IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 5 Issue 4, April 2018
ISSN (Online) 2348 – 7968
www.ijiset.com

Impact Study on Concrete Columns Confined by GFRP Tube and Steel Isotruss Reinforcement

Anitha Kurian[1] and Vidya Vijayan[2]

[1]Civil Engineering Department, APJ Abdul Kalam Technological University, Mar Baselios Institute of Technology and Science Nellimatam, Ernakulam, India

[2] Civil Engineering Department, APJ Abdul Kalam Technological University, Mar Baselios Institute of Technology and Science Nellimatam, Ernakulam, India

Abstract

Concrete structures are subject to impacts, blasts, earthquakes, heavy loads, etc which can lead to collapse. According to previous studies concrete column confined with GFRP and steel spiral reinforcement shows better impact resistance compared with glass fiber reinforced polymer (GFRP) confined concrete column or conventional concrete column with inner steel spiral reinforcement. In this study, the axial impact behavior of GFRP confined concrete columns reinforced with steel isotruss reinforcement is studied. An impact hammer of weight 588 kg is used. The test variable considered the different shape of isotruss (triangle, square, pentagon, hexagon). The mass of the isotruss reinforcement is constant for all the models. Also isotruss with external longitudinal members were studied. The GFRP-hexagonal isotruss reinforcement confined concrete column has higher impact resistance compared with other shape of isotruss reinforcement. When external longitudinal members are added to isotruss the impact resistance of the column increases.

Keywords: *Concrete Column, Steel Isotruss Reinforcement, GFRP Confinement, Axial Impact, Time Displacement Histories, Damage.*

1. Introduction

Nowadays, composite columns are widely used in high-rise building, offshore structures and bridges due to their high strength-to weight ratio and increased deformability .In this system, the prefabricated GFRP tubes serve as permanent formwork for fresh concreteand also provide confinement to the concrete as well as protect the concrete from outer aggressive environment. The advantages of FRP composite materials are their light weight, high stiffness and strength and corrosive-resistance, which enable them to be an excellent alternative to conventional steel reinforcement. The isotruss is a three dimensional lattice structure and iswoven with a distinct helical configuration that employs isosceles triangles to support axial, bending and torsional loads.The isotruss concept is unique because of its geometry and the fact that it utilizes composites in a way that allows the fibre to remain straight.

The overall structure of an isotruss is a cage-like tubular lattice, formed by a series of intersecting triangles. When viewed in cross-section, the all-composite structure appears as a symmetrical star shape. It could be made of strips of metal, wood, or similar material overlapped or overlaid in a regular, usually crisscross pattern. The components in isotruss structure are longitudinal member and helical member. Longitudinal members carry bending and compressive load and helical members carry transverse shear and torsional loads. Isotruss products are highly damage tolerant due to their highly redundant design. if one or more members is removed, the resulting performance will be reduced substantially less than for a traditional truss design.

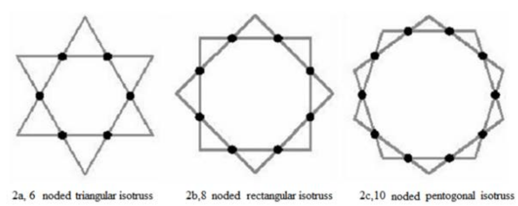


Fig. 1. Isotruss cross sections

(GFRP) elements have grown steadily during the last years. Fiber glass is a common type of fiber-reinforced plastic using glass fiber. GFRP is a category of plastic composite that specifically uses glass fiber materials to mechanically improve the strength and stiffness of plastics, the resin provides additional protection to the fiber due to the bonding between materials. Advantages of GFRP are high strength, lightweight, resistant to salt water, chemicals, and the environment, seamless construction, low maintenance and high durability.

ISSN (Online) 2348 – 7968
www.ijiset.com

An impact can be defined as a high force or shock applied over a short time period when two or more bodies collide. The effect depends critically on the relative velocity of the bodies to one another. Examples of impact are force applied in an accident is an impact load, hammering is another example of impact load.

2. Objectives

(1) Axial hammer impact study on concrete column confined by both GFRP tube and different shape of steel isotruss reinforcement.

(2) Impact study on concrete column with external longitudinal members.

3. Axial Hammer Impact Study on Concrete Columns Confined by GFRP Tube and Steel Isotruss Reinforcement

The concrete columns are confined by both GFRP tube and different shapes of isotruss reinforcement with and without external longitudinal members. 4 models of concrete column confined by GFRP tube are prepared with varying the shape of steel isotruss reinforcement. Triangular, square, pentagonal and hexagonal shapes are considered. In next 4 models the shape of isotruss reinforcement is varied and also external longitudinal members are added. Also studied the effect of GFRP thickness on concrete column under axial impact. Displacement time curves are plotted to find the maximum displacement on each models under axial impact.

3.1 Material properties

The Riedel, Hiermaier, and Thoma (RHT) model built into Autodyn was used to capture the dynamic nonlinearity of concrete. The compressive strength of M35 concrete is 3.4×10^{4} kPa and the principal tensile failure stress is 3.4×10^{3} kPa. The density of GFRP is 2250 kg/m^3 and modulus of elasticity is 60000 MPa. The ultimate tensile strength is 967 MPa. For the steel the Young's modulus, density and poisson's ratio are 200000 MPa, 7850 kg/m^3 and 0.3 respectively.

3.2 Modelling

GFRP-Isotruss-confined concrete cylinders with a diameter of 150 mm and a height of 300 mm were constructed and tested using drop (axial) hammer impact testing. . The thickness of the GFRP laminate is1.308 mm. A steel plate with thickness of 5 mm was bonded to the ends of the GFRP-Isotruss-confined concrete cylinder. The varying parameters include the shape of isotruss (triangular, square, pentagonal and hexagonal) reinforcement with diameter of bars 6mm. 4 other models are prepared by varying the shapes of isotruss and also external longitudinal members are added to isotruss reinforcement. The mass of the impact hammer is 588 kg. Fig. 2 shows the model of GFRP-triangular isotruss-confined concrete cylinder and in Fig. 3, the cross section of triangular isotruss reinforcement is shown. The spacing of triangular isotruss reinforcement provided is 32mm.

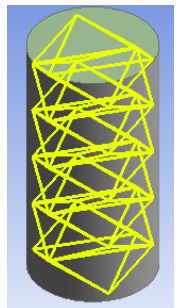


Fig. 2 GFRP-triangular isotruss confined concrete column

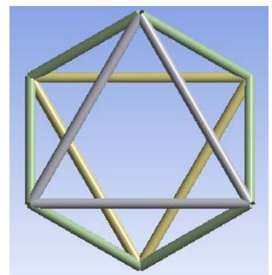


Fig. 3 Cross section of triangular isotruss

Figure. 4 and Fig. 5 shows the GFRP-square isotruss-confined concrete cylinder and the cross section of square isotruss reinforcement. The spacing of square isotruss reinforcement is 35mm.

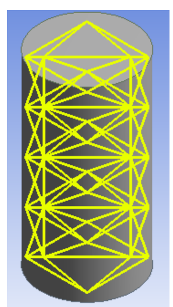


Fig. 4 GFRP-square isotruss confined concrete column

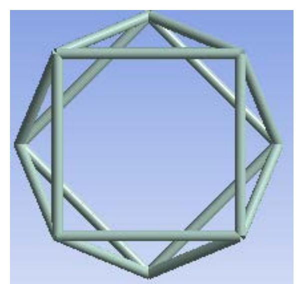


Fig. 5 Cross section of square isotruss

GFRP-pentagonal isotruss-confined concrete cylinder and the cross section of pentagonal isotruss reinforcement are shown in Fig. 6 and Fig. 7. The spacing of pentagonal isotruss reinforcement provided is 35mm. The mass of isotruss reinforcement is constant.

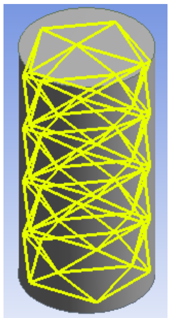


Fig. 6 GFRP-pentagonal isotruss confined concrete column

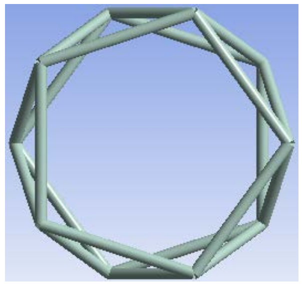


Fig. 7 Cross section of pentagonal isotruss

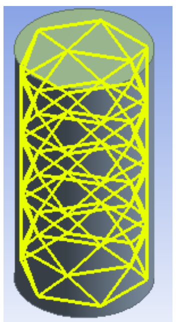


Fig. 8 GFRP- hexagonal isotruss confined concrete column

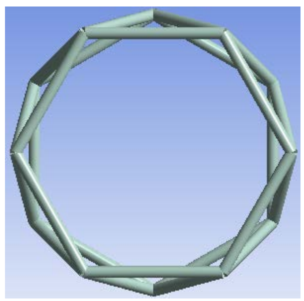
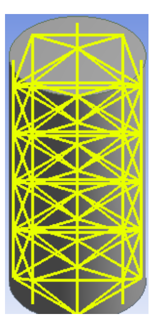


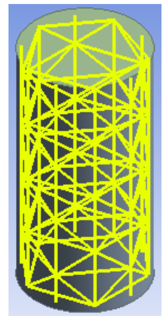
Fig. 9 Cross section of hexagonal isotruss

In the next 4 models GFRP-isotruss confined concrete cylinders with external longitudinal members are considered. Figure.10 (a) shows concrete column confined by both GFRP tube and triangular isotruss reinforcement with external longitudinal members, provided at a spacing of 26 mm. In Fig. 10 (b), (c), (d) shows concrete column confined by both GFRP tube and square, pentagonal, hexagonal isotruss reinforcement with external longitudinal members, provided at a spacing of 32mm, 36mm, 40mm. The mass of isotruss reinforcement with external longitudinal members were kept constant for all the models.

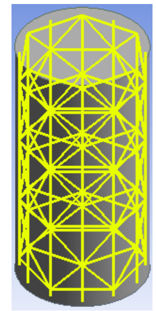
(a) Triangular



(b) Square



(b) Pentagonal



(d) Hexagonal

Fig .10 Isotruss with External Longitudinal Members

3.3 Meshing

It is the most important part of an analysis and is done to discretize the structure. Meshing divides the structure in to elements. Therefore, a lot of time is given to meshing of complex models. In the present study, the bodies are meshed with an element size of 15 mm. Also all quad mesh are used as shown in Fig. 11.

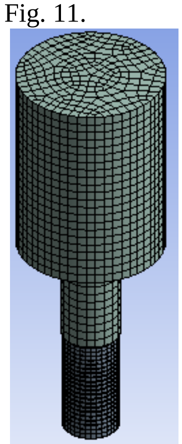


Fig. 11 Meshed View

Fixed support is given to the bottom of the column as shown in Fig. 12.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 5 Issue 4, April 2018
ISSN (Online) 2348 – 7968
www.ijiset.com

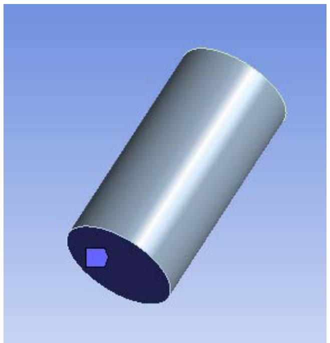


Fig.12 Boundary Condition

The direction of velocity of impact is shown in Fig .13

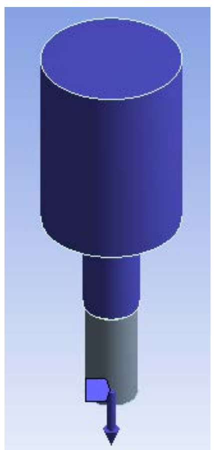


Fig. 13 Direction of Velocity

4. Results and Discussions

4.1 Isotruss reinforcement without external longitudinal members

Different shape of steel isotruss reinforcements were provided for concrete column confined by GFRP tube and studied under axial hammer impact loading. The different shapes used were triangle, square, pentagon and hexagon. Fig. 14 shows Displacement-Time histories of various shape of isotruss under axial impact.

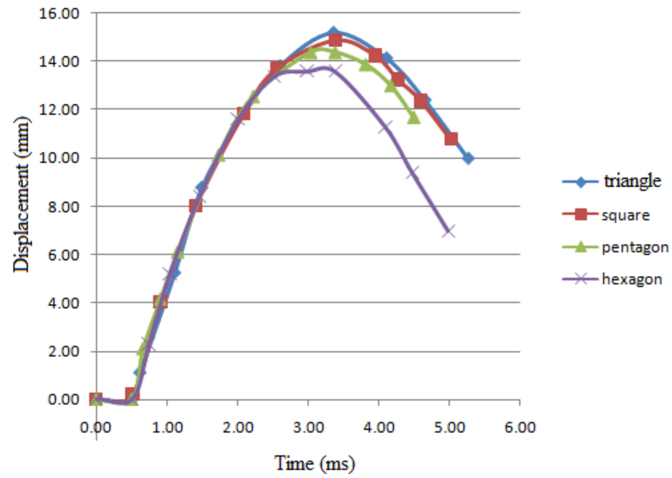


Fig . 14 Isotruss without external longitudinal members

From the graph it is clear that, the maximum displacement under axial impact is low for hexagonal isotruss reinforcement. Maximum displacement of triangular, square, pentagonal and hexagonal isotruss reinforcement under axial hammer impact were 15.18mm, 14.98mm, 14.69mm and 13.91mm. . When the shape of isotruss reinforcement changes from triangular to hexagonal the impact resistance of the column increases.

4.2 Isotruss reinforcement with external longitdinal members

Different shape of steel isotruss reinforcements were provided for concrete column confined by GFRP tube and studied under axial hammer impact loading. The different shapes used were triangle, square, pentagon and hexagon. Fig. 15 shows Displacement-Time histories of various shape of isotruss with external longitudinal members under axial impact.

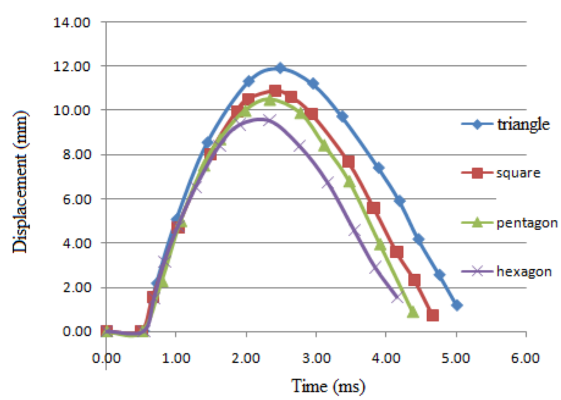


Fig. 15 Isotruss with external longitudinal members

When external longitudinal members were added to the isotruss the maximum displacement of the column reduces.

ISSN (Online) 2348 – 7968
www.ijiset.com

The maximum displacement in triangular, square, pentagonal and hexagonal isotruss with external longitudinal reinforcement were 11.307mm, 10.925mm, 10.514mm and 9.56mm respectively.

4.3 Damage

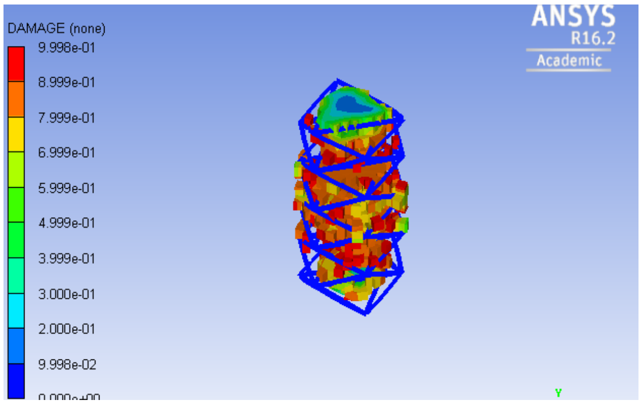


Fig. 16 Damage of GFRP-Isotruss Confined Concrete Column

Figure.16 shows damage of GFRP-Isotruss Confined Concrete Column. In this figure we can see that the concrete and GFRP is fully damaged. A large portion of concrete and GFRP was fractured and disappeared. There was no damage to the steel reinforcement.

Conclusions

On comparing different shape of isotruss reinforcement in concrete column under axial impact hexagonal isotruss reinforcement shows better displacement values. When external longitudinal members are added to isotruss the impact resistance of the column increases . A large portion of concrete and GFRP was fractured and disappeared under the impact. Hexagonal isotruss reinforcement with external longitudinal member has good impact resistance compared to other shapes.

Acknowledgments

I express my deepest sense of gratitude to Mrs. Vidya Vijayan, Asst. Professor, MBITS, Nellimattom, my esteemed guide and my cordial thanks for her warm encouragement, thoughtful guidance, insightful decision, critical comments and correction of the thesis. I also express my sincere thanks to all the faculty members and students of the Civil Engineering Department of Mar Baselios Institute of Technology and Science for their co-operation and support.

References

[1] Liang Huang , Xiaoxun Sun , Libo Yan , Bohumil Kasal, Impact Behavior Of Concrete Columns Confined By Both GFRP Tube And Steel Spiral Reinforcement, Construction And Building Materials, 2017, pp 438–448

[2] Asisha Mary Mammen, Minu Antony, Experimental Study On Frp-Pvc Confined Circular Columns, International Research Journal of Engineering and Technology (IRJET), Volume. 4, Issue 5, May -2017

[3] Mahfoud Touhari, Ratiba Mitiche-Kettab, Behaviour of FRP Confined ConcreteCylinders:Experimental Investigation and Strength Model, 2016, pp. 647–660

[4] Dr.R.Kumutha, Dr.K.Vijai, External Confinement Of Plain And Reinforced Concrete Columns Using Pvc Pipes, 2nd International Conference on Structural Architectural and Civil Engineering, 2016, pp 72-78

[5] Jung-Yoon Lee, Young-Jun Oh, Ji-Sun Park and Mohamad Y. Mansour, Behaviors Of Concrete Columns Confined With Both Spiral And Fiber Composites, 13th World Conference on Earthquake Engineering, Paper No. 3051, 2004

[6] C. Ramesh Babu, S. Prabavathy and M. Saranya, Experimental and Analytical Studies on Compressive Behaviour of Concrete Filled Circular GFRP Tubes, Indian Journal of Science and Technology, Vol 9, 2016

[7] Liang Huang, Xiaoxun Sun, Libo Yan, Deju Zhu, Compressive Behavior of Concrete Confined with GFRP Tubes and Steel Spirals, 2015, pp 851-875

[8] H. Mohamed, R. Masmoudi, O. Chaallal, Compressive behavior of filament winded GFRP tube-encased concrete columns, International Conference on FRP Composites in Civil Engineering, 2008, pp 1-6

[9] Muhammad N. S Hadi, Qasim Khan, M Neaz Sheikh, Axial And Flexural Behavior Of Unreinforced And FRP Bar Reinforced Circular Concrete Filled FRP Tube Columns, Faculty of Engineering and Information Sciences, 2016

[10] Asmaa Abdeldaim Ahmed, Radhouane Masmoudi, Behaviour of FRP reinforced CFFT columns under axial compression loading, 2016

[11] M.H. Lai , J.C.M. Ho, Effectiveness Of External Confinement on The Uni-Axial Behaviour of CFST Columns, pp 689-696

[12] A. Rajasekaran, P.N. Raghunath and K. Suguna, Effect of Confinement on the Axial Performance of Fibre Reinforced Polymer Wrapped RC Column, American Journal of Engineering and Applied Sciences, 2008, pp 110-117

[13] Woraphot Prachasaree, Sitthichai Piriyakootorn,Athawit Sangsrijun, Suchart Limkatanyu, Behavior and Performance of GFRP Reinforced Concrete Columns with Various Types of Stirrups, International Journal of Polymer Science, 2015, pp 1-9

[14] Hamdy Mohamed, Radhouane Masmoudi, Behavior of FRP Tubes-Encased Concrete Columns under Concentric and Eccentric Loads, American Composites Manufacturers Association, 2009

[15] SruthySagaran V, SruthiK Chandran, Behaviour of Concrete Filled Fiber Reinforced Polymer Tube Under Blast Loading, International Journal of Scientific & Engineering Research, Volume 7, Issue 10, 2016