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EVALUATION OF STRENGTH PROPERTIES OF FERRO GEOPOLYMER WRAPPED CONCRETE SPECIMENS

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Abstract: Built up substantial designs in chilly regions frequently weaken right on time because of steel erosion. Fiber-Supported Concrete (FRC) offers a practical choice to upgrade strength and break opposition. This study looks at hybrid ferro fiber-reinforced concrete slabs that use spot-welded mesh, polypropylene fibers (PPF), and silica fume in varying proportions in a mortar mix (1:2). A control RCC slab (1:2:4) and ferrocement slabs with 0.10%, 0.30%, and 0.50% PPF were among the thirteen one-way slabs tested. The steel proportion in ferrocement sections shifted from 25% to 100 percent of the control chunk's steel region. Under third-point loading, deflection, stress-strain behavior, cracking load, and energy absorption were used to evaluate structural performance. When compared to the RCC control slab, the results showed that slabs with 0.5% PPF and 10% silica fume had a 15.25 percent increase in first cracking load and a 13.2% increase in ultimate deflection. This suggests that slabs with higher PPF and steel mesh reinforcement had better post-cracking behavior and were better able to absorb energy.

Keywords: fiber-reinforced concrete slab; deflection; failure; stress-strain curve

. Introduction

With civil engineering structures and rising material requirements, the construction industry faces difficulties. Concrete, containing around 10% concrete by weight, frequently shapes miniature breaks prior to stacking, prompting low rigidity and restricted pliability. Crack propagation and brittle failure are both a result of this, and cement production releases greenhouse gases. As a result, environmentally friendly alternatives are required. In developing nations, local materials are preferred to avoid high import costs. Concrete's ductility can be improved by adding fibers, making ferrocement, a lightweight and adaptable material, an affordable alternative for roofing systems. Due to its impact resistance, strength, and ductility, ferrocement, also known as thin reinforced concrete, is utilized in a variety of structural applications. It is made up of hydraulic cement mortar and closely spaced wire mesh. Ongoing examination investigates ferrocement's mechanical presentation, taking note of that firmly divided network layers improve flexibility and break opposition, however exorbitant layers can cause spalling and delamination [1-2].

The properties of concrete, such as flexural strength and toughness, are enhanced by including silica fume (SF) and fibers like aluminum, steel, and polypropylene. Steel fibers improve tensile strength, while SF improves permeability, according to studies. Ferrocement's applications incorporate slender primary components and reinforcing existing designs. To make the best use of it, especially for slabs, more research is required. Mashrei et al. looked at 13 ferrocement slabs and found that adding steel fibers increased load capacity and ductility while adding SF and superplasticizers increased strength. Polypropylene fibers significantly increased tensile and flexural strength, according to Shuxin et al. Expanded wire mesh and steel fibers, according to Murali et al., significantly improved load capacity, flexural strength, and ductility. According to Ziadoon et al., the optimal reinforcement wire content increased strength and energy dissipation, while other fibers improved slab ductility. The purpose of this study is to compare the structural performance of hybrid ferro fiber reinforced concrete slabs to that of conventional RCC slabs. The review will evaluate breaking load, pliability, stress-strain connections, and energy retention, advancing mixture ferro fiber supported substantial's utilization in satisfying material needs in the development business [3-5].

2. Resources and Approaches

The objective of this experimental study was to contrast the flexural behavior of one-way ferrocement slabs with that of standard reinforced concrete slabs as the control specimen. The materials' properties, mix proportion, specimen casting, and flexure loading tests are discussed in this section.

2.1. Cement

The slabs were cast using ordinary Portland cement (Type–I) from Pakistan's Bestway cement company, according to ASTM C-150 [6].

2.2. Fine Aggregate

Lawrencepur, Pakistan, is the location of the quarry that produces the finest fine aggregates. According to ASTM C136–05, the sieve analysis test was carried out. The fineness modulus of the fine aggregate (Lawrencepur sand) used in this study was 2.70. Explicit gravity and water retention of fine total (sand) were evaluated as per ASTM C 128-04a [7] and mathematical upsides of 2.63 and 1.18% were gotten.

2.3. Coarse Aggregate

Coarse aggregates were obtained from the Pakistani quarry Margalla. A sieve analysis test in accordance with ASTM C136-0 was performed on a sample consisting of 50% coarse aggregates passing through a 20 mm (0.79 inch) sieve and 50% passing through a 37.5 mm (1.5 inch) sieve. Figure 1 depicts the outcome graphically. According to ASTM C 127-04 the specific gravity and coarse aggregate water absorption were evaluated, and the resulting numbers were 2.67 and 0.83 percent, respectively. As per ASTM C 29/C 29M-97 [8], the coarse aggregate's unit weight and bulk density were also evaluated, and a value of 1499.6 kg/m3 was determined.

2.4. Water

The water used to prepare and cure the control and cement slabs was free of organic matter, sugar, oil, acids, and chlorides, among other things, and had a hydrogen ion concentration of 7 on the PH scale.

2.5. Silica Fume (SF)

The Imporient Chemicals Private Limited (ICPL) supplied the silica fume used in this study. It contains incredibly fine, inactively responsive silicon dioxide. High-strength, long-lasting concrete is made possible by the significantly denser cement matrix created by the additional crystal formation.

2.6. Polypropylene Fibers

This study made use of chemrite polypropylene fibers that were obtained from Pakistan's Imporient chemicals private limited (ICPL).

2.7. Steel Reinforcing Mesh

Ferrocement slabs were reinforced with imperial standard wire gauge (SWG) No.12 mild steel (MS) wires with a diameter of 2.64 mm (0.104 inches) spot-welded into a square mesh of 25.4 mm (1 inch).

2.8. Steel Reinforcement

The control example was projected utilizing the disfigured steel bars of size #3 having 9.5 mm (0.375 inches) distance across. Three of these bars were subjected to tension testing in accordance with ASTM A615, and reinforcement detailing was carried out in accordance with ACI 319 [9]. The yield and ultimate strength were determined to be 586.05 MPa and 413.68 MPa, respectively (60,000 psi). (85,000 psi) in each case.

3. Consequences and Negotiations

3.1. Compressive Strength of Mortar Cubes

For the purpose of assessing the performance of concrete once it had hardened, cube specimens were subjected to compression tests. X-ray diffraction (XRD) and scanning electron microscope (SEM) analyses reveal in the literature that Polypropylene Fibers (PPF) do not undergo chemical reactions. During the manufacturing process of PPFs, a small amount of air is entrained, resulting in a more interfacial transition zone in concrete that can lower compressive strength and density. After three days of curing, ferrocement mortar cubes exhibit this trend. However, silica fume (SF), fly ash, and slag can significantly improve the mechanical properties of fiber-reinforced concrete. At 7, 28, and 28 days after curing, the mortar matrix's compressive strength was enhanced by the addition of SF and higher PPF percentages.

The cement paste-aggregate bond is strengthened by SF, which aids in the dispersion of PPF. Among the solid shape examples tried following 28 days, the ferro-concrete block (C1) with 0.5% PPF and 10% SF showed the most noteworthy compressive strength of 39.9 MPa, which is 37.1% more prominent than the control blend (CS) strength of 29.1 MPa without PPF. Lower measurements of PPF (0.10% and 0.30%) likewise further developed the 28-day compressive strength of CS 3D shapes to 29.3 MPa and 38.0 MPa, separately. Ferro-cement cubes have a higher compressive strength because they contain more SF and more PPF fibers, which effectively stop microcracks from spreading throughout the concrete mass [10].

3.2. First Cracking and Ultimate Failure Load of Slab Specimens

The "First Cracking Load" is the load at which the first crack in a slab appears. These cracks typically begin in the span's center and move upward in control and ferrocement slabs, indicating pure flexural failure. When polypropylene fibers (PPF) were added to the flexure-tested ferrocement slabs, the first cracking load had higher values. The highest first cracking load was experienced by specimens from the C1 group, according to graphs. These specimens had the highest percentage of PPF. With four layers of wire mesh (equivalent to the steel area of the control slab) and 0.5% PPF, the specimen F4MC1PPF-S had a cracking load of 40.8 kN, which was 15.2% higher than the first cracking load of the control slab (CS), which was 35.4 kN. This increment is because of the bigger explicit surface region of the cross-section support, total strength of consistently scattered steel networks, and the rising level of PPF [11].

The PPF fibers bridged cracks and increased the first cracking load by acting as crack arrestors. The first cracking load in group F3MB1PPF-S, which had three layers of wire mesh covering 75 percent of the steel area and 0.30 percent PPF, was 22.9 kN, which was lower than in group F2MB1PPF-S, which had two mesh layers covering 25 percent of the steel area. This could be the result of premature failure brought on by buckling or slippage of the mortar matrix's wire mesh. For various proportions of PPF, the ultimate load, or maximum load that a specimen can withstand, was also tested. Steel/welded wire mesh provides resistance to this load in the tension zone, and mortar/concrete, either by itself or in conjunction with the tension zone, provides resistance to this load in the compression zone. Stresses move to the tensile zone when cracks form in the tension zone. Among the ferro fiber built up chunk examples, F4MB1PPF-S (with 100 percent steel region comparable to the controlled piece) accomplished the most noteworthy extreme burden limit.

When compared to the corresponding slabs made of one layer of wire mesh (F1MB1PPF-S), two layers of wire mesh (F2MB1PPF-S), and three layers of wire mesh (F3MB1PPF-S), the ultimate load capacity of the F4MB1PPF-S ferrocement slab increased by 171.2 percent, 70.7%, and 60.0%, respectively. By increasing the matrix's overall cracking resistance and stopping the formation of micro-cracks following load application, the random orientation of PPF in the mortar matrix aids in the control of crack propagation. This keeps more modest breaks from venturing into significant breaks, bringing about higher extreme burden conveying limit. Instead of their dispersion, the increased number of wire mesh layers (from one to four) and the increased volume fraction of reinforcement in the loading direction are to blame for the increase in ultimate strength [12-13].

3.3. Ductility Ratio

Malleability proportion is characterized as the proportion of mid-range diversion at extreme burden to mid-length redirection at first break load. Flexible way of behaving is liked in plan to limit the death toll and property. Steel, including rebar in control slabs and wire mesh in ferrocement slabs, is the primary factor in ductility. The ductility ratios for various proportions of wire meshes and polypropylene fiber (PPF) are shown in Table 1. Lower doses of PPF further develop opposition against break development, improving pliability through a break connecting impact. The F4MB1PPF-S slab had the highest ductility ratio, 1.77, while the F1MC1PPF-S slab had the lowest, 1.16. As PPF and wire meshes act as crack arrestors, the trend demonstrates increased ductility with higher reinforcement mesh volume fractions [14].

Table 1. Ductility ratio of ferrocement and controlled slabs.

Sr. No	**Type of Slab**	**ıtage of PPF (%)**	**Cracking Load in Flexure (A)**	**Ultimate Load in Flexure (B)**	**tility Ratio (B/A)**
1	Control	NIL	33	66	1.9
2	F1MA1PPF-S F1MB1PPF-S	0.2 0.4	14 21	20 24	1.5 1.1
	F1MC1PPF-S	0.6	23	25	1.1
3	F2MA1PPF-S F2MB1PPF-S	0.2 0.4	27 27	41 39	1.6 1.4
	F2MC1PPF-S	0.6	29	36	1.3
4	F3MA1PPF-S F3MB1PPF-S	0.2 0.4	28 27	48 42	1.7 1.5
	F3MC1PPF-S	0.6	34	47	1.3
5	F4MA1PPF-S F4MB1PPF-S	0.2 0.4	35 37	61 66	1.7 1.7
	F4MC1PPF-S	0.6	41	57	1.4

3.4. Load Deflection Response

The load-deflection behavior of various steel wire mesh and PPF percentages is compared and contrasted. The stages of failure and elastic transition through all load-deflection curves. In groups A1, B1, and C1, both load-carrying capacity and deflection significantly improve as the reinforcement ratio rises. Slabs with two, three, or four mesh layers increase deflection at failure by 1.70 percent, 5.81 percent, and 10.15 percent, respectively, in group A1. Due to a lower reinforcement ratio (0.429%), the F1MA1PPF-S maximum deflection is 7.96% lower than the control slab's 12.9 mm. Deflection at failure increases by 0.23 percent, 6.59 percent, and 21.9 percent for two, three, and four mesh layers, respectively, in group B1.

However, due to steel mesh slippage in the mortar matrix, the deflection of F1MB1PPF-S with a single mesh layer decreases by 33.33 percent in comparison to the control specimen. F4MB1PPF-S shows the most elevated load-conveying limit inside the gathering because of the fantastic holding impact of 0.30% PPF and the uniform appropriation of lattices across the cross-area. The load-carrying capacity of the 0.30 percent PPF is nearly identical to that of the control specimen because it effectively stretches against crack separation. Slabs with two, three, or four mesh layers increase deflection at failure by 0.62 percent, 0.93 percent, and 13.17 percent, respectively, in group C1. Because higher PPF percentages weaken the bond strength between the mortar matrix and meshes, this group's load-carrying capacity is lower than that of groups A1 and B1. Higher PPF volumes reduce the strength of the mortar matrix by interfering with its cohesiveness [15].

3.5. Stress-Strain Response

Ferrocement slab stress-strain curves behave similarly to load-deflection curves. Due to a lower reinforcement ratio (Vr) for wire mesh, the strain at maximum flexural stress for specimen F1MA1PPF-S is 0.0027, which is 11.67 percent lower than the control specimen. Due to wire mesh slippage, the strain for F1MB1PPF-S is 0.00212, 29.33% lower than the control slab. Due to a lower Vr of reinforcement, F1MC1PPF-S exhibits a strain of 0.00213, which is 29% lower than that of the control specimen. For chunks with two wire networks, F2MA1PPF-S records a kind of 0.00225, 24.97% not exactly the control example. Due to PPF arresting cracks, F2MB1PPF-S and F2MC1PPF-S both exhibit a strain of 0.0023, which is 22.50% lower than the control slab. This results in a lower rate of strain increase with increasing load. F3MA1PPF-S exhibits a strain of 0.00312, 4 percent higher than the control specimen, for slabs with three wire meshes.

The strains of F3MB1PPF-S and F3MC1PPF-S are 0.0032 and 0.0031, respectively, higher than the control specimen. PPF acting as a crack arrestor and the mobilized flexural capacity of the ferrocement slab both contribute to the steady increase in load with each strain increase. For pieces with four wire networks, F4MA1PPF-S shows a kind of 0.0032, 6.67% more than the control example. F4MB1PPF-S records a kind of 0.0040, 33.33% more than the control example, because of the presence of 0.30% PPF framing an organization structure that lessens pressure focus at break tips. Due to the uniform distribution of wire mesh and the 0.50 percent PPF that controls intrinsic cracking, F4MC1PPF-S exhibits a strain of 0.0033, which is 15.29% higher than the control slab. The expansion in pressure at any deformity is because of PPF framing a lattice structure that brings down pressure focus at break tips, alongside the commitment of the portion volume of support in the heap heading.

3.6. Energy Absorbed

During the deflection hardening stage, energy absorption is one of the most important characteristics of ferro fiber-reinforced composites. The toughness of deflection at mid-span is measured by calculating the entire area under the load-deflection curve from origin to failure. MATLAB programming was utilized to work out the energy consumed by finding the region under the heap diversion bends. Ferrocement and control slabs' absorbed energy results were presented. The energy absorption values of the ferrocement slab with four layers of wire mesh were significantly higher when compared to the control slab. Slabs with 0.10%, 0.30%, and 0.50% PPF saw increases of 23.16%, 24.16%, and 2.95 percent, respectively. The excellent bonding effect of fibers with the mortar matrix is to blame for the slabs with 0.10% and 0.30% PPF's higher energy absorption capacities. However, the higher dosage rate of fibers affected the cohesiveness of the mortar matrix and decreased its strength, resulting in a smaller increase in energy absorption in the slab with 0.50 percent PPF.

3.7. Crack Pattern

Flexural disappointment mode was noticed for all the tried piece examples, i.e., yielding of the steel wires without any sign of mortar pounding at the pressure face of the cross areas. The patterns of cracks in control and cement slabs made of equivalent steel (four wire mesh). The control slab was made of standard concrete and had a profile of crack patterns that was not entirely clear. The difference in resistive strength between the slabs' compression and tension zones was the cause. From tension to the compression zone, each crack began. While noticing the twisting way of behaving of all the ferrocement sections, the principal break design showed up underneath the heap application point. When the load increased at higher levels, additional cracks appeared on either side of the initial crack [12]. As the polypropylene fiber begins to act in the tension zone, the mortar matrix cracks. The load is transferred from one side of the lattice to the other by the fiber carrying it across the crack. Cracks have short paths because the fiber is distributed randomly, increasing the mortar matrix's load-bearing capacity [68]. Multiple cracks with relatively smaller widths than in the control slab specimen were caused by PPF in the ferrocement slab.

4. Conclusions

The aim of the study was to use varying proportions of polypropylene fibers (PPF) and 10% silica fume (SF) to improve the performance of ferrocement slabs. The goal of this strategy was to make up for any potential losses in ductility by strengthening the bond that cement paste has with aggregates. The review affirmed that ferrocement pieces displayed unrivaled break control and higher breaking loads contrasted with customary substantial sections. Key findings included:

1. Adding 10% SF and 0.50% PPF brought about a huge expansion in compressive strength, arriving at up to 37.11% improvement contrasted with controls.
2. The number of wire mesh layers incorporated into the ferrocement slabs had an effect on the initial cracking and final loads.
3. The ductility of the material increased as the number of uniformly distributed wire meshes increased, resulting in narrower cracks when stressed.
4. The first cracking load of ferrocement slabs optimized with 0.50 percent PPF and 10 percent SF was 15.25 percent higher than that of control slabs.
5. Higher percentages of PPF increased energy absorption capacity and strain at peak stress levels, demonstrating superior crack resistance and improved ductile behavior in ferrocement slabs.

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