EXPERIMENTAL STUDY ON LIGHTWEIGHT POLYMER CONCRETE WITH SILICA FUME PUMICE AND CARPET FIBERS

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ABSTRACT The construction industry is increasingly pivoting toward sustainable "Green Concrete" solutions to mitigate the environmental impact of traditional Portland cement and the depletion of natural aggregates. The study utilizes Recycled Carpet Fibers (CFs) as a primary reinforcement to enhance ductility, while Pumice are employed as partial-to-full replacements for conventional aggregates to achieve a lightweight structural matrix. A critical challenge in fiber-reinforced lightweight concrete is the inherent loss of compressive strength and reduced workability.

Experimental investigations involve varying the cement proportions Pumice, Silica Fume and carpet fiber dosages (0.5–1.5% by volume). In the present study an experimental investigation was conducted on M30 grade concrete by using carpet fibres, pumice and silica fume. The percentage of carpet fibres, and silica fume pumice are 0+0+0, 0.25+2.5+5, 0.5+5+10, 0.75+7.5+15, and 1+10+20. The results like compressive strength, tensile strength and flexural strength values are studied along with this strength values durability is also studied for M30 self compacting concrete

Key words : Self compacting concrete, steel fibres, corn husk fibres, strength, durability

1. INTRODUCTION

High-strength lightweight polymer concrete (HSLWPC) is an advanced composite construction material that combines the advantages of lightweight aggregates, polymer binders, recycled fibers, and supplementary cementitious materials to produce concrete with superior mechanical strength, durability, and sustainability. As the construction industry moves toward environmentally responsible and high-performance materials, the development of innovative concrete mixtures that reduce structural weight while maintaining excellent strength has become increasingly important. High-strength lightweight polymer concrete reinforced with recycled fibers and silica fume represents one such sustainable solution, offering enhanced structural performance while utilizing industrial and post-consumer waste materials.

Unlike conventional cement concrete, polymer concrete employs polymer resins such as epoxy, polyester, vinyl ester, or acrylic as the primary binder or as a modifier to improve the bonding characteristics of the composite. The incorporation of polymers significantly enhances compressive strength, tensile strength, flexural strength, chemical resistance, water impermeability, and resistance to environmental degradation. Polymer-modified concrete also exhibits rapid curing, improved adhesion, and greater durability under aggressive environmental conditions, making it suitable for bridge decks, marine structures, industrial flooring, repair works, and precast structural elements.

To reduce the self-weight of concrete, lightweight aggregates such as pumice, expanded clay, expanded shale, perlite, or expanded glass are incorporated into the mixture. These aggregates lower the density of concrete while maintaining adequate structural strength. Lightweight concrete reduces the dead load acting on buildings and bridges, resulting in smaller foundation sizes, improved seismic performance, lower transportation costs, and easier handling during construction. Such characteristics are particularly beneficial in high-rise buildings and infrastructure projects located in earthquake-prone regions.

The addition of recycled fibers further improves the mechanical performance of lightweight polymer concrete. Recycled fibers obtained from waste carpet materials, plastic bottles (PET), discarded tires, industrial textiles, or other polymer-based wastes act as crack-arresting reinforcements within the concrete matrix. These fibers bridge microcracks, delay crack propagation, improve tensile and flexural strength, enhance ductility, and increase impact and fatigue resistance. Utilizing recycled fibers also supports waste management initiatives by diverting large quantities of non-biodegradable materials from landfills and promoting a circular economy.

Silica fume, an ultrafine by-product of silicon and ferrosilicon alloy production, is one of the most effective supplementary cementitious materials used in high-performance concrete. Due to its extremely fine particle size and high amorphous silica content, silica fume fills microscopic voids within the concrete matrix and reacts with calcium hydroxide produced during cement hydration to form additional calcium silicate hydrate (C-S-H) gel.

The combined use of polymer binders, lightweight aggregates, recycled fibers, and silica fume creates a highly dense and durable composite material with exceptional structural properties. The synergistic interaction among these components results in improved load-carrying capacity, better crack resistance, lower shrinkage, enhanced thermal insulation, superior fire resistance, and prolonged service life. Furthermore, the incorporation of recycled materials contributes to sustainable construction by reducing carbon emissions, minimizing landfill waste, conserving natural resources, and lowering the environmental impact associated with conventional concrete production.

In recent years, researchers have extensively investigated the optimization of mix proportions and curing techniques for high-strength lightweight polymer concrete containing recycled fibers and silica fume. Experimental studies have demonstrated significant improvements in compressive, tensile, and flexural strengths, along with enhanced durability and long-term performance. Consequently, this innovative concrete has emerged as a promising material for modern infrastructure, precast construction, repair and rehabilitation projects, and green building applications where high strength, reduced weight, and environmental sustainability are critical requirements.

2. LITERATURE REVIEWS

Merli et al. (2020) conducted a comprehensive systematic review on the application of recycled fibers in concrete to evaluate their influence on mechanical performance and sustainability. The review examined 194 published studies involving recycled steel, polymer, glass, textile, and synthetic fibers used in cementitious composites. The authors concluded that recycled fibers significantly improve tensile strength, flexural strength, impact resistance, toughness, and crack control while reducing environmental impacts by diverting waste materials from landfills.

Shmlls et al. (2021) reviewed the effects of silica fume, fly ash, and steel fibers on recycled aggregate concrete with the objective of improving its mechanical and durability properties. The study concluded that silica fume is one of the most effective supplementary cementitious materials because its ultrafine particles fill microvoids and participate in pozzolanic reactions, producing additional calcium silicate hydrate (C-S-H) gel. This process significantly increases compressive strength, reduces permeability, enhances resistance to chloride penetration, and improves durability under aggressive environments. The review further explained that the incorporation of fibers provides crack-bridging capability, leading to higher tensile and flexural strength.

3. MATERIALS USED FOR THE STUDY

For this experimental study initially we have collect the necessary materials to make self compacting concrete the details of materials collection and specification are discussed in the below

2.1 Cement

Ordinary Portland cement of 53 grade was utilized in this experimentation adjusting to I.S. – 12269-1987. For the current examination I was gathered ultra tech cement of 53 grade from local area

Hyderabad. The example cement bag utilized in this investigation is appeared in the below figure 1

Figure 1: Ultra Tech OPC 53 Grade cement Bag

2.2 Silica Fume

Silica fume, likewise called miniature silica, It is a ultrafine powder accumulated because of the silicon and ferrosilicon blend creation and involves round particles with an ordinary atom estimation of 150 nm. The fundamental field of usage is as pozzolanic material for unrivaled concrete. The general case of silica fume is showed up in the figure 2 which is assembled from mechanical territory near Hyderabad city.

Figure 2: Silica Fume

2.3 PUMICE

Pumice is a naturally occurring volcanic rock that is formed when molten lava containing high concentrations of dissolved gases cools and solidifies rapidly during volcanic eruptions. As the lava cools, the trapped gases escape, creating numerous interconnected air-filled pores that give pumice its characteristic lightweight and highly porous structure. Due to its low density, high surface area, and excellent insulating properties, pumice has been widely used in construction, horticulture, abrasives, filtration systems, and cosmetic products.

Pumice

Carpet fiber

Carpet fiber refers to the synthetic or natural fibers used in the manufacturing of carpets and floor coverings. Common carpet fibers include nylon, polypropylene (olefin), polyester, acrylic, and wool. Among these, synthetic fibers dominate the global carpet industry because of their durability, affordability, and resistance to wear. As carpets reach the end of their service life, they generate a significant amount of solid waste, much of which is disposed of in landfills. The increasing accumulation of carpet waste has raised environmental concerns, encouraging researchers to explore sustainable methods of recycling and reusing carpet fibers in construction materials, particularly concrete.

Carpet fiber

2.5 Fine Aggregates

Locally open sand zone II with specific gravity 2.65, water absorption 2% and fineness modulus 2.92, changing as per I.S. – 383-1970. It is the aggregate the a lot of which passes 4.75 mm IS sifter and contains basically such an unprecedented proportion of coarser as is allowed by detail.

Figure 5: Fine aggregates

2.6 Coarse Aggregates

Coarse aggregates are those stones which are held on IS4.75 strainer number squashed stone mix of 20mm size is incorporated from near to quarry. Aggregates of length more critical than 20mm size are secluded by using sieving. The underneath figure shows the example of Coarse totals which are utilized in this investigation.

Figure 6: Coarse aggregates

2.7 Mix Design And Trials Used For The Study

The mix design used for this study is 1:1.58:1.44 for M30 grade design mix as per the materials properties

For this study of experimentation I was taken five trials to get the optimum value of strength and durability values which are shown in the below discussions

Concrete Mix proportions for Trial Number 1

Cement = 490 kg/m3

Water = 220.5 kg/m3

Fine aggregates = 671.22 kg/m3

Coarse aggregate = 1078 kg/m3

Water-cement ratio = 0.45

3. METHODOLOGY

In order to test the strength and durability of concrete using silica fume pumice and carpet fibers for M30 grade concrete we need to cast the cubes, cylinders and prism specimens for compressive strength, split tensile strength, flexural strength and durability of various curing periods. Along with those strength tests workability is also studied for various trial mixes. For this project the following methodology is used

3.1 Batching

Batching is the process of taking the quantity of materials required for the project. Generally measuring the material quantity is done by two methods one is weight batching, second is volume batching. In the present study I was taken weight batching to measure the materials quantity.

3.2 Mixing Of The Concrete

After measuring the materials quantity we mixed the materials as per the trails. Firstly we have to mix coarse aggregates, fine aggregates, silica fume pumice and carpet fibers for some time to get uniform mix after that add cement and silica fume to the mixture again mix for some more time to get same mix throughout the material. Now add the water as per the calculations from the mix design to make freshly prepared concrete for M3 grade concrete.

3.3 Casting of specimens

After mixing the concrete materials we have to cast the specimens like cubes, cylinders, prisms to check the strength and durability. For this study we have to cast 45 cubes, 45 cylinder and 45 prisms to check the compressive strength, split tensile strength and flexural strength at 7days, 14 days and 28 days curing period along with these strength we have to cast 15 cubes for the durability of concrete for these five trial mixes.

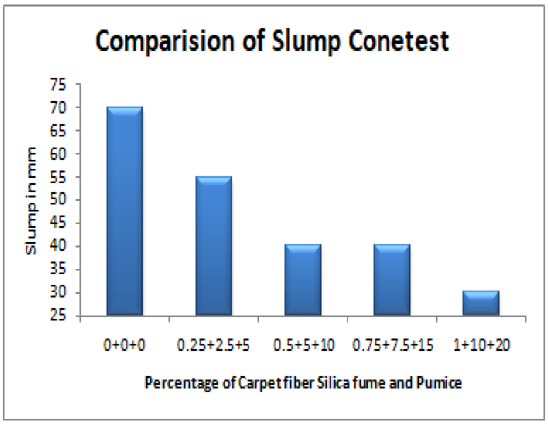
3.4 Curing of the Specimens

In case of compressive strength, split tensile and flexural strength studies we have to cure the specimens for 7 days, 14 days and 28 days of curing periods with all five trial mixes. While in case of durability we have to cure the specimens to at least for acid attack and alkaline attack tests.

4. RESULTS AND ANALYSIS

4.1 Workability Of Concrete

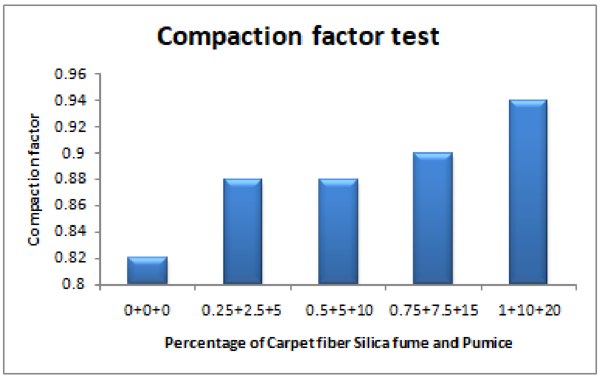
Workability is one of the most important property of the freshly prepared concrete mixtures in the present study workability of concrete mix is find out with the help of the slump cone test and compaction factor tests the below graph shows the slump cone comparison for various mixes



Graph 1: Comparison of slump cone test

4.2 Compaction Factor

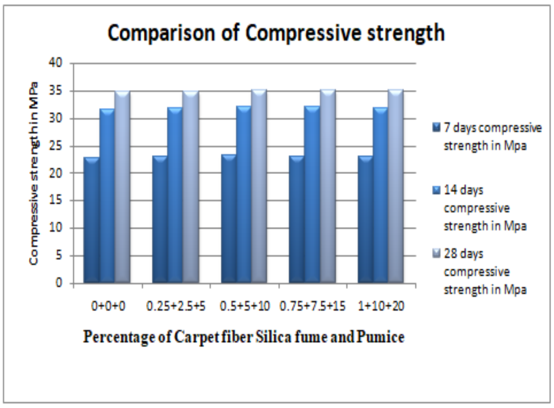
Compaction factor is the weight of partially compacted concrete to the weight of full compacted concrete. For the present study compaction factor is determined with the help of mix trials from mix trial 1 to mix trial 5 the below graph shows the compaction factor test results.



Graph 2: Comparison of compaction factor

4.3 Compressive Strength Of Concrete

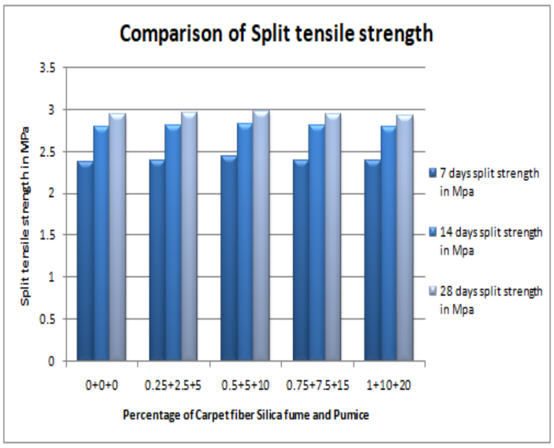
After curing cubes the compressive strength of concrete is resolved with the assistance of universal testing machine (UTM) for trial 1 to trial 5. The below figure shows the compressive strength of concrete for 7 days, 14 days and 28 days curing.



Graph 3: Comparison of Compressive strength

4.4 Split Tensile Strength

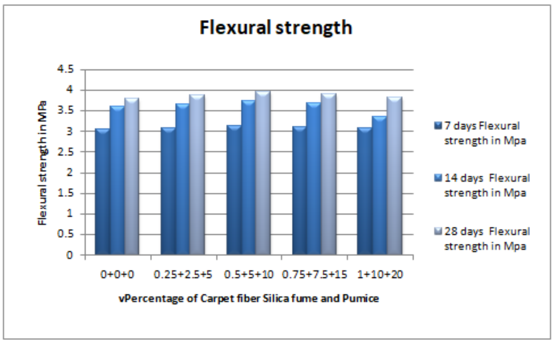
Split tensile strength of concrete is determined for M35 grade concrete with the help of cylinder specimens for various mix trials from trial 1 to trail. The dimension of the cylinder was taken as 150mm diameter and 300mm length. The below graph shows the split tensile strength for 7days, 14 days and 28 days.



Graph 4: Comparison of Tensile strength

4.5 Flexural Strength Of Concrete

Generally flexural strength of concrete is determined for prism specimens of 150mmX150mmX700mm dimensions. The flexural strength of prism specimens is determined for trials 1 to trails 5 for M35 grade concrete, the below graph shows the flexural strength of concrete for 7days, 14 days and 28 days curing

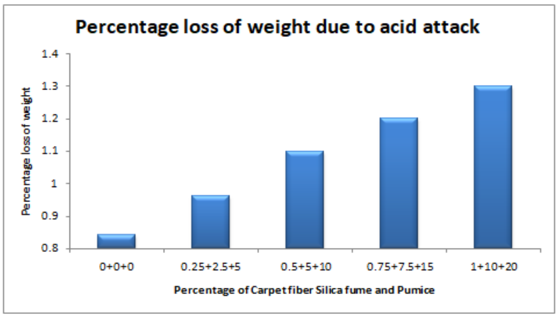


Graph 5: Comparison of flexural strength

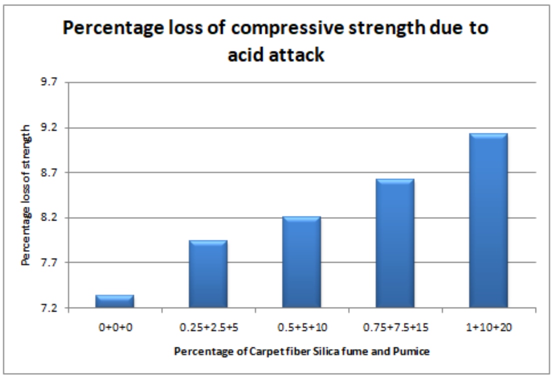
4.6 Durability Of Concrete

Durability is one of the most critical pieces of concrete on account of its focal rate in the usefulness life of structures. In such manner, breaking accept a key activity in the quality of strong structures. Durability is one of the most significant viewpoint in concrete this property is controlled by restoring the block samples in corrosive arrangement and basic arrangement the beneath chart shows the rate loss of weight and rate loss of compressive quality for both relieving techniques.

4.6.1 Acid attack

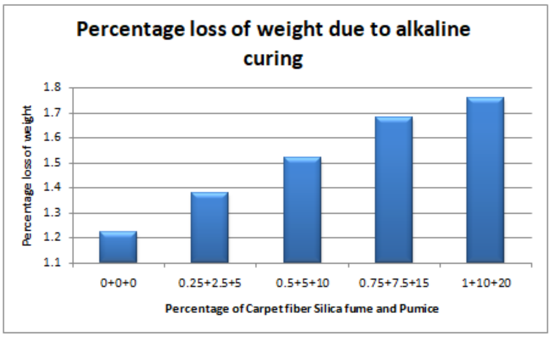


Graph 6: Comparison of percentage loss of weight

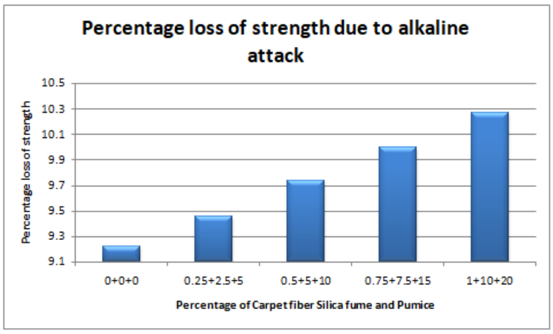


Graph 7: Comparison of percentage loss of strength

4.6.2 Alkaline attack



Graph 8: Comparison of weight loss



Graph 9: Comparison of percentage loss of strength

5. CONCLUSIONS

1. Low density concrete is made with the help of the various mineral admixtures.
2. The strength of low density concrete is varies than the normal concrete mixture.
3. By using carpet fibers and silica fume the cracking effect of concrete will be reduces and it is also helps to increase the strength values related to compressive, split tensile and flexural.
4. The determination of slump cone esteem diminishes from trial 1 to trial 5. The most extreme estimation of compaction factor was seen at mix 1.
5. The most extreme estimation of compressive , tensile and flexural was observed at mix 3 which is of 0.5% carpet fiber, 5% silica fume and 10% pumice.
6. The rate loss of weight and the rate loss of compressive quality for corrosive relieving and soluble restoring increments from trial 1 to trial 5.

7. As per the strength characteristics the maximum strength is obtained at trial 3 0.5% carpet fiber, 5% silica fume and 10% pumice

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