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STRENGTH PROPERTIES OF GEOPOLYMER CONCRETE USING STEEL FIBRE

[1]A.Dhanalakshmi, [2]Dr.M.Shahul Hameed, [3]S.Kathiresan, [4]A.Leema Margret, [5]P.Aarthi

[1]Research Scholar, [2]Professor, [3,4]Assistant Professor, [5]PG Student

[1,2,3,5]Department of Civil Engineering, P.S.R Engineering College, Sivakasi

[4]Department of Civil Engineering, Ramco Institute of Technology, Rajapalayam

Corresponding author E-mail: dhanalakshmicvl@psr.edu.in

Abstract:

The building industry's rising carbon emissions have made the utilisation of alternate materials called Geopolymer Concrete (GPC) which is absolutely necessary for construction. Concurrently, the vulnerability of concrete as a material to severe climatic conditions has necessitated the development of weather-resistant geopolymer concrete. It has been demonstrated that the addition of steel fibres to traditional fiber-reinforced concrete can improve the material's resistance to cracking, which in turn can favourably working in the construction field. Despite this, there have only been a few research that investigate the addition of steel fibre on the property attributes of geopolymer concrete that has been cured at room temperature and has a low NaOH content of 8 millilitres per litre. Fly ash, ground granulated blast furnace slag (GGBS), sodium hydroxide, sodium silicate, Manufacture sand (M-Sand), Fine aggregate and Coarse aggregate were used in the preparation of an ambiently cured geopolymer concrete for the purpose of this investigation. In addition, steel fibres with an aspect ratio of 60 were added to mixture in doses of 0%, 0.5%, 1%, 1.5%, and 2% based on the volume fraction of the mixture. The incorporation of fibres resulted in an increase in the compressive strength, split tensile strength, and flexural strength of geopolymer concrete. The optimal fibre dose was 1%, which resulted in a maximum strength of $26.6\ N/mm^2$, $4.2\ N/mm^2$ and $5.1\ N/mm^2$ respectively, for compressive strength, split tensile strength, and flexural strength. When the dose was increased beyond what was considered to be optimal, the GPC strength also gets decreased.

Keywords: Geopolymer Concrete, Steel Fibre, Mechanical Property

1. Introduction:

The most recent development in the field of study is substituting geopolymer concrete with concrete made with Portland cement. Geopolymers are a type of mineral polymer that are part of their own family and have a chemical makeup that is analogous to that of zeolite materials. Raw materials for the production of geopolymer consist of reactive silica and alumina, and they are combined with alkaline activators throughout the synthesis process. Geopolymer concrete has the advantage of being able to incorporate a variety of different types of industrial waste, which opens the door for its use in a number of diverse construction applications. In some uses of specialty concrete, it can also be beneficial by improving the concrete's mechanical and thermal qualities. Because of the alkaline solution, the formulation of geopolymer concrete requires a considerable degree of caution in order to acquire the qualities that are desirable for practical applications. Previous research has demonstrated that geopolymer concrete possesses exceptional strength characteristics which are comparable to, or even superior to, those of traditional Portland cement concrete. However, because concrete materials are frequently subjected to unfavourable climatic conditions, it has become necessary to develop a geopolymer concrete that is more durable and environmentally friendly. Because of this, there has been a growing interest in the development of fiber-reinforced geopolymer concrete that is more long-lasting. In ordinary concrete, the use of fibres to improve the material's mechanical qualities has seen widespread adoption in recent years. In the past, researchers have investigated a wide variety of fibres, including steel fibres, glass fibres, carbon nanofibers, fibres from the sheaths of banana and palm leaves, polypropylene fibre, and many others. Although fibres increase a variety of the concrete's qualities, there are also some restrictions associated with their use. For example, the incorporation of steel fibres into concrete reduces its endurance in extremely corrosive environments, particularly in situations in which the concrete develops fissures. In most cases, the desired improvement in concrete characteristics can be accomplished by using a fibre dose that is just right. Because of this, particular caution is required when formulating concrete mixes that include the insertion of steel fibres. The study that has been done in the past on the usage of steel fibres in geopolymer concrete will be discussed in the next paragraph.

Improving the functionality of building materials is one strategy for lowering emissions of greenhouse gases and increasing the usage of materials with a low carbon footprint. It is abundantly obvious from the existing body of research that the performance of geopolymer concrete can be improved by the addition of steel fibres. However, it is also true that a number of other elements, including as the qualities of the raw materials, and the curing circumstances, all have a role in determining these performance features. In addition, the main aim is to investigate addition of steel fibres in GPC with a low concentration of NaOH of 8M. In addition, there hasn't been a lot of research done on the durability properties of steel fibre geopolymer concrete. In light of the aforementioned knowledge gaps, the purpose of this study is to fill in some of those gaps by investigating the usage of steel fibres in GPC.

2. MATERIALS AND MIX PROPORTION

Materials Used

1. Flyash
2. GGBS
3. Sodium Silicate
4. Sodium hydroxide
5. Fine Aggregate
6. Coarse Aggregate

7. Water reducer
8. Steel Fiber

Mix Proportion:

Table 1. Mix Proportion of GPC (kg/m^3)

Specimen	Flyash	GGBS	FA	CA	NaOH	Na_2SiO_3	Steel Fibre
GPC1	270	110	730	1080	47	120	0
GPC2	270	110	730	1080	47	120	40
GPC3	270	110	730	1080	47	120	80
GPC4	270	110	730	1080	47	120	120
GPC5	270	110	730	1080	47	120	160

3. PREPARATION OF GPC

In order to make a solution with Amixing of sodium silicate and sodium hydroxide solution was properly mixed. This was done in order to prepare GPC. Until the flakes are allowed to dissolve, the mixture was agitated with a metallic stirrer until it was thoroughly combined. Because the reaction generates heat, the solution is allowed to sit for twenty-four hours. The following day, before beginning to mix the concrete, the necessary quantity of sodium silicate and sodium hydroxide solution were combined in order to make an alkaline solution. The following procedures were utilised in the preparation of the GPC mixtures. After mixing for two minutes in a pan mixer, all the ingredients were thoroughly combined. After adding the predetermined quantity of steel fibres to the mixture in discrete amounts at predetermined intervals in order to ensure that the fibres were evenly dispersed throughout the dry mixture, the mixing process was maintained for an additional two minutes. The superplasticizer and additional water were added to this alkaline solution, and the mixture was then stirred for a further two minutes. At long last, the fresh GPC was completed, and without delay, it was put to use in both the casting of the specimens and the investigation of the fresh characteristics.

4. RESULTS AND DISCUSSION

4.1 Compressive strength

The findings of the compressive strength (CS) test are displayed in Figure 1. Following curing for a period of 28 days, the average compressive strength ranged from 23.7 MPa to 26.6 MPa. The use of steel fibres has resulted in a significant increase in the strength of the geopolymer concrete. The improvement in compressive strength that can be attributed to the insertion of steel fibres is the result of a number of different variables working together. As illustrated in Figure 1, the addition of steel fibres to GPC resulted in a higher density, which in turn leads to an increase in the material's compressive strength. According to this study, the optimal dose of fibres to improve the compressive strength was determined to be 1%. However, there is a maximum dosage of fibres that can strengthen the compressive strength. It is possible that the excessive random distribution of fibres in the GPC, which causes lower in the compressive strength of the GPC. It is abundantly obvious that typical GPC that does not include fibres has suffered severe fracture, which contributes to the total failure of the concrete specimen.

Table 2. Test Results on Compressive Strength

Specimen	Compressive Strength (MPa)	
	7 Days	28 Days
GPC1	19.2	23.7
GPC2	20.2	24.8
GPC3	22.8	26.6
GPC4	21.6	25.4
GPC5	20.2	23.8

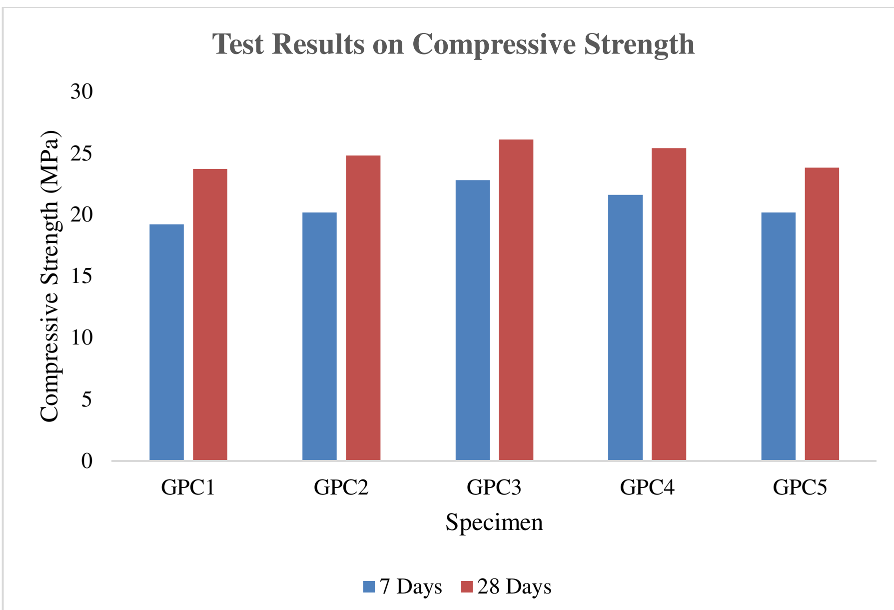

Fig. 1. Test Results on Compressive Strength

4.2 Split tensile strength (STS)

The outcomes of the split tensile strength (STS) test are depicted in figure 2. The results are in conformity with those found in previous research, which found that the testing results of split tensile strength (STS) at the age of 28 days RANGES FROM 3.1 N/mm^2 and 4.2 N/mm^2. In addition, there was an increase in the split tensile strength of the GPC3 material compared to that of the GPC. When compared to the GPC, neither GPC4 nor GPC5 demonstrated an increase in the split tensile strength of the material. The maximum STS of 4.2 MPa was found for GPC with 1% steel fibres, and same percentage was also found to be optimal for compressive strength. The growth in the tensile behaviour of GPC that comes about as a result of the addition of steel fibres is the primary factor responsible for the rise in STS. In addition, this growth is superior to compressive strength due to the fact that stretching and straining of fibres increases under tensile stresses. As a result, fibres actively contribute to load sharing and increase the tensile properties of the material. These kinds of findings have been validated in other research.

Table 3. Test Results on Split Tensile Strength

Specimen	Split Tensile Strength (MPa)	
	7 Days	28 Days
GPC1	2.7	3.1
GPC2	2.9	3.6
GPC3	3.5	4.2
GPC4	3.1	3.8
GPC5	2.8	3.3

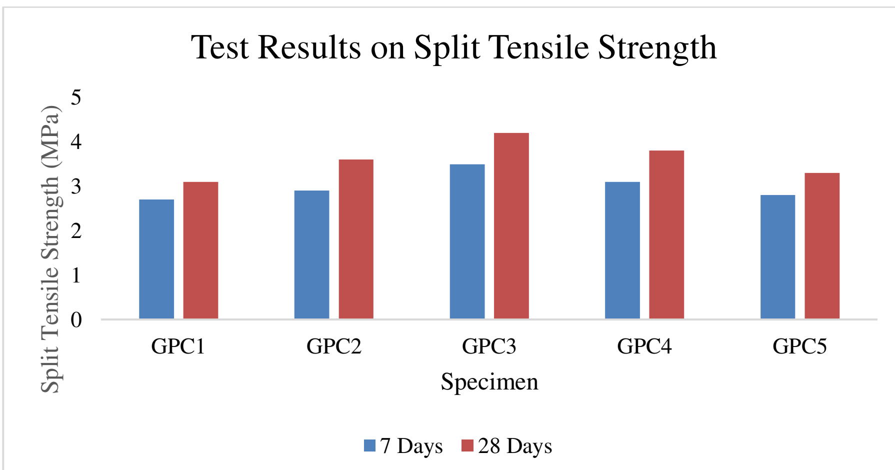

Figure 2.Test Results on Split tensile Strength

4.3 Flexural strength

The outcomes of the flexural strength test are depicted in figure 3. After curing for 28 days, the average flexural strength ranged anywhere from 4.3 MPa to 5.1 MPa, and similar increases in strength have been documented in the past. The inclusion of steel fibres resulted in an increase in the material's flexural strength. The GPC that had 1% steel fibres achieved the highest flexural strength, which was measured at 5.1 MPa. In flexural strength of GPC the optimal percentage of steel fibre was 1%, same as it was for the compressive strength (CS) and the split tensile strength (STS). The growth in GPC's flexural strength, on the other hand, was superior to its STS and CS. An increase in the flexural strength of GPC can be attributed to the contributions of a number of different causes. Because of their bridging action, the steel fibres are particularly good at preventing the creation of macrocracks, and as a result, they delay the process by which cracks emerge. In addition, the incorporation of steel fibres enhances the post-crack behaviour of the GPC, which in turn contributes to the enhancement of the flexural strength of GPC. It can be seen that the fibres efficiently span the damaged portion and stop the propagation of the cracks, which contributes to an increase in the load carrying capacity. This shows that the optimal dose of steel fibres will play a crucial role in GPC and will therefore assist towards the development of low carbon materials for use in the building sector.

Table 4. Test Results on Flexural Strength

Specimen	Flexural Strength (MPa)	
	7 Days	28 Days
GPC1	3.2	4.3
GPC2	3.5	4.6
GPC3	4.1	5.1
GPC4	3.7	4.6
GPC5	3.5	4.4

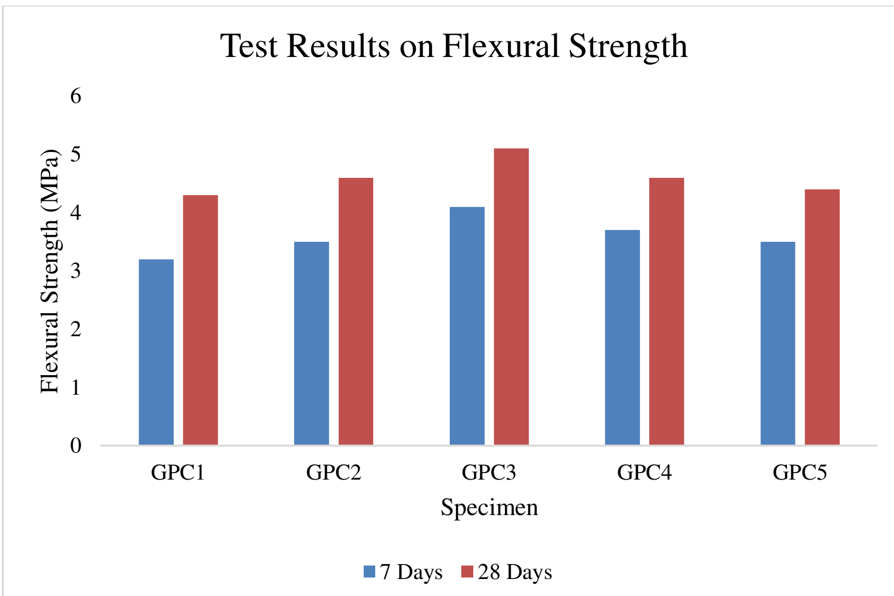

Figure 3. Test Results on Flexural Strength

5. CONCLUSION

The investigation was carried out with the intention of determining how these properties are affected. The fibre dose of 1% produced the highest compressive strength (CS) after 28 days, which was 26.6 MPa. This will be attributable to the excessive random distribution of fibres in the GPC matrix, which has an unfavourable influence on the inner structure of the concrete. The compressive strength decreased with larger fibre doses, and this can be explained by this phenomenon. A fibre dose of one percent yielded the highest 28-day split tensile strength (STS) of 4.2 MPa when the material was tested. It's possible that the effective load sharing done by the steel fibres as a result of stretching and straining under tensile pressures is what led to the growth in the split tensile strength (STS). A fibre dose of 1% produced a flexural strength of 5.1 MPa after 28 days, which was the highest value found. The growth in flexural strength was more noticeable in the GPC when compared to the improvements in compressive strength (CS) and split tensile strength (STS). Even at a lower concentration of NaOH, the steel fibres made a considerable contribution to the flexural strength of the geopolymer concrete(GPC).

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