Journal of Structural Engineering and Management

Volume 1, Issue 1
www.stmjournals.com

Comparative Study of PSC Spun Pole using Higher Grade Concrete without and with Discontinuous Glass Fiber

M. B. Varma, S. T. Patil*
Department of Applied Mechanics, Government College of Engineering Aurangabad, Maharashtra, India

Abstract
This experimental study was carried out on the prestressed concrete spun pole of length 13 m with and without use of anti-crack discontinuous glass fiber in high-strength concrete. The pole is having outer diameter at top and bottom as 206 mm and 379 mm respectively. The pole is having thickness 50~55 mm. The investigations were done to study the effect of use of high dispersion discontinuous glass fiber on deflection of spun pole when design load of 350 kg is applied to it. The investigations were also done to study final recovery of deflection after removal of the load. The horizontal load is applied and increased in specific fractions up to design load and corresponding deflections of the pole is measured. Simultaneously, the pole is observed for the appearance of the cracks on the surface area. Final recovery of the deflection is noted after removal of the design load. The same procedure was repeated by increasing the load beyond the designed load. All the above parameters (deflection, crack pattern, recovery) were observed. Considerable improvement in the properties of PSC spun poles was observed during practical investigations.

***Keywords:** PSC, GFRC, deflection, cracks, recovery*

***Author for Correspondence** E-mail: ssunilpatil7@gmail.com

INTRODUCTION

Weaknesses of concrete are taken care of by adding appropriate percentage of reinforcement in the concrete. Since the last two decades, a technique of prestressed concrete was introduced and is being used widely as it has many advantages over conventional RCC.

Considering the weaknesses of concrete and importance of concrete in the construction industry, glass fiber started to be used in the concrete to improve its various parameters. Main parameter is its tensile strength. Some of the types of glass fiber are: E-glass fiber, S-glass fiber, alkali-resistant glass fiber, etc. [1]. Experimental studies were made to study different properties of concrete by many investigators. From the experimental investigations, it was proved that the workability of GFRC reduces with increase in the fiber content as compared to the normal concrete, the 7-day and 28-day compressive strength of concrete increases with increase in the fiber content, the flexural deflection increases with increase in the fiber content, flexural strength, bond strength [2], and shear strength increases with increase in the fiber content [3].

However, up till now, the use of glass fiber is mostly restricted to plain and RCC. It is yet not used on a large scale for prestressed concrete. In this paper, the use of “anti-crack glass fiber” in prestressed concrete and its effect on the deflection of the structural component when horizontal load is applied to it has been highlighted. The actual casting of a 13.0 m length spun pole was done at the factory and it was tested for its bent test which is mainly related to the parameters of deflection and cracking of PSC spun pole.

EXPERIMENTAL INVESTIGATIONS

The manufacturing of prestressed concrete tubular spun pole was being done at Beton Concrete Product Pvt. Ltd. located 50 km away from Aurangabad in Maharashtra.

Presently, the manufacturing of 13.0 m long pole is in progress. The same pole was considered for experimental investigations, just by adding anti-crack glass fiber, in the proportion of 600 g/cum concrete, as suggested by the manufacturer. The details of the materials [4] used for the pole under investigation are as under:

1. Cement

The type of the cement used is OPC, Orient Gold 53 grade having specific gravity of 2.90 and fineness of 2800 cm^2/g.

2. Fine Aggregate

The sand used is procured from Godavari River. The sieve analysis was carried out and it was having fineness modulus as 4.10, specific gravity 2.75, other parameters observed were silt content 1.3%, water absorption 1.0% and bulk density 1718 kg/cum.

3. Coarse Aggregate

Machined crushed, cubical shaped aggregates of maximum size of 12.00 mm were used. The properties were, specific gravity 2.60, fineness modulus 7.80, bulk density 1511 kg/cum and water absorption 0.5%.

4. Admixture

In addition to above regular ingredients, Starex cement additive powder was used as admixture. The proportion used was 120 g per pole.

5. Concrete Mix

The M50 grade of high-strength concrete [5] was used for casting of the pole and the quantities of various ingredients per cum are as shown in Table 1. The table includes the quantities of cement, fine aggregates, and coarse aggregates in kilograms and water required in liters. These quantities were obtained from concrete mix design adopted for the work.

Table 1: *Material Required for 1 cum Concrete.*

Grade	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	W/C Ratio
M 50	1	1.29	2.47	0.40(0.36)
M 50	502	648	1239	200 Liters

The proportion of the mix related to above ingredient quantities is 1:1.29:2.47 with 0.4 w/c ratio. Water cement ratio 0.4 is including the wastage of water during the process of spinning which is nearly 10%. While spinning, excess water comes out and theoretical w/c ratio considered is 0.36.

6. Anti-crack Glass Fiber

Anti-crack glass fiber is alkali-resistant glass fiber especially developed for the reinforcement of cementatious mortars and cement concrete mix. The properties of anti-crack glass fiber given by supplier are as shown in Table 2. Technical specifications and parameters shown in Table 2 were given by the manufacturer of the anti-crack glass fiber.

Table 2: *Properties of Highly Dispersed Anti Crack Glass Fibers.*

Fiber	Density kg/cum	Elastic Modulus GPa	Tensile Strength MPa	Filament Dia. mm	Length mm	No. of Fibers Million/kg	Aspect Ratio	Specific surface area m^2/kg
Anti crack (HD)	2.60	72	1700	14	12	>200	857:1	105

Important Parameters of the Pole

The important design parameters adopted for the design of the pole were as below:

Length of the pole 13 m, working load 350 kg, ultimate load 700 kg, top diameter of the pole (OD) 206 mm, bottom diameter of the pole (OD) 379 mm, thickness of the pole 50~55 mm, weight of the pole 1374 kg.

Details of the reinforcement used are as below:

Prestressing steel: 3 mm × 3 ply – 12 nos.

Unmentioned steel: 4 mm × 6 no.

Prestressing force required for design load: 31620 kN

Total weight of steel in one pole: 39.61 kg

Methodology

To cast the PSC pole, following steps were **[6]** followed:

1. Mixing of Various Ingredients
The mixing of various ingredients of the concrete as per concrete mix design was done in a ready mixed concrete (RMC) plant established at the factory site, as per the normal procedure generally adopted.

***2. Mixing of Anti-crack Glass Fiber in the Concrete* [7]**
The anti-crack glass fiber is added in the given proportion, after thorough mixing of all the ingredients is completed to achieve uniform dispersion of fiber in the concrete mix. The mixing period of glass fiber is kept as 1 min. [8]. Anti-crack glass fiber shall not be added at the initial stage, as in dry mix there is a possibility of glass fiber to stick up to sand or aggregate and the uniform dispersion may not be achieved.

3. Casting of Concrete Cubes
The cubes of the size 150 × 150 × 150 mm were cast to ascertain the compressive strength of the concrete at various stages of prestressing. The cube test results without and with anti-crack glass fiber are tabulated in Table 3.

Table 3: *Cube Test Results*

Stage of Concrete	Compressive Strength of Concrete (without glass fibers) kg/cm^2	Compressive Strength of Concrete (with glass fibers) kg/cm^2
24 hours	265	270
7 days	380	390
14 days	535	550

Rate of addition of anti-crack glass fiber was comparatively low; no significant increase in the compressive strength was recorded after 24 h. However the strength at 7 days and 28 days was seen to have increased approximately by 2.5 and 3% respectively.

4. Manufacturing of PSC Tubular Spun Pole
Once the mix was prepared, the casting of the pole was done by spinning process. The spin cycle time was of 20 min and the rate of increase of spinning is as follows:
First 3 min @ 300 rpm, next 2 min @ 600 rpm, final 15 min @ 1200 rpm

5. Curing Practice
a. Steam Curing
1. Steam pressure: 3.5 to 5.00 kg/cm^2
2. Steam temperature: 65 to 70 °C
3. Steam cycle time: 2 h pre-heating + 6 h heating + 2 h pre-cooling.

b. Water curing cycle time: One day steam curing followed by 13 days water curing.

TESTING OF POLE AND DISCUSSION OF RESULTS

The important test to be carried out on the tubular spun pole was the bent test. It is a measure of deflection after application of horizontal load in a specific fraction and the increase to the design load. The deflection is further related to the cracking pattern and its behavior.

Procedure for Bent Test

While actual erecting of the pole on the site or at work place, the depth of foundation was considered as 2.15 m and the point of application of wind load (designed load in this case) was at a distance of 600 mm from the top of the pipe.

While taking the bent test, the arrangement was made such that 2.15 m length portion towards bottom side was anchored in the ground and load was applied at a distance of 600 m from the top with the help of chain pulley arrangement. The whole setup was then connected to a digital meter through electro-cell, which measures the applied load. A steel scale is provided towards the top end of the pole on which the deflection of the pole is measured for every load increment.

Table 4 shows the deflection recorded at design load and further increased load beyond design load. Also it indicates recovery of the deflection when the load is removed. The results are shown for the poles without use of glass fiber.

Table 4: *Recovery of the Deflection after Removal of the Load (Pole without GFR).*

Sr. No.	Load (kg)	Deflection (mm)	Deflection after removal of load(mm)	Recovery (mm)	% Recovery	Remark
1	350	112	-			No cracks seen
2	0 (removal of load)	-	12	100	89.29	
3	400	152	-			3 hair cracks seen
4	0 (removal of load)	-	15 (after one hour)	187	90	Hair cracks completely closed

Table 5 shows the deflection recorded for each loading increment and recovery at the end after removal of load. The increment of the increase of the load is generally considered as 10% of the design load, i.e., 35 kg in this case as the design load considered for the pole is 350 kg [6].

Table 5: *Deflection Results after Application of Horizontal Load.*

Sr. No.	Load (kg)	Deflection of pole Without glass fiber(mm)	Deflection of pole With glass fiber(mm)	Remark
1	35	12	3	
2	70	18	8	
3	105	21	13.5	
4	140	37	24	
5	175	45	33.5	
6	210	56	45	
7	245	67	49	
8	280	75	62	
9	315	90	75.4	
10	350	112	88	
11	0	12	2	After recovery
12	400	152	130	
13	0	15		After recovery
14	450		180	
15	0		8	After recovery

Table 6 shows the deflection recorded at design load and further increased load beyond design load. It indicates the recovery of the deflection when the load was removed. The results were shown for the poles with use of glass fiber. The photograph referred to in Figure 4 shows **c**rack after application of load greater than the designed load of the poles. On application of design load, no cracks shall appear on the surface of the pole. When the load is increased beyond design load, the cracks start appearing on the surface. However, the cracks shall disappear or close when the increasd load is removed. This is one of the acceptance criteria of the pole under consideration.

Table 6: *Recovery of the Deflection after Removal of the Load (Pole using GFR).*

Sr. No.	Load (kg)	Deflection (mm)	Deflection after removal of load(mm)	Recovery (mm)	% Recovery	Remark
1	350	88	-			No cracks seen
2	0(removal of load)		2	86	97.73	
3	400	130	-			4 hair cracks seen
4	450	180	-			5 hair cracks seen
5	0(removal of load)		8 (after one hour)	172	95.56	Hair cracks completely closed

The above tabulated results of deflections at various load increments, recovery of deflection after removal of load, both for poles with and without use of glass fiber, can be graphically shown as in the graphs given in Figure 1.

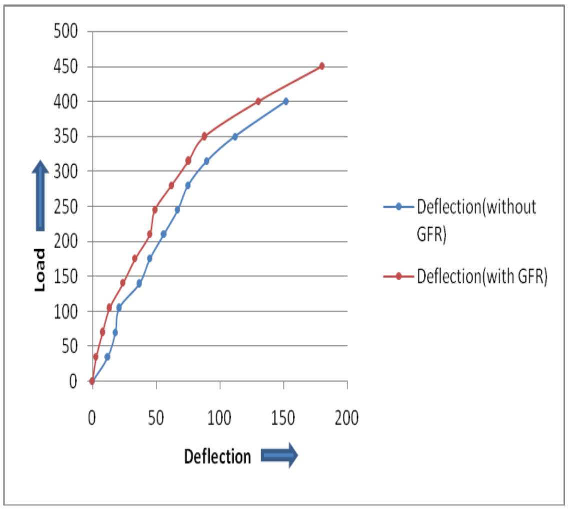

Fig. 1: *Graph of Load v/s Deflection(Deflection in mm on X axis and load in kN on y axis).*

In Figure 2, graphs showing variation of load versus recovery were plotted for the poles. The deflection of the pole goes on increasing with increase in the load. When the applied load is removed, the deflection is reduced. However some amount of deflection is retained even after the total load is removed.This is permanent deflection in the pole. The difference between the maximum deflection observed and permanent deflection is the recovery of the deflection. The difference between the two red points and two blue points on x-axis is the recovery of deflection for pole with and without GFR, respectively.

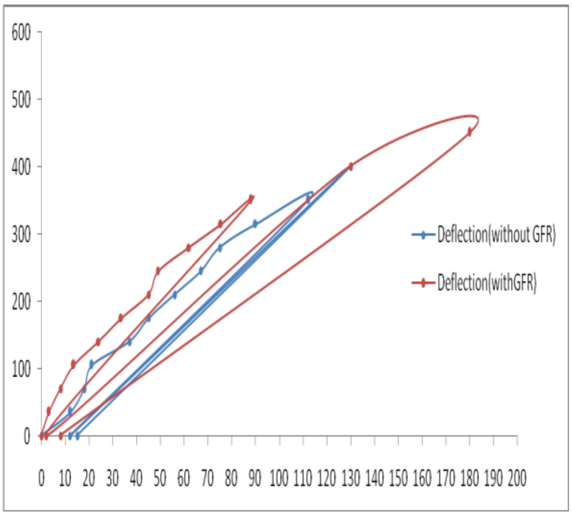

Fig .2: *Graph Showing Recovery after Removal of Load (Deflection in mm on X axis and load in kN on Y axis)*

The photograph refered to in Figure 3, shows stack of PSC spun poles. After completing curing period, the bent test is carried out on each and every pole by applying the required horizontal load, to study the deflection and cracking pattern, as discussed above. The pipes giving satisfactory results are finally accepted and stacked, as shown.

Fig. 3: *Photograph showing Stack of Pipe Ready for Dispatch.*

Fig. 4: *Photograph showing Crack after application of Load Greater than Design Load.*

RESULT ANALYSIS

1. Concrete Cube Test Results

From Table 3, it is seen that there is no significant increase in the compressive strength of the concrete using anti-crack glass fiber, added at the rate of 600 g/cum.

2. Deflections of the Pole

From Table 4, it is observed that the deflection of the pole is reduced when anti-crack glass fiber is added to the concrete.

3. Percentage Recovery of Deflection

From Tables 5 and 6, it is observed that percentage of final recovery of deflection in case of pole without adding glass fiber is up to 90%. In case of pole with glass fiber, final recovery of deflection is increased up to 95.58% (6.2% more).

4. Appearance of Cracks and Their Behavior

On application of design load, no cracks are observed for the pole without and with use of anti-crack glass fiber. When the load is increased beyond the design load, the hair cracks appear in both cases. After removal of load and after 1 h period, the hair cracks are seen disappearing in both the cases. However, the rate of closing of the hair cracks is comparatively fast in case of pole with use of anti-crack glass fiber.

CONCLUSIONS

1. From the load deflection curve, it was concluded that at every stage of increase of load the deflection of the pole cast using anti crack glass fiber was less than that of the pole without use of glass fiber.
2. With use of anti-crack glass fiber for PSC spun pole, after removal of load, the final recovery is more. This indicates that permanent deflection of the pole with anti-crack glass fiber is comparatively less.
3. With use of anti-crack glass fiber, the closing of hair cracks appeared on the pipe surface and took place within a shorter period as compared to the pole without use of anti-crack fiber.
4. There is no significant increase in the wet density of the concrete when anti-crack glass fiber is added to it in a lesser proportion.

REFERENCES

1. Technical paper on High strength glass fibers. *AGY*. 2006.
2. Gugal Yuwaraj M, Deshmukh Santosh B. Performance of alkali resistant glass fiber reinforced concrete. Journal of Reinforced Plastics and Composites, Composites. 2006; 25(6): 619–21, 623, 626–9p.
3. Swami BLP, Asthana AK, Masod U. Studies on glass fiber reinforced concrete composites-Strength and behavior. In: Ghafoori (Ed.). *Challenges, Opportunities and Solutions in Structural Engineering and Construction*. London: Taylor & Francis group; 2010; 601–4p. IBN 978-0-415-56809-8.
4. IS 1343-1980. *Indian Standard code of Practice for Prestressed Concrete*.
5. IS 456-2000. *Indian Standard Code of Practice for Plain and Reinforced Cement Concrete.*
6. IS 13158-1991. *Indian Standard Prestressed Concrete Circular Spun Poles for Overhead Power, Traction and Telecommunication Lines-Specifications*.
7. *Technical Specification Booklet.* Beton Concrete Products Pvt. Ltd. 2009-10.
8. Shakor Pashtiwan N, Pimpalikar SS. Glass fiber reinforced concrete used in construction. *AKGEC Journal of Technology*. 2009; 2(1): 58p.