

Strength characteristics of Glass Fiber Reinforced Concrete (GFRC) using Calcium Chloride Integral Curing Method

Jaison Joy Memadam ¹, Dr. T.V.S Vara Lakshmi ²

¹ Research Scholar, Department of Civil Engineering, Acharya Nagarjuna University, Guntur, India ² Assistant professor, Head of Department of Civil Engineering, Acharya Nagarjuna University, Guntur, India.

Abstract. Concrete is weak in tension and strong in compression. The inclusions of fibers in concrete significantly improves its compressive as well as tensile strength. The use of different types of fibers have shown positive responses among the researchers. It has long been known that curing concrete during cold weather can result in an inferior product with substandard properties. Curing also takes much longer, adding to job costs and extending the time before the concrete surface can be used. There are many accelerators available in the market, but Calcium Chloride continues to be one of the most preferred one. In this study, Alkali resistant glass fibers (0%, 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5% and 4%) were used in the concrete M30 mix. The optimum glass fiber percentage that can be added to the concrete is found by comparing both tensile and compressive strength of the GFRC. Trial mixes of normal M30 concrete by adding different percentages of Calcium Chloride (0%, 0.5%, 1%, 1.5%, 2%, and 2.5%) as curing agent is also prepared. The optimum percentage of calcium chloride that can be added to the concrete is found by comparing the compressive strength of the concrete. The compressive strength of the GFRC using calcium chloride integral curing is found after 7, 14 and 28 days. The test results are then compared with GFRC using normal curing.

Keywords: Calcium chloride, Integral Curing, Accelerator, GFRC, Glass Fiber

1 Introduction

Concrete is the most widely used construction material having several desirable properties like high compressive strength, stiffness and durability under usual environmental conditions. It is obtained by mixing cementing materials, water and aggregates, and sometimes admixtures, in required proportions. The mixture when placed in forms and allowed to cure, hardens into a rock-like mass known as concrete. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, on the proportions of mix, the method of compaction and other controls during placing, compaction and curing. All concrete requires curing in order that cement hydration can proceed so as to allow for development of strength, durability and other mechanical characteristics.

1.1 Glass Fiber

Fiber reinforced concrete is a new construction material which is defined as composite material of cement mortar and the fibers. Addition of glass fiber into cement mortar eliminates the cracks and shrinkage in the surface. It also increases the tensile strength of concrete. Glass fibers can be incorporated into a matrix either in continuous or discontinuous (chopped) lengths. Glass fibers have large tensile strength and elastic modulus but have brittle stress-strain characteristics and low creep at room temperature. Glass fibers are usually round and straight with diameters ranging from 0.005 mm to 0.015 mm.

Glass fiber also called fiberglass. Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. Glass is the oldest, and most familiar, performance fiber. Fibers have been manufactured from glass since the 1930s. Glass fiber is chemical inorganic fiber, obtained from molten glass of a specific composition. This glass is compound of quartz sand, limestone, kaolin, calcium fluoride (fluorspar), boric acid, sodium sulphate, and clay. Glass fiber is made of natural materials, so that its products are ecologically pure and not harmful to human health. Glass fiber is highly light permeable and can be a semiconductor having excellent electronic, heat, and sound insulation capacities.

1.2 Calcium chloride (CaCl₂)

It is a chemical admixture and a by-product of the Solvay process in the manufacturing of sodium carbonate. Calcium chloride is available in two forms: (i) Regular flake calcium chloride and (ii) concentrated flake, pellet, or granular calcium chloride. Calcium

chloride has been used in concrete since 1885 and finds application mainly in cold weather, when it allows the strength gain to approach that of concrete cured under normal curing temperatures.

In normal conditions, calcium chloride is used to speed up the setting and hardening process for earlier finishing or mould turnaround. Aside from affecting setting time, calcium chloride has a minor effect on fresh concrete properties. It has been observed that addition of CaCl₂ reduces bleeding. Initial and final setting times of concrete are significantly reduced by using calcium chloride. Historically, the use of calcium, particularly in the form of calcium chloride, was thought to be an effective acceleration technique in concrete. In applications in which metal is not embedded in concrete, the use of calcium chloride as an accelerator is still permitted. Additional suggestions regarding the use of calcium chloride as an accelerator include never using concentrations greater than 2% by cement weight as told by American Concrete Institute.

2 Materials and Methods

2.1 Cement

Ordinary Portland cement was used for the experiments. The physical properties of the cement after the tests are given below.

Table 1. Physical properties of Cement

S.No	Property	Value
1	Grade	53
2	Specific Gravity	3.12
3	Fineness(cm ² /gms)	2100
4	Standard Consistency (%)	27
5	Initial Setting Time (min.)	35
6	Final Setting Time (min.)	420

2.2 Coarse and Fine aggregate

Fine aggregate used for the study is having specific gravity 2.68. The sample is conforming to zone II and fineness modulus is 3.18. Coarse Aggregate used is 10 mm and 20 mm crushed gravel of 2.71 specific gravity. Both coarse and fine aggregate was air-dried in the laboratory and sieve analysis was carried out. The fineness modulus was found out to be 7.13 for the coarse aggregate.

2.3 Mix Proportions

The investigation was aimed at studying the compressive strength of M30 grade Concrete for different type of colored polythene paper curing. The mix proportions are calculated based on the IS 10262 and SP 23. The proportions of Cement: Sand: Coarse Aggregate: w/c = (1: 1.87: 3.37:0.45) was used for mixing.

2.4 Calcium chloride

Properties of calcium chloride (CaCl₂) -

- Appearance/Physical State - Powder
- Color - White
- Odor - Odorless or no characteristic odor
- Solubility description - Soluble in water

2.5 Glass Fiber

- Type : Alkali Resistant
- Specific gravity : 2.68
- Elastic Modulus : 72 GPa
- Tensile Strength : 2100 MPa
- Length : 12 mm
- Density : 2680 Kg/ m³
- Aspect Ratio : 857.1
- Color : White
- Filament Diameter : 14 micron

2.6 Workability

The internal surface of the cone mould used was thoroughly cleaned and applied with a light coat of oil. The mould was placed on a smooth, horizontal, rigid and non- absorb- bent surface. The mould was then filled in three layers with freshly mixed concrete, and each layer was tamped 25 times with tamping rod. After the top layer was rodded, the concrete was struck off the level with a trowel. The mould was removed from the con- crete immediately by raising it slowly in vertical direction. The difference in level be- tween the height of the mould and that of the highest point of the subsided concrete was measured using a meter rule. This difference in height in millimeter is recorded as the slump of the concrete.

2.7 Curing

The curing were carried out for 28 days. During mixing of concrete, Calcium chloride is added to the mix as an accelerator. Then after dismantling from the mould, the spec- imen is kept in water for 28 days.

2.8 Compressive strength and Tensile strength

The compressive strength and tensile strength of the concrete is determined by using a Universal testing machine. Three cube(150*150*150 mm) specimens and three Cylin- drical(150 mm diameter and 300 mm height) specimen were tested at 7, 14 and 28 days of curing

3 Results and Discussion

The following are the results obtained from the experiments.

Table 2. Workability of GFRC

S.No	Glass Fiber(%)	Slump(mm)
1	0	78
2	0.5	74
3	1	73
4	1.5	71
5	2	70
6	2.5	68
7	3	66
8	3.5	64
9	4	63

Table 3. Workability of M30 concrete with calcium chloride integral curing

S.No	Calcium chloride(%)	Slump(mm)
1	0	78
2	0.5	76
3	1	74
4	1.5	71
5	2	69
6	2.5	67

Table 4. Compressive strength of GFRC after 7 days curing

S.No	Glass Fiber(%)	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	Average (MPa)
1	0	24.63	24.74	24.82	24.73
2	0.5	25.40	25.92	25.04	25.42
3	1	26.12	25.98	26.43	26.18
4	1.5	26.28	23.13	26.84	26.42
5	2	26.97	27.03	26.59	26.86
6	2.5	27.22	27.27	27.44	27.31
7	3	27.92	27.57	27.34	27.61
8	3.5	27.14	26.98	27.34	27.15
9	4	27.02	27.12	25.92	26.69

Table 5. Compressive strength of GFRC after 14 days curing

S.No	Glass Fiber(%)	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	Average (MPa)
1	0	34.64	35.24	34.84	34.91
2	0.5	35.17	34.92	35.73	35.27
3	1	36.14	35.78	36.02	35.98
4	1.5	36.22	36.12	36.33	36.22
5	2	36.49	37.12	36.87	36.83
6	2.5	36.88	37.45	36.75	37.03
7	3	37.62	37.49	37.87	37.66
8	3.5	37.13	36.82	36.91	36.95
9	4	37.02	36.89	35.21	36.37

Table 6. Compressive strength of GFRC after 28 days curing

S.No	Glass Fiber(%)	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	Average (MPa)
1	0	38.68	39.54	38.12	38.78
2	0.5	38.77	39.79	39.82	39.46
3	1	38.89	39.98	40.12	39.66
4	1.5	39.77	40.79	40.92	40.49
5	2	40.91	41.23	41.37	41.17
6	2.5	41.41	41.83	41.89	41.71
7	3	42.13	41.97	42.49	42.26
8	3.5	40.73	40.93	41.12	40.93
9	4	40.13	39.45	39.98	39.85

Table 7. Tensile strength of GFRC after 7 days curing

S.No	Glass Fiber(%)	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	Average (MPa)
1	0	3.43	3.49	3.32	3.41
2	0.5	3.51	3.57	3.58	3.55
3	1	3.63	3.71	3.79	3.71
4	1.5	3.89	3.85	3.92	3.89
5	2	3.94	3.97	4.11	4.01
6	2.5	4.07	4.13	4.22	4.14
7	3	4.27	4.31	4.29	4.29
8	3.5	4.13	4.09	4.22	4.15
9	4	4.11	4.05	4.01	4.06

Table 8. Tensile strength of GFRC after 28 days curing

S.No	Glass Fiber(%)	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	Average (MPa)
1	0	5.38	5.12	5.47	5.32
2	0.5	5.49	5.61	5.55	5.55
3	1	5.69	5.77	5.81	5.76
4	1.5	6.01	5.91	5.88	5.93
5	2	6.17	6.31	6.21	6.23
6	2.5	6.32	6.29	6.45	6.35
7	3	6.49	6.46	6.59	6.51
8	3.5	6.40	6.31	6.38	6.38
9	4	6.31	6.37	6.29	6.32

Table 9. Compressive strength of M30 concrete after 7 days curing

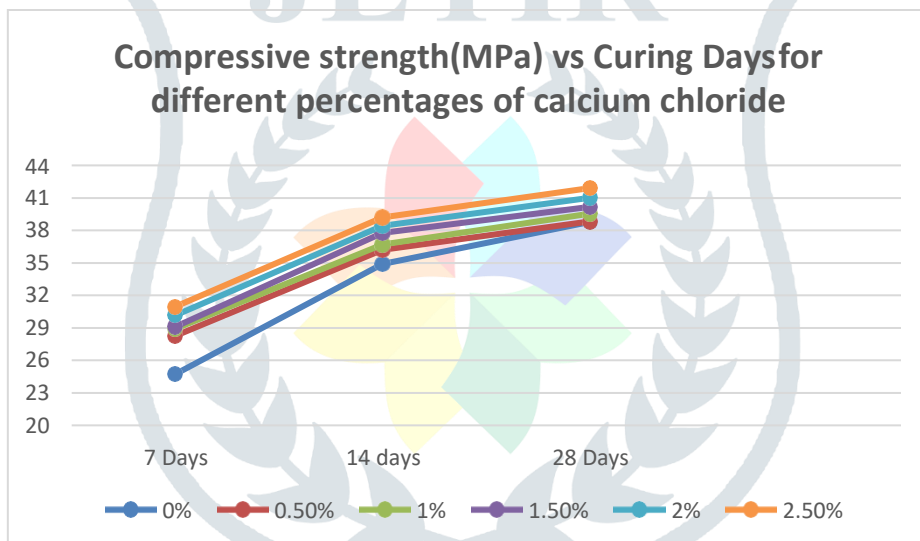
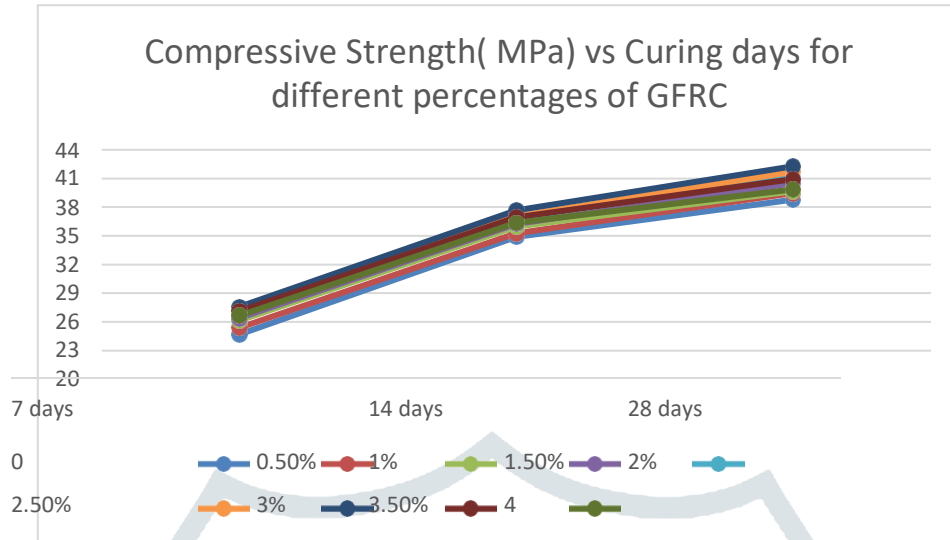
S.No	Calcium Chloride(%)	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	Average (MPa)
1	0	24.63	24.74	24.82	24.73
2	0.5	28.08	29.14	27.56	28.26
3	1	27.82	29.11	29.85	28.92
4	1.5	28.84	29.13	29.77	29.10
5	2	29.47	30.83	30.17	30.16
6	2.5	30.54	30.89	31.43	30.95

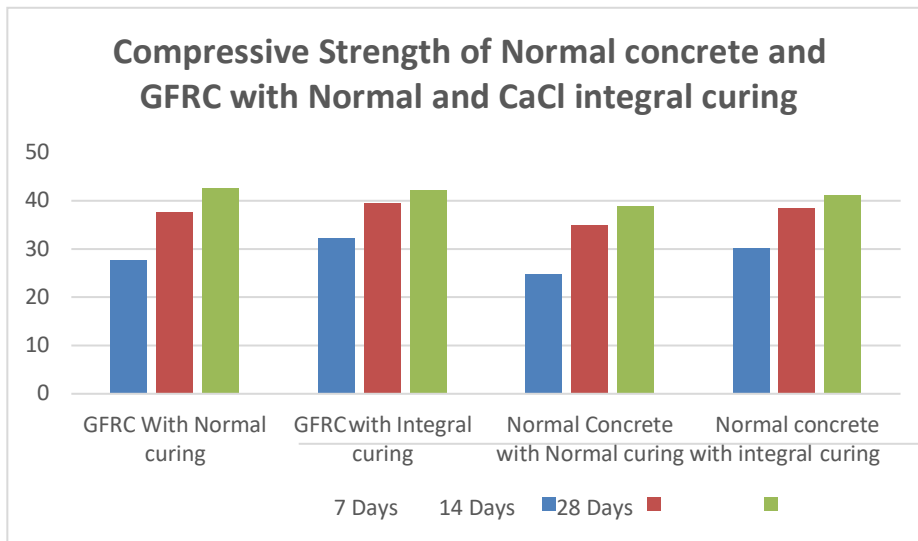
Table 10. Compressive strength of M30 concrete after 14 days curing

S.No	Calcium Chloride(%)	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	Average (MPa)
1	0	34.64	35.24	34.84	34.91
2	0.5	36.92	35.48	36.19	36.20
3	1	35.94	36.77	37.41	36.71
4	1.5	37.32	37.94	36.81	37.36
5	2	38.12	38.77	38.41	38.43
6	2.5	38.72	39.79	39.08	39.20

Table 11. Compressive strength of M30 concrete after 28 days curing

S.No	Calcium Chloride(%)	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	Average (MPa)
1	0	38.68	39.54	38.12	38.78
2	0.5	38.44	38.79	39.27	38.83
3	1	38.97	39.74	39.91	39.54
4	1.5	40.24	40.31	39.97	40.17
5	2	40.79	40.88	41.37	41.01
6	2.5	41.44	42.03	42.24	41.90





4 Conclusions

The following conclusions were made from the observations.

- a) The optimum amount of glass fiber that can be added to M30 concrete is 3% and it leads to
 - 6.17 % increase in the compressive strength of concrete
 - 22.37 % increase in the tensile strength of concrete
 - Reduction in workability (78mm to 66 mm)
- b) The optimum amount of Calcium chloride that can be added to M30 concrete is 2 % (ACI doesn't permits more than 2 % as an accelerator) and it leads to
 - 22 % increase in compressive strength at 7 days of curing
 - 10 % increase in compressive strength at 14 days of curing
 - No much variation in compressive strength after 28 days of curing
 - Reduction in workability (78 mm to 65 mm)
- c) GFRC with 3 % glass fiber under calcium chloride integral curing (2 %) leads to
 - 16 % increase in compressive strength at 7 days of curing
 - 4 % increase in compressive strength at 14 days of curing
 - No much variation in compressive strength after 28 days of curing

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