The calcium hydroxide generated through the hydration process combines with the pozzolanic ingredients to create new cementitious compounds that strengthen and extend the life of the concrete. PPC is especially appreciated for its lower heat of hydration, less permeability, and enhanced resistance to chemical attacks. It is perfect for use in many construction projects, including those involving dams, bridges, & coastal constructions because of these qualities. Furthermore, PPC helps the environment by lowering CO2 emissions by using industrial byproducts as pozzolanic materials.

Table 1: Results of Cement Testing Investigations

TEST	RESULT
Standard of Consistency	32%
Setting Time	
Start Time	33 min
Completion Time	65 Min
Cement's fineness	2.27%
SG	3.1
Density of Mass	3140 kg/m ³
Shrinkage Maximum	Less than 0.15 percent

Fine Aggregate:

The small particles used in concrete compositions as fine aggregate are usually crushed stone or natural sand. These tiny particles are essential for producing a smooth finish on the surface and filling up gaps in the concrete mix. The particles of fine aggregate are smaller than those of coarse aggregate and typically go via a 4.75-millimeter sieve. Their inclusion in concrete is crucial to improving the material's workability, strength, and longevity. Fine aggregates are essential to the general efficiency and durability of concrete because they create a well-packed & cohesive mix, which makes them an important part of building projects.

Table 2: Tests and results conducted on aggregate

TESTS	RESULTS
S G og aggregate	2.65
Fineness Modulus	2.69
Surface Moisture of aggregate	Graded
Water Absorbed by aggregate	1.68 %
Aggregate's mass density	1.1 %

Aggregate fines gradation	1750 kg / m ³
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Coarse Aggregate:

Larger particles, such crushed stone or gravel, make up coarse aggregate, which gives concrete its main structural strength. These aggregates, which typically have sizes between 4.75 mm and 38 mm, are the foundation of the concrete and help to maintain its durability and volume stability. Its workability, strength, and general performance for the concrete are significantly influenced by the size, shape, and texture of the coarse particles. Because coarse aggregate selection directly affects the stability and lifetime of the material, it is essential to selecting the suitable one for building projects in order to achieve the necessary qualities.

Table 3 Tested coarse aggregate yield significant outcome.

TEST	RESULT
SG of CA	2.76
Fineness Modules	7.02
Moisture on the Surface	0.2%
Absorption of Water	0.53%

Polypropylene Granules:

Granules made of polypropylene are thermoplastic polymers that are flexible and originate through the polymer of propylene. These granules have a high melting point, exceptional chemical resistance, and are widely employed in a variety of sectors. They are very useful in the processes used in the production of plastic goods including textiles, car parts, and packaging materials. Polypropylene granules are a cost-effective and easily processed material that is used to produce a wide range of goods for both consumers and industries. Their extensive use in a variety of applications is a result of their efficiency and versatility.

Table 4: Polypropylene Granules Chemical & Physical Characteristics summarized.

TESTS	RESLTS
PP Granules size	2 mm
Maximum Shell thickness	0.0254-0.102 mm
SG of polypropylene	0.90-0.96
Water Absorption	1.5-0.266% (1h)

Mix Proportion:

A M20 grade of concrete is intended to cure for 28 days before reaching its typical compression strength for 20 MPa (2900 psi). M20 concrete typically has a mix ratio of 1:1.5:3, meaning that there is one part of cement, 1.5 parts fine aggregate (sand), and 3 parts coarse aggregate (crushed stone or gravel). The water is mixed in to cement to provide optimum hydration and workability; the water-to-cement ratio is typically approximately 0.5. This proportion is appropriate for a range of building applications because it offers a well-balanced combination of durability, strength, and workability.

RICE HUSK ASH:

More and more people are realizing the benefits of rice husk ash (RHA) for concrete, especially when it's used to partially replace cement. RHA lowers the temperatures of hydration and increases the workability, durability, and strength of concrete. By forming denser, less porous concrete through the pozzolanic interaction with calcium hydroxide, it increases the longevity of structures and reduces maintenance expenses. Moreover, the fine particles in RHA enhance particle packing, which increases mechanical characteristics. RHA's value as an addition in contemporary concrete technology is still being confirmed by ongoing study.

Table 5: Examined Rice Husk Ash and results are mentioned below.

TESTS	RESULTS
S G of rice husk ash	1.87
Fineness Modulus	2.148
Surface Moisture of rice husk	Grade
Water Absorbed by rice husk	5-6%

Specimen preparation and testing:

COMPRESSION STRENGTH OF CONCRETE:

Compressive strength, which is influenced by variables including specimen size and the ratio of cement to water, is the main criterion for evaluating the quality of concrete. In key testing, 150 mm cubes are used, a constant force is applied using a compressive testing apparatus, and strength is determined by taking the maximum load into account. Accurate strength evaluation is ensured by tests conducted at 28 and 56 days.



Fig 6: Casting process of compression strength of concrete



Figure 7: Test procedure of concrete compression strength.

FLEXURAL STRENGTH OF CONCRETE:

Applying transverse stresses to conventional concrete beams allows for the testing of flexural strength, an important property of concrete used in pavements and highways. This technique evaluates the concrete's resistance to bending and is based on guidelines such as IS 516-1956 along with ASTM C: 78-10. In the procedure, beams are mixed, cured, tested, and their strength is determined using particular formulas.



Fig 8: Procedure of casting of Flexural strength of concrete Table



Fig 9: Concrete bending strength testing

SPLIT- TENSILE STRENGTH OF CONCRETE:

The split tensile test provides an indirect substitute in situations where it is not possible to evaluate tensile strength directly because of a shortage of samples or equipment. Using this method, the tensile strength of cylindrical concrete specimens is determined through applying an upward compressive load to them. Using the compression machine, cylinders with dimensions of around 150 mm in diameter as well as 300 mm in height are tested. The applied force is used to calculate the cylinder's tensile strength. The process involves loading, curing, measuring, and averaging data from several specimens.



Figure 10: procedure of casting Split-Tensile strength of concrete



Figure 11: Test conducted on cylinder

TEST ON EDS:

Using a variety of forms, including a variety of, short answers, projects, and essays, EDX assessments evaluate your understanding of the course material. These assessments, which are incorporated into the course modules, assess your knowledge and development. They are essential to achieving the highest possible grade and earning certifications, and they could have deadlines or special guidelines.

TEST ON SEM:

Using an electron beam to examine samples at high magnification is a test for scanning electron microscopy (SEM). Using this method, surface structures can be seen in great detail, displaying textures and minute details that are not apparent using light microscopy. SEM is useful for examining particle size, surface morphology, and material characteristics.

Result and discussion:

TEST ON COMPRESSION STRENGTH:

Table 12: Concrete Compression Strength Control Mix (14,28,56 Days)

SL.NO	COMPRESSION STRENGTH TEST IN (N/mm ²)			% OF PP GRANULES
	14 days	28 days	56 days	
1	1.417.18	25.2	31.335	0
2	19.778	23.6	27.12	5
3	16.44	21.076	11.942	10
4	10.653	19.425	14.899	15

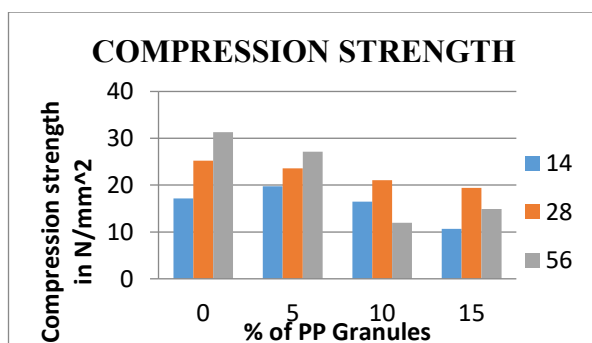


Fig 13: Effect of Curing Duration on concrete compression strength (14, 28, 56 days)

The performance in concrete mixtures with different quantities containing polypropylene (PP) granule over 14, 28, and 56 days is revealed by the strength of compression test results, which are displayed in the graph. Peaking around 31.335 N/mm² after 56 days, the control mixes devoid of PP granules had the maximum compressive strength. The strength with 5 percent PP granules increased slightly at day 14 but decreased at day 28 and day 56. A blend containing 10% PP granules demonstrated a significant decline in intensity over time, reaching 11.942 N/mm² after 56 days. In a similar

vein, the strength of the mixture containing 15% PP granules steadily decreased, reaching 14.899 N/mm² after 56 days. These results imply that greater PP granule percentages generally lower the strength of compression, with the greatest effects being seen at elevated values as well as lengthier curing times.

FLEXURAL STRENGTH OF CONCRETE:

Table 14: Flexural Strength Testing of Concrete Beam Specimens in Control Mix (14,28,56 Days)

SL.NO	FLEXURAL STRENGTH TEST IN (N/mm ²)			% OF PP GRANULES
	14 days	28 days	56 days	
1	6.375	4.55	7.08	0
2	8.405	6.71	6.85	5
3	4.66	5.788	4.288	10
4	6.358	4.763	4.8	15

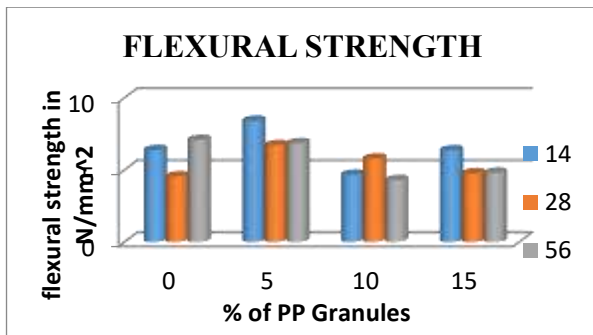


Figure 15: Effect of Curing Duration concrete's Flexural strength (14, 28, 56 days)

The graph displays the results of the flexural strength test, which compares concrete mixtures over 14, 28, and 56 days that contain different amounts of polypropylene (PP) granules. The flexural strength of the control mix, which contained no PP granules, remained constant and peaked at roughly 7 N/mm³ after 56 days. At 14 days, the five percent PP granules mix showed the maximum flexural strength of around 8.5 N/mm²; however, this strength started to decrease at 28 and 56 days. The strength of the 10 percent PP granules mix decreased over time, reaching 5 N/mm² after 56 days in particular. Likewise, after 56 days, the strength of the 15 percent PP granules mixes steadily decreased, reaching values of about 5.5 N/mm². These findings imply that whereas adding 5% PP granules can initially increase flexural strength, greater Longer curing durations and percentage reductions usually lower it.

SPLIT-TENSILE STRENGTH TEST:

Table 16: Conducting split tensile strength tests on concrete cylinder specimens with in the control mixture (14,28,56 Days)

SL.NO	SPLIT TENSILE STRENGTH TEST IN (N/mm ²)			% OF PP GRANULES
	14 days	28 days	56 days	
1	3.463	1	4.28	0
2	2.489	2	3.828	5
3	2.501	3	2.527	10
4	2.396	4	2.134	15

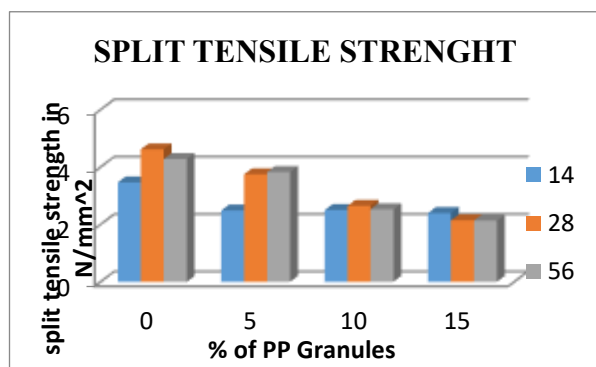


Fig 17: Curing duration versus tensile splitting Strength for the control mix(14,28,56-days)

The findings of the splitting tensile strength test show a trend with different percentages of polypropylene (PP) granules. The strongest mixture was a control mix (0% PP), with values of 3.463 N/mm² at day 14, 4.617 N/mm² at day 28, and 4.28 N/mm² at day 56. Tensile strength was reduced with the addition of PP granules; the lowest values were recorded at 15% PP granules during 14 days, 2.141 N/mm² for 28 days, & 2.134 N/mm² at the end of 56 days. This suggests that split tensile strength decreases with increased PP granule content over time.

3.4 WATER ABSORPTION TEST:

Table 18: Results of the test to evaluate the water absorption of concrete cube specimens (14,28,56 Days)

SL.NO	WATER ABSORPTION TEST			% OF PP GRANULES
	14 days	28 days	56 days	
1	1.4	1.546	1.35	0
2	1.971	1.870	0.810	5
3	1.891	1.031	0.677	10
4	1.0653	2.230	0.815	15

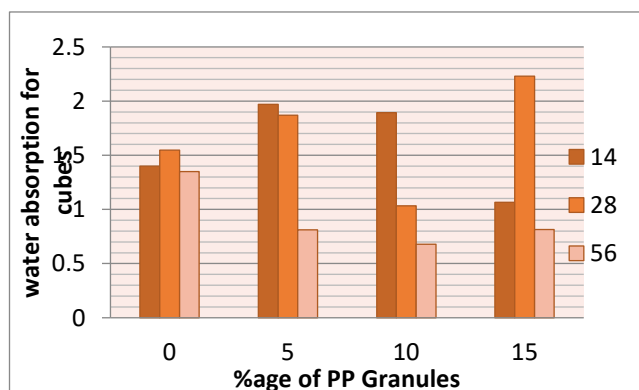


Fig 19: Relationship b/w % substitution and Absorption of Water in 14, 28, 56-days of curing

The outcomes of the water absorption test for cubes with different polypropylene (PP) granule counts exhibit erratic patterns. At 14, 28, and 56 days, the values of the control mixture mix (0% PP) were 1.4%, 1.546%, and 1.35%, respectively. Absorption rose initially with 5% PP but gradually declined. Absorption fell to 0.678% after 56 days at 10% PP. Variable results were seen with the 15% PP mix, peaking at 2.230% after 28 days and then declining. Generally, for the majority of mixes, water absorption decreased over time.

TEST RESULT ON EDS OF CONCRETE SAMPLE:

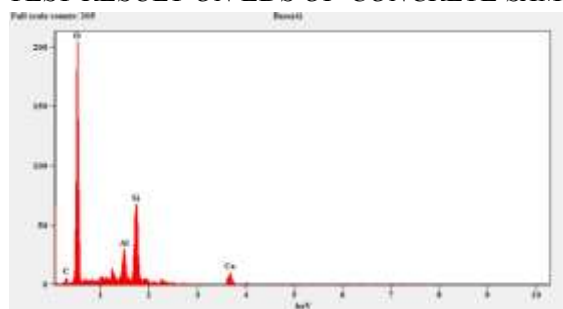


Fig 20: Graph of EDS for the maximum cube percentage obtained for optimum curing days for 0%.

With the axis of x showing X-ray energy levels by kiloelectronvolts (keV) with a y-axis displaying intensity or counts, signifying element quantities, the elemental makeup of a material is displayed on the EDS spectrum graph. Elemental peaks include the elements carbon (C), oxygen (O), silicon (Si), aluminum (Al), and calcium (Ca). Lower concentrations of silicon, aluminum, and calcium are indicated by smaller peak at higher energies, but a noticeable peak about 0.5 keV indicate a high amount of oxygen. Overall, the spectrum shows that oxygen and carbon are highly concentrated, whereas other element concentrations are comparatively modest.

Quantitative Results for Base(4)

Element Line	Weight %	Weight % Error	Atom %
C K	5.83	± 2.27	8.42
O K	72.42	± 1.95	78.59
Al K	5.74	± 0.42	3.70
Si K	12.74	± 0.81	7.88
Si L	—	—	—
Ca K	3.28	± 0.45	1.42
Ca L	—	—	—
Total	100.00		100.00

Tables 21: Quantitative results of EDS for the maximum cube percentage obtained for optimum curing days for 0%

Oxygen makes up 72.44% of the sample's weight as well as 78.59% its total atomic percentage, according to the EDS spectrum analysis, which suggests that oxide compounds predominate. Additionally, silicates or aluminosilicate are suggested by the presence of silicon and aluminum. Carbon, which makes up 5.83% of the weight, suggests the presence of carbonates or organic compounds. The least common element is calcium, which makes up 3.28% of the total weight and may come from trace minerals that contain calcium. With notable concentrations of silicon and aluminum and lesser amounts of carbon and calcium, the sample is primarily composed of oxides overall.

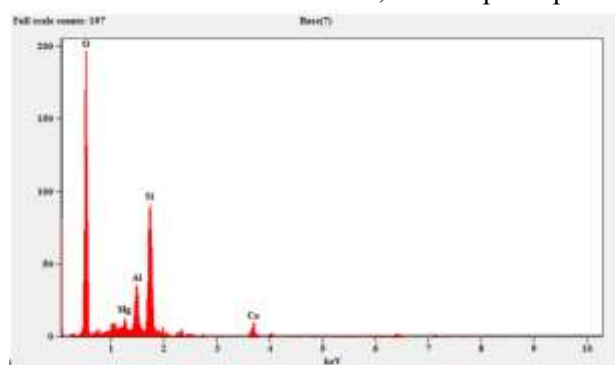


Fig 22: Graph of EDS for the maximum cube percentage obtained for optimum curing days for 5%.

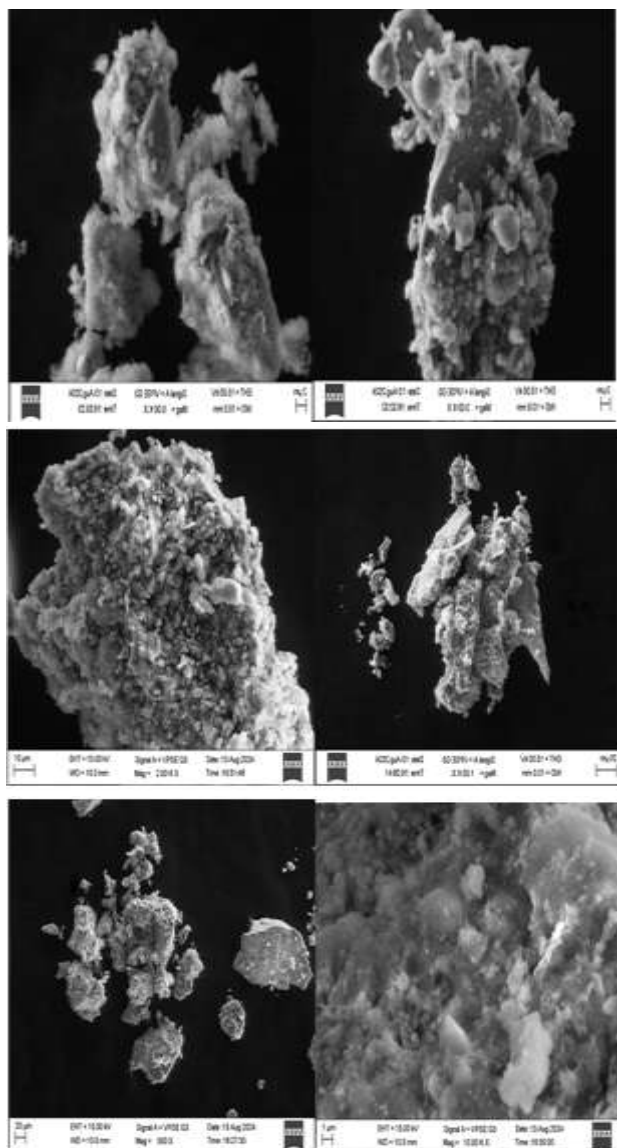
Quantitative Results for: EDS[7]

Element Line	Weight %	Weight % Error	Atom %
O K	69.56	± 1.81	80.28
Mg K	1.72	± 0.40	1.31
Al K	7.30	± 0.48	5.00
Si K	18.01	± 0.91	11.84
Si L	—	—	—
Ca K	3.41	± 0.52	1.57
Ca L	—	—	—
Total	100.00		100.00

Tables 23: Quantitative results of EDS for the maximum cube percentage obtained for optimum curing days for 5%

Oxygen makes up 72.44% of the sample's weight as well as 78.59% its total atomic percentage, according to the EDS spectrum analysis, which suggests that oxide compounds predominate. Additionally, silicates or alumina silicates are suggested by the presence of silicon and aluminium. Carbon, which makes up 5.83% of the weight, suggests the presence of carbonates or organic compounds. The least common element is calcium, which makes up 3.28% of the total weight and may come from trace minerals that contain calcium. With notable concentrations of silicon and aluminium and lesser amounts of carbon and calcium, the sample is primarily composed of oxides overall.

SCANNING ELECTRON MICROSCOPIC:



CONCLUSION:

- i. Concrete becomes more resilient to wear and environmental conditions when polypropylene granules are added to it.
- ii. The structure becomes stronger and more resilient as a result of these granules' assistance in reducing crack formation and propagation.
- iii. By adding polypropylene granules, concrete becomes more flexible and can withstand greater stress levels without breaking.
- iv. Granules made of polypropylene reduce the permeability of concrete, which minimizes water intrusion and possible freeze-thaw damage.
- v. Concrete is more workable with the granules, which facilitates mixing, transporting, and placing.
- vi. Concrete is strengthened against impact by polypropylene granules, which also shield it from severe weights and mechanical shocks.
- vii. Because it encourages recycling and lessens dependency on traditional concrete components, utilizing polypropylene granules serves as a sustainable technique.
- viii. Under varied testing settings, concrete containing polypropylene granules performs consistently, guaranteeing dependability throughout many uses.

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