# COMPARATIVE STUDY ON SETTLEMENT BEHAVIOUR OF FRP COMPOSITE PILES AND RCC PILES IN SAND

**Christymol Zacharia[1], Joe G Philip[2]**

[1]P.G. Student, Department of Civil Engineering, Saintgits College of Engineering, Kerala, India
[2]Assistant Professor, Department of Civil Engineering, Saintgits College of Engineering, Kerala, India

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**Abstract –** *Pile foundations are employed in areas where the soil strata below the superstructure is found to be weak or incompressible. Nowadays there is a need for an alternative material for pile especially when it comes to piles in harsh corrosive environment. Fiber composite materials are found to have high strength, stiffness and corrosion resistant. This led to introduction of new type of pile namely fiber reinforced polymer composite piles which is gaining value in civil industry. Fiber reinforced polymer (FRP) composites represent an alternative construction material for deep foundations that can eliminate most of the durability concerns associated with traditional piling materials. Research studies related to the use of FRP composite material for pile foundation is very limited. This project was undertaken to investigate the settlement behavior of concrete filled Glass fiber reinforced composite piles (GFRP) and RCC piles in sand. Laboratory model study on axial and lateral pile load tests is done. p- y curves are plotted to estimate the allowable load capacity of piles. Laboratory model study on axial and lateral pile load tests are done for piles with L/d ratios of 10, 12 and 15.Thereafter comparison of settlement behavior of both piles are done.*

***Key Words*: Pile load tests, polymer composite piles, static load tests.**

## 1. INTRODUCTION

Pile foundations are employed in areas having weak or compressible soils. The materials commonly used for pile construction are concrete, timber, steel etc. Fiber reinforced polymer composites represents a novel and attractive material in civil construction industry. Nowadays fibre reinforced polymer composite piles are employed in pile construction. The main advantage of these composite piles are these are more durable and have good strength qualities as compared to many traditional piles. Thus these are more advantageous when used as fender piles and in marine environments. The commonly used fibre reinforced polymer composite materials are carbon fibre, Glass fibre, Aramid fibre etc. Among these Glass fibers are found to be more economical and they are found to have appreciably high strength properties. The pile Piles transfer load from the superstructure to the soil below. The load bearing of piles is either by end bearing or friction or by combination of end bearing and friction.

In this study the axial and lateral load response of Glass fibre reinforced polymer piles are studied by conducting laboratory model study. The results are then compared with that of RCC piles. In order to conduct model study the prototype pile is scaled down by scaling law given by wood (2002). The bearing capacity of piles are found out by conducting load tests on piles with varying L/d ratios. Here, an experimental method will be discussed to determine the allowable load on piles by conducting laboratory tests.

## 2. LITERATURE REVIEW

**J .D Frost** [1999] studied the interface behavior of fiber reinforced polymer and sand. He found that interface friction between FRP and sand decreases as mean grain size increases. Interface coefficient also decreases with increase in surface roughness. Initial density of sand does not have much influence. They found that interface friction coefficient decreases with increase in normal stress. As angularity of material increases interface friction coefficient also increases. Rate of shearing has very small effect on coefficient of friction value. Thickness of the specimen is also found to have significant effect on friction behaviour of glass fibre polymer material and sand.

**Migual pando** [2003] studied the axial and lateral performance of three piles a prestressed pile, concrete filled composite pile and a polythene pile. The test program was conducted in the field. He found that axial stiffness of FRP pile and prestressed concrete pile are almost similar and it is about 2 and half times that of plastic pile. The prestressed concrete pile is found to have higher flexural stiffness than other 2 piles .In static lateral load test the behaviour of prestressed concrete pile and FRP pile was found to be almost similar and plastic pile exhibited much larger deflection for same lateral loads.

**Mohammed Sakr** [2012] conducted experimental study to determine the load transfer mechanism of fibre reinforced polymer piles in dense sand. The tests are conducted in both tapered ended and cylindrical polymer composite piles and steel piles. His findings concluded that the performance of fibre reinforced concrete piles and steel piles are almost comparable. Also tapered FRP composite piles was found to perform better than cylindrical FRP composite piles.

**R.Anandakumar** [2013] conducted a study to check the possible benefits of retrofitting piles using basalt fibers. Experimental studied are done on cubes, cylinders, prisms and rcc piles. He studied on the effect of both single wrapping and double wrapping. It is found from their study that conventional specimen posses only one by fourth of the compressive strength of the specimen in which basalt fibers are double wrapped. The split tensile strength of the doubly wrapped specimen is very high compared to conventional one. Also the flexure tests conducted showed that the flexural strength of specimens doubly wrapped with basalt is found to possess high flexural strength as compared to the conventional specimen.

**J. Giraldo** [2014] studied the pile performance of both carbon fibre polymer compoite piles (CFRP) and glass fibre polymer composite piles (CFRP) with different fibre orientations and results are compared with that of steel piles. They found that the surface nature of GFRP is found to have better performing than CFRP when it comes to be used as pile materials. As compared to steel piles both CFRP and GFRP piles is found to have high skin friction resistance and pile resistance. As compared to steel FRP is found to posses low stiffness thus they undergo much larger deflection in the lateral direction than steel piles when subjected to lateral loading. They also concluded that fibre orientation has a major role in determining the pile capacity.

**Kujtim Zyka** [2016] gives a brief description of nature of composite piles by giving details of history and uses of composite piles, their design considerations, durability and manufacturing methods. Their findings shows that FRP piles perform better than prestresses concrete piles in marine and corrosive environment Also the FRP material is said to be environmental friendly thus safe to use.

**Pedram sedeghain** [2017] studied the lateral behaviour of fiber reinforced polymer piles using finite element model analysis. He pointed that the orientation of fibers with respect to longitudinal direction is suitable as it results in higher strength and stiffness characteristics. Both material and geometric non linearity is considered in the model. A study on lateral displacement for each load increment at different depth of the pile is done.

## 3. MATERIALS

Foundation medium used is dry sand collected from Bharathapuzha Palakkad district, Kerala. Various laboratory tests were conducted to find the properties of sand like specific gravity, sieve analysis, permeability ,direct shear as per IS: 2720.The laboratory test results on sand are as follows :

**Table -1:** Properties of sand

| Sl no. | Properties | Value |
|---|---|---|
| 1 | Specific gravity | 2.6 |
| 2 | Dry density | 1.76g/cc |
| 3 | Permeability, k | 0.0136cm/s |
| 4 | Cohesion, c | 0° |
| 5 | Angle of internal friction | 33° |
| 6 | Coefficient of curvature , Cc | 1.37 |
| 7 | Uniformity coefficient ,Cu | 4.54 |
| 8 | % of fine sand | 21% |
| 9 | % of medium sand | 60% |
| 10 | % of coarse sand | 13% |
| 11 | % of Gravel | 6% |
| 12 | Sand type | SP |

## 4. METHODOLOGY

### 4.1 Pile types

The material used for GFRP piles are E glass fibre rovings and Isophtalic acid polyester resin. The tubes are made by filament winding technique. The tubes are then filled with concrete. The rcc piles are made by taking cement: sand in the ratio 1:1.5 and water cement ratio of 0.5. The diameter of piles taken are 4 cm. 2.5mm thick Glass fiber tubes with 4 cm diameter are filled with concrete.Diameter of RCC piles taken is 4 cm. Scaling of test set up is done as per wood[2002].The cement used is OPC 53 grade. The properties of cement used are follows:

**Table -2:** Properties of cement.

| Sl. no | Property | Result | IScode recommendation |
|---|---|---|---|
| 1 | Specific gravity | 3.15 | 3.12-3.19 |
| 2 | Standard consistency | 27% | 26- 33 % |
| 3 | Initial setting time | 45 min | >30 min |
| 4 | Final setting time | 300 min | <600 min |
| 5 | Fineness of cement | 7 % | < 10 % |

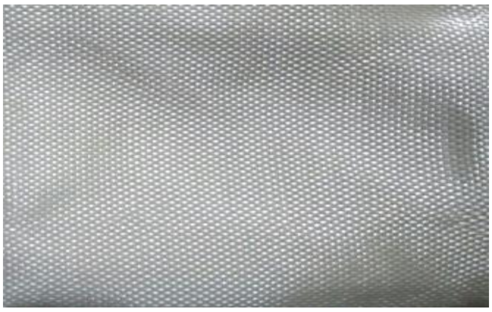

**Fig 1: E – glass fiber rovings**

### 4.1 Model tank

The dimensions of the model test tank adopted is 1m×1m×0.75 m. Fabrication of tank is done using mild steel materials. It is then connected to a detachable frame which has the facility of applying loads at axial and lateral direction. Also both vertical and horizontal dial gauges are provided in order to measure the horizontal and vertical deflection. The loading arrangement is made such that the load is applied manually. Thus the loading system consists of a handle for load application, a load transfer unit, and proving ring for measuring the load. Allowable bearing capacity of pile is estimated as the load corresponding to 10 % of pile diameter.

### 4.2 Foundation medium and pile installation

The sand is filled into the tank by rise and fall method. The falling height of the sand for filling tank is fixed by free fall method. By conducting free fall method a graph of sand density v/s height is drawn. The falling height is fixed such that by checking the heights which doesn't show much change in density. The tank is filled accordingly with this free fall density and piles are given as bored piles. Piles corresponding to different L/d ratios are installed. The l/d ratios taken are 60 cm, 48 cm and 40cm.

**Fig 2:** Model test tank and

Axial loading arrangement

**Fig 3:** Model test tank and

Lateral loading arrangement

## 5. RESULTS AND DISCUSSIONS

Axial and lateral Pile load tests are conducted in the laboratory for both glass fiber composite piles and RCC piles. The load settlement curves are plotted for both FRP and RCC piles and graphs are plotted.

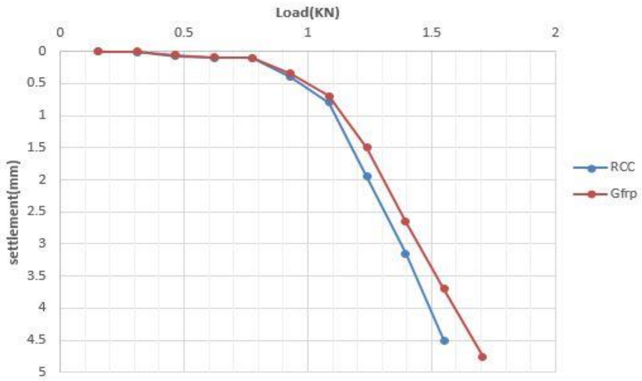


**Chart 1:** p-y curve for axial loading with l/D =15

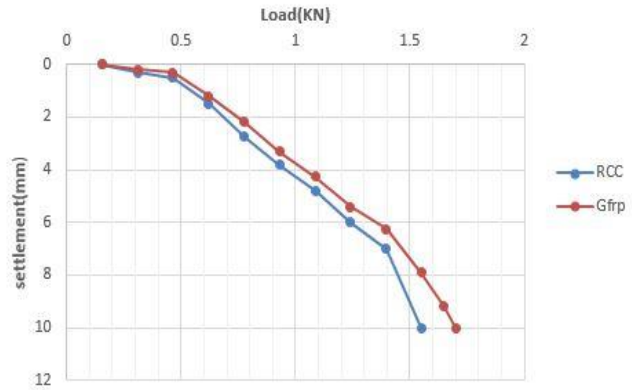


**Chart 2:** p-y curve for axial loading with l/D =12

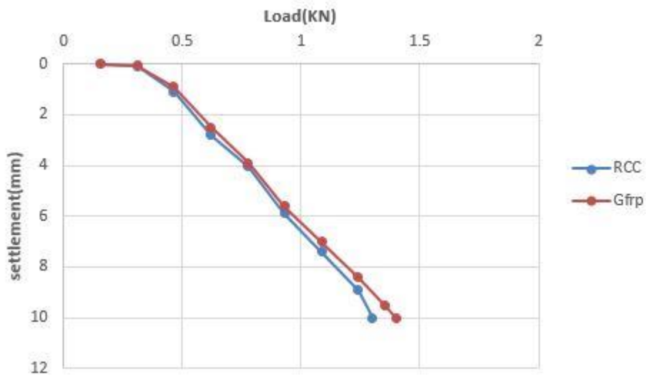


**Chart 3:** p-y curve for axial loading with l/D =10

Load settlement curves are plotted. For equal load increment variation in settlement behavior of each of the pile are noted and allowable settlement is taken as load corresponding to 10% of pile diameter. Similarly Lateral load v/s lateral displacement curves are plotted for lateral loading tests in the lab as follows:

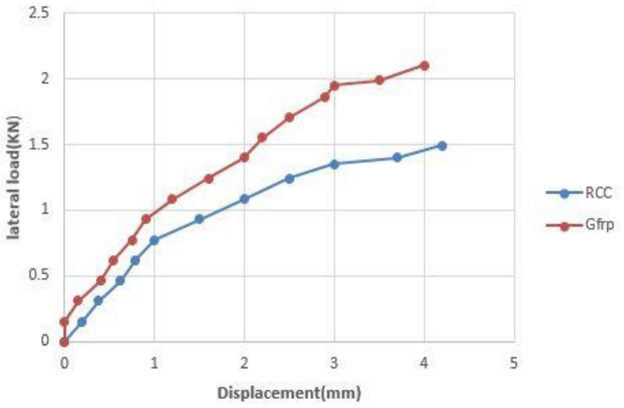


**Chart 4:** p-y curve for lateral loading with l/D =15

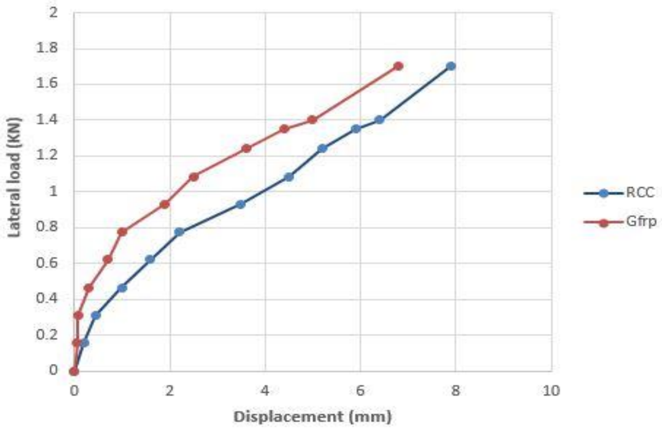


**Chart 5:** p-y curve for lateral loading with l/D =12

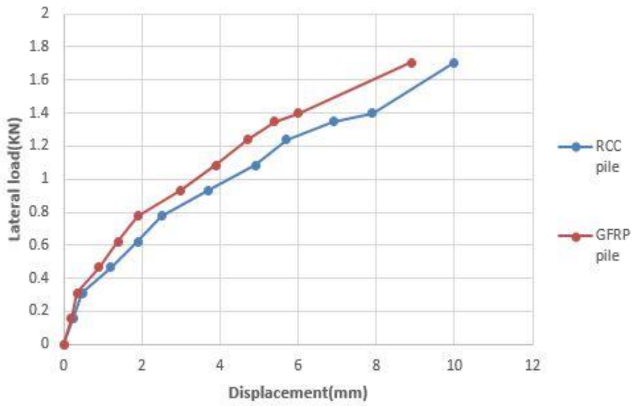


**Chart 6:** p-y curve for lateral loading with l/D =10

Based on the values obtained, experimentally p-y curves are plotted. From p-y curves GFRP piles are found to be better performing than RCC piles especially during lateral loading.

## 6. CONCLUSIONS

- For axial loading load deflection response of GFRP piles are almost similar to that of RCC piles.
- The lateral load deformation response of FRP piles are higher than that of RCC piles. Allowable lateral load capacity of model GFRP piles is 1.2 to 1.4 times to that of RCC piles.
- Increase in allowable load capacity is due to increased flexural rigidity of GFRP piles.
- Increment in load capacity with increase in L/d ratios is due to increasing passive resistance of soil with increase in pile length.

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