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Vinylester Resin As A Matrix Material In Frp Composite Concrete

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Abstract:
The use of vinyl ester resin as a matrix in polymer composite materials for use in civil engineering applications is covered in this study. The research starts out by going over the growing trend of composite development and applications in civil engineering, as well as the associated factors. Because of their low life cycle costs, ease of application, and customizable performance characteristics, their employment in the restoration of concrete structures has expanded recently. Due to these qualities as well as the effectiveness of structural rehabilitation techniques, new lightweight structural ideas that make use of all FRP systems or new FRP concrete composite systems have been developed. These days, a lot of attention has been paid to the application of Fiber Reinforced Polymer (FRP) composites in concrete structures because of its high strength-to-weight ratio, longevity, and resistance to corrosion. Usually, a polymer matrix material reinforced with high-strength fibers like carbon, glass, or aramid is used to create FRP composites. The purpose of this paper is to examine the application of vinyl ester resin as a matrix material in fiber-reinforced polymer (FRP) composite concrete and assess its performance with regard to strength parameters, weight ratio, and durability. Because of its superior mechanical qualities, resilience to chemicals, and minimal shrinkage, vinyl ester resin is frequently used as the matrix material in fiber reinforced polymer (FRP) composites. High strength glass fibers will be used as reinforcement and vinyl ester resin as the matrix material to create FRP composite concrete specimens for the study. A potential new supply of structural aggregate material is synthetic light weight aggregate. Greater design flexibility, significant cost savings, better cyclic loading, less dead load, increased structural response, longer spans, higher fire ratings, thinner sections, smaller structural components, less reinforcing steel, and cheaper foundations are all made possible by the use of light weight concrete. Construction costs and labour can be reduced by a relatively slight reduction in dead weight, especially for members in flexure in high-rise buildings. Lightweight concrete's reduced modulus of elasticity and sufficient ductility, in addition to its decreased dead weight, might be helpful for designing structures for seismic activity. The investigation's outcomes and conclusions will offer insightful information on the possible uses of FRP composites based on vinyl ester resin in the building sector. Compared to traditional M40 concrete, we achieved improvements in strength parameters, durability, and weight reduction in addition to glass fiber and Vinylester resin.
***Key Word**: Vinylester Resin; Glass Fiber; Composite Concrete; FRP; Fiber Reinforced Concrete.*

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I. Introduction

The search for creative and sustainable solutions is still critical in the dynamic fields of materials science and structural engineering. These days, a lot of attention has been paid to the application of Fiber Reinforced Polymer (FRP) composites in concrete structures because of its high strength-to-weight ratio, longevity, and resistance to corrosion. Usually, a matrix composed of polymer material reinforced with high-strength fibers like carbon, glass, or aramid is used to create FRP composites. Recently, a lot of attention has been paid to the application of Fiber Reinforced Polymer (FRP) composites in concrete structures because of its high strength-to- weight ratio, endurance, and resistance to corrosion. Polymer composite is a material that always consists of two phases: reinforcement and matrix. The reinforcement is made of fibers arranged in a discrete or fabric form. Materials like carbon, glass, aramid, or natural fibers are commonly used to make the fibers, whilst polyester, vinyl ester, epoxy, or nylon can be used to make the resin. A composite material that is stronger and more resilient than each material alone is produced when the fibers are incorporated in the polymer resin. Moreover, the widespread adoption of FRP composite can be attributed to its cost-effectiveness and ease of installation. They can offer good strength, ductility, and energy absorption capability when used to enclose concrete structures with fiber-reinforced polymers.

Materials

Cement

In construction, cement is a binding substance that keeps materials together. Usually, it is manufactured by heating and grinding clay, limestone, and other minerals into a fine powder. To make concrete, cement and water are combined to generate a paste that solidifies and binds components like sand, gravel, and stone. For the investigations, Ordinary Portland Cement (OPC) of grade 53 in accordance with IS: 10262-1982 was utilized.

Table 2.1: Physical Properties of Cement

Sl.no.	Test on cement	Result
1	Specific Gravity of Cement	3.1
2	Fineness of Cement	3.2%
3	Normal consistency of Cement	31%
4	Initial setting time	50min

Coarse and Fine Aggregate

The experiment's demonstrating aggregates adhere to IS 383: 1970. Larger chunks of material, like crushed stone or gravel, make up coarse aggregate, whereas finer particles, like sand, make up fine aggregate. 20 mm and 10 mm down size quartzite aggregate that is readily available locally is employed as fine aggregate and coarseaggregate, respectively.

Table 2.2: Physical Properties of Coarse Aggregate

Sl.no.	**Test on Coarse Aggregate**	**Result**
1	Specific Gravity of coarse aggregate	2.714
2	Grain size analysis coarse aggregate	• Effective size in microns = 0.17 • Uniformity coefficient = 5.44 • Fineness modulus = 3.75
3	Bulk density coarse aggregate	• Loosely packed = 1.39 kg/l • Compacted = 1.58 kg/l
4	Percentage air voids of coarse aggregate	• Loosely packed = 45.76% • Compacted = 38.34%
5	Aggregate Crushing Value	27.90
6	Water Absorption of Coarse Aggregate	1.6%

Table 2.3: Physical Properties of Fine Aggregate

Sl.no.	**Test on fine Aggregate**	**Result**
1	Specific Gravity of fine aggregate	2.720
2	Grain size analysis fine aggregate	•Effective size in microns = 0.17 •Uniformity coefficient = 5.44 •Fineness modulus = 3.75
3	Bulk density fine aggregate	•Loosely packed = 1.67 kg/l •Compacted = 1.93 kg/l
4	Percentage air voids of fine aggregate	•Loosely packed = 39.7% •Compacted = 29.04%
5	Bulking of Sand	•Percentage of bulking occurred = 35.71 •Percentage of water content at max. Bulking = 6%

Glass Fiber

Glass fiber is a reinforcing material that is added to concrete to improve its tensile strength, impact resistance, and durability. It helps to prevent cracking and increase the overall performance of the concrete, especially in applications where high strength and durability are required. Glass fiber-reinforced concrete is commonly used in construction projects such as building facades, precast concrete products, and architectural elements. The addition of glass fiber to concrete can enhance its properties and make it a versatile and reliable construction material. The glassfibers of 12 mm length, used in the study were tested for salient properties.

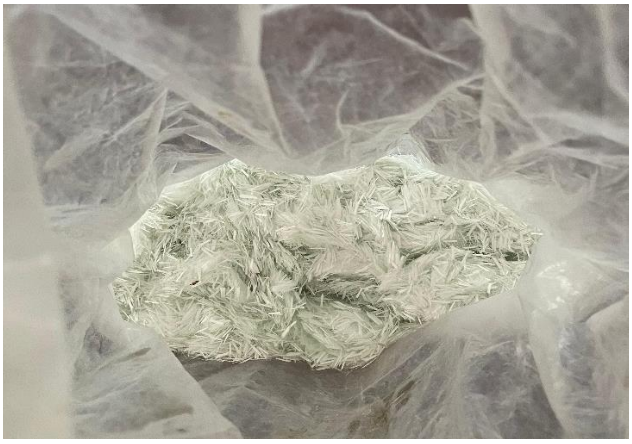


Table 2.4: Salient Properties of Glass Fiber

Property	Value
Modulus of elasticity	72GPA
Fiber length	6 mm
Specific gravity	2.68

Vinylester Resin

Vinyl ester resin has strong tensile elongation, durability, and resistance to heat. Additionally, it is not easily corroded by the majority of chemicals, fumes, or fuels. It resists deterioration from water and solvents. It resists heat as well as effectively. A tack forms when vinyl ester resin cures. In terms of price, epoxy resin is less expensive than vinyl ester resin, while polyester resin is more expensive. The resin is resistant to a wide range of chemicals and fluids for exposure and application, making it particularly well-suited for filament winding, lay-up/spray-up, pultrusion pipelines, and chemical process equipment such as reactors, blowers, and fume extraction equipment's.

Admixtures

Additional substances known as adjuvants are mixed into concrete to change its characteristics or improve its performance. Concrete can be mixed with a variety of admixtures, such as superplasticizers, water reducers, accelerators, retarders, and air-entraining agents. In this study, catalysts, promoters, and accelerators were employed.

II. Methodology

Preliminary Tests

Every and every component utilized in a project is tested. For cement, the coarse and fine aggregate are assessed first. For compressive strength, tensile strength, and flexural strength, a preliminary experiment using different glass fiber proportions resulted in a varied ratio of fiber dose of 0.25, 0.50, 0.75, percent by volume of concrete. 150 x 150 x 150 mm experimental concrete cubes containing experimental fibers were formed for the current investigation, and after 7, 14, and 28 days of curing, their tensile strength, flexural strength and compression were measured. After28 days optimum percentage of glass fiber is determined.

Mix Proportion

Fibers of an extra 6 mm in length were added to the concrete mixture to create the FRC mix. This approach seemed to yield a consistent FRC mix, thus the 0.5% of glass fibers were added (optimum) to the dry mix first, in place of cement, before water was added. OPC 53 grade cement is required to be utilized. The materials to be utilized include fine sand with a fineness modulus of 4.16, 20 mm of stone aggregate, and 10 mm with a minimum fineness modulus of 3.75. A design combination of grade of 1: 1.32: 2.34: 0.41 has been given to FRC.

Table 3.1: Mix Proportion for M40 Concrete (Conventional)

Material required for 1m^3 of concrete(kg)				w/c ratio	Mix proportion
Cement	Coarse Aggregate	Fine Aggregate	water		
481	1129	635.50	197.16	0.41	1:1.32:2.34

Casting and Curing

The standard cube specimen, measuring 150 mm × 150 mm × 150 mm, was utilized to ascertain the compressive strength of the concrete. Three specimens were evaluated using varying amounts of Vinylester resin in place of cement for 7, 14, and 28 days. The adopted water cementitious ratio was 0.41 (w/cm). Layers of concrete were added, and each layer was squashed. Following a 24-hour curing period in clean water for 7, 14, and 28 days, the specimen was taken out of the mould and its compressive strength was measured in accordance with Indian Standard. Using the amounts of dry ingredients in the prescribed proportions, the components for each batch of moulds were combined separately, and the amount of water was calculated. Resin is added in different proportions (5%,10%,15%) in different batches to determine the optimum percentage. Along with this, the remaining cubes and beams for flexural and tensile testing in accordance with Indian standards are cast. Every beam and cube is cast in accordance with IS 516.

III. Result

Compressive Strength: A compression testing equipment is used to test the compressive strength of concrete. In the compression testing machine, the fiber-filled cube is maintained perpendicular to the load, and testing is done. A check of the compressive strength is conducted after 7, 14, and 28 days. Testing is the process of subjecting a sample of the material to increasing compressive forces until it fails in order to ascertain its compressive strength.

The material's compressive strength is defined as the greatest force applied prior to failure. The following formula can be used to determine compressive strength:
(Compressive Load / Surface Area) = Compressive Strength

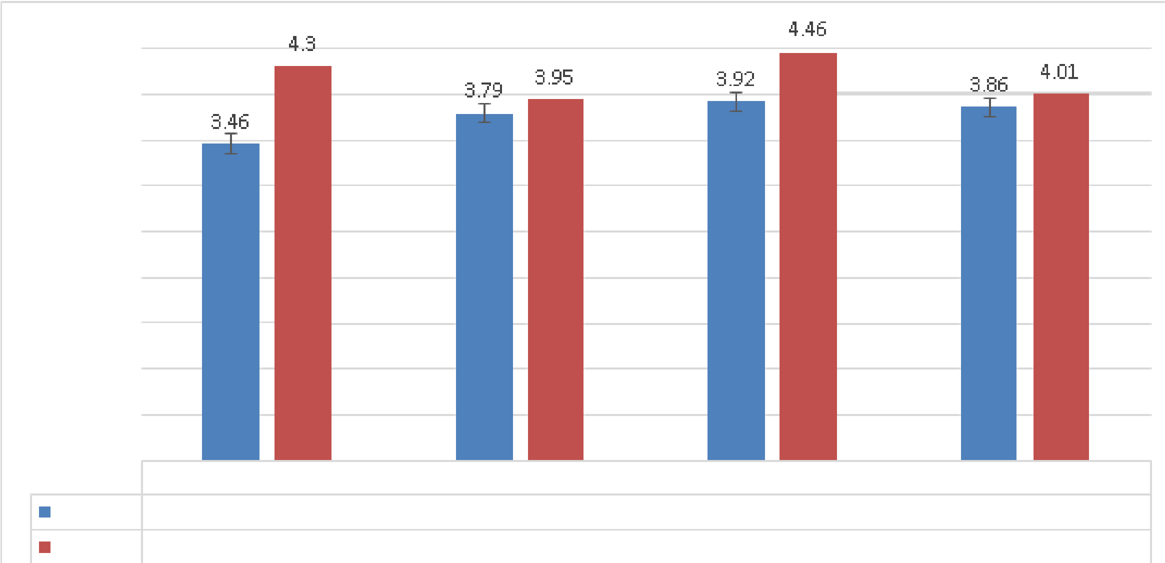
Table 4.1: Compressive strength of composite concrete in 7/14/28 days

SAMPLE NAME	COMPRESSIVE STRENGTH (MPa)		
	7/Days	14/Days	28/Days
VE00GF0	24.45	33.85	39.61
VE00GF25	23.14	32.04	38.60
VE00GF50	28.22	39.07	43.41
VE00GF75	26.56	36.77	40.86
VE05GF50	29.46	40.79	45.32
VE10GF50	31.38	43.44	48.27
VE15GF50	30.37	42.04	46.72

Split Tensile Strength: Concrete is known to be poor in tension and good in compression. The split tensile strength was tested after 7 and 28 days using the 300 x 150 mm cylinders. Specimens for the control mix have been created and compared with varying amounts of VER (cement) replacement, such as 5%, 10%, and 15%. For different replacement times, the split tensile strength of each mix was measured at 7 and 28 days of age.
The following is the formula for split tensile strength: Split Tensile Strength = (2 x Tensile Load / Surface area)

Table 4.2: 7&28 day's split tensile strength of composite concrete.

SAMPLE NAME	Split Tensile (MPa)	
	7/ Days	28/Days
VE00GF0	3.46	4.30
VE05GF50	3.79	3.95
VE10GF50	3.92	4.46
VE15GF50	3.86	4.01

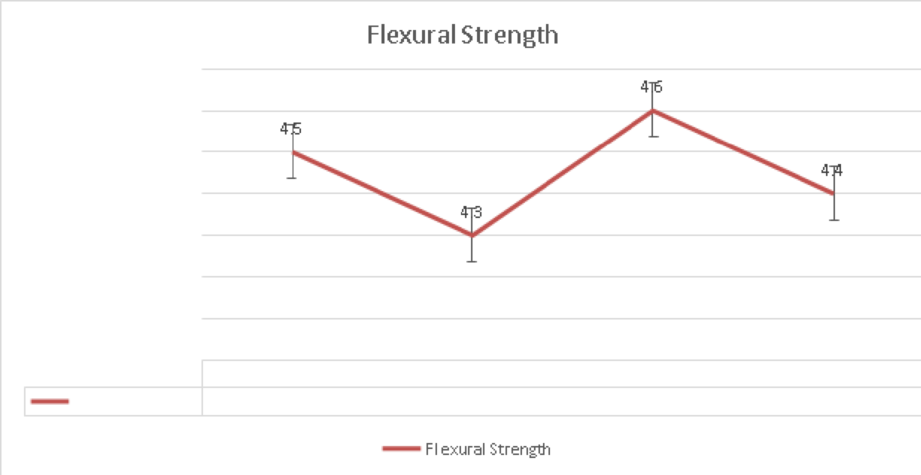


Flexural Strength

The highest stress a material can sustain before breaking under bending is called its flexural strength sometimes referred to as its modulus of rupture. By bending a sample and measuring the stress at the failure point, it can be ascertained. The ability of a material to withstand bending and deformation is indicated by its flexural strength, which is significant in structural design. Flexural strength tests were conducted on beam specimens measuring 100 mm x 100 mm x 500 mm at 28 days. Specimens for the control mix have been created and compared with several amounts of VER (cement replacement), such as 5%, 10%, and 15%.

Table 4.3: Flexural strength of composite concrete in 28 days

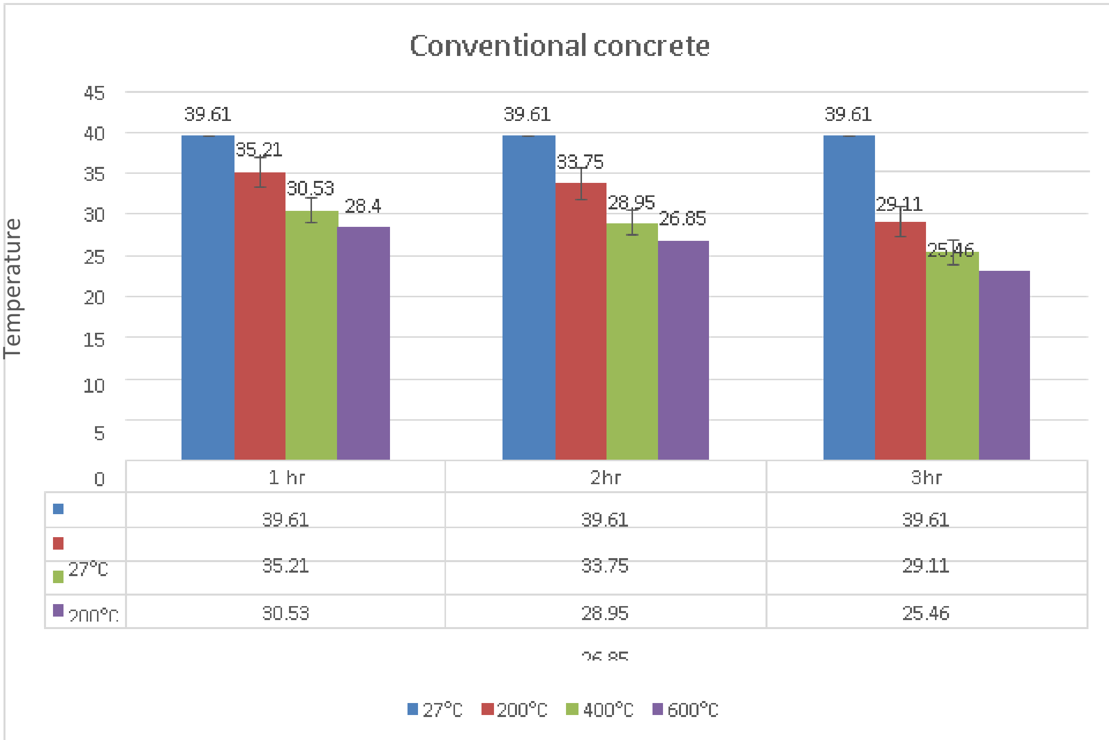
Sample Name	Flexural Strength (MPa)
VE00GF0(Control Mix)	4.5
VE05GF50	4.3
VE10GF50	4.6
VE15GF50	4.4

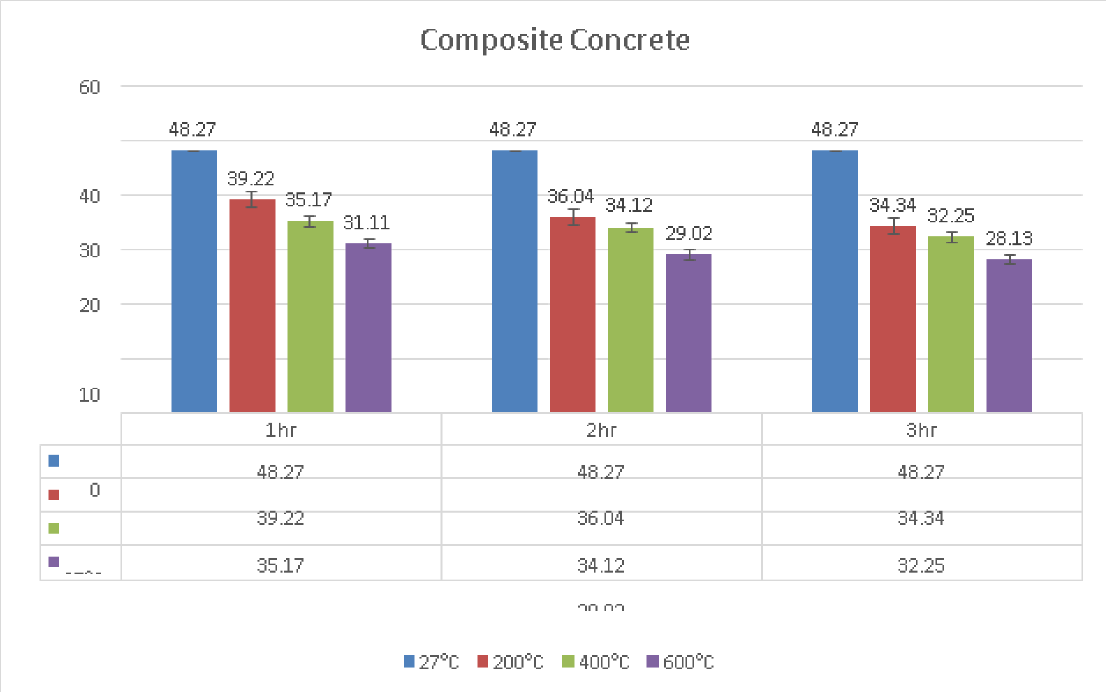


Fire Resistance: Fire resistance refers to the ability of a material or structure to withstand exposure to fire or hightemperatures without losing its structural integrity or performance.

Table 4.4: fire resistance of composite concrete after 28 days of curing

Temp°C	Conventional Concrete (M40)						Composite Concrete					
	Weight loss (g)			Compressive strength(N/mm²)			Weight loss (g)			Compressive strength (N/mm²)		
	1h	2h	3h	1h	2h	3h	1h	2h	3h	1h	2h	3h
27	0.00	0.00	0.00	39.61	39.61	39.61	0.00	0.00	0.00	48.27	48.27	48.27
200	5.00	8.00	12.00	35.21	33.75	29.11	7.00	13.00	19.00	39.23	36.04	34.34
400	7.00	17.00	20.00	30.53	28.95	25.46	9.00	16.00	22.00	35.17	34.12	32.27



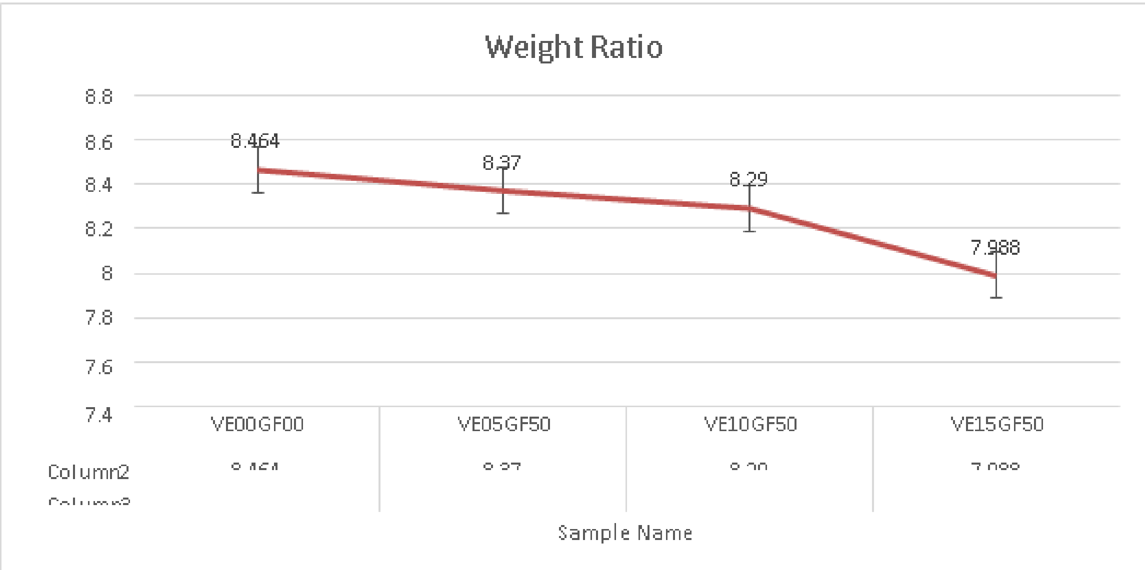


Weight Ratio

The weight ratio describes how much one material or thing weighs in relation to another material or substance. It is acomparison of two distinct items or components' masses.

Table 4.5: Weight comparison of conventional concrete and composite concrete

SAMPLE NAME	WEIGHT (Kg)
VE00GF0 (CONTROL MIX)	8.464
VE05GF50	8.370
VE10GF50	8.290
VE15GF50	7.988



IV. Discussion Of Study

Resources and the natural environment are being overly exploited as concrete usage rises. A potential new supply of structural aggregate material is synthetic light weight aggregate. Greater design flexibility, significant cost savings, better cyclic loading, less dead load, increased structural response, longer spans, higher fire ratings, thinner sections, smaller structural components, less reinforcing steel, and cheaper foundations are all made possible by the use of light weight concrete. Lightweight concrete's reduced modulus of elasticity and sufficient ductility, in addition to its decreased dead weight, might be helpful for designing structures for seismic activity. Increased fire resistance, low thermal conductivity, a low coefficient of thermal expansion, and less transportation and erection costs for prefabricated parts are further benefits.

V. Conclusion

Construction costs and labour can be reduced by a relatively slight reduction in dead weight, especially for members in flexure in high-rise buildings. Lightweight concrete's reduced modulus of elasticity and sufficient ductility, in addition to its decreased dead weight, might be helpful for designing structures for seismic activity. Increased fire resistance, low coefficient of thermal expansion, and less transportation and erection costs for prefabricated parts are further benefits. . Based on the findings, it can be concluded that glass fiber and VER are superior cement substitutes. In GFRC, strength gains occur at a rapid pace. The following conclusions can be drawn after runningeach test and examining the results:

[1] The strength of concrete diminishes as the w/cm ratio rises.
[2] The ideal compressive strength can be attained with 10% VER and 0.50% glass fiber substitution.
[3] VER concrete has a stronger 10% cement replacement than conventional concrete.
[4] As the percentage of Vinylester resin increases, the workability of concrete diminishes.
[5] Compressive strength drops above 15% of VER when cement replacement is used.

References

[1] Y. Tao, S.A. Hadigheh, And Y. Wei(2023). Recycling Of Glass Fibre Reinforced Polymer (Gfrp) Composite Wastes In Concrete: A Critical Review And Cost Benefit Analysis," Structures, Vol. 53, Pp. 1540–1556.
[2] Q. Wang Et Al (2023). Preparation And Application Research Of Hybrid Alkali-Resistant Glass Fiber Reinforced Cement Grout. Case Studies In Construction Materials, Vol. 19, P. E02674.
[3] Y. Chen Et Al (2022). Experimental Investigation On Mechanical Properties Of Glass Fiber Reinforced Recycled Aggregate Concrete Under Uniaxial Cyclic Compression. Cleaner Materials, Vol. 6, P. 100164.
[4] V. Kodur, S. Venkatachari, V. A. Matsagar And S. B. Singh (2022). Test Methods For Characterizing The Properties Of Fiber- Reinforced Polymer Composites At Elevated Temperatures. Polymers.
[5] Hatem H. Almasaeid, Akram Suleiman, Rami Alawneh (2022). Assessment Of High-Temperature Damaged Concrete Using Non- Destructive Tests And Artificial Neural Network Modelling. Case Studies In Construction Materials, 2214-5095/2022 Elsevier Ltd.
[6] M. H. Omar, I. Almeshal, B. A. Tayeh, And B.H. Abu Bakar (2022). Studying The Properties Of Epoxy Polymer Concrete Reinforced With Steel And Glass Fibers Subjected To Cycles Of Petroleum Products. Case Studies In Construction Materials, Vol. 17, P. E01668.
[7] Mahmoud H. Akeed (2022). Ultra-High-Performance Fiber-Reinforced Concrete. Part I: Developments, Principles, Raw Materials, Case Studies In Construction Materials 17, E01290, Page No 7.
[8] Andreas J. “Brunner (2022). Can Simple Estimates From Neat Polymers Provide Safe Fatigue Fracture Design Limits For Fiber-Reinforced Polymer Matrix Composites. 23 European Conference On Fracture-Ecf23,2452-3216/ 2022 Elsevier B.V.
[9] B. S. Ramji And M. S. Lakshmi (2018). An Experimental Study On Gfrc By Partial Replacement Of Coarse Aggregate With Pumice Stone And Cement With Fly Ash. International Journal Of Latest Trends In Engineering And Technology, Vol. 11, No. 4, Pp. 053-061.
[10] M. İskender And B. Karasu (2018). Glass Fibre Reinforced Concrete (Gfrc). El-Cezeri Fen Ve Mühendislik Dergisi.
[11] B. Benmokrane, A. H. Ali, H. M. Mohamed, A. Elsafty, And A. Manalo (2017). Laboratory Assessment And Durability Performance Of Vinyl-Ester, Polyester, And Epoxy Glass-Frp Bars For Concrete Structures. Composites Part B: Engineering, 114, Pp. 163-174.
[12] A. Dehghan, K. Peterson, And A. Shvarzman (2017). Recycled Glass Fiber Reinforced Polymer Additions To Portland Cement Concrete.
[13] Construction And Building Materials, Vol. 146, Pp. 238–250.