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Evaluation of FRC Beams Using Steel and PVA Fibres in Concrete

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ABSTRACT

The conventional concrete is enhanced by the addition of fibers in it. The brittleness in concrete is reduced and the adequate ductility of concrete is ensured by the addition of fibers in concrete. The fibers used are polyvinyl alcohol powders and steel fibers in various volume combinations. The main reason for adding fiber to concrete matrix is to find its compressive strength, split tensile strength, flexural strength and deflection test. The base polyvinyl alcohol is highly resistant to the majority of aggressive agent and will never oxidize when exposed to the condition which causes the steel to rust. The hybrid fibers of various combinations in polyvinyl alcohol powder is 0.1%, 0.25%, 0.5% and steel fibre 0.5%, 0.75%, 1.0% are decided to use in concrete mix. The workability of these fiber reinforced concrete mix will be increased by addition of super plasticizer.

Keywords: *Polyvinyl Alcohol Powders; Steel Fibers; Compressive Strength; Split Tensile Strength; Flexural Strength.*

1.0 Introduction

In ancient time's fibres are used as reinforcements. In mortars horse hair is used and in mud, bricks straw is used. In 1950's fibre reinforced concrete got great importance. By 1960's fibres such as steel, glass, synthetic fibres such as poly-propylene fibres, polyole-fin fibres has got great importance. Fibres have great role to control cracking due to plastic shrinkage and due to drying shrinkage. Fibres such as polypropylene when added to concrete reduce the Compressive strength, but increases both split tensile strength and flexural strength. They are more porous compared to the plain concrete. Moreover the bridging effect by this fibre leads to the improvement in the tensile and flexural strength. The fibre also improves the resistance to ion penetration which results in corrosion reduction of reinforcing bars. Steel fibre reinforced concrete (SFRC) offers good tensile strength, ultimate strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest. Some researches show that SFRC shows a slight tendency to reduce the young's modulus as the fibre content decreases. Some of the experimental results show that the beams reinforced with steel fibres shows a similar or even better post cracking behavior than beams with minimum amount of transverse reinforcement. When fibres are used in addition to the conventional transverse reinforcement the shear strength significantly increases. Steel fibre also reduce the width of shear cracks, thus improve durability. The surface corrosion of steel fibre reinforced concrete mostly depends on the cover and the water-cement ratio. In some other research the combined effect of silica flume and steel fibre improved the impact resistance and mechanical properties of concrete.

When fibres are added to concrete, it becomes homogeneous, isotropic and transforms it to a ductile material. These fibres will act as secondary reinforcement in concrete and reduces crack formation and propagation. Fibre reinforced concrete can be defined as a composite material consisting of cement, concrete and discontinuous, discrete, uniformly dispersed suitable fibres. In a research with polyvinyl alcohol and silica fume, specimens with the both components have more ductility than control and silica fume specimens. If more than one fibre is used in concrete, it is called Hybrid Fibre Reinforced Concrete (HFRC). If the fibre used is large and strong, it will control crack formation and if it is small and soft, it reduces the crack formation and propagation. Researches shows that when the fibres are used in the hybrid form-steel and polypropylene,

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increases ductility. Steel fibre bridging across cracks in concrete mix will increase joint shear strength. The PVA fibre increases the ductility and energy dissipating capacity. Further researches were done to study about the fracture properties and impact properties of hybrid fibre reinforced concrete. Research works indicate that the hybrid fibre addition leads to significant improvement to compressive strength, modulus of elasticity, splitting tensile strength, and modulus of rupture of pumice light weight aggregate concrete and meet the specification for structural purpose. Other research works with steel and polyvinyl alcohol show that they increase the compressive strength, flexure, modulus of rupture and ductility.

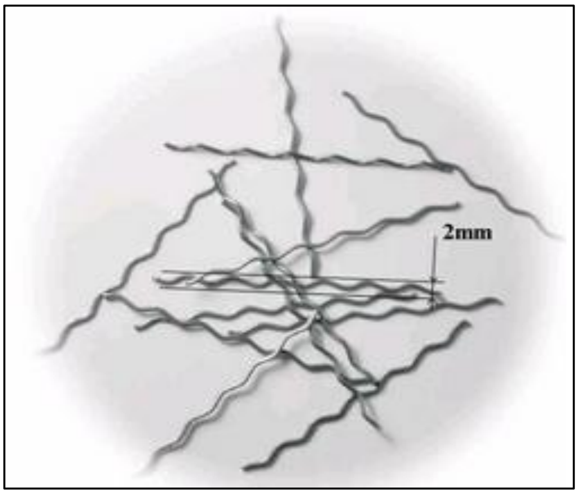
2.0 Steel Fibres

Steel Fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. It is a cold drawn wire Fibre with corrugated and flatted shape. Steel fibers intended for reinforcing concrete are defined as short, discrete lengths of steel having an aspect ratio in the range of 20-100, with any cross section and that are sufficiently small to be randomly dispersed in a fresh concrete mixture using usual mixing procedures. Steel fibers are available in lengths between 6 and 80 mm and with a cross-sectional area between 0.1, 1.5 and 2 mm. The Tensile strength is normally in the range between 300 and 2400MPa. They are circular or rectangular cross-sectional shape and are produced by cutting or chopping steel wires or by shearing sheets of flattened metal sheets and steel bars. The fibers are usually crimped or deformed with either a hook at each fiber end or a small head in order to improve the anchorage in the concrete matrix as shown in figure 1.

2.1 Polyvinyl alcohol fibres

Polyvinyl alcohol fiber (PVA) is an ideal environment-friendly cement reinforced material, which possesses alkali and weather resistance due to its unique molecular structure, taking on good affinity to cement, effectively prevent and suppress the crack formation and development, improve bending strength, impact strength and crack strength, improve permeability, impact and seismic resistance of concrete.

Fig 1: Steel Fibre – Crimped



This product can be widely used in industrial and civil buildings, walls, roofing, flooring and roads, bridges, tunnels, slope reinforcement. Currently, in cement concrete engineering sector, due to PVA fiber per se unique properties, with a broad prospect for its future in the engineering, PVA fiber is a novel product ideal to completely replace the asbestos as shown in figure 2.

3.0 Objective of the Investigation

The objective of the present investigations is investigate the workability, mechanical and flexural characteristics of concrete for various proportion of two different fiber and comparing the results with conventional concrete. The investigation is aimed in finding out the Compressive strength of cube, Split tensile strength of cylinder, Flexural strength of prism and Load Vs deflection of beam

Fig 2: Polyvinyl Alcohol powder

3.1 Scope of the present investigation

The scope of the investigation can be summarized as follows

a) To enhance the flexural strength and toughness by adding steel fiber.
b) To enhance the bridging of smaller micro cracks by addition of polyvinyl alcohol powder.
c) To examine the effect of hybrid fibers on structural behavior RC beams and
d) To investigate the hybrid fibers influence on strengthening of RC beams.

4.0 Collection of Materials

4.1 Cement

Portland Pozzolanic cement (PPC) of Fly ash based is used for casting concrete and the specific gravity of cement was found to be 3.05.And the properties were given in Table 1.

4.2 Fine aggregate

The fine aggregate (sand) used was clean dry river sand conforming to IS 383:1970. The sand was sieved to remove all pebbles. The specific gravity was found to be 2.61.And the properties were given in Table 2.

4.3 Coarse aggregate

Hard granite broken stones of 20 mm size were used as coarse aggregate conforming to IS 383: 1970. The specific gravity is 2.64.And the properties were given in Table 3.

4.4 Steel fibre

Steel fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. It is a cold drawn wire fibre with corrugated and flatted shape. Crimped steel fibers are used in this study and the properties were given in table 4. Polyvinyl alcohol Fibre Polyvinyl alcohol fibres have attracted more attention for reinforcing cementitious materials in the recent years. In this part emphasis is given on Polyvinyl alcohol fibres as they were used throughout the experimental program. The properties were given in Table 5.4. Super Plasticizer

Super Plasticizers, also known as high range water reducer**s**, are chemicals used as admixtures where well-dispersed particle suspensions are required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics (rheology) of suspensions such asin concrete applications.

4.5 Polycarboxylate ether super plasticizer (pce)

It work differently from sulfonate based super plasticizers, giving cement dispersion by steric stabilization, instead of electrostatic repulsion. This form of dispersion is more powerful in its effect and gives improved workability retention to the cementitious mix and it is shown in figure 3.

5.0 Test Results of Material Properties Cement

5.1 Cement inference

The specific gravity and all other properties are within the allowable limits.

5.2 Fine aggregate inference

The properties of fine aggregate satisfy the allowable limits of IS 383: 1970

5.3 Coarse aggregate inference

The properties of coarse aggregate satisfy the allowable limits of IS 383: 1970.

5.4 Properties of fibre inference

- The properties of polyvinyl alcohol powder are obtained from the supplier Padma Traders, Coimbatore.
- The properties of steel fiber are obtained from the supplier Jeetmull Jaichandlall Pvt(Ltd), Chennai.

Fig 3: Superplasticizer

Table 1: Properties of Cement

S. No	PROPERTIES	VALUES
1	Fineness	10%
2	Initial setting time	30min
3	Final setting time	2-3hours
4	Standard consistency	33%
5	Specific gravity	3.05
6	Fineness (by sieve	4.6%

Table 2: Properties of Fine Aggregate

S. No	PROPERTIES	VALUES
1	Specific gravity	2.61
2	Bulk density	1653.06 Kg/m^3
3	Surface moisture	0.11%
4	Water absorption	1%
5	Soundness	0.90%
6	Fineness modulus	2.64

Table 3: Properties of Coarse Aggregate

S. No	PROPERTIES	VALUES
1	Specific gravity	2.64
2	Bulk density	1350 Kg/m^3
3	Surface moisture	0.086%
4	Water absorption	0.5%
5	Soundness	0.55%
6	Fineness modulus	4.17

5.5 Concrete Mix Design Inference

As per IS10262-1982 the concrete mix design prepared for M25 grade concrete from IS10262-1982 for maintain workability

Table 4: Properties of fibre

S.NO	PROPERTIES	STEEL FIBER	POLYVINYL ALCOHOL FIBER
1	Length(mm)	30	15
2	Diameter(mm)	0.5	0.1
3	Shape	Crimped	Straight round
4	Aspect ratio	60	150
5	Density (g/cm3)	7.8	0.9
6	Elongation at	3.2	8.1
7	Tensile strength (MPa)	1500	800

Table 5: Concrete Mix

MATERIALS	WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE
By weight(kg)	187.52	450.78	509.93	1182.57
By volume	0.416	1	1.13	2.623

The above Mix proportion is made for Grade of concrete M25 in this its considered size of Coarse aggregate is 20mm, with mild exposure condition and the degree of workability is 0.9. All the necessary test data (physical properties) for the materials used in this mix design were calculated with the observation made from corresponding test results as per the codal provisions.

The mix design is made for the target mean strength of concrete of 33.745N/mm^2 which is computed as per IS 10262:1982.

Based on this target value the water cement ratio, cement, fine aggregate, Coarse aggregate are calculated.

Here the required water content is computed by referring the table 5 and 6 of IS 10263:1982 where we considered water/cement ratio, compaction factor, and sand zone in turn the cement content also determined. Then fine and coarse aggregate contents were obtained by using the total volume formula by referring the IS code book.

Table 6: Mix Proportion of Concrete with % of Fibres Ontent

Mix (M25)	Cement	Fine Aggregate	Coarse Aggregate	w/c ratio	Polyvinyl alcohol Fiber in volume %	Steel Fiber in volume %
CC	1	1.13	2.623	0.416	-	-
Addition of PVA fiber					0.1	-
	1	1.13	2.623	0.416	0.25	-
					0.5	-
Addition of Steel fiber					-	0.5
	1	1.13	2.623	0.416	-	0.75
					-	1.0
Hybrid fiber					0.3	0.7
	1	1.13	2.623	0.416	0.25	0.75
					0.2	0.8

6.0 Details of Casting

6.1 Preparation of the mould

The moulds used for testing were cube, cylinder, prism and beam which were made up of cast iron and the inside faces were machined plane. All the faces of the mould were assembled by using nuts and bolts and are clamped to the base plate. All the internal angle of the mould must be 90°. The faces must be thinly coated with mould oil to prevent leakage during filling. The inside of the mould must also be oiled to prevent the concrete from sticking to it.

6.2 Mixing

Thorough mixing of materials is essential for the production of uniform course. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. In this project, we adopted machine mixing. As the mixing cannot be thorough, it is desirable to add 10% more materials. A concrete mixer operated by current and of tilting type was used.

6.3 Compaction Of Concrete

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of mixing, transporting and placing of concrete, air is likely to get entrapped in the concrete. The lower the workability, higher is the amount of air entrapped. Hand compaction by using a tamping rod. When hand compaction is adopted, the consistency of concrete is maintained at a higher level.

Table 7: Details of Moulds

Type of Mould	Size(in mm)
Cube	150 x 150
Cylinder	150 x 300
Prism	100 x 100 x 500
Beam	1000 x 100 x 120

Fig 4: Mixing of Concrete

Fig. 5: Compaction of Concrete

6.4 Curing

The test specimens after compaction were kept as such for a period of 24 hours. After that period of time the moulds were removed and the specimens were kept in ordinary curing tank and allowed to cure for a period of 7 and 28 days.

Fig 6: Curing

7.0 Test Results and Discussion

The specimens were casted and allowed to cure for 7 and 28 days and were tested.

7.1 Slump value of fresh concrete

Table 8: Slump Value of Concrete

Proportion		Slump value (mm)	
PVA fiber	Steel Fiber	PVA fiber	Steel Fiber
0	0	92	92
0.1	0.5	93	90
0.25	0.75	94	89
0.5	1.00	92	85

Fig 7: Slump Value of Fresh Concretes for Polyvinyl Alcohol Fiber

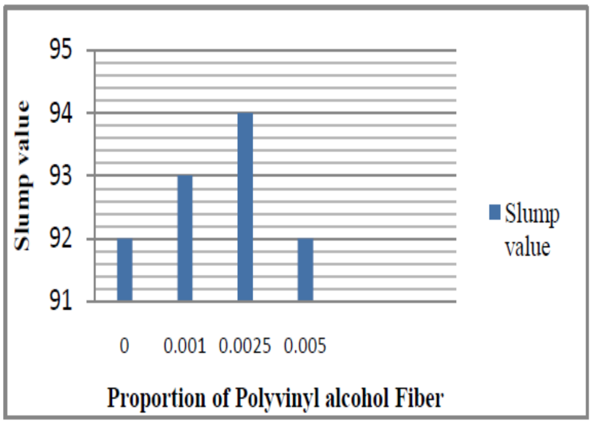
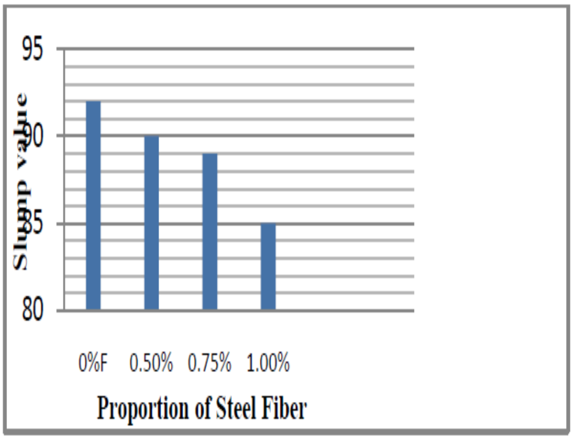


Fig 8: Slump Value of Fresh Concretes for Polyvinyl alcohol Fiber

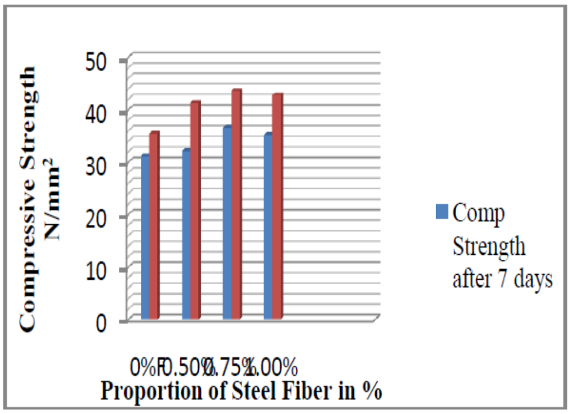


7.1.1 Inference:

It was found that workability of polyvinyl alcohol fiber is good when compared to steel fiber at higher volume fraction of steel fiber, slump value of concrete increases by adding super plasticizers.

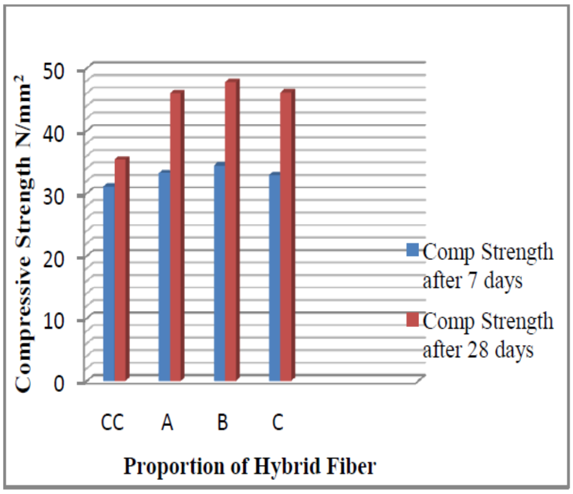
7.2 Compressive strength

Fig 9: Compressive Strength of Steel Fiber After 7th and 28th Days Inference



- The compressive strength of concrete improves by adding fiber compared to controlled concrete.
- Volume fraction of polyvinyl alcohol fiber should be minimum, it should not exceed 0.35%.
- The optimum level of compressive strength for polyvinyl alcohol fiber and steel fiber is 0.25% & 0.75% for compressive strength of concrete.
- So, the volume fraction of hybrid fiber is taken as 1% i.e. 0.25%PVA & 0.75% SF.

Fig 10: Compressive Strength of Hybrid Fiber After 7th and 28th Days

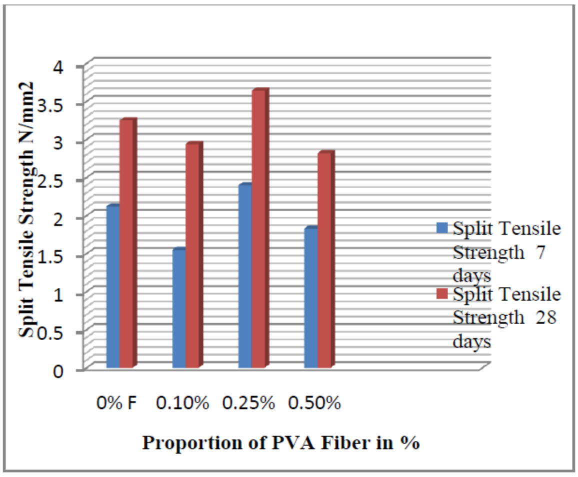


7.2.1 Inference

In various volume fraction of fiber, maximum compressive strength of concrete achieves at the volume fraction of 0.25% PVA and 0.75% SF.

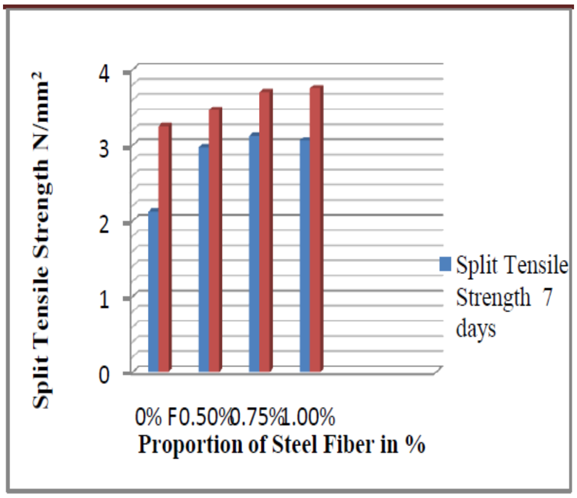
7.3 Split tensile strength

Fig 11: Split Tensile Strength of Polyvinyl Alcohol Fiber After 7th and 28th Days



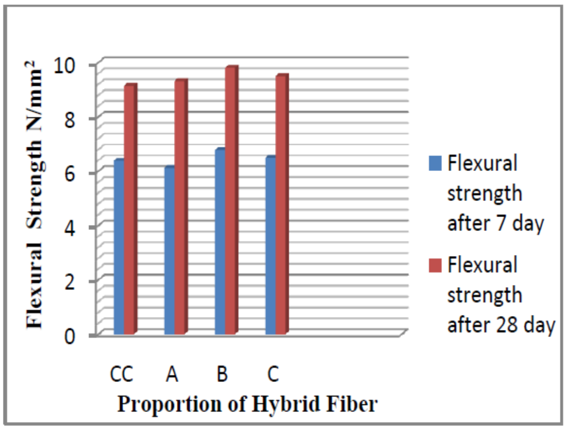
- Enhancement of split tensile strength of concrete by the addition of fiber, compared to controlled concrete.
- The optimum split tensile strength perk up at 0.25% PVA & 0.75% SF.
- The volume fraction of hybrid fiber is taken as 1%. i.e 0.25% PVA & 0.75% SF

Fig 12: Split Tensile Strength of Steel Fiber After 7th and 28th Days Inference



7.4 Flexural strength

Fig 13: Flexural Strength of Hybrid Fiber After 7th and 28th Days Inference



Flexural strength of prism for hybrid fiber, which enhances at 0.25% PVA & 0.75% SF compared to conventional concrete prism

7.5.1 Inference

- For conventional concrete beam, the first crack arrives at the load of 10.5 KN, the deflection at the mid span and L/3 of span is 1.728mm & 1.456mm
- For conventional concrete beam , the beam fails at the ultimate load of 32.1 KN and the maximum deflection at mid span and L/3 of span is 19.36 & 16.785.

7.5 Beam Deflection for Conventional Concrete

Table 7: Test Results of Load Vs Deflection for Conventional Concrete Beam

Load	Deflection at mid span	Deflection at L/3 of span	Remarks
0	0	0	
2.2	0.282	0.261	

Table 8: Test Results of Load Vs Deflection for Hybrid Fiber Reinforced Concrete

Load	Deflection at mid span	Deflection at L/3 of span	Remarks
0	0	0	
2.8	0.261	0.224	
4.2	0.615	0.462	
6.1	0.928	0.685	
8.9	1.365	1.043	
10.2	1.628	1.356	
12.7	2.380	1.764	First crack
14.9	3.137	2.218	
16.1	3.621	2.756	
18.3	4.280	3.271	
20.5	4.880	3.682	
22.7	5.287	4.132	
24.9	5.987	4.654	
26.2	6.546	5.158	
28.4	6.742	5.916	
30.5	7.392	6.484	
32.7	9.863	7.402	
34.9	13.254	11.946	
36.8	16.165	14.358	
38.6	20.576	17.875	
40.9	24.451	20.432	Ultimate load

7.6 Beam deflection for hybrid fiber reinforced concrete

7.6.1 Inference

- For Hybrid Fiber Reinforced Concrete Beam, the first crack arrives at the load of 12.7 KN, the deflection at the mid span and L/3 of span is 2.38mm & 1.764mm
- For Hybrid Fiber Reinforced Concrete Beam, the beam fails at the ultimate load of 40.9 KN and the maximum deflection at mid span and L/3 of span is 24.451 & 20.432

8.0 Conclusions

- From the Experimental Investigation it is concluded that,In addition of polyvinyl alcohol fiber, the crack formation had been arrested and mechanical and flexural properties of concrete achieves 30% higher than conventional concrete at lower volume fraction of fiber(0.25%).
- In addition of Steel fiber, mechanical and flexural properties of concrete achieves 33% higher than conventional concrete at higher volume fraction of fiber(0.75%).
- The hybrid fiber reinforced concrete at the volume fraction of 1% enhances compressive strength by 34%, split tensile strength by 15% and flexural strength by 10% compared to conventional concrete.
- The hybrid fiber reinforced beam at volume fraction of 1% (0.25% PVA & 0.75% SF) shows higher deflection when compared to convention concrete beam.

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