EXPERIMENTAL BEHAVIOUR OF HYBRID FIBER REINFORCED LOW CALCIUM FERRO-GEOPOLYMER PAVER BLOCK

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Abstract. The environment friendly and creative material in the construction field is the Geopolymer concrete. The two main constituents of Geopolymer are the source material and the alkaline liquids. In previous studies, alternate for alumino silicate source material as wood ash in geopolymer concrete was found and optimized with fly ash. Moreover, from the previous literatures it could be noted that, GPC had a less brittleness and energy absorbent. To improve the brittleness and energy absorption capacity polypropylene fibre and rubber fibre were added by 0, 0.25, 0.5, 0.75, and 1 % of volume fraction at different ratios. Further, effects on addition of polypropylene and rubber fibres of the optimized wood ash-fly ash based low calcium geopolymer were studied. In the previous study, hybridization of fibres was found out. On other hand, concrete paver block has major disadvantages of less skid resistance, less strength, less energy absorbent, less slip resistance. Hence, the research on finding an alternative to the cement paver block is needed. Ferro-cement was a wonderful technology in the construction industry which have tendency to give more strength to the structure. In this study, the low calcium ferro-geopolymer paver block for an alternate of cement paver block was proposed. Meanwhile, the ferro-geopolymer technology was used by varying the different type of meshes and different layout patterns of meshes. The optimized ferro-geopolymer paver block is going to be produced by varying the shape and size of paver block, surface texture of the paver block. The compressive behaviour, split tensile behaviour, and flexural behaviour is going to be studied for the optimization of low calcium ferro-geopolymer paver block. Micro-structural characterization is also going to be studied for the detailed understanding of inside reaction of low calcium ferro-geopolymer paver block by SEM and EDX.

Keywords. Hybrid fibers, Mechanical properties, Low calcium ferrocement, Geopolymer Concrete, Paver block, Water absorption.

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1. Introduction

The Cement is the most common binding material in practice. It consist of lime , alumina , iron oxide & silica . Cement was introduced in 1900s from that on the material is present in a wide variety of construction sites replacing most of the other binding materials from that time [1]. The main benefit of cement is its low cost, durability, strength and resistance. It requires less maintenance. The cement manufacturing is considered as the manufacturing of pollution, during the production of cement large amount of heat released into the atmosphere [2]. In 2019 survey the usage of concrete is of 10 billion cum, the concrete factory was contributed the 85% of the carbon dioxide emission and it gives about 7% of global CO2 emission[3,4]. In the survey conducted in 2010 said that 3300 million tons of OPC was produced in that year it made the release of 5% man made CO2 emission [5,6].

The heat from the cement was released in two stages. One due to high lime content in the cement, the production of the cement evaporates the heat and another was after the placing of the concrete by the heat of hydration [7]. The release of the heat due to concrete increases the global warming in the world. The next major problem in the industry was the disposal of the waste like flyash, GGBS, rubber waste etc. these are the two major problems in the industries to overcome these problems the geopolymer concrete was used now a days to reduce the emission of the heat in the atmosphere [8–11]. In order to overcome this situation we use geopolymers. By using the industrial byproduct flyash and wood ash [12,13]. Geopolymers are mixed with NaOH and Na2SiO3. In India the production of flyash was about 226.13 million tones per year. The availability of flyash is reduced and there are so many problems are associated with flyash it include menace to the environment and it requires large area for its disposal [14,15]. But it helps to increase the strength and durability of the final product. The aluminous and siliceous materials are presented in the flyash which makes the flyash as pozzolanic materials, when it mixed with water it have the property like cement. In order to improve the brittle character we add wood ash along with flyash. The burning of wood and the wooden products generate power from residue, the residue was the wooden ash used in the cement [12,16]. The increases in the % wooden ash, reduces the strength of concrete initially but it attain strength after some days, the cost of wooden ash is very low and it is eco-friendly.

Here we are adding low modulus fiber and high modulus fiber, the fibers used are Rubber fiber and polypropene fiber which improve the brittle of the concrete and it also help to control the formation and develop of cracks. Optimization of number of Steel Wire Mesh (SWM) reinforcement layers, type of steel wire meshes and laying pattern of steel wire mesh reinforcement are carried out [17,18]. In addition, the mechanical behaviour of Hybrid Fibre and Steel Wire Mesh Reinforced Geopolymer Concrete (HFSWMRGPC) paver block is investigated [19]. The shape of the paver block is also varied to understand the performance of optimized hybrid fibre reinforced geopolymer concrete on various shapes is also examined. The number of SWM layers and type of SWM is optimized by analyzing the mechanical property of the rectangular paver block. The number of SWM layers is varied by single, double and triple layers. The type of SWM is varied by chicken mesh, woven mesh and welded wire mesh. Chicken mesh is low cost and its last upto 5 years. It act as a binder. The advantage of the mesh is that it is more durable and versatile, making it perfect for sprucing up, outdoor spaces. Woven mesh is woven with rigid wires it is more secure. Welded wire mesh are welded together to create strong and durable fence. It is strong enough to withstand harsh weather conditions because of the galvanized property in the mesh. The laying patterns are varied square, flat and zigzag to optimize the number of mesh layers and their types. all the above are used towards the strengthening of the geopolymer paver block for withstanding low and medium traffic conditions only. Ferrocement is added as an
additional compound for withstanding high traffic. The number, type and pattern of the geopolymer paver block varies as single, double and triple layers, the laying patterns are square, flat and zigzag.

2. Material Properties

Fly ash has the remarkable changes in every composition. When the residue is mixed with the flue gases it have the property to produce the power [20]. When it mixed with water it can have the property like cement. The combination of flyash and cement can also increase the strength of the concrete with less emission of the heat. Wood ash is the residue powder left after the combution of wood, such as burning wood in a home fireplace or an industrial power plant. It is used traditionally by gardeners as a good source of potash. We have analyzed the Chemical composition of wood ash through EDX and SEM. Alkaline solution was used as the combination of sodium hydroxide solution and sodium silicate solution. The concentration of sodium hydroxide was fixed as 10M [21]. Portable water will be used throughout the study, to watering NaOH chip, for producing the GPC and for forming aggressive liquids. River sand is locally available material used as fine aggregate. We collected river sand from nearby construction site. Crushed granite coarse aggregate were obtained from locally available quarry and were size of 10 mm [15]. fibers used are polypropylene and rubber fiber. Length of these fibers is 20mm and diameter is 0.5mm. Rubber tubes are cut in form of fibers and their dimension are of 20mm length and 5 mm breath [16].

<table>
<thead>
<tr>
<th>Properties</th>
<th>Consistency</th>
<th>Initial setting time</th>
<th>Final setting time</th>
<th>Fineness modulus</th>
<th>Specific gravity</th>
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<td>18 hrs</td>
<td>36 hrs</td>
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<tr>
<td>Wood ash</td>
<td>58%</td>
<td>2:30hrs</td>
<td>3hrs</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>Na2SiO3</td>
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<td>-</td>
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<td>1.47</td>
</tr>
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</table>

3. Mix Design and Methodology

In this research, the mix proportion for low calcium geopolymer concrete was designed by the Indian standard modified guidelines for geopolymer concrete mix design. The design mix was calculated as 1:1.05:1.57 with an activator to binder ratio of 0.45 [22]. polypropylene and rubber fibres which are independent in nature are added as 0%,.5%,1%,1.5%,2% of volume. The materials and its quality in kg/m3 values in kg/m3 are PP fibre (2.41), Rubber fibre (2.41), Fly ash (385),LCWA (96.3) NaOH (110.2),Na2SiO3 (275.59), sand (666.58), CA (993.7) [19,23].

Universal testing machine is used to determine the compressive strength ,flexural strength, split tensile strength of the mix [24]. Cubes made of size 100mmx100mmx100mm for the standard specimens for the compressive strength testing. Testing of the tensile behaviour of the specimen of size 75mm x 150 mm was used to identify the split tensile behaviour of the geopolymer concrete with the polypropylene and the rubber fibre [25].
flexural strength of the geopolymer concrete with the polypropylene and the rubber fibre was cased in the specimen of size 500×100×100 mm [26]. The specimens are tested at a particular time period of 7, 14, 28 days.

4. RESULTS AND DISCUSSIONS

The number of SWM layers and type of SWM is optimized by analyzing the mechanical property of the rectangular paver block. The number of SWM layers is varied by single, double and triple layers. The type of SWM is varied by chicken mesh, woven mesh and welded wire mesh. The shape of the paver block is rectangular to optimize the number of mesh layers and their types. The mechanical strength of specimens varied with the various number of SWM layers and SWM types are represented in Fig 1. The mix ID represents Geopolymer Paver Block in Rectangular shape reinforced with Single layer Chicken mesh (GPB-R-SC).

4.1. Compressible strength of rectangular paver block specimen varied with SWM layers and types

The effect of various SWM layers and SWM types over the compressive strength of HFRGPC was assessed at 7 days and 28 days. From the Fig 1, we can observe that the maximum compressive strength of GPB-R-Two is 43.89 mpa and 56.93mpa at 7&28 days respectively. It shows that maximum compressive strength was attained by triple layer type. And according to the type of mesh used, the woven mesh greatly influences the compressive strength by making an increase of 9.5, 9.2, 18.3 % in 28 days [27]. The utilization of SWM in paver block helped improve the compressive strength of the paver block, and it can be used as the paver block in heavy traffic floors. However, the impact of various mesh types and layers on the splitting tensile strength of the rectangular paver block has to be studied.

![Figure 1. Compressive strength of rectangular paver block specimen varied with SWM layers and types](image-url)
4.2. Splitting tensile strength of rectangular paver block specimen varied with SWM layers and types

The impact of various SWM layers and SWM types over the splitting tensile strength of HFRGPC was assessed at 7 days and 28 days. The rectangular paver block specimen of size 200 mm X 100 mm X 100 mm was used to measure the splitting tensile strength in the Compression Testing Machine as per IS 15658-2006 [28]. Fig 2 represents the splitting tensile strength of specimens varied with the number of SWM layers and SWM types.

![Figure 2. Tensile strength of rectangular paver block specimen varied with SWM layers and types](image)

From the results, it is clear that the specimen GPB-R-TWo observed the maximum splitting tensile strength of 6.28 MPa and 7.98 MPa at 7 and 28 days, respectively. The specimens reinforced with a triple layer of any SWM obtained maximum splitting tensile strength than the other specimens [29]. The specimen with a triple layer of woven mesh exhibits 18.2 percent and 17.0 percent increment in 7 and 28 days splitting tensile strength than the specimen without SWM reinforcement. The specimens reinforced with single-layer woven mesh, double-layer woven mesh and triple-layer woven mesh exhibit 8.7, 8.4 and 17.0 percent increase in 28 days splitting tensile strength. However, the effect of various mesh types and layers on the flexural strength of the rectangular paver block has to be investigated.

4.3 Flexural strength of rectangular paver block specimen varied with SWM layers and types

From the results, it is clear that the specimen GPB-R-TWo observed the maximum flexural strength of 9.43 MPa and 12.04 MPa at 7 and 28 days, respectively. The specimens reinforced with a triple layer of any type of SWM obtained maximum flexural strength than the other specimens. The specimen with a triple layer of woven mesh exhibits 18.7 percent and 17.3 percent increment in 7 and 28 days flexural strength than the specimen without SWM reinforcement.
According to the type of mesh, the woven mesh greatly increases the flexural strength compared to other SWM types. The specimens reinforced with single-layer woven mesh, double-layer woven mesh and triple-layer woven mesh exhibit 8.9, 8.6 and 17.3 percent increase in 28days flexural strength. Compared to other meshes, the woven mesh performed well in all age flexural strength due to its bond strength with the wavering of meshes. The study conducted by [29] also confirmed that the woven mesh pe performed well in mechanical properties. The utilization of SWM in paver block helped improve the flexural strength of the paver block, and it can way a path to use the paver block in heavy traffic floors.

5. CONCLUSIONS

According to the type of mesh, the woven mesh greatly influencing in increasing the compressive strength, splitting tensile strength and flexural strength compared to other type SWM due to its bond strength with the wavering of meshes. The woven mesh enhanced the mechanical strengths to the range of 6.7-20.1 percent increment.

- The incorporation of SWM helped to increase the compressive strength to the range of 7.5-20.1 percent increment. Meanwhile the splitting tensile and flexural strength was enhanced to the range of 6.7-18.2 and 6.9 to 18.7 percent.
- All the mechanical characters are gradually increasing with increasing the number of layers of mesh. The specimen with triple layer of woven mesh exhibit 18.3, 17.0 and 17.3 percent increment in compressive strength, splitting tensile and flexural strength than the specimen without SWM reinforcement.
- From the mechanical properties of rectangular paver block specimen varied with SWM layers and types, the triple layer woven mesh observed maximum strength in all strength characters.
- The rectangular paver block specimen reinforced with triple layer of woven mesh arranged as square wave pattern exhibit 1.9, 1.8 and 1.8 percent increment in compressive strength, splitting tensile strength and flexural strength than the specimen reinforced with triple layer woven SWM arranged as flat pattern.
- The square wave pattern has an equal length of plane in both horizontal and vertical direction and it helps to withstand the load and crack propagation.
- The rectangular paver block specimen reinforced with triple layer woven mesh arranged as square wave pattern observed the water absorption percentage of 2.11 at 28 days of water immersion. Due to the solid state of SWM reinforcement, the laying pattern, SWM type and number of SWM reinforcement could not induce any effect in water absorption capacity.

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