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ANALYSIS OF CONCRETE FILLED CFRP TUBE

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ABSTRACT

Reinforced concrete is used as a structural material for construction of buildings, harbours and dock piles in many marine locations. Structures located in coastal regions frequently suffer from corrosion phenomena. Corrosion is one of the basic factor that constitutes the degradation of reinforced concrete (RC) structures. The ingression of chloride ion into the RC structures leads to the premature failure of in-service structures. A study on structural performance deterioration of marine RC structures affected by rebar corrosion in Kozhikode was conducted. To address this vexed question, Concrete Filled CFRP tubes (CFCFRP Tubes) can be introduced in marine regions due to its superior corrosion resistance. CFCFRP tubes are composite members which consists of a hollow CFRP tube infilled with concrete. In this structure CFRP tube provides lateral confinement to concrete core. At the same time, the concrete core prevents the CFRP tube from local buckling. In this study, the comparative analysis of RC Column, Concrete Filled Steel Tubes (CFST columns), CFRP Ring Confined CFST columns and CFCFRP Tubes is done by considering buckling and dynamic loading in ABAQUS Software. From these results it can be concluded whether CFCFRP Tubes can be used as piers in marine environment. Considering the future scope, CFCFRP Tubes can also be used as piles in offshore structures.

Keywords - Corrosion, CFCFRP Tubes, Buckling, Dynamic Loading, Deformation.

1. INTRODUCTION

In aggressive marine environment the corrosion of reinforced concrete (RC) structures due to the ingression of chloride ion leads to the deterioration of the in-service structures. The cost of repair of the deteriorated structures is significantly high. To overcome this issue various studies have been conducted on the use of Fibre Reinforced Polymer in civil engineering structures.

Ali Raza et. Al. Conducted Numerical Investigation of Load Carrying Capacity of GFRP Reinforced Rectangular Concrete Members using ABAQUS software [1] to propose a model which accurately simulates the behaviour of reinforced concrete and to validate it with previous results. They also compared the behaviour of 13 steel and GFRP reinforced rectangular concentric and eccentric columns each of which were subjected to identical axial load. As a result, GFRP was selected due to its high resistance to corrosion and high strength. The results showed that the FE model that was suggested was in agreement with the experimental and theoretical results and could be used for analysis on columns in the future. Neetu Devi Singh and Anurag Wahane had analysed CFST of different size [2] , where the steel tube of thickness 1mm shows much higher displacement or deformation comparing to steel tubes of thickness 5 mm. And they have also concluded that the CFST columns having size 250 mm having deformation 0.056mm is approximately 30% more than that of 160mm. Therefore, greater the slenderness ratio, lesser the deformation in CFST columns. And greater the size of CFST column, lesser the deformation in steel tube columns. After the complete study on CFST, they have came to a conclusion that the CFST columns are performing better in terms of deformation compared to RCC columns due to outside steel shell in CFST.

The main objectives are:

- To model and analyse the Concrete Filled CFRP Tube columns.
- To design and compare RCC column, Concrete Filled Steel Tube (CFST) columns and CFRP ring confined CFST columns with CFCFRP Tubes.
    - To understand the reliability of CFCFRP Tubes in offshore construction works.

Concrete Filled CFRP (Carbon Fiber Reinforced Polymer) tubes (CFCFRP Tubes) are composite structures in which outer CFRP tube is infilled with concrete. The benefit of this composite structure is that the outer CFRP tube provides confinement to the concrete core and the concrete core provides stability to the tube, thus delaying the buckling phenomena.

The CFCFRP Tubes are recommended as it have superior corrosion resistance and improved load carrying capacity than normal RC columns. It also have other properties like low maintenance cost, easy implementation, light weight, high resistance to being deformed and low thermal expansion.

In this analysis apart from RC column, the CFST columns are considered, as CFST columns have similar structural composition as that of CFCFRP Tubes i.e. outer steel tube is infilled with concrete. The main advantage of using CFST column is that it has increased load carrying capacity as that of RC columns. But despite of this advantage it is not prominently used because the outer steel tube is prone to corrosion. To prevent this corrosion CFRP wrap can be used around the steel tube. But the risk with CFRP confined CFST column is that any manual error during the wrapping process using epoxy can trigger corrosion and can lead to the collapse of a high load demanding structure. So CFCFRP Tubes can be recommended because it will have high load carrying capacity along with corrosion resistance.

2. METHODOLOGY

2.1 Study on offshore structures

The offshore structures at KOZHIKODE (Old Sea Bridge) was analysed. On October 1st 2019, a portion of the Old Sea Bridge collapsed with a count of 13 people injured. The cause of failure of the bridge was the reduced strength of the structure due to the rebar corrosion caused by the adverse marine environment.

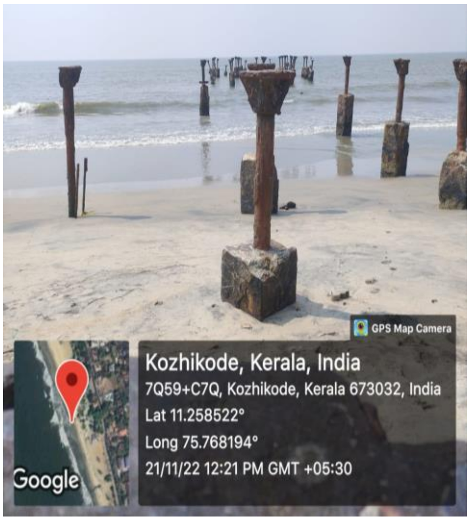


Fig.1 Structural deterioration of Old Sea Bridge

2.2 Development of models in Abaqus software

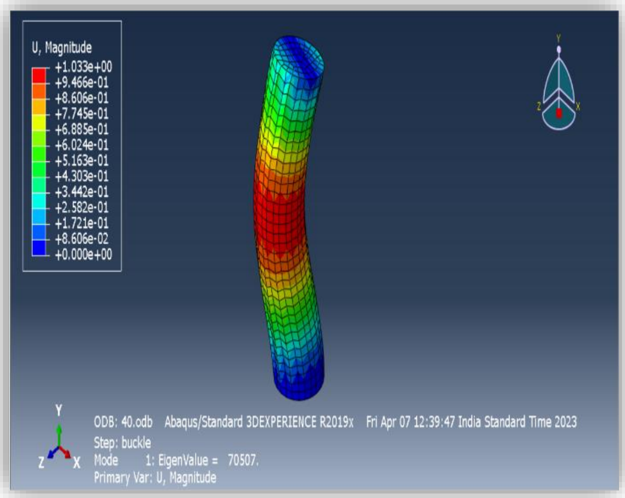
Numerical simulations of concrete filled CFRP tubes, RC column, CFST columns and CFRP ring confined CFST columns were done using the ABAQUS Software.

2.2.1 Model Geometry

The concrete core was modelled as homogeneous 3D solid structure with a diameter of 150 mm and 675 mm height. For RC columns a cover of 20 mm was provided. Rebars used are of 20 mm diameter and stirrups 6 mm diameter. All parameters are designed as per the code IS 456.The steel tube in CFST column was designed as homogeneous 3D solid with a thickness of 5mm.For CFRP ring confined CFST Columns the wrapping was provided through homogeneous 3D shell with shell thickness of 2mm.The CFRP tube was provided with a thickness of 10mm.The concrete mix used was M40 grade. Mild steel tubes with density of 7850 kg/m^3 was designed. The concrete damaged plasticity model values and properties of CFRP wrap was obtained from [3] and [4] respectively.

2.2.2 Boundary conditions and Loading

All columns were fixed at the bottom surface and for the buckling analysis a load of 1KN was provided in the Y direction. For dynamic explicit model a load of 1 KN was given in the Y direction to get the corresponding deformation.



The boundary condition was applied to the surface using the coupling constraint. The embedded region constraint was provided for the RC column to define the bond between the concrete, rebar and stirrups. The interaction between concrete and steel tube was defined using master and slave surface. The outer surface of concrete was taken as master surface and inner surface of steel was taken as slave surface for the analysis. Meshing was provided with a mesh size of 20 mm.

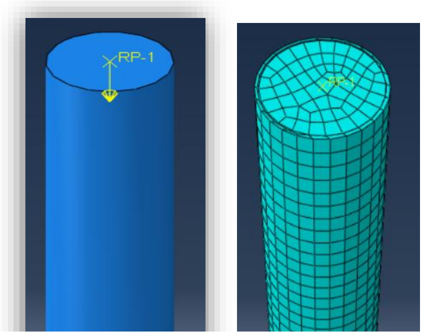


Fig.3. Buckling analysis of (a) RC Column (b) CFST Column (c) CFRP ring confined CFST column(d) CFCFRP Tube

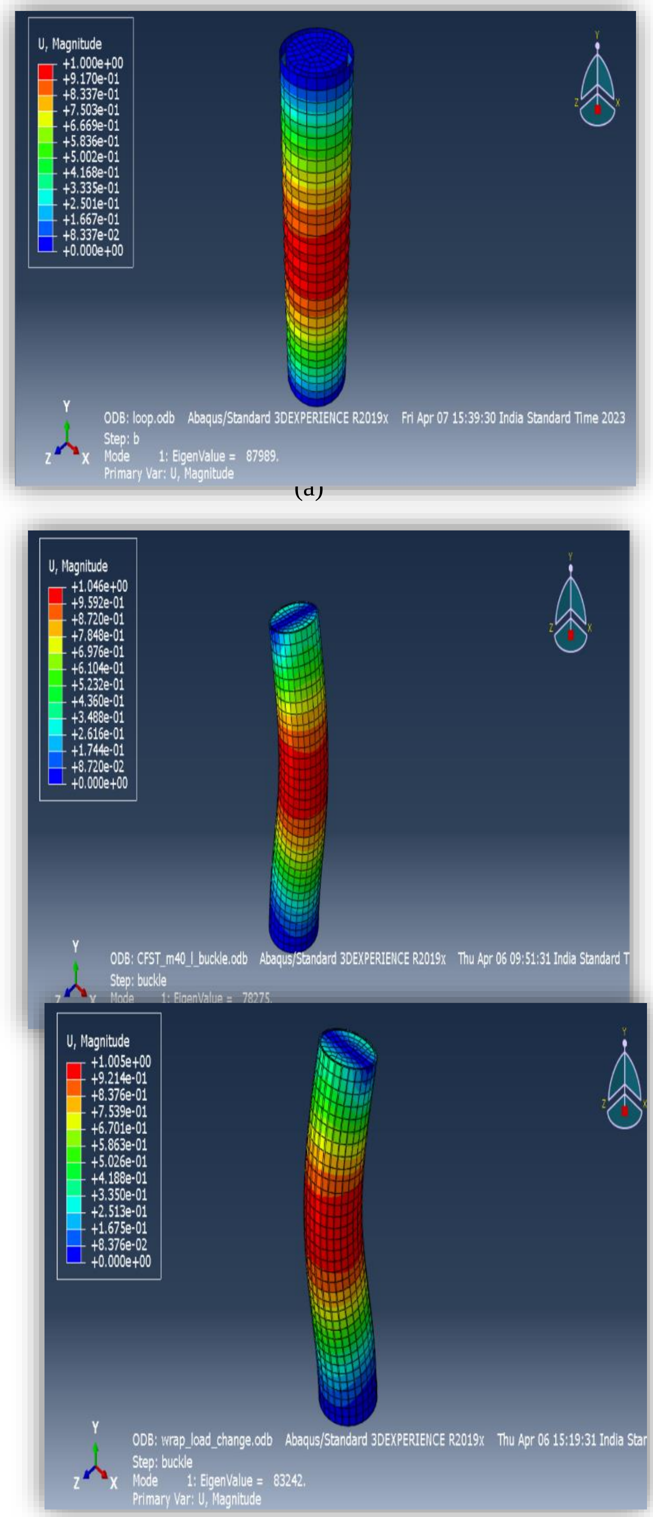
(a) (b)

3. RESULTS AND DISCUSSIONS

After the analysis in the ABAQUS Software a comparative study on the modelled structures was done considering the critical buckling load and the deformation upon dynamic loading. If the load carrying capacity of CFCFRP Tubes is approximately equal to or greater than the other models and the deformation is approximately equal to or less than other columns then it can be concluded that the CFCFRP tubes can be recommended for marine construction works. Critical buckling load is the maximum load that a column can withstand when it is on the verge of buckling.

3.1 Critical Buckling Load of Columns

The critical buckling load is obtained when the eigen value from buckling analysis is multiplied with the applied load. The following are the results of the FEA analysis:



(a)

(c)

Load

The critical buckling load of CFCFRP TUBE is 87989 KN which is greater than the other three models. When compared with RC column the critical buckling load increases by about 11.02% for CFST columns,18.06% for wrapped columns and 24.79% for CFCFRP Tube columns. This indicates that the CFCFRP TUBES are having an increased load carrying capacity than the RC column, CFST Columns and CFRP confined CFST columns.

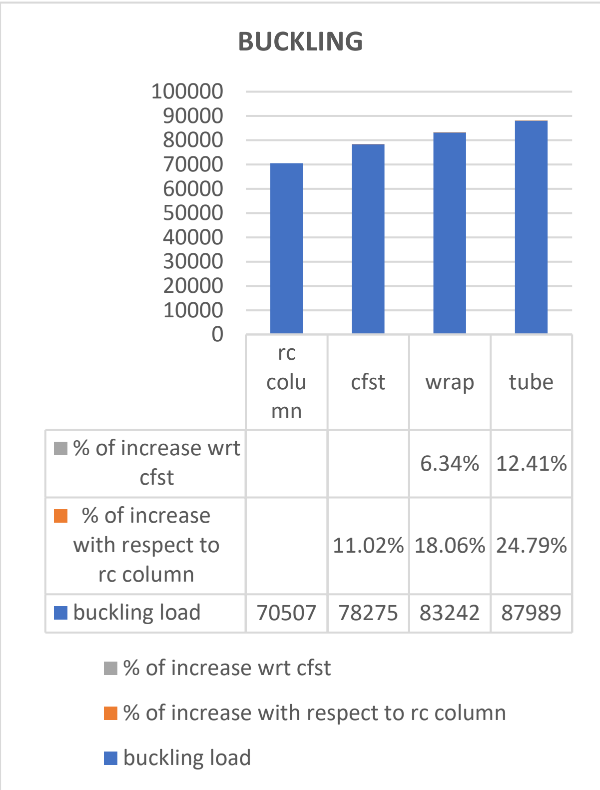


Fig.4. FEA result of Buckling analysis

3.2 Dynamic Loading of Columns

This analysis shows that upon dynamic loading the maximum deformation is obtained for RC column which decreases with CFST columns, CFRP ring confined CFST column and CFCFRP tubes. It can be concluded that the least deformation is obtained for the CFCFRP Tubes when compared with the other columns.

Fig.5. FEA result of dynamic loading

4. CONCLUSION

In this research paper a comparative study on RC

columns, CFST columns, CFRP ring confined CFST columns and CFCFRP TUBES was done on the basis of critical buckling load and deformation. This analysis was done to understand the reliability of CFCFRP Tubes in offshore construction works with respect to other columns.

Based on the results the following main conclusions were made:

- The critical buckling load increases from 10 - 15% for CFST column, 16 – 20% for CFRP ring confined column and 22 – 26% for CFCFRP tubes when compared with RC columns.
- The percentage of increase in critical buckling load of CFCFRP tube is about 13% than CFST columns which indicates an increased load carrying capacity of CFCFRP Tube when compared with CFST.
- The maximum deformation of CFCFRP Tube upon dynamic loading is less than RC columns, CFST columns and CFRP wrapped columns.
- According to the analysis CFCFRP Tubes have the highest load carrying capacity and minimum deformation along with it's superior corrosion resistance and can be implemented in offshore construction work.
- Considering the benefits and reliability of CFCFRP Tubes and considering the future scope these tubes can be used for pile construction works.

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