International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-10, Issue-07, Oct 2024

Numerical Study on Hybrid Fibre Reinforced Concrete Framed Structures Subjected to Earthquake Load Using ABAQUS 6.14-5 software

Sunilkumar Hiremath. Asst Prof, FoET Sharanbasva University Kalaburagi & India, sunilhiremath2011@gmail.com

Gajendra H & FoET Sharanbasva University Kalaburagi & India

Venkatesh, Designation, FoET Sharanbasva University Kalaburagi & India, Email

Chandrakant, Designation, FoET Sharanbasva University Kalaburagi & India, Email

Abstract **This numerical study focuses on the structural behaviour of Hybrid Fibre Reinforced Concrete (HFRC) framed structures subjected to earthquake loads. In this investigation, six numbers of three-story hybrid fibre reinforced concrete (steel and polypropylene) framed structures are modeled using eight-noded solid elements, which accurately provide the constitutive law integration and are suitable for nonlinear static and dynamic analyses. Steel fibres with an aspect ratio of 60 and polypropylene fibres with an aspect ratio of 231 were used, maintaining a total fibre volume of 1% of the specimen volume. In this study dynamic implicit type of analysis is used, and the load being applied is Vrancea Earthquake N-S data (acceleration with time). Finite element analysis is carried out using ABAQUS 6.14-5 software. This study shows the addition of 0.825% of steel and 0.125% of polypropylene fibres to conventional concrete, significantly enhances the performance of framed structures.**

Keywords — Steel and polypropylene fibre, Earthquake load, ABAQUS 6.14-5

I. INTRODUCTION

Due to extended use of concrete framed structures subjected to impact loads that vary both in velocity and intensity. However, brittle nature of concrete is highly susceptible to impact loads. Being a quasi-brittle material, concrete looses its loading capacity of taking loads once the cracks are initiated. The energy consumed during impact loading is utilized for the process of development of cracks and their propagation in concrete. Microcracks are developed at relatively low stress levels and these microcracks propagate and link up into larger cracks. Controlling of cracks goes a long way in protecting the integrity of the structure. Vulnerability of structures due to seismic loads became major threat for researchers and engineers across the world, it poses major loss of life due to instability of structures..

Hybrid fibre-reinforced concrete beams are made by combining different types of fibres, such as steel and polypropylene fibres, with concrete to enhance their mechanical properties and performance. This combination can provide improved strength, ductility, durability, and crack resistance compared to traditional concrete beams. Steel fibres provide tensile strength and ductility, while polypropylene fibres improve crack resistance and durability. The combination of these fibres in concrete can lead to a more balanced and enhanced performance in terms of mechanical properties and overall structural behavior.

ABAQUS 6.14-5 is a suite of powerful engineering simulation programs, based on the finite element method that can solve problems ranging from relatively simple linear analyses to the most challenging nonlinear simulations. ABAQUS can be used to study more than just structural (stress/displacement) problems.

II. METHODOLOGY

FINITE ELEMENT MODELLING

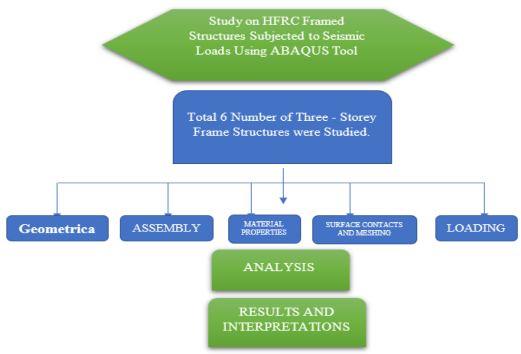

Figure 1. Showing the flowchart of workflow..

 DOI : 10.35291/2454-9150.2024.0386

Commercially available finite element analysis software ABAQUS is used for modelling and analysis of hybrid fibre reinforced concrete framed structure. The following steps are followed in modelling and analysis of framed structure using ABAQUS 6.14-5 software.

- **Geometrical model of the framed structure**

In the present study, the structural components such as beam, and column are created. The dimensions of the beam and column are (200 X 200 X 2800) mm. The eight-nodded solid elements (C3D8R) are used to model the beam and column component.

- **Assigning Material Properties**

HFRC framed structure are modeled by using their combined material properties. The materials properties required are compressive and tensile strength of HFRC along with modulus of elasticity and poisons ratio. While modeling, the fibres are not being considered as a separate modeling entity, but the strength of concrete with different fibre combinations/ proportions are studied separately.

Two types of fibre are used, polypropylene fibre

S.No.	Material	Aspect ratio
01	Steel Fibers	60
02	Polypropylene Fibers	240

S.No.	Material	Size& Specifications	Property	Results
01	Steel Fibers	Large	Arrest growth of macro cracks	Improving fracture energy of concrete
02	Polypropylene Fibers	Shorter, thin, flexible, smooth	Helps in resisting micro cracks	--

Mixture Designation	Steel Fibre (%)	PP Fibre (%)	Total Volume (%)	Density (kg/m^3)	Compressive Strength (MPa)	Tensile Strength (MPa)	Young's modulus (E) (MPa)
PC1	0	0	0	2293.33	38.5	3.5	31024.2
PC2	1	0	1	2304.44	37.4	3.8	32372.0
PC3	0.9	0.1	1	2337.8	48.4	5.1	36335.2
PC4	0.825	0.175	1	2322.73	41.8	4.6	33749.7
PC5	0.75	0.25	1	2240.33	35.6	3.9	31129.5
PC6	0	1	1	2166.37	24.7	2.4	24681.1

A. Defining Contact interactions

In impact simulation, creating a proper mechanical interaction between different joints of framed structure is important in order to generate accurate normal and frictional forces that arise during physical contact interaction. The joints are connected by creating column top and bottom surface, column and beam lateral surface. Then connected through the tie constraint between column to column and column lateral surface to beam lateral surface as shown in figure 3.

Instance Name	Color	# Elements	# Nodes	Element type (# elements)
BEAM-1-LIN-2-1-LIN-1-3		896	1425	C3D8R : (896),
BEAM-1		896	1425	C3D8R : (896),
BEAM-1-LIN-2-1-LIN-1-2		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2-LIN-2-1-LIN-1-3		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2-LIN-2-1-LIN-1-2		896	1425	C3D8R : (896),
BEAM-1-LIN-2-1		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2-LIN-2-1-LIN-2-1-LIN-1-2		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2-LIN-2-1-LIN-2-1-LIN-1-3		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-1		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-LIN-2-1-LIN-2-1		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2-LIN-2-1-LIN-2-1		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-LIN-1-3		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-LIN-1-2		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2-LIN-2-1		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2		896	1425	C3D8R : (896),
BEAM-1-LIN-1-3		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2-LIN-1-2		896	1425	C3D8R : (896),
BEAM-1-LIN-2-2-LIN-1-3		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-LIN-2-1-LIN-2-1-LIN-1-3		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-LIN-2-1-LIN-2-1-LIN-1-2		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-LIN-2-1		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-LIN-2-1-LIN-1-2		896	1425	C3D8R : (896),
BEAM-1-LIN-1-2-LIN-2-1-LIN-1-3		896	1425	C3D8R : (896),

Figure 2. Showing of part instance in ABAQUS

A. Mesh configuration, load & boundary conditions

It is important to use a sufficiently refined mesh in order to ensure that, the model produces a nearly accurate mathematical solution and requires minimum computational time. In general, numerical result of FE model tends towards a unique value because of the dense mesh. In the present case mesh size of 50 mm as shown in figure 4. The frames are subjected to gravity load and earthquake load in north and south directions. Model is provided with fixed and moving support boundary condition.

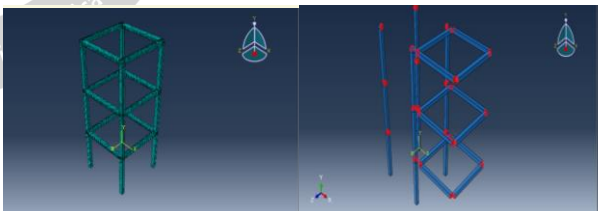

Figure 4. Showing the beam and hammer meshing & Surface contact interactions of framed components..

Analysis of Framed structure.

Here it is to choose the type of analysis and the required results as output along with run time of simulation. A time history analysis is performed to simulate the structural response over time. The analysis provides valuable insights into deformations, stresses, strains, and dynamic characteristics of the structure. Post-processing involves visualizing and interpreting the obtained results. In this study dynamic implicit type of analysis is used, and the load being applied is Vrancea Earthquake N-S data (acceleration with time). The output results selected are

 DOI : 10.35291/2454-9150.2024.0386

storey displacements, storey drift, and stress & strainFormat and save your graphic images using a suitable graphics processing program that will allow you to create the images as PostScript (PS), Encapsulated PostScript (EPS), or Tagged Image File Format (TIFF), sizes them, and adjusts the resolution settings. If you created your source files in one of the following you will be able to submit the graphics without converting to a PS, EPS, or TIFF file: Microsoft Word, Microsoft PowerPoint, Microsoft Excel, or Portable Document Format (PDF).

III. RESULTS AND DISCUSSION

Total six number of framed structures are modeled and analysed using advanced FEA techniques (i.e., ABAQUS 6.14-5) under earthquake loads. These results help in understanding the time-dependent variation of stresses and the effects of different design parameters.

1. Stress

The variation of stresses with time in a hybrid fibre reinforced concrete (HFRC) framed structure subjected to earthquake load is a complex phenomenon influenced by different factors such as the material properties, structural configuration, and characteristics of the earthquake load itself. Hybrid fibre (steel and polypropylene) improves the mechanical properties of concrete and enhance the tensile strength, ductility, and energy absorption capacity, which are critical for earthquake resistance. The design and layout of the framed structure, including the size and spacing of beams and columns, influence the distribution and variation of stresses during an earthquake. The connections between different structural elements (beams, columns, and slabs) are critical in transferring loads and absorbing energy during seismic events.

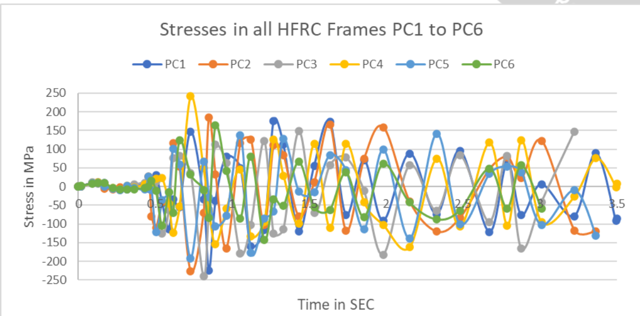

Figure 5. Variation of stresses with time in all HFRC framed structure.

All the six number of models are showing similar response. It is observed that, at the beginning of the earthquake, the HFRC framed structure shows an initial spike in stresses due to the sudden application of lateral forces for 0.5sec as shown in figure 7. As the earthquake progresses, the HFRC framed structure undergoes dynamic oscillations, resulting in cyclic variations in stresses. The PC4 framed structure shows the higher stress as it contains 0.825% of steel and 0.175% of polypropylene fibres and PC5 framed structure shows less stress as it contains 0.75% of steel and 0.25% of polypropylene fibre.

2. Strain

The variation of strain with time in hybrid fibre reinforced concrete (HFRC) framed structures subjected to earthquake loads is a complex phenomenon. The steel and polypropylene fibres help in controlling crack propagation and improving the strain capacity of the concrete. The dynamic response of the structure to earthquake loading involves complex interactions between the inertial forces, damping, and stiffness of the structure. This response determines how strains develop and change over time.

\

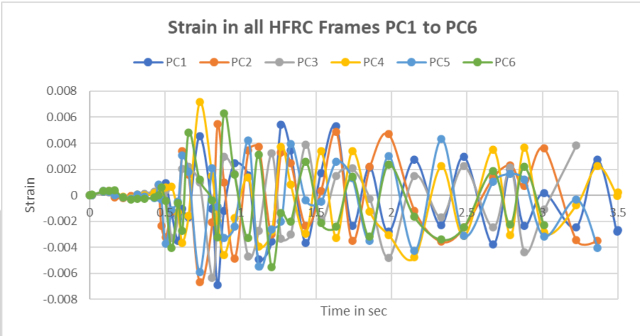

Figure 6. Variation of strain with time in all HFRC framed structure.

All the six number of models are showing similar response. From figure 8 it is observed that initially, when the earthquake load is applied to framed structure the variation of strains is relatively small for 0.5sec. Then as the load increases, the HFRC framed structure undergoes dynamic oscillations, resulting in cyclic variations in strain. The HFRC helps to reduce the failure by delaying the transition from the elastic to the plastic phase. The cyclic loading leads to hysteresis in the stress-strain relationship, which means that the strain does not return to zero even when the load is removed. HFRC helps in dissipating energy during these cycles, reducing the overall strain accumulation. After the earthquake load is removed, residual strains remain in the structure due to plastic deformations and unrecovered hysteresis.

3. Displacement

earthquake loads, the variation of storey displacement with the number of storeys is an important factor in assessing the structural performance and seismic resilience. The use of hybrid fibre-reinforced concrete is significantly influencing the displacement profile of a hybrid fibre reinforced concrete framed structure during an earthquake. The different combination of steel and polypropylene fibres enhanced properties lead to better performance in terms of reduced displacements and improved energy dissipation. Understanding this variation helps in designing more resilient buildings that can better withstand seismic events.

 DOI : 10.35291/2454-9150.2024.0386

Storey Displacement in All RC Frames PC1 to PC6						
Storey	PC1	PC2	PC3	PC4	PC5	PC6
0	0	0	0	0	0	0
1	6.9012	6.9429	7.8307	6.8369	7.1107	6.9016
2	7.8882	7.9206	9.2595	7.7498	8.1025	8.0304
3	8.6372	8.6522	10.18439	8.1927	8.71385	9.3093

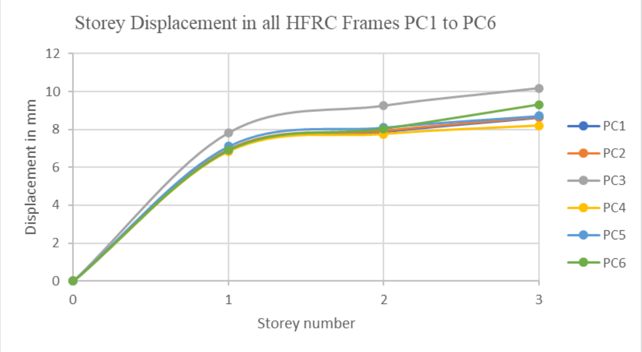

Figure 7. Variation of displacement with number of storey in all HFRC framed structure.

Storey displacement measures the horizontal movement or shift of each floor in a framed structure during an earthquake. Initially, the displacements are smaller at lower storeys due to the higher stiffness and mass contribution from the upper storeys as shown in figure 9. Further the displacements are increases as height of storey increases, reaching a maximum displacement and building tends to be more flexible and experiences the maximum sway. All the models show a gradual increase in displacement from the ground floor to the top floor, with a peak displacement at top storey. It is observed that the addition of 0.825% steel and 0.175% polypropylene fibre (PC4) to the framed structure, is reducing cracking and maintaining structural integrity, which in terns to smaller displacements compared to other combination of fibre.

4. Storey Drift

Storey drift is a critical parameter in assessing the performance of a structure during an earthquake. It refers to the relative horizontal displacement between two consecutive storeys. In a hybrid fibre-reinforced concrete (HFRC) framed structure, the presence of fibres can significantly impact the drift behaviour. The distribution of stiffness and mass along the height of the building affects the drift profile. Structures with uniform stiffness and mass distribution tend to have more predictable drift patterns.

Storey Drift in All RC Frames PC1 to PC6						
Storey	PC1	PC2	PC3	PC4	PC5	PC6
0	0	0	0	0	0	0
1	0.022037	0.029113	0.033315	0.00285	0.031232	0.021287
2	0.025417	0.032604	0.051471	0.011199	0.033663	0.050453
3	0.013078	0.015819	0.037594	0.01034	0.010633	0.045674

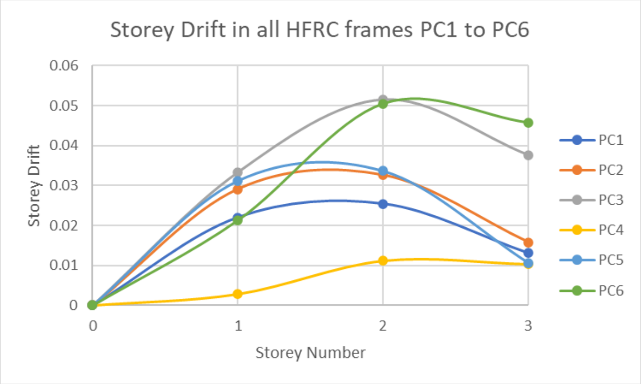

Figure 8. Variation of storey drift with number of storey in all HFRC framed structure.

Storey drift is the relative horizontal movement between two consecutive floors. High storey drift is lead to structural damage and potential collapse. Figure 10 shows that storey drift values are smaller at the lower storeys because these storeys are stiffer, owing to the cumulative mass and rigidity of the upper storeys. Storey drift values increase towards the middle storeys, where the structure is more flexible, and the effects of higher modes of vibration are more pronounced. The storey drift values then slightly decrease towards the top storeys. From figure 10, it is found that the framed structure with a combination of 0.825% steel and 0.175% polypropylene fibre (PC4) exhibits lesser drift compared to other combinations and does not fail due to storey drift. In contrast, the remaining frames fail due to storey drift according to IS 1893 Part 1 code provisions.

IV. Conclusion

Based on the critical observation, it is observed that the hybrid fibre reinforced concrete framed structure which is having a combination of 0.825% steel and 0.175% polypropylene fibre (PC4) experience superior resistance to stress and strain, allowing it to withstand greater forces without significant deformation or damage. It also exhibited minimal displacement and lower storey drift compared to other fibre combinations, enhancing the building's overall seismic performance. Thus, the study suggests that the specific mix of 0.825% steel fibres and 0.175% polypropylene fibres in the HFRC framed structure offers enhanced strength and stability against earthquake loads. This improved performance makes it a promising choice for construction in earthquake-prone areas.

References

[1] Emad A. Alwesabi, B.H. Abu Bakar, Ibrahim M.H. Alshaikh and Hazizan Md Akil, “Impact resistance of plain and rubberized concrete containing steel and polypropylene hybrid fibre” Materials Today Communications 25, 8 Sep. (2020), 101640, pp. 1-11..

[2] ABAQUS 6.14-5 manual

 DOI : 10.35291/2454-9150.2024.0386

ISSN : 2454-9150 Vol-10, Issue-07, Oct 2024

[3] Milad Hafezolghorani, Farzad Hejazi, Ramin Vaghei, Mohd Saleh Bin Jaafar and Keyhan Karimzade "Simplified Damage Plasticity Model for Concrete" Structural Engineering International Nr. 1/2017, December 17, **(2015)**, pp. 68-78..

[4] Gajendra, Rajendra Kumar Harsoor "Response of Simply Supported Beam Reinforced with Steel and Polypropylene Fibre Under Influence of Low velocity impact" Journal of Emerging Technologies and Innovative Research, Vol. 10, Issue 12, 2023, Page

 DOI : 10.35291/2454-9150.2024.0386