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MICROSTRUCTURAL BEHAVIOUR OF GEOPOLYMER CONCRETE UNDER THE INFLUENCE OF PLASTIC AS A PARTIAL REPLACEMENT OF FINE AND COARSE AGGREGATE

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Abstract

In the present study, partial replacement of fine aggregates and coarse aggregates is done using two different types of plastic waste HDPE (High density Polyethylene) and LDPE (High density Polyethylene) with different percentages (0%, 5%, 10%, 15% for Fine Aggregate (F.A) and 0%, 5%, 10% for Coarse Aggregate (C.A)) in geo-polymer concrete. The effect of plastic as partial replacement of fine aggregates and coarse aggregates is carried through out. Compression strength test is carried out and then the high compression strength specimens are selected for Micro structural analysis by SEM, FTIR and XRD. From the micro structural analysis the bonding between the plastic granules and geopolymer concrete inside the matrix is good and has high strength at lower percentage than compared to higher percentage replacement of HDPE and LDPE. The properties of fine aggregate partial replacement geo-polymer concrete have improved at 10% replacement of HDPE and in coarse aggregate partial replacement geo-polymer concrete have improved at 5% replacement of LDPE. Increases in replacement level lowered the characteristics of both types of geopolymer concrete.

Keywords: High density poly ethylene (HDPE), Low density poly ethylene (LDPE), Aggregate, Fly ash, Ground Granulated Blast furnace Slag (GGBS), Geopolymer concrete

1. INTRODUCTION

Rao and Kumar [1] studied the large-scale cement production harms the environment and depletes resources. Portland cement manufacture releases one tonne of CO_2 every tonne. Geopolymer is the finest cement substitute after extensive research. Sood and Kumar [2] investigated the geopolymer technology lets us make a sustainable cement alternative that

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emits less CO2. Geopolymer binders can substitute Portland cement in many applications, reducing concrete production's carbon footprint by up to 80%. Amorphous or glassy industrial waste should be used to make geopolymer concrete. Lazorenko et al. [3] studied the polymeric waste (PW) can replace concrete aggregate. This waste comes from industrial-scale manufacture of thermoplastics like polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polystyrene (PS), polyvinyl chloride (PVC), and elastomers (rubbers). Polymer waste pollutes the world. Lazorenko et al. [4] studied the recycling plastics by using them as an aggregate in building materials is a feasible option because of the technological and economic benefits it offers while also reducing environmental impact. Ganesh et al. [5] influence the majority of these wastes are deposited in landfills, which degrades the environment. For efficient plastic waste disposal, they can be incorporated into construction materials.

Yolcu et al. [6] to maintain a healthy ecosystem and productive economic cycle, it is important to highlight the existence of a novel building material that eliminates the need for cement and favours the use of waste tyre particles as aggregate. Shah et al. [7] influence the hardened binder is polymerized into large molecular chains and networks. Nanomaterials in geopolymer mixes improve concrete's mechanical properties. Paul [8] usage of geopolymer concrete in building will reduce the amount of cement needed for construction, resulting in environmentally friendly buildings. Luo et al. examined fly ash geopolymer concrete with 2% NT and nano SiO2 (NS) microstructure and micromechanics. Both nanomaterials improved micromechanical and compressive strength [9]. Aldahdooh et al. used the recycled plastic wastes have been studied on fresh and cured concrete qualities. Plastic component lowers concrete density and compressive strength [10].

Pooja et al. [11] used the most eco-friendly solution to the problem of garbage disposal is the recycling of large trash items. Plastic is one example of trash that could be put to better use elsewhere. Manzoor and EhtishamUddin due to increased urbanisation and population growth, natural resources including fine and coarse aggregates are used heavily. This method has caused waste productivity and natural construction material shortages. Since these resources are non-renewable, alternative solutions are needed to meet demand while safeguarding natural resources and the environment [12]. Tahir et al. used the numerous approaches to resolving this problem, one of which is to improve multiple reuse and recycling methods for these materials, such as material recycling [13]. Overall, it is suggested

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that the use of e-waste in construction products offers enormous potential benefits, thereby reducing e-waste management issues and preventing environmental pollution [14]. The plastic's quality determines how well it recycles. After going too far, they can no longer be recycled. Part of the fine aggregates in concrete are made from recycled plastics like polyethylene terephthalate (PET) and polypropylene (PP) [15].

The scanning electron microscope (SEM) is a specific kind of electron microscope that creates images by raster-scanning a sample with a beam of high-energy electrons. Electrons collide with the sample's atoms, generating signals that reveal the surface's topography, composition, and other features. The gold standard of infrared spectroscopy is FTIR (Fourier Transform Infrared Spectroscopy). In FTIR, the chemical bonds are rotated, bent, and vibrated. After light has interacted with the sample, its intensity is read out by a detector. X-ray powder diffraction (XRD) is a fast analytical method for determining the crystalline phase of a material. You need to finely grind, homogenise, and determine the average bulk composition of the tested sample. By replacing LDPE granules for coarse aggregate and HDPE granules for fine aggregate, this study investigated the effect of plastic on the microstructural behaviour of Geo Polymer Concrete. Both coarse and fine aggregate partially replaced geo-polymer concrete are studied for their micro-structural behaviour and compared.

2. MATERIALS USED

The materials used are given in the Table 1 with their specific gravity

Table 1: Materials used and their specific gravity

S.No	Material Name	Specific Gravity
1.	HDPE (High-density Polyethylene)	1.00
2.	LDPE (Low-density Polyethylene)	1.30
3.	Fine Aggregate	2.7
4.	Coarse Aggregate	2.9
5.	Sodium silicate liquid (Alkaline)	-
6.	Sodium Hydroxide	-
7.	Super plasticizer	-
8.	Fly Ash	-
9.	GGBS (Ground Granulated Blast furnace Slag)	-

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3. EXPERIMENTAL METHODOLOGY

3.1 Mix Design

Geo-Polymer concrete design doesn't have any standard guidelines. It is done by trail and error method basis. Based on the literature review and previous works held by the author the materials were proportioned based on B. V. Rangan mix design which is similar to 10262:2002.

3.2 Casting, Curing and Testing Process

Concrete cubical moulds of size 100mm x 100mm x 100mm were casted. After 24 hours of casting, specimens are de-moulded and allowed for air curing for 28 days respectively, then compression strength test is conducted to the specimens after that the high strength specimens are taken and concrete cube is broken into fine powder form and taken for the micro structural analysis.

3.3 Mix Proportions

Different percentages of HDPE 0%, 5%, 10%, 15% for Fine Aggregate and LDPE 0%, 5%, 10% for Coarse Aggregate replacement was done and design description was given in Table 2. The mix proportions for these mixes are given in the Table 3.

Table 2 : Mix code and Mix description

S.NO	MIX CODE	MIX DESCRIPTION
1.	R1	Conventional concrete mix (Geo-polymer concrete)
2.	F1	Replacement of F.A with 5% of HDPE plastic
3.	F2	Replacement of F.A with 10% of HDPE plastic
4.	F3	Replacement of F.A with 15% of HDPE plastic
5.	C1	Replacement of C.A with 5% of LDPE plastic
6.	C2	Replacement of C.A with 10% of LDPE plastic

Table 3: Mix proportions

Mix code	R1	F1	F2	F3	C1	C2
Fly Ash (70 %) kg/m^3	295	295	295	295	295	295
GGBS (30%) kg/m^3	125.45	125.45	125.45	125.45	125.45	125.45
NaoH kg/m^3	46.87	46.87	46.87	46.87	46.87	46.87
Na_2SiO_3 kg/m^3	119.50	119.50	119.50	119.50	119.50	119.50

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Coarse aggregate (60%) kg/m^3	645 (20mm); 429 (12.5mm)	645 (20mm); 429 (12.5mm)	645 (20mm); 429 (12.5mm)	645 (20mm); 429 (12.5mm)	645 (20mm); 407.55 (12.5mm)	645 (20mm); 386.1 (12.5mm)
Fine aggregate (40%) kg/m^3	715	679.25	6483.5	607.75	715	715
Super plasticiser	2% of binder	2% of binder	2% of binder	2% of binder	2% of binder	2% of binder
HDPE Plastic kg/m^3	-	35.75	71.5	107.25	-	-
LDPE plastic kg/m^3	-	-	-	-	21.45	42.9

4. RESULTS AND DISCUSSIONS

4.1 Compressive Strength

The compressive strength of HDPE and LDPE replaced geo-polymer concrete at 28 days are given in the below Table 4 and shown in the Figure-1. In HDPE replaced geopolymer concrete the compressive strength is increased when replaced with 10% of HDPE granules and it gets decreased when more than 10% is added. When 5% of the LDPE in geopolymer concrete is replaced with LDPE, the compressive strength of the concrete increases; however, the compressive strength decreases when 10% of the LDPE is replaced.

Compression Strength, $\sigma_c = \frac{P}{A}$

Where P = Compressive Load, N

A = Area of the cube, mm^2

Table 4: Compressive Strength results of the specimen cubes

MIX CODE	COMPRESSIVE STRENGTH (Mpa)
R1	43.03
F1	44.45
F2	45.89
F3	41.84
C1	44
C2	38.11

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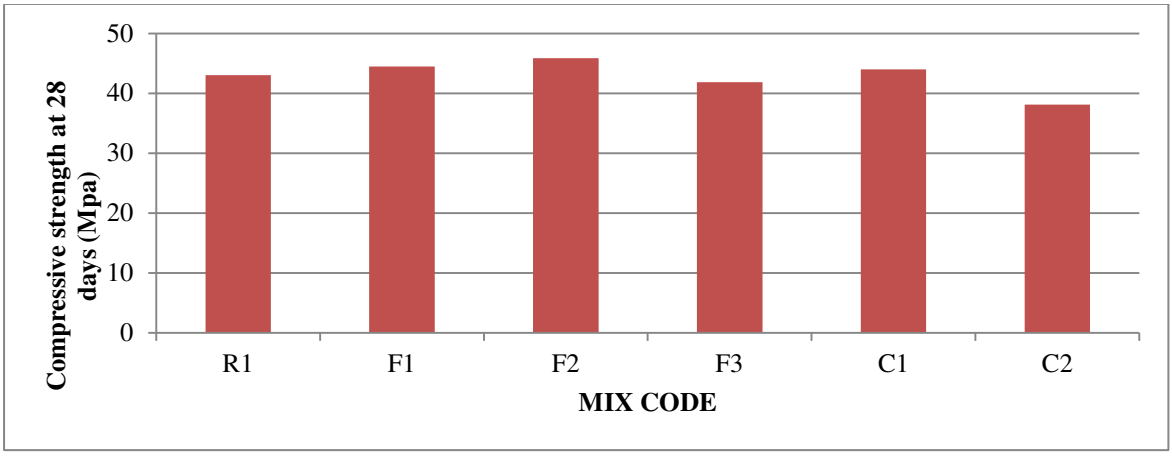

Figure 1: Compressive Strength of HDPE and LDPE geopolymer concrete at 28 days

4.2 MICRO-STRUCTURAL ANALYSIS

4.2.1 Scanning Electron Microscope (SEM)

To identify the morphology of HDPE, LDPE and Control mix samples of mix designations of R1, F2, C1. For the purpose of gaining an understanding of the microstructure of HDPE and LDPE blended concrete, SEM images of concrete mixtures were obtained. Scanning electron microscope (SEM) analysis was performed on concrete mixes that contained HDPE and LDPE at replacement and addition levels of 0%, 10% HDPE, and 5% LDPE after 28 days of curing. Figures 2–4 show the images obtained from the scanning electron microscope of various mixtures. It can be shown in Figure 2 that the microstructure of the reference concrete mix contains both partially hydrated and unhydrated calcium compounds. The microstructure of concrete mixes has become thick as a result of the carbon and hydrogen of plastic in replacements of 10% HDPE (Figure 3) and 5% LDPE (Figure 4). This density is high in replacements containing 10% HDPE and low in replacements containing 5% LDPE. Both the microscopic level and the mechanical qualities are affected when carbon and hydrogen are present. By rastering a focussed electron beam across the surface of the sample and detecting secondary or back scattered electron signal with SEM, comprehensive high resolution pictures of the sample can be obtained.

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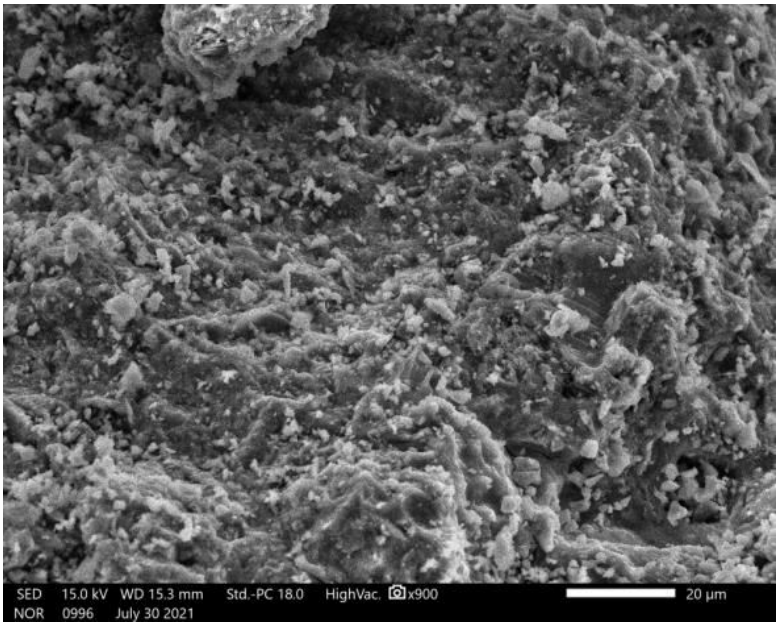

Figure 2: SEM image of Conventional concrete mix

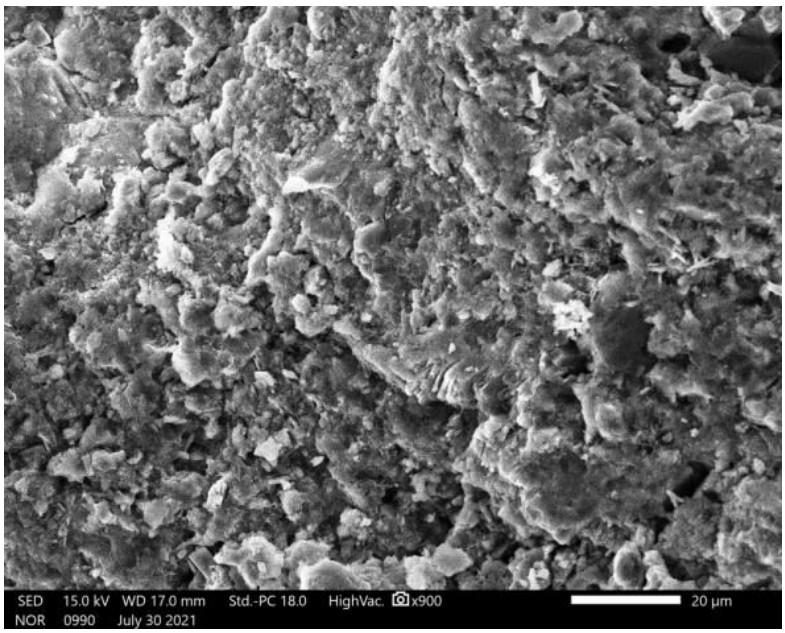

Figure 3: SEM images of 10% HDPE mix

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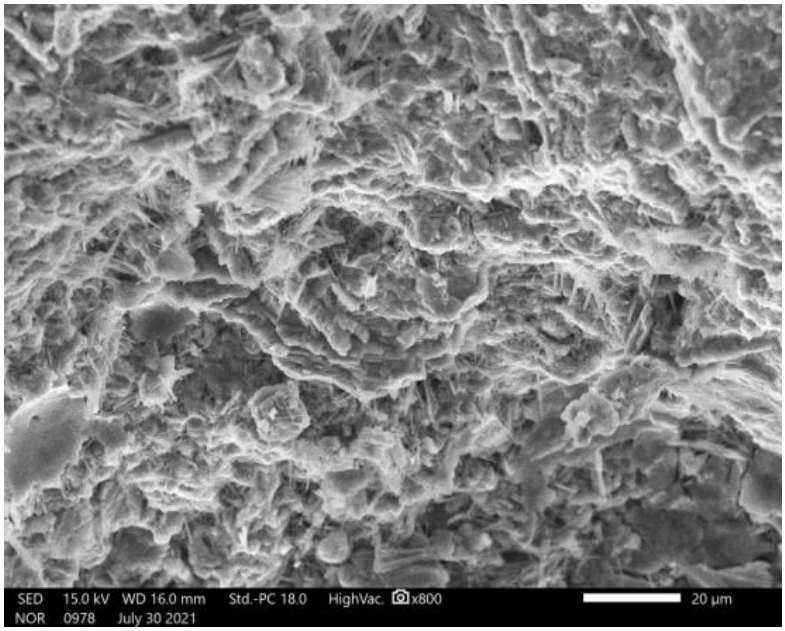

Figure 4: SEM images of 5% LDPE mix

4.2.2 Fourier Transform Infrared Spectrology (FTIR)

Fourier Transform Infrared Spectroscopy was done to mix designations R1, F2, C1. FTIR graph was plotted between wave number cm^{-1} and Transmittance percentage (%). The FTIR graphs are presented in Figures 5-7. It is observed that the peak range 1.00005% is at 3500 cm^{-1} in Figure 4. In Figure 5 the peak range 1.0055% is at 3500 cm^{-1} and in Figure 6 the peak range 1.0097% is at 3500 cm^{-1}. The arrangement and strength of chemical bonds within a molecule have a direct effect on the characteristic modes of vibration and vibrational hood frequencies of a molecule, resulting in the formation of a series characteristic mid infrared absorption bands (4000-400 cm).

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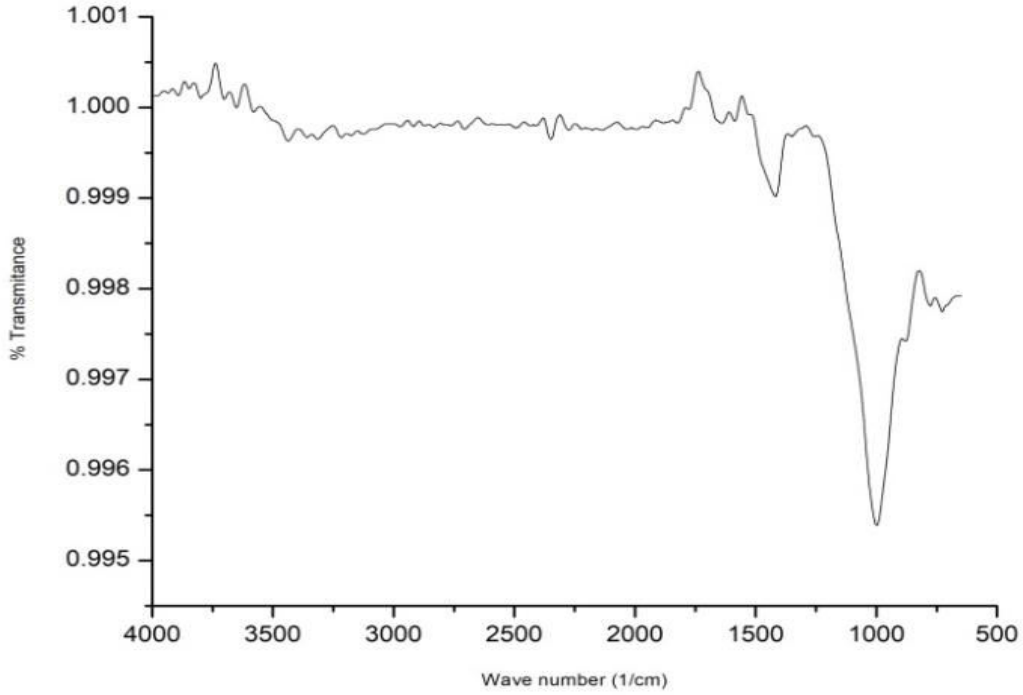

Figure 5: FTIR graph of 0% mix

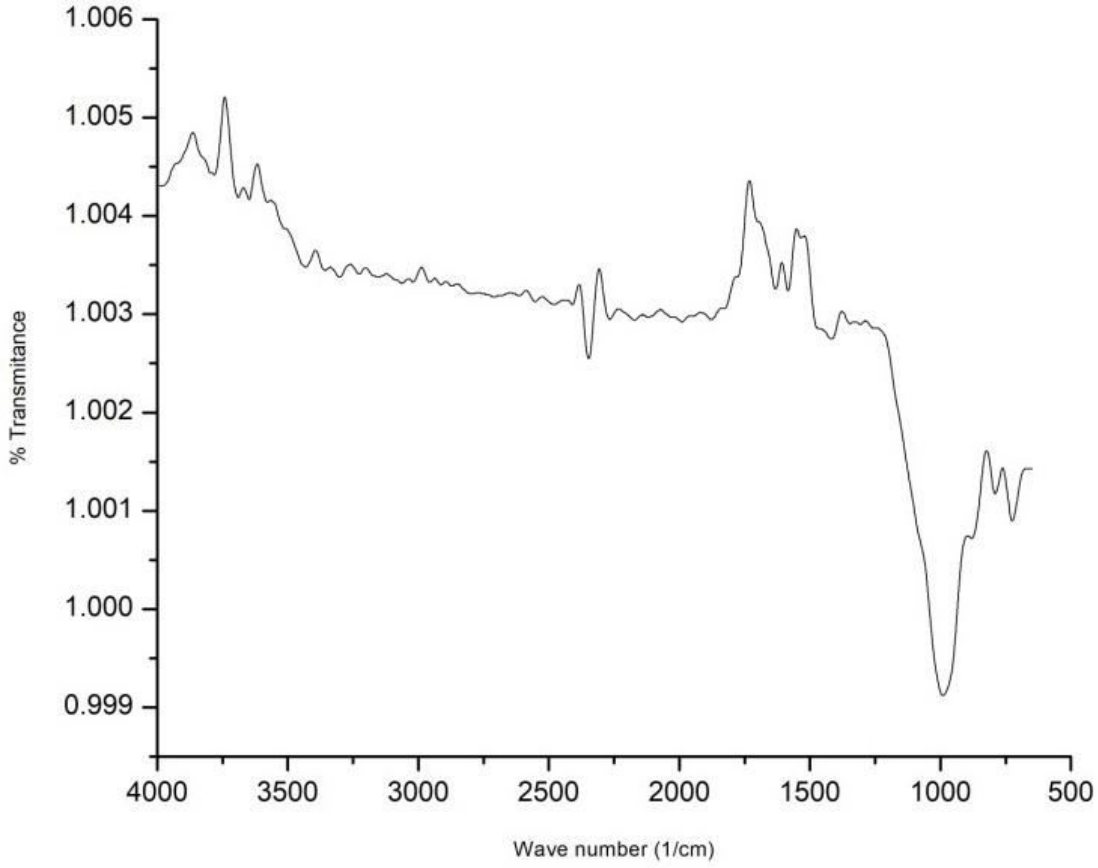

Figure 6: FTIR graph of 10% HDPE mix

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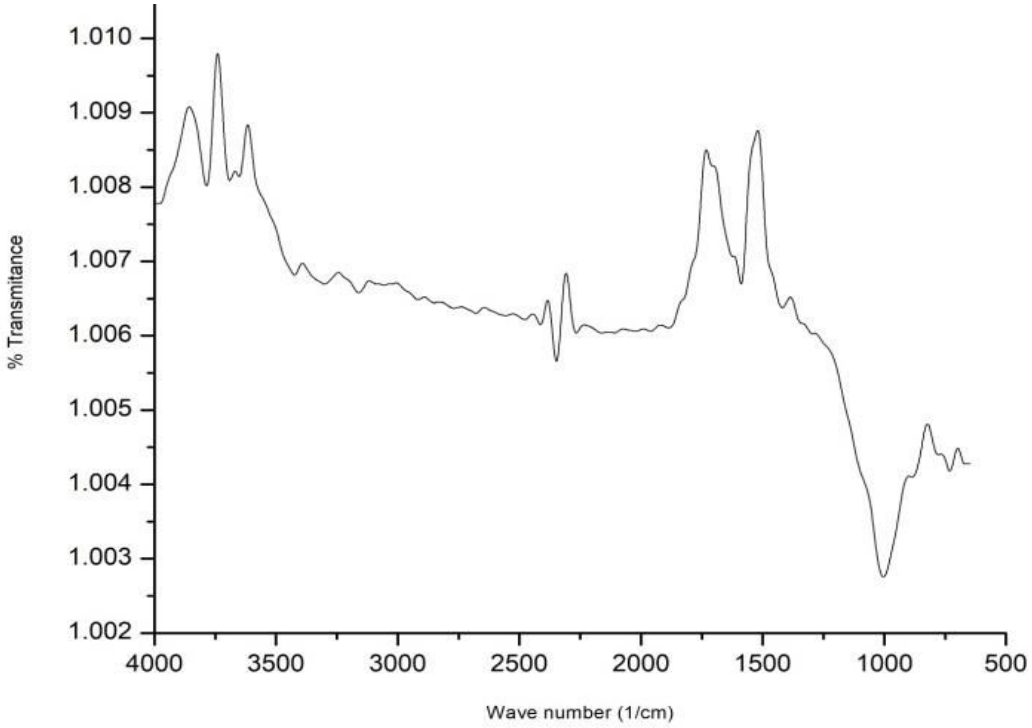

Figure 7: FTIR graph of 5% LDPE mix

4.2.3 X-Ray Diffraction (XRD)

X-Ray Powder Diffraction was done to mix designations R1, F2, C1. XRD graph was plotted between 2θ and intensity. The XRD graphs are shown in Figures 8-10. In Figure 8 the intensity is peak at 30 and gradually decreases further. In Figure 9 the intensity is peak at 30 and again it tend to increase at 70. In Figure 10 the intensity is peak at 35 and decreases. A peak in intensity occurs when the mineral contains lattice planes with d-spacings appropriate to diffract X-rays at that value of θ. Although each peak consists of two separate reflections (K_a and K_{ag}), at small values of 2θ the peak locations overlap with K_a, appearing as a hump on the side of K_{uy}.

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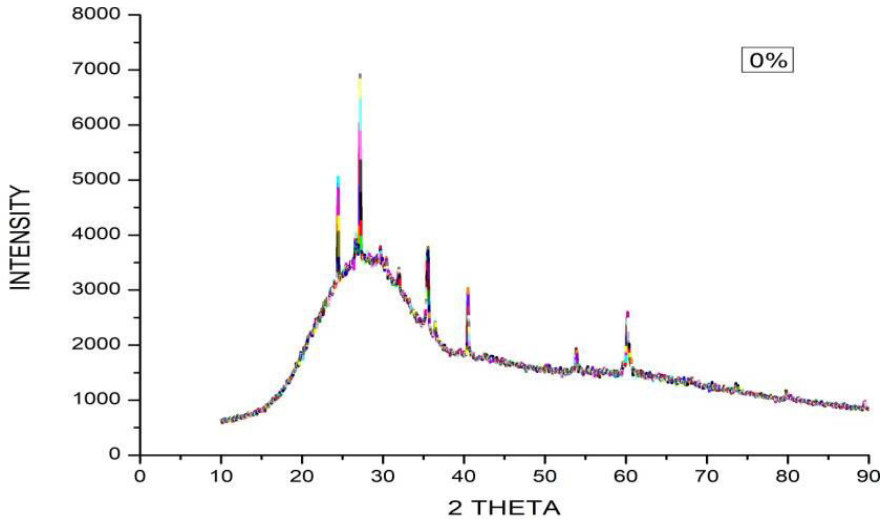

Figure 8: XRD graph of 0% mix

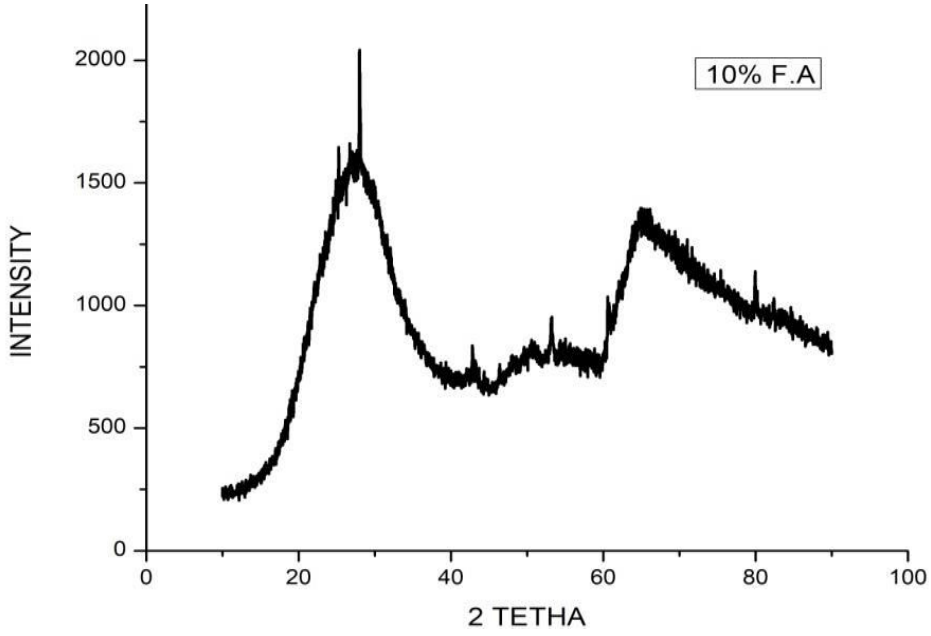

Figure 9: XRD graph of 10% HDPE mix

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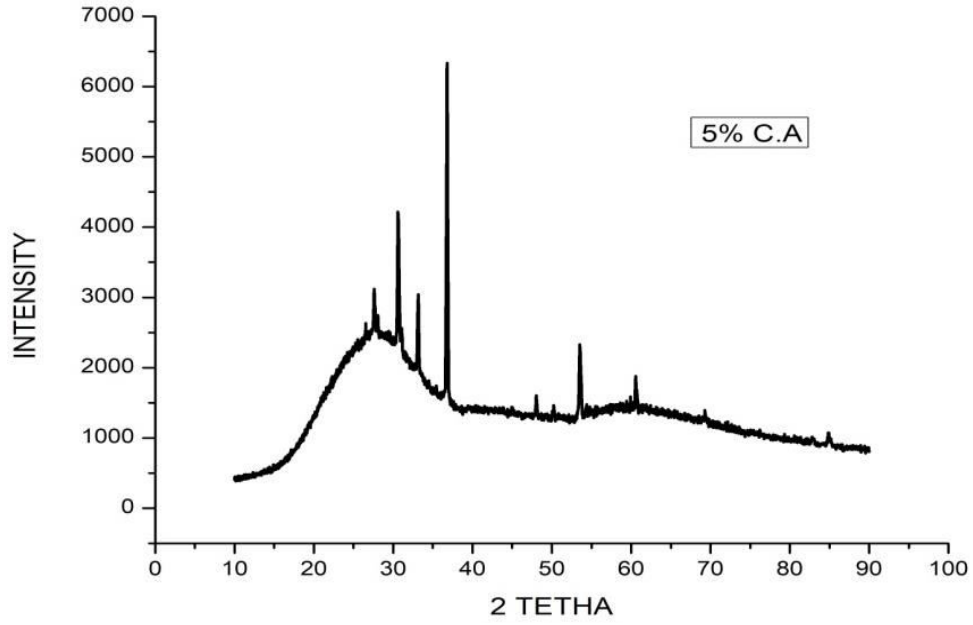

Figure 10: XRD graph of 5% LDPE mix

5. CONCLUSIONS

This study presents a clear picture about the utilization of plastic as fine aggregate and coarse aggregate inside the geopolymer concrete. The conclusions are as follows.

- At lower percentage replacement of HDPE and LDPE there is a good bond between the plastic granules and geopolymer concrete inside the matrix.
- At higher percentage replacement of HDPE and LDPE due to the differences in the particle size distribution, development of voids takes place which leads to the reduction of strength.
- With this study, the use of plastic is more effective as fine aggregate when compared to coarse aggregate because plastic as coarse aggregate gives low strength and has lower density than plastic as fine aggregate, and in plastic as fine aggregate also it can be used at certain replacement rates only.
- The environmental impact with incorporating waste plastic into geopolymer concrete mixtures is perceived as a promising solution for reducing environmental impact in terms of pollution, waste disposal and global warming.

REFERENCES

1. Rao, A. K., & Kumar, D. R. (2023). Experimental and microstructural analysis on flyash-GGBS based geopolymer concrete under ambient curing condition. Materials Today: Proceedings.

ISSN: 2366-1313

2. Sood, H., & Kumar, R. (2022). Effect of using plastic waste on mechanical properties of fly ash based geopolymer concrete. *Materials Today: Proceedings*, *69*, 147-152.
3. Lazorenko, G., Kasprzhitskii, A., & Fini, E. H. (2022). Polyethylene terephthalate (PET) waste plastic as natural aggregate replacement in geopolymer mortar production. Journal of Cleaner Production, 375, 134083.
4. Lazorenko, G., Kasprzhitskii, A., & Fini, E. H. (2022). Sustainable construction via novel geopolymer composites incorporating waste plastic of different sizes and shapes. Construction and Building Materials, 324, 126697.
5. Ganesh, A. C., Deepak, N., Deepak, V., Ajay, S., & Pandian, A. (2021). Utilization of PET bottles and plastic granules in geopolymer concrete. Materials Today: Proceedings, 42, 444-449.
6. Yolcu, A., Karakoç, M. B., Ekinci, E., Özcan, A., & Sağır, M. A. (2022). Effect of binder dosage and the use of waste rubber fiber on the mechanical and durability performance of geopolymer concrete. Journal of Building Engineering, 61, 105162
7. Shah, F., Oza, R., Vyas, D., Joshi, T., Thakkar, S., & Dave, U. (2023). Effect on mechanical properties of geopolymer concrete by addition of polypropylene fibers. Materials Today: Proceedings.
8. Paul, E. (2021). Performance assessment of geopolymer concrete using various industrial wastes. Materials Today: Proceedings, 45, 5149-5152.
9. Jumaa, N. H., Ali, I. M., Nasr, M. S., & Falah, M. W. (2022). Strength and microstructural properties of binary and ternary blends in fly ash-based geopolymer concrete. Case Studies in Construction Materials, 17, e01317.
10. Aldahdooh, M. A. A., Jamrah, A., Alnuaimi, A., Martini, M. I., Ahmed, M. S. R., & Ahmed, A. S. R. (2018). Influence of various plastics-waste aggregates on properties of normal concrete. Journal of Building Engineering, 17, 13-22.
11. Pooja, P., Vaitla, M., Sravan, G., Reddy, M. P., & Bhagyawati, M. (2019). Study on behavior of concrete with partial replacement of fine aggregate with waste plastics. Materials Today: Proceedings, 8, 182-187.
12. Manzoor, K. M., & EhtishamUddin, S. (2023). Utilization of a mixture of waste plastic materials and granite particles as a partial replacement of coarse aggregate in concrete blocks. Materials Today: Proceedings.

ISSN: 2366-1313

13. Tahir, F., Sbahieh, S., & Al-Ghamdi, S. G. (2022). Environmental impacts of using recycled plastics in concrete. Materials Today: Proceedings, 62, 4013-4017.
14. Kaliyavaradhan, S. K., Prem, P. R., Ambily, P. S., & Mo, K. H. (2022). Effective utilization of e-waste plastics and glasses in construction products-a review and future research directions. Resources, Conservation and Recycling, 176, 105936.
15. Harihanandh, M., & Karthik, P. (2022). Feasibility study of recycled plastic waste as fine aggregates in concrete. Materials Today: Proceedings, 52, 1807-1811.
16. Kopparthi PK, Gemaraju S, Pathakokila BR, Gamini S. Experimental investigations on flexural behaviour of delaminated carbon/epoxy composite using three dimensional digital image correlation. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science. 2021;235(12):2265-2275.
17. Srinivasababu, N., Kumar, K. P., & Srikar, G. (2015). Mechanical Performance of Polycarbonate/ABS, Glass Filled Polycarbonate Blends – Review. In Applied Mechanics and Materials (Vols. 766–767, pp. 27–33)..
18. Gemaraju Srikar, Shaik Javeed. (2022). Mechanical Characterization of Carbon Fabric Reinforced Polymer Composites. Mathematical Statistician and Engineering Applications, 71(2), 425–429.