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Development of high strength hybrid fiber reinforced engineered cementitious composites using Silica Fumes, Polyvinyl Alcohol fibers and Steel fibers

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Abstract : To resist some seismic and earthquake calamities, the need for more tensile and flexural properties in high strength concrete is required. So, high strength concrete along with good ductility and bendability properties are required. Previous studies proved that polyvinyl alcohol fibers have good ductility and bendability properties and other materials like silica fumes and steel fibers played a vital role in improving the strength performance of mortar, especially the splitting tensile and the flexural strengths. This research aims to improve high strength to the concrete along with ductility and bendability by replacing fine aggregates in mortar with silica fumes of 10%, polyvinyl alcohol fibers (PVA) and steel fibers both fibers of 2%. The addition of silica fumes also reduces the cement content thereby improving sustainability. Mix design is done for various proportions of Polyvinyl Alcohol Fiber (PVA) and Steel Fiber as replacement of fine aggregate from (0.5 - 1.5) %. Specimens were cast, tested and compared in terms of compressive strength and flexural strength to the mortar. These tests were carried out to find out the mechanical properties of concrete such as workability, compressive strength and flexural strength after a curing period of 7days, 14days and 28days. Results showed that Polyvinyl Alcohol Fiber of 0.5% and Steel fiber of 1.5% is Partial Replacement of Fine aggregate makes a considerable increase in compressive strength and flexural strength.

Keywords: Tensile strength, Flexural strength, Ductility, Polyvinyl Alcohol Fibers, Steel Fibers, Silica Fumes, Mortar and Compressive strength.

1.Introduction :

A type of fibre called polyvinyl-alcohol (PVA) fibre is created from polyvinyl alcohol by wet spinning, crimping-oiling, and heat treating in water that is kept at room temperature. According to Georgiou et al. (2016), this type of fibre is well known for having outstanding physical and mechanical characteristics such a high elastic modulus, high strength, and low ductility. The PVA fibres also have significant corrosion resistance in harsh settings, high dimensional stability against moisture and heat, and superior chemical resistance. The PVA fibres in particular show a strong affinity for cement and polymers. As a result, PVA fibres have been widely used in the construction industry to reinforce cement slabs, beams, and columns. PVA fibre reinforced concrete is created by adding PVA fibres to concrete in a specific ratio PVA fiber-reinforced concrete has the advantage of a low self-weight and high toughness compared to regular concrete and steel fiber-reinforced concrete. This indicates that the PVA fibres can significantly increase the ductility of the concrete. Currently, PVA fiber-reinforced concrete is widely used in civil engineering and architecture.
There has been a lot of attention lately in enhancing the characteristics of concrete by adding different pozzolanic ingredients to the concrete mix. Due to the beneficial effects it has on the characteristics of portland cement concrete, silica fume is one of these components that has drawn a lot of attention. A byproduct of making ferrosilicon and silicon metal in an electric arc furnace is silica fumes. The majority of this byproduct is typically silicon dioxide, with traces of other oxides present depending on the furnace charge and the silicon metal being generated.

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Previous studies proved that polyvinyl alcohol fibers have good ductility and bendability properties and other materials like silica fumes and played a vital role in improving the strength performance of concrete, particularly the splitting tensile and the flexural strengths. This research aims to improve high strength to the concrete along with ductility and bendability by replacing fine aggregates in concrete with polyvinyl alcohol fibers, silica fumes and steel fibers. In the present scenario in the construction industry, almost all the materials using in the construction industry is non-renewable. So, we must find out the alternative materials to overcome the scarcity of non-renewable materials

2.Literature Survey:

Dr. M. Dev(2018): PVA (polyvinyl alcohol) fibre can be used in place of cement in concrete mixtures. In this research, a retrofitting technique called SHCC (strain hardening cement based composite) is employed to increase the compressive and tensile strength of concrete. For attaining objectives such limiting thermal cracking, plastic shrinkage, durability, toughness, and abrasion resistance, polyvinyl alcohol fibre concrete is the perfect material. With this sort of cement replacement, there are two major problems to consider: the economic analysis of alternatives and the changes in the physical qualities of concrete in terms of compressive and tensile strength. The study's findings indicate that strength linearly decreases as PVA fiber's relative age to cement increases. Concrete mixtures with PVA fibre contents of 0%, 1%, 2%, 3%, 6%, and 9% were used in the experiments. Based on compressive and tensile strength, the ideal PVA fibre content was found to be 1%. For SHCC, the cube specimens of size (150mm150mm150mm) with mild steel rods were utilised for early setting and hardening, and the dumble form moulds were employed for tensile strength. After the sample has been cured, the compressive strength has been tested at 3, 7, and 28 days, and the tensile strength is tested at 28 days.

3 . Methodology :

This methodology proposed scheme aims to test from 0.5% - 1.5% of PVA fibers along with 0.5% - 1.5% steel fibers where total of 2% from both of the fibers replaced with fine aggregates in addition to that replacing 10% of silica fumes for sustainable development. The proposed flow chart is depicted in fig 3.1

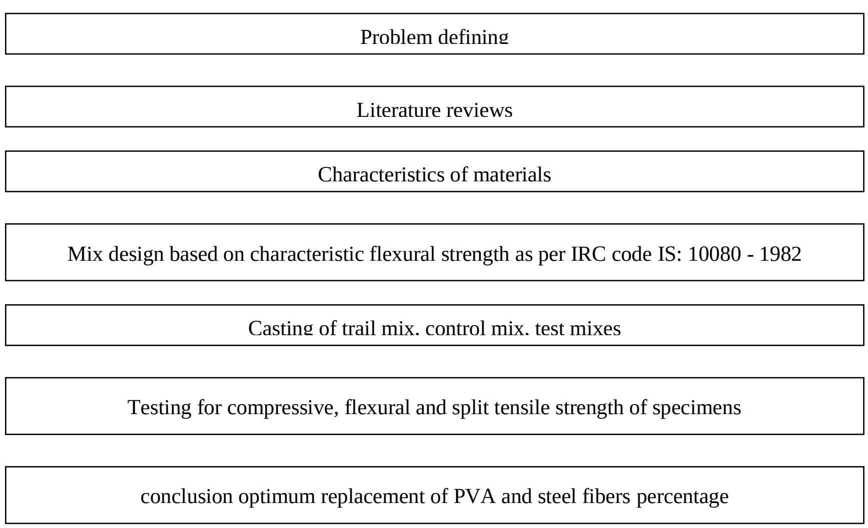


Fig 3: Methodology

4.Required materials:

- Polyvinyl alcohol fibers (0.5% - 1.5%)
- Steel fibers (0.5% - 1.5%)
- Silica fumes 10%

- Cement 38%
- Sand 50%

5.Mix design :

Specimen preparation: Mix Proportions and Mixing

Table: **MIX DESIGN TABLE**

PROPORTIONS	PVA	STEEL FIBERS	SILICA FUMES	CEMENT	FINE AGGREGATE
1st proportion	1.5%	0.5%	10%	38%	50%
2nd proportion	1%	1%	10%	38%	50%
3rd proportion	0.5%	1.5%	10%	38%	50%

6.Result and Discussion :

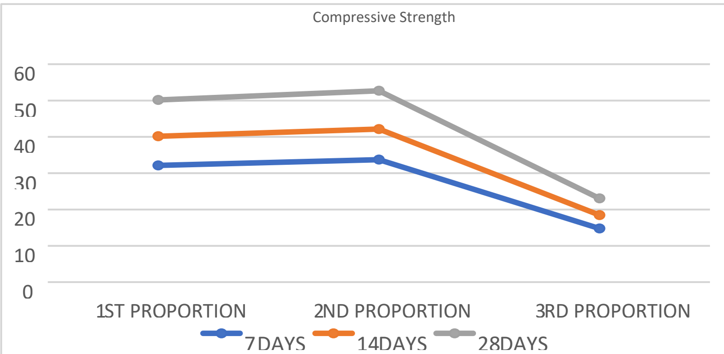
6.1 Results of cube:

- The study was conducted to find the optimum mix percentage of the cubes. How ever the Cube specimen of size 70mm x 70mm x 70mm were casted for different mix percentage of Silica Fumes (10%), OPC (38%), River sand (50%), PVA fiber (0.5 to 1.5%), steel fiber(0.5 to 1.5%).
- How ever the specimens have been tested for 3 mix proportions. The cube specimen of size 70mm x 70mm x 70mm were casted for different mix percentage of Silica Fumes, OPC, pva fiber, steel fiber for 7,14 & 28 days of curing.

Table 5.4.1: compression strength values for cubes

CURING	1ST PROPORTION	2ND PROPORTION	3RD PROPORTION
7 Days	32.1 Mpa	33.7 Mpa	14.74 Mpa
14 Days	40.12 Mpa	42.13 Mpa	18.43 Mpa
28 Days	50.16 Mpa	52.66 Mpa	23.03 Mpa

Graph 6.1: Compressive Strength of Cube



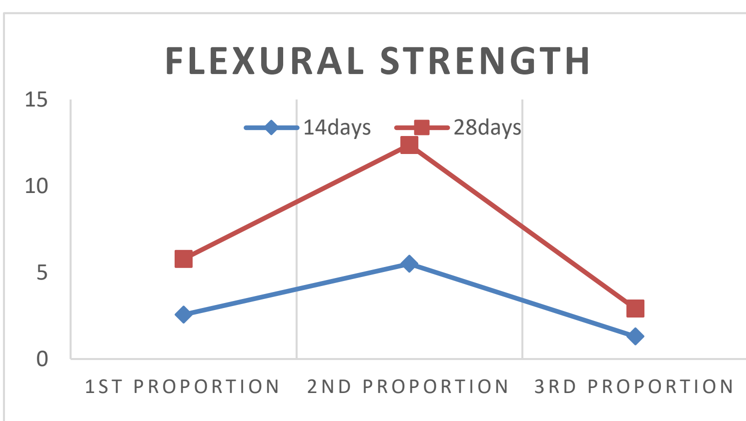
6.2 Results of prism:

- The study was conducted to find the optimum mix percentage of the prisms.
- How ever the prism specimen of size 40mm x 40mm x 160mm were casted for different mix percentage of Silica Fumes (10%), OPC (38%), River sand (50%), Pva fiber (0.5 to 1.5%) and steel fiber(0.5 to 1.5%).
- How ever the specimens have been tested for 3 mix proportions.
- The prism specimen of size (40x40x160)mm were casted for different mix percentage of Silica Fumes, OPC, Sand, Pva fiber and Steel fiber for 14 & 28 days of curing.

Table 5.5.1: Flexural strength values for prisms

CURING	1ST PROPORTION	2ND PROPORTION	3RD PROPORTION
14 DAYS	2.57 Mpa	5.5 Mpa	1.3 Mpa
28 DAYS	3.21 Mpa	6.87 Mpa	1.62 Mpa

Graph 6.1: Flexural strength of a Prism



7.Conclusion and Future Scope :

From the results it was concluded that, among the three proportions the maximum optimized compressive strength is obtained for optimal mix percentage of Silica fumes-10% opc-38%, sand-50%, pva fiber-0.5 to 1.5% and steel fiber-0.5 to 1.5% as 54 Mpa and optimized flexural strength is obtained for optimal mix percentage of Silica fumes-5% opc-38%, sand-50%, Pva fiber(0.5 to 1.5%) and steel fiber(0.5 to 1.5%) as 6.87Mpa.

Overall, the future scope of PVA and steel fibers is wide-ranging and holds significant potential for advancements in various fields, including construction, sustainability, advanced manufacturing, biomedical applications, smart materials, and nanocomposites. Continued research and development efforts in these areas are likely to drive innovation and open new possibilities for these materials in the future.

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