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ANALYSIS OF SELF-CENTERING FRAMES COMPOSED OF PRECAST POST-TENSIONED CONCRETE COLUMNS

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Abstract - *This project studied the performance of continuous and segmented precast post-tensioned concrete columns confined by fiber reinforced polymer (FRP) tubes used to construct moment resisting frames that were 1524 mm high and 2083 mm wide. Four un-bonded post-tensioned frames constructed using precast members were designed to re-center in the direction of the original position after lateral loading. The columns were 203 mm in diameter and 1143 mm in clear height. The FRP columns were composed of either continuous 1143 mm long segments or by stacking three 381 mm long segments on top of each other. A monolithic reinforced concrete moment resisting frame with similar dimensions of the FRP specimens designed according to the provisions of the American Concrete Institute Building Code Requirements for Structural Concrete was constructed as a control specimen. Three FRP specimens were constructed from segmented columns while one was constructed from continuous columns. Neoprene layers were added to the column-beam and column-base interfaces of one segmented FRP specimen to dissipate energy, reduce damage to the structural members, and to lengthen the period of the frame. External sacrificial energy dissipating devices in the form of modified steel angles were attached to another segmented FRP specimen to dissipate energy.*

Key Words: **Self-centering frame, RCC frame, FRP, FEA**

1. INTRODUCTION

Using precast components in bridges provides a faster method of construction. It is also favorable since it provides increased work-zone safety and reduces the environmental impacts of constructing bridges. Another advantage is the higher quality structural components of a precast system since they are manufactured in quality controlled plants. Most applications of precast systems have been in areas of relatively low seismic potential. The behavior of such systems under seismic loading thus needs to be studied further. To improve their behavior under lateral loads, the strength capabilities of post-tensioned concrete columns comprising precast moment resisting frames may be enhanced by confining the columns with external jackets composed of various options of different materials. Recent earthquake events have highlighted the limitations of traditional seismic lateral load resisting systems, which can experience significant damage and large residual deformation that is difficult and costly to repair. As a current state-of-the-art branch of structural design to resist seismic loads, self-centering structures can protect a structure by concentrating the majority of the structural damage in replaceable energy-dissipation devices, while eliminating or minimizing the residual deformation. Self-centering Reinforced concrete moment frames consist of concrete beams and columns horizontally post-tensioned together so that a gap can open at the beam-column interface when subjected to a specific applied moment. Energy dissipation is supplied at the beam-to-column joint through a variety of mechanisms such as un-bonded mild reinforcing steel, friction damping elements and other devices.

1.1 objectives of the study

This analytical study was conducted to investigate the performance of bridge frames with post-tensioned concrete columns confined with FRP tubes while undergoing lateral loads and to compare their behavior to the conventional cast-in-place monolithic reinforced concrete bridge frames.

1. Analyzing and designing of conventional monolithic concrete frames.
2. Analyzing and designing of Self-centering frames having precast post-tensioned column encased in FRP tubes.
3. Comparing deformation of Self-centering frames having precast post-tensioned column encased in FRP tubes with those of a conventional monolithic reinforced concrete frame of similar dimensions.

Table1. Summary of Test specimen

F-RC	Control
F-FRP1	Post-tensioned FRP confined columns of single segment

2. TEST SPECIMEN DIMENSIONS

A cast-in-place monolithic RC moment-resisting frame was used as a control specimen (Fig. 1). A typical column had a diameter of 203 mm and a clear height of 1,143 mm. The frame clear span was 1,676 mm, and the cross beam was 203 mm wide by 381 mm deep. Specimen F-RC was a monolithic reinforced concrete specimen. Each column of the frame was provided with six No. 3 Grade 60 longitudinal rebar (with yield strength of 414 MPa), representing a reinforcement ratio of 1.3%. The rebar did not have any lap splices. The transverse reinforcement consisted of No. 2 Grade 40 rebar (with yield strength of 276 MPa) spiral at a pitch of 88 mm representing a volumetric reinforcement ratio of 0.8%. Each footing was 406 mm wide, 610 mm thick, and 660 mm long.

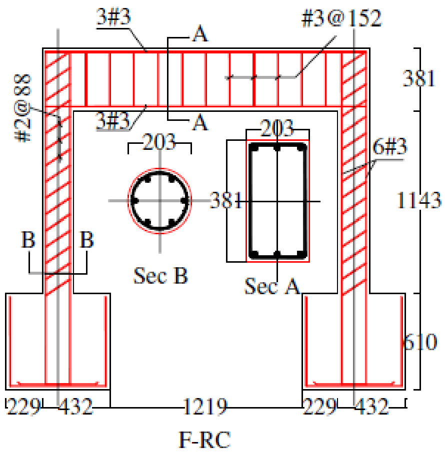


Fig -1: Reinforcement of control specimen

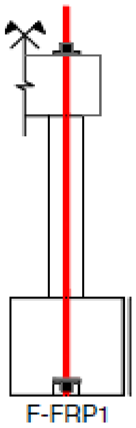


Fig -2: Schematic drawing of tested specimen

The lateral load was applied at a height of approximately 1,334 mm above the top of the footing. The applied posttensioning force, after initial losses, was 151 kN corresponding to 18% of the ultimate strength of the posttensioning tendon and approximately an axial stress of 0:28f c'

2.1 Loading pattern

The loading pattern consisted of applying three cycles at displacement levels of +_0:5, +_1, +_1:5, +_2, +_2:5, +_4, +_5, an+_6 times the horizontal displacement to cause first yield (Δy) in the longitudinal reinforcement of the monolithic specimen. By using moment curvature analysis, Δy was theoretically determined as 10 mm, corresponding to a drift angle of 0.8%. For more information about the test setup and procedure, please refer to Sha'lan (2009).

3. ANALYSIS OF TEST SPECIMENS

3.1 Specimen F-RC

Specimen FRC was the control specimen, designed according to ACI318-05 recommendations, and was composed of monolithic beam-column connections. Spiral reinforcement was used as shear reinforcement.

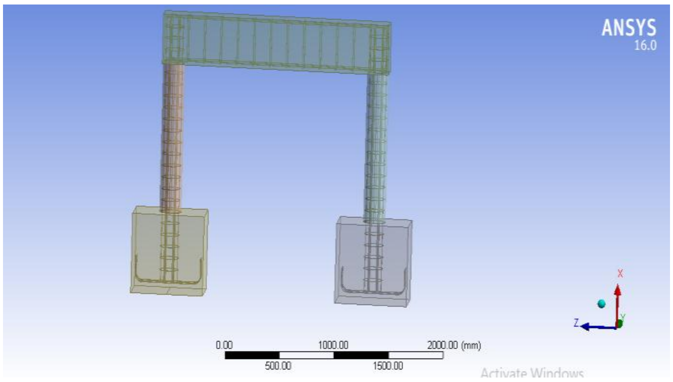
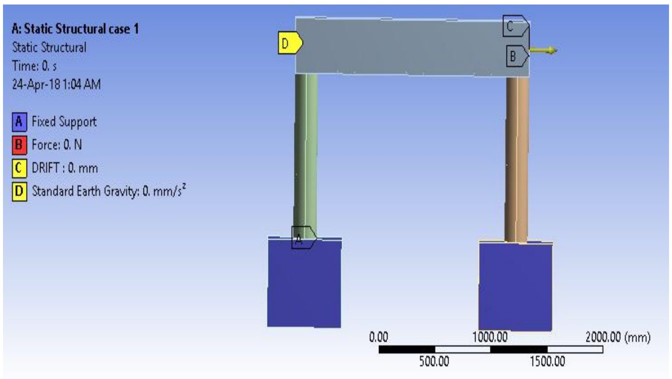


Fig -3: 3D Model of control specimen

Fixed support is given to both of the footing. A lateral cyclic load of 53 kN is applied at the height of 1334 mm above the footing.

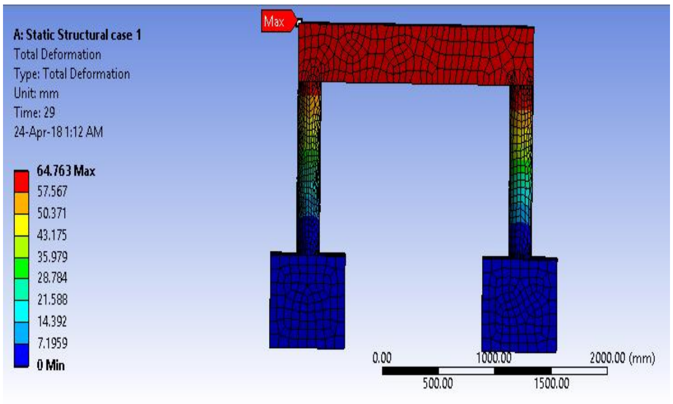


A: Static Structural case 1
Static Structural
Time: 0. s
24-Apr-18 1:04 AM

A Fixed Support
B Force: 0. N
C DRIFT : 0. mm
D Standard Earth Gravity: 0. mm/s²

Fig-4: Loading conditions

The specimen reached a deformation of 64.76 mm at an imposed load of 53 kN.



A: Static Structural case 1
Total Deformation
Type: Total Deformation
Unit: mm
Time: 29
24-Apr-18 1:12 AM

Fig-5: Deformation of control specimen F-RC

3.2 Specimen F-FRP1

The columns included central un-bonded post-tensioning strands, no columns included any reinforcement, but were cast inside fiber reinforced polymer (FRP) composite tubes for shear strengthening and concrete confinement.

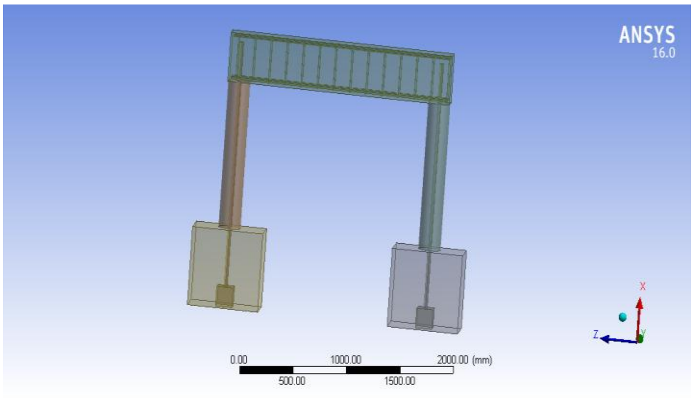
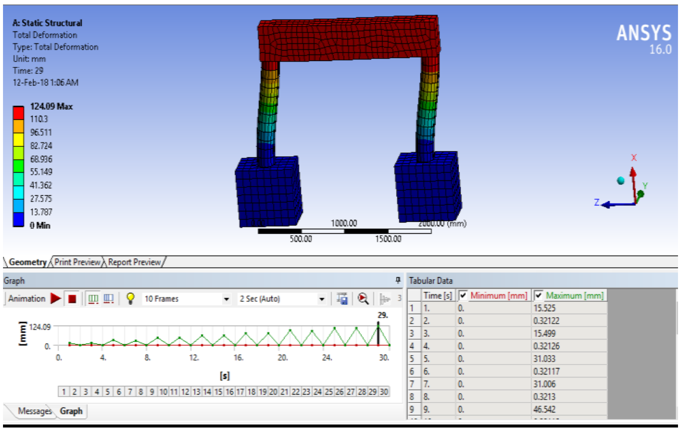


Fig-6:3D Model of specimen F-FRP1

Fixed support is given to both of the footing. A lateral cyclic load of 102 kN is applied at the height of 1334 mm above the footing.



A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 29
12-Feb-18 1:06 AM

Tabular Data

	Time [s]	☑ Minimum [mm]	☑ Maximum [mm]
1	1.	0.	15.525
2	2.	0.	0.32122
3	3.	0.	15.499
4	4.	0.	0.32126
5	5.	0.	31.033
6	6.	0.	0.32117
7	7.	0.	31.006
8	8.	0.	0.3213
9	9.	0.	46.542

Fig-7: Deformation of specimen F-FRP1

The specimen F-FRP1 reached a deformation of 124.09 mm at an applied cyclic load of 102 kN.

4 RESULTS AND CONCLUSIONS

4.1 Summary

Bridge construction using conventional reinforced concrete poses several disadvantages including the long period of time for construction, high susceptibility to damage during seismic events, the difficulty of repair after seismic events, and the harmful effects on local surroundings in close proximity to bridge construction projects

In this research, the precast system was used to offer solutions to some of the above problems. Construction using the precast system is much faster than conventional reinforced concrete construction. The effect on local surroundings is much lower when the precast system is utilized since mostly the members are only to be assembled on site and no building formwork or concrete pouring occurs at the construction site. Using the precast system also offers additional advantages in terms of higher efficiency and quality control of the production of structural members due to production at specialized plants.

The concept of confinement of concrete was then applied to improve strength (compressive and shear) capabilities of bridge columns. Tubes fabricated from fiber reinforced polymers were used because they proved to offer better confinement than steel jackets due to their higher strength properties, with the advantages of lower density (which is important for decreasing seismic force attraction to the structure) as well as not being susceptible to corrosion as steel is.

Post-tensioning was utilized in this research to provide a solution to the high residual displacements of bridges after seismic events. Un-bonded post-tensioning resolved the problem of local yielding of post-tensioning steel bars and maintained them in their elastic phase of response.

4.2 Conclusions

Although the conventional monolithic reinforced concrete specimen (specimen F-RC) shared the same geometric properties as that of post-tensioned precast concrete with FRP specimens ,the specified unconfined concrete strength was constant for all the columns, the monolithic frame (specimen F-RC) showed significantly lower lateral load resistance than the other specimens. The maximum lateral load resisted by specimen F-RC was about 50% of the maximum lateral load of specimens F-FRP1.

4.3 Deformation

The maximum load applied on specimen F-RC was 53 kN and it occurred at a displacement level of 64.76 mm. The maximum load applied on the specimen FRP-1 was 102 kN and it occurred at a displacement of 124.46 mm.

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