Experimental Study of Prefabricated Steel Cage Columns Infilled Banana Stem Fiber Concrete

Abdul Rahim T.H. and Amritha E. K.

Abstract - Prefabricated steel cage is a hollow rectangular section fabricated by perforating steel tubes or connecting steel angles and steel plates. PSC columns placed externally and infilled with banana stem fiber concrete. Reinforcement functions as both the longitudinal angles and transverse plates connected monolithically and working compositely with the banana fiber concrete to resist loads applied and to get good confinement. PSC columns attained its consequence over normal RCC structures and HSS structures because of its structural properties like high axial strength, good fire confrontation, superior ductility, construction easiness and economy. Concrete delay the local buckling of hollow steel section and consequently improves the ductility of the section. PSC columns can be used to reinforce almost any kind of structural members as concrete filled steel tube (CFST) members. In this project, I had done the comparison of the behaviour of PSC columns infilled with banana stem fiber concrete, hollow PSC columns and conventional RCC columns under uniaxial compressive loads. A total 12 specimens were tested inorder to investigate the behaviour of PSC columns. Test results indicate that PSC columns have comparable axial capacities with lower displacement deformation than rebar reinforced specimens. It is cost and time savings occur due to faster construction and can easily strengthened by joining steel plates outside.

Index Terms—: Prefabricated steel cage column, Concrete filled steel tube column, Banana stem fiber, Compression member

1 Introduction

Reinforced concrete, a composite material consisting of steel and concrete, is commonly used in the construction of buildings and other structures, and has been for many decades. Concrete, by itself, is very strong in compression but very weak in tension. Steel is strong in both tension and compression. The benefit from concrete comes from its relatively low cost compared to steel. When a small amount of steel is added to a concrete member in the tension zone, the result is a load bearing member that is strong in both tension and compression. While reinforced concrete is used in the construction of a variety of different structural members, such as shear walls, footings, columns and retaining walls, one of its most common applications is in the construction of columns.

The application of reinforced concrete in rectangular columns will be examined in this research project. Recently an alternative method, known as prefabricated cage system (PSC) reinforcement, has recently been proposed. For the purpose of this research project only two methods, rebar and PSC infilled with fiber concrete, will be tested and compared. In a traditional reinforced concrete column, a reinforcing cage is formed using steel bars known as rebar. The cage consists of two types of bars; longitudinal, which carry any compressive or tensile loads, and transverse, which serve to confine the concrete inside of the reinforcement, known as the core concrete. Prefabricated steel Cage System (PSC) reinforcement is a monolithic reinforcing cage constructed from a hollow steel tube. A grid is cut into the tube through the use of a laser, resulting in a reinforcing cage that is very similar to a rebar cage. Various methods could be used to fabricate PCS reinforcement such as; punching, cutting methods, and casting.

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PCS reinforcement is prefabricated off-site and then placed inside the formwork eliminating the time consuming and costly labor associated with cutting, bending, and tying steel bars in traditional rebar construction.

A rapid increase of high rise building is found because of the increase in urbanization and shortage in land availability. The major difficulty in design of such high rise buildings is the larger gravity and lateral loads. PSC columns can be used as a substitute for RCC and steel columns in case of high rise buildings. PSC column members are connected to steel or reinforced concrete beam to form a combined frame system. Use of PSC column members in frame system of high rise buildings reduces the cost of construction. Also with its enhanced ductile behavior, PSC frame systems serves better on high rise buildings in seismic prone areas.

Various types of bridges like arch bridges, cable bridges, suspension bridges etc. are there using PSC columns as piers and briges towers. Ease in erection of hollow tubes saves the construction time and cost. PSC infilled with concrete have more load carrying capacity and ductility than reinforced cement concrete structures.

1.2 Objectives and Scope

Two steel reinforcement methods, rebar and PSC, are to be test through the testing of small-scale columns. The test columns are to be loaded under axial load to failure at a constant rate of approximately 0.004 in. / sec. The axial load versus deflection performance for each column will be recorded. Certain responses throughout the testing process will be marked, such as the first appearance of cracking, spalling of the cover concrete, yielding of the steel reinforcement and fracture of the transverse reinforcement. The behavior of the PSC fiber reinforced columns will be compared to the behavior of the rebar reinforced columns, in order to determine the advantages and disadvantages of each method. This project will consist of two test groups, four PSC samples with four rebar sample. PSC columns to the corresponding rebar column to determine how the strength and deflection of PSC reinforcement compares to rebar reinforcement of equal cross-sectional areas of steel.

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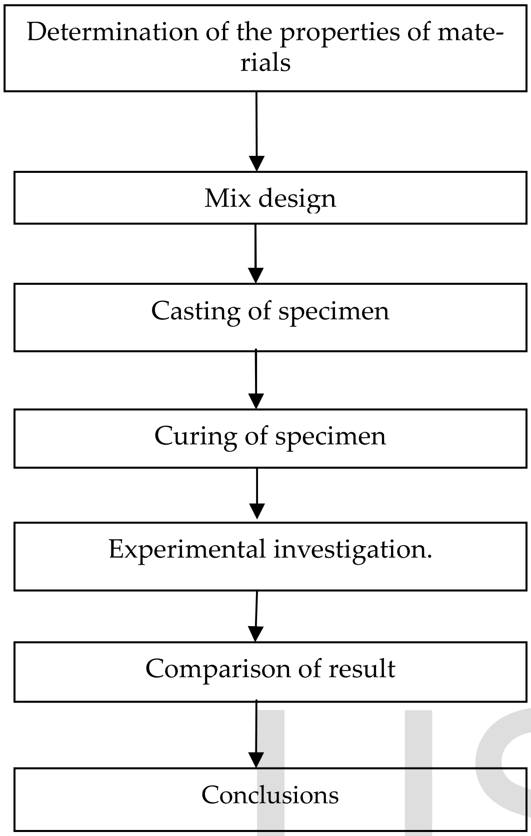
2 Methodology



3 Materials

3.1 Normal Concrete & Banana Stem Fiber

The normal strength concrete on compression zone is self-compacting concrete. Self-compacting concrete or simply SCC is also called as self-leveling concrete, self-consolidating concrete or vibration free concrete. SCC is highly flowable, non-segregating and cohesive concrete which can spread and fill the formwork with reinforcement by means of its self-weight. High deformability, low yield stress, moderate viscosities are the important parameters of self-compacting concrete, which ensure the uniform suspension of solid particles during the process of manufacturing of concrete. Self-compacting concrete are generally used for casting complicated or heavily reinforced sections, raft foundations, retaining walls, pile foundations, repair, restoring and for renewal works. Banana stem fibers are used to reinforce concrete inside and to get good confinement. Diameter of fiber is less than 1mm and length of the fiber is 50 mm.

3.2 Material Properties

Properties of material used in this study were obtained either by testing of the corresponding material or by referring the user's manual provided by the Manufacturer. Properties of materials are mentioned in following table 1, 2, 3 and properties of concrete are mentioned in table 4.

TABLE 1
PROPERTIES OF CEMENT

PROPERTIES OF CEMENT	
Specific gravity	3.1
Consistency	32%
Fineness	1.3%
Initial setting time	150 minutes
Final setting time	360 minutes

TABLE 2
PROPERTIES OF FINE AGGREGATE

PROPERTIES OF FINE AGGREATE	
Specific gravity	2.67
Water absorption	1.9%
Grain size distribution	3.81
Grading zone	II

TABLE 3
PROPERTIES OF COARSE AGGREGATE

PROPERTIES OF COARSE AGREGATE	
Specific gravity	2.87
Grain size distribution	6.16

TABLE 4
PROPERTIES OF CONCRETE

PROPERTIES OF CONCRETE	
Slump	75 mm
Average 28 days Compressive strength	29.4 N/mm^2

4 MIX DESIGN

For reinforced cement concrete column and prefabricated steel cage columns is filled with same mix of concrete and banana stem fibers are added extra to this mix in PSC columns. The mix design proportions are given in table 6.

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TABLE 5
MIX DESIGN DETAILS

MATERILAS	COMPOSITION /m^3
Cement	417.15 kg
Water	208.57 kg
Fine aggregate	878.43 kg
Coarse aggregate	908.04 kg
Mix proportion = 1: 2.1: 2.17	

5 EXPERIMENTAL INVESTIGATION

5.1 General

The intend of these experimental programme is to study the behaviour of Prefabricated cage column infilled with fiber reinforced concrete and reinforced cement concrete column for short columns with emphasizes on the ultimate strength, ductility, axial deformation and failure mode. A total 6 square PSC column and 6 RC columns were casted and had been tested under concentric axial compression. The specimens were tested after the infill concrete attained the required 28 day strength. The results are compared and discussed.

5.2 Materials Used

The materials used for the preparation of PSC columns infilled with banana stem fiber concrete specimens are 4 angles 100x100x3 mm placed corners and welded 3 mm plate welded transverse direction, M-sand as fine aggregate, 20mm crushed stones as coarse aggregate, Portland Pozzolana Cement as cementitious material and banana stem fiber 1mm diameter and 50mm length.

5.3 Column Specimen

In order to determine the effect of prefabricated steel cage column infilled with banana stem fiber and normal reinforced cement concrete column with normal cement concrete were casted and tested. The results were then compared i.e., compressive strength and vertical deformation of column specimens. Columns of size 150 mm x 150 mm x 600 mm were used for the experiment. A total of 12 specimens were casted and tested. Main rebars of reinforced cement concrete columns are 10mm and 8mm stirrups 150mm c/c. Prefabricated steel cage columns Size are same 150 mm x 150 mm x 600 mm and 4 numbers 100 mm x 100 mm x 3 mm angles and 100 mm x 3 mm plate welded to angles.

5.4 Preparation of Specimen

The required quantities of cement, fine aggregate, coarse aggregate and water was taken for the specimens. Initially cement, fine aggregate and coarse aggregate was hand mixed in dry state for about 2 minutes. The measured quantity of water was added stage by stage. Then prepare M20 mix. The mould was prepared by applying oil on all contact surfaces. Reinforcement cage was placed in the column moulds with suitable cover blocks. In case PSC column steel cages are provided outside of column. Therefore cages are provided in formwork without cover block.

FIG 1 RCC COLUMN REBAR & PSC ARRANGMENTS

The mould was filled with the prepared concrete mix with uniform compaction. Casting of specimens was done in two layers and each layer properly compacted using a tamping rod. Proper surface finishing was also done. The specimen after 24 hours of casting, were demoulded and kept for curing. The casted specimens were demoulded after 24 hours and were subjected to water curing for a period of 28 days. Columns after strengthening were subjected to compressive strength test. The deflection of the column was determined by attaching a dial gauge at the bottom of the support column. For testing of the specimens, the supports were provided at a centre of the column. Compressive strength readings are taken at specified interval of the dial guage reading.

The compressive strength of column is tested with compressive testing machine. The behavior of column from beginning to the failure was observed carefully. The loading of the column was terminated just on the verge of collapse. The development and propagation of first crack was observed keenly. The values of applied loads and the corresponding deflections were noted and the load-deflection curve is plotted which is taken as the output. The load is applied uniformly perpendicular to the column and is incremented up to the breaking point or failure of the material.

FIG 2 PSC COLUMN AFTER FORMWORK REMOVAL

6 TESTING AND INSTRUMENTATION

Columns after curing were subjected to compressive strength test. The test setup consists of a compressive strength testing machine. The deflection of the column was determined by attaching a dial gauge at the top of the column support. The compressive strength of column is tested with centre point with the help of compressive testing machine. The behavior of column from beginning to the failure was observed carefully. The loading of the column was terminated just on the verge of collapse. The development and propagation of first crack was observed keenly. The values of applied loads and the corresponding deflections were noted and the load-deflection curve is plotted which is taken as the output. The load is applied uniformly perpendicular to the column and is incremented to the breaking point or failure of the material.

FIG 3 TEST SETUP

7 EXPERIMENTAL TEST RESULTS

Various results were derived from the two point loading test of Reinforced Concrete columns. The results include load deflection behavior, ultimate load carrying capacity, ultimate deflection, crack patterns and failure modes. It is observed that the strengthening of columns provide additional stiffness to the columns. The values of loads and corresponding deflections of PSC columns and RCC columns are given in Table 6.

TABLE 6
TEST RESULTS

SL NO.	DESIGNATION	EXPERIMENTAL RESULT	
		LOAD (KN)	DEFORMATION (MM)
1	PSC 1	575	11.25
2	PSC 2	560	11.5
3	PSC 3	570	11.75
4	PSC 4	575	10.50
5	RCC 1	375	10.25
6	RCC 2	425	10.10
7	RCC 3	475	9.25
8	RCC 4	430	10.40

All the specimens show a straight line relationship between applied load and corresponding deflection up to cracking load. The deflections are found to increase rapidly with considerable deviation from linearity after cracking until failure of the column. The load Vs deflection curves for PSC columns and RCC columns are given in Figure 4 and Figure 5. It can be observed that the PSC columns are stiffer compared to RCC columns. The curves for all the PSC columns showed similar response in the initial stage of loading till the formation of first crack. But with the increase in load, a variation was observed.

7.1 Load Carrying Capacity

The initial crack loads for PSC columns are higher than that for RCC columns, i.e., for PSC columns the initial crack has occurred at higher loads. For RCC specimens, the load carrying capacity of columns is reduced after the formation of first crack. The appearance of first crack occurs at a lower load for RCC specimen compared to PSC. No peeling or debonding of glass wrap was observed; even at failure. The graph comparing the initial crack load and failure load is shown in Figure 6. The values of ultimate load carrying capacity of PSC column is more than RCC specimens.

7.2 Ultimate Deflection

The ultimate central deflections for the column specimens were noted. It was observed that the ultimate deflections for PSC and RC specimens were the almost same; using dial guage reading.

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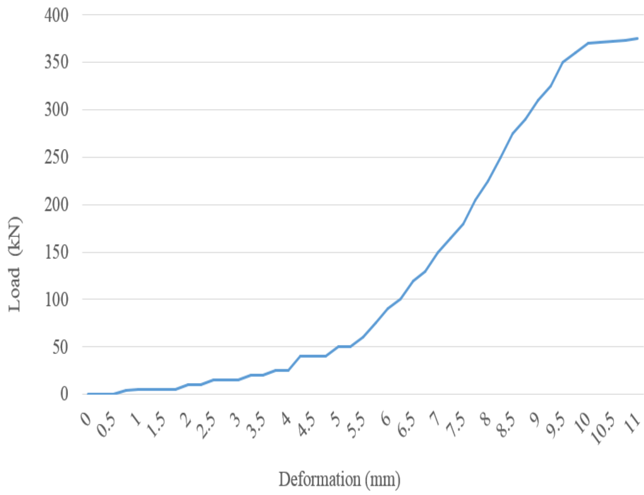

FIG 4 LOAD VS DEFLECTION CURVE OF RCC COLUMN

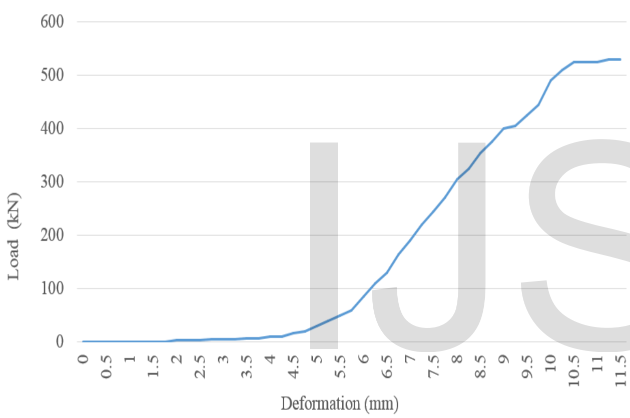

FIG 5 LOAD VS DEFLECTION CURVE OF PSC COLUMN

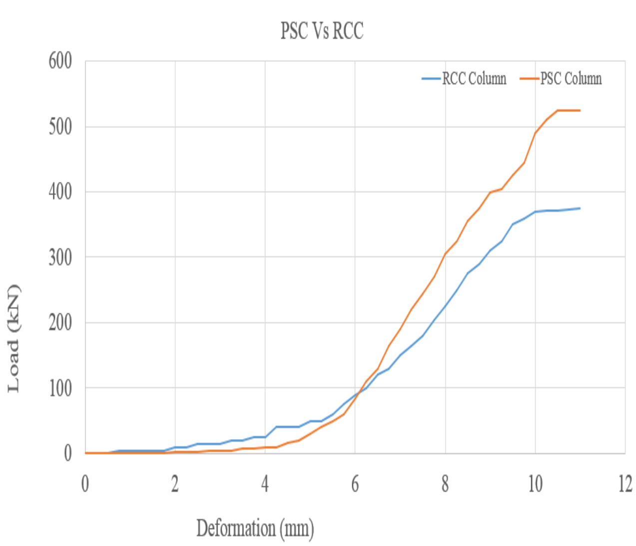

FIG 6 LOAD VS DEFLECTION CURVE COMPARISON PSC & RCC

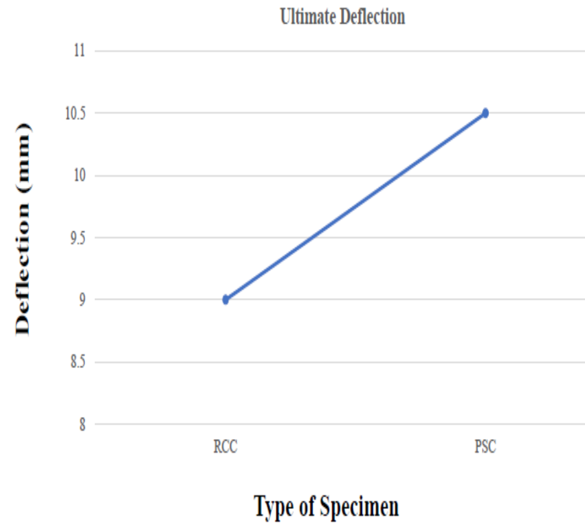

FIG 7 ULTIMATE DEFLECTION COMPARISON PSC & RCC COLUMN

7.3 Crack Patterns

During the test, cracks were initiated from the top face of the column and propagated upwards towards the bottom side of the column. As the load increased, more cracks were initiated and propagated. The number of cracks occurred, length of crack and its propagation pattern, width of crack and the spacing between cracks which occurred was different for each strengthening technique.

FIG 8 CRACKING OF SPECIMEN

All the column specimens showed an increase in initial crack load when compared to PSC and RCC specimen. In all the cases, the crack concentration was located in top region. Cracking loads for first, second and third cracks in all the tested specimens are found. The formation of cracks showed a similar pattern for PSC and RCC columns. The graph showing cracking loads of column specimens are shown in Figure.

7.4 Failure Modes

All the specimens were designed for compressive failure. The PSC and RCC specimen failed through pure compressive failure by the development of cracks. Rupture of bottom of column or crushing of concrete at top of column was not observed till failure.

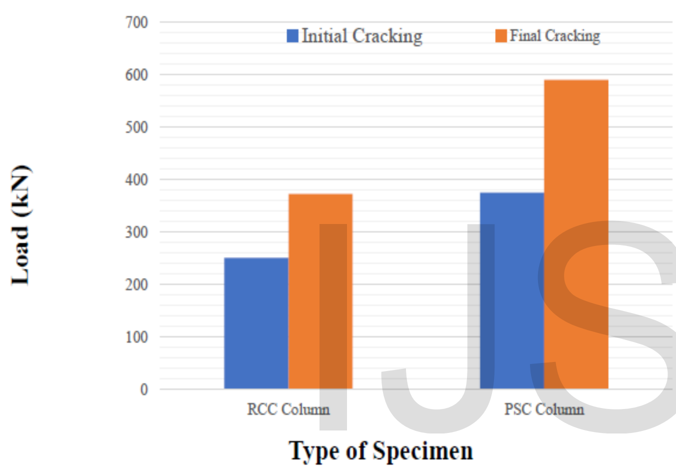

FIG 9 INITIAL AND FINAL CRACKING

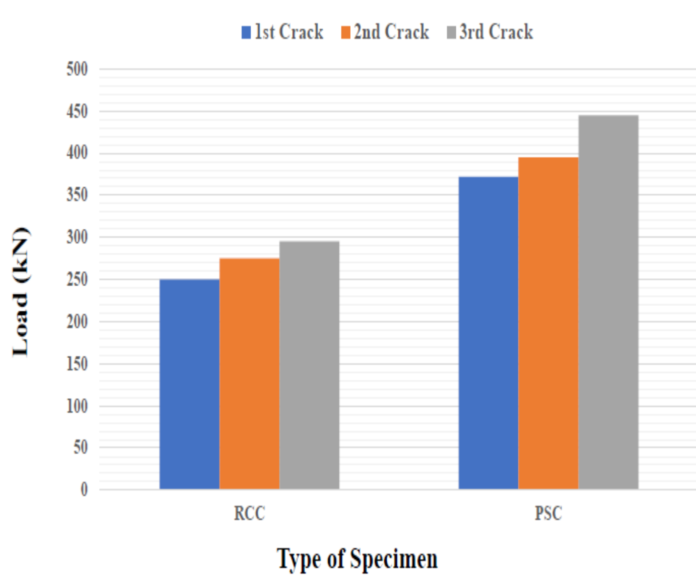

FIG 10 CRACK LOADS OF RCC AND PSC COLUMN

8 CONCLUSIONS

With reference to the experimental study carried out through the work, contain conclusions are drawn. They are summarized as follows:

- PSC columns have comparable axial capacities with lower displacement deformation than RCC columns.
- RC Columns without fiber concrete starts cracking at lower loads, and the cracks continue towards from top to bottom of columns.
- Load deformation curve of prefabricated steel cage column infilled with fiber reinforced concrete clearly indicated improved ductility when compared to reinforced columns and hollow PSC columns. Short columns were found to fail by crushing of concrete accompanied by the yielding of steel. When the concrete filled steel tubular short columns are loaded axially, formation of bulges was observed at the top of the specimen which was observed to be a trait in short column alone.
- Cost and time savings due to faster construction of PSC columns infilled fiber concrete than reinforced concrete column.
- It can easily strengthened by joining steel plates outside by welding or bolting than RC columns.
- According to the experimental results, it is found that additional of fibers reduce cracks width of concrete and its post-cracking load carrying capacity.
- Formwork requirement is less for PSC columns than Rc columns.

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