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Explicit Dynamics of Hollow FRC Beams

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Abstract: **Finite element analysis (FEA) is a powerful computational technique used to obtain approximate solution to complex engineering problems by dividing a larger system into smaller parts called finite elements. ANSYS is one of the leading software tools for performing FEA. This study explores the dynamic response of the hollow fiber reinforced beams subjected to various loading using ANSYS explicit dynamics. The analysis utilizes the explicit finite element method to accurately model the beam's behaviour under the application of various loading conditions. The primary findings include the impact of reinforcement on load bearing capacity and benefits of the hollow design for material efficiency while ensuring structural strength. For this purpose, hollow fibre reinforced beams of four different cross-sections, with varying thickness has been modelled. They are subjected to varying velocities and analysed. The insights obtained from this analysis aims to provide better design practices and material optimization for advanced engineering applications.**

Keywords* — *ANSYS Software, Explicit Dynamics, Finite Element Analysis, FRC beams, Hollow beams, Structural Analysis, Total Deformation.

I. INTRODUCTION

1.1 FINITE ELEMENT ANALYSIS (FEA)

Finite element analysis is a computational technique used to resolve the complex engineering problems by dividing a complex structure into smaller manageable parts called as finite elements. FEA allows engineers to predict how structure will behave under various conditions such as forces, temperature and other influences, by applying mathematical equations to these elements.

FEA includes the following.

- Defining the systems geometry
- Specifying material characteristics
- Applying boundary conditions
- Solving the equation that arrive

FEA is extensively used in engineering fields for tasks like analysing stress, heat distribution and vibrations, helping designers to ensure their products are safe and perform as intended. Many softwares are used for finite element analysis. Here are few of the prominent softwares used.

- ANSYS
- ABAQUS
- COMSOL Multiphysics
- Nastran
- Solidworks Simulation
- LS DYNA
- Altair Hyperworks
- Inventor Nastran
- ANSYS Discovery

Each of these softwares have unique features and strengths, making them suitable for different types of analysis and industry applications.

1.2 ANSYS

ANSYS is premier engineering simulation software designed to help engineers and a broad range of simulation capabilities across various domains.

1.3 APPLICATION OF ANSYS IN STRUCTURAL ENGINEERING

1. **Structural analysis**: ANSYS enables engineers to assess how structures will deform, experience stress and strain under various loads, using both linear and nonlinear static analysis.
2. **Dynamic analysis**: ANSYS evaluates how structures respond to dynamic forces such as vibrations, seismic activity and impacts, through techniques like modal and harmonic response analysis.
3. **Fatigue analysis**: ANYS predicts the fatigue life of components by analyzing their behavior under cyclic loading, helping to identify and address potential failure points.
4. **Thermal analysis**: It examines how temperature variations affect structures, considering factors such as thermal expansion and heat transfer.
5. **Optimization**: ANSYS offers tools for refining design parameters to enhance structural performance, reduce material use and lowers the cost.
6. **Crash and impact analysis:** ANSYS supports the

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analysis of composite materials, aiding in the design and evaluation of structures made from these advanced materials.

1.4. ANSYS EXPLICIT DYNAMICS

It is a powerful module within the ANSYS software suite, designed for simulating high speed, transient events. This module is designed for scenarios with rapid changes and severe deformations, such as impacts, explosions and crashes where traditional methods might be less effective. It uses explicit time integration to solve motion equations directly at each time step, making it ideal for capturing fast, dynamic responses and complex behavior. It provides advanced tools for modelling interactions and contact between different bodies, including friction and contact mechanics essential for accurate impact ad crash simulations. By using Ansys Explicit Dynamics, engineers can accurately predict how structures behave under extreme conditions and enhance design and safety of various structures.

1.5. STEEL FIBER REINFORCED CONCRETE

Fiber reinforced concrete is a concrete mix enhanced with various types of fibers to improve its performance and durability. The Tensile strength, impact resistance and flexibility of the concrete improves with the addition of fibers to it. It also helps control cracking and increases overall durability.

Types of fibers used:

- Steel fibers
- Glass fibers
- Synthetic fibers
- Natural fibers

FRC is used in range of projects, including pavements, industrial floors, precast concrete elements and structures exposed to high stress and impact.

1.6. ADVANTAGES OF SFRC

- Imp/roved structural strength
- Tensile strength and toughness increases
- Resistance to impact increases
- Resistance to freezing and thawing
- Reduced crack width
- Ductility is imp/roved
- Repair and maintenance cost is reduced
- Abrasion resistance is increased

1.7. APPLICATIONS OF SFRC

- SFRC is used in highway pavement
- Aircraft runways
- Tunnel lining
- precast structures
- beams and slabs

1.7. APPLICATIONS OF SFRC

- To evaluate the response of beams to dynamic loading
- To identify potential failure mechanism in the beam structure under dynamic stresses
- Optimize the beam design for improved performance, safety and durability.

II. LITERATURE REVIEW

Dynamic Analysis of Pine Flat Concrete Dam: Acoustic Fluid-Structural Interaction with ANSYS Workbench" (2020), T. Menouillardet.al- In this paper, a numerical analysis of the Pine Flat Dam, a 120-meter-high concrete gravity dam is provided. It deals with dynamic finite element analysis under various loading conditions and water levels. The study incudes fluid-structure interaction by explicitly portraying the reservoir as an acoustic domain within ANSYS. The main objective is to investigate how water levels affect the dynamic behavior of dam. Additionally, it emphasizes the differences in dynamic responses between 2D and 3D modeling results.

"Static and Dynamic Analysis of Smart Functionally Graded Beams" (2020), A. Sahu et.al - This study explores the static and dynamic analysis of smart functionally graded beams. By using finite element (FE) method, analysis has been done for separate boundary conditions and loading. The study evaluates the effectiveness of integrating piezoelectric materials into functionally graded (FG) beams. Using ANSYS Workbench simulation models are created, utilizing a suitable 20-node quadratic element (SOLID 226) for model discretization. Multiple static and dynamic analyses are conducted by using different power law constants and boundary conditions, and for the validation, the observations are compared with findings reported in previous research papers. Material properties and the impact of boundary conditions are studied. For both static and dynamic analyses, the results are compared between functionally graded beams and smart functionally graded beams.

"Crack Identification and Analysis of Rcc Beam Using Ansys" (2020), Shubham et.al-- The reinforced concrete beam has been modelled and analysed in this research using Ansys 15.0. Beam is subjected to two-point loads at one third of span from each of the support. The size of the beam used is 5000mm x 300mm x 450mm. Here 3 numbers of 12mm diameter bars have been used as main reinforcement, 2 numbers of 8mm diameter bars as hanger bars and 8mm diameter bars at 100mm c/c as shear reinforcement. The analysis and discussion of the beam on the basis of mesh density, varying depths, reinforcements, crack pattern at various load conditions are done. Loading applied are 100KN, 250KN, 350KN, 450KN, 550KN and 650KN. From the study, it was observed that the fracture instability is affected as the depth of the beam increases. additionally,

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there is rise in the load carrying capacity of the beam with the increase in depth, while deflection of the beam increases first then decreases.

“Experimental research on torsional strength of synthetic/steel fiber reinforced hollow concrete” (2020), Rafea F. Hassan- This paper aims to analyse the torsional performance of hollow concrete beams reinforced with various fibre type. 1% of the fibre content with three varying lengths of SY. F, 19, 38 and 57mm along with 13mm of ST. F, was used. Four hollow beams were casted with ST. F and SY. F and two beams were cast with normal concrete as control beams without using fibres. At first crack load and failure load and also at every interval of the load the twisting angle of the tested beams were calculated. The results show that use of SY. F and ST. F in the reinforced concrete beams improved the overall performance under the application of torsional load when compared to the behaviour of control beam. As the fibre length of SYF increased, the ultimate load capacity of the beams increased. For the beams cast with fibre length of 19mm, 37mm and 55mm, the ultimate load capacity of the beam was increased by 4.7, 9.4, and 21.9% respectively. And for the concrete beam reinforced with ST. F, the ultimate load capacity was increased by 5.5%. Hence this paper recommends the use of SY. F with the normal concrete, because of its significant influence on the torsional performance.

“Finite Element Analysis of Impact Load on Reinforced Concrete” (2021), Indrajeeth Singh et.al- In this study, the effects of low and high-velocity impacts on reinforced concrete (RC) beams and slabs are investigated. A standard-sized spherical ball was utilized as the impactor. The deformation responses of both conventional and geopolymer reinforced concrete specimens were analyzed by applying impact loads. By using ANSYS Explicit Dynamics 19.2 software, finite element analysis was conducted. The results shows that geopolymer concrete demonstrates better impact resistance compared to conventional concrete.

“Comparative assessment of finite element macro-modelling approaches for seismic analysis of non-engineered masonry constructions” (2021), Ravichandran et.al- This paper investigates various modeling options for the finite element analysis of non-engineered masonry buildings. The study aimed to determine the modeling option that offers the optimal balance between computational efficiency and result accuracy, specifically for assessing the seismic risk of non-engineered constructions on a regional scale. The seismic response analysis of detailed 3D models in ANSYS was compared to that of a simplified 2D model using nonlinear layered shell elements in SAP2000, reflecting the experimental behavior of a single-storey structure representative of Indian non-engineered masonry buildings.

“Modal analysis of cracked cantilever beam using ANSYS software” (2022), Dhiraj Ahiwale et.al- This study examines, a mild steel cantilever beam that measures 3 meters in length, 0.25 meters in width, and 0.20 meters in depth. To investigate the natural frequency, mode shapes, and deflection of the first three modes of transverse vibration for a cracked cantilever beam, modal analysis was conducted. The analysis focused on a crack positioned at distances of 0.5 m, 1 m, 1.5 m, 2 m, and 2.5 m from the fixed end, affecting the top, middle, and bottom faces of the beam. Using ANSYS software, the FEA simulation is performed. To ensure accuracy, the theoretically obtained results are validated against the finite element analysis results, and the derived results are closely aligned.

“Dynamic characteristic of graphene reinforced axial functionally graded beam using finite element analysis” (2022), A.K. Gantayat et.al- In this paper, an analysis of a graphene nanoparticle-reinforced functionally graded beam (FGB) with varying concentrations in an epoxy matrix along the beam's axial direction is represented. The dimensionless natural frequencies for the first four modes of vibration using the finite element software ANSYS is investigated using this software. Results of this analysis are compared with the previously modeled carbon nanotube (CNT) reinforced axially functionally graded beams**.** The comparison demonstrates satisfactory results, highlighting superior parameters that can be applied for further analysis.

“Analysis of Blended Concrete Cubes under Impact loading using ANSYS” (2022), Janhavi Singh- This study aims to perform a finite element method (FEM) analysis of blended concrete cubes under impact loads. Deformation and stress responses are derived from velocity impact simulations conducted using the ANSYS Explicit Dynamics module. A parametric analysis is conducted by varying the height and shape of the impactor, boundary conditions, and the degree of cement replacement in the blended concrete with various supplementary cementitious materials. The results indicate that the strength of the blended concrete cubes decreases s the height of the impact increases.

“Using ultra-high performance Fiber reinforced concrete in improvement shear strength of reinforced concrete beams” (2022), Asmaa Said et.al- This study aims to examine the effectiveness of using ultra-high performance fiber reinforced concrete (UHPFRC) as strengthening technique to enhance the shear strength of reinforced concrete beams. In this experiment, twelve reinforced concrete beams were casted and tested under a four-point loading test up to failure and one beam was unstrengthened and kept as control beam. Rest of the eleven beams were strengthened by adopting different

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strengthening methods. The experimental results indicate that using UHPFRC for strengthening RC beams in shear shows notable enhancements. Strengthened beams showed up to 1.54 times higher ultimate shear strength, up to 2.75 times higher initial stiffness, up to 3.37 times increased ductility and up to 4.77 times increased toughness compared to their un-strengthened beams. Additionally, strengthening the beams with vertical or inclined strips significantly boosted their shear capacity.

“Behaviour of self-compacting concrete hybrid fiber reinforced hollow beams” (2022), V. Anuradha and T. Ch Madhavi- This paper aims to examine how introducing longitudinal openings in a beam influences on its flexural strength and behaviour. In this research, 10 hollow hybrid fiber reinforced self-compacting concrete beams which are simply supported and which has a cross section of 150x300mm and span 3m were used. They were subjected to two-point loading tests and their behaviour was compared with that of the solid beam. Structural analysis was carried out. The experimental setup comprised three groups of beams along with one solid control beam without any opening. This setup included five beams in first group with hybrid fiber in different proportion. The second group had three beams with longitudinal openings in varying positions. The third group had four beams with different shapes of openings i.e. circular, square, triangular and rectangular. The beams were reinforced with varying percentage of micro steel fibers i.e. 0.1%, 0.2%, 0.3% and 0.4%, and 0.1% of nylon fibers. The best performance in terms of workability, durability and strength was obtained with the use of hybrid fibers containing 0.1% nylon fibers and 0.3% of micro steel fibers. Results indicated that both first crack loads and ultimate loads reduced as the result of openings. Minimum loss of strength was observed when the openings were present in the tension zone of the beam. Among the different shapes, the circular shaped opening was found to be the most optimum shape.

“Dynamic, fatigue and harmonic analysis of beam-to-beam system with various cross sections under impact load” (2022), Saeed Ahmed Asiri -In this research dynamic, fatigue and harmonic analysis of two beams in contact with a combination of cross-sections are carried out. ANSYS is used for numerical modelling of deformations and stresses developed within the two-beam system. Beams of three different combinations were simulated, i.e., square with square, circular with circular and square with circular. The results of the dynamic and fatigue analysis showed that the deformation is lowest and the fatigue life and safety factor is highest when one of the beams is square and the other is circular. When both beams have square cross-section, a slightly higher deformation occurs and the highest deformation occurs when both beams have circular cross-section. This concludes that square cross section beams have higher bending resistance while circular cross section beams have low bending resistance. Hence, peak performance in a beam-to-beam system for structural and machine design application is observed when the combination of beam cross sections is used.

“Finite Element Analysis and Parametric Study of Concrete Beams Under Impact Loading” (2022), Arya Sajith and Shilpa Pal- This study focuses on the finite element analysis of concrete beams subjected to impact load. Velocity impact simulations were conducted using the ANSYS Explicit Dynamics module to study the behaviour of concrete beams based on the resulting deformation and stress responses. By focusing on the height of the impact, shape of the impactor, material of the impactor, position of the impact and grade of concrete, a detailed parametric study has been conducted. The result indicates that the residual strength of the beam decreases with increase in the height of the impact. Higher-grade concrete offers greater resistance to deformation, while the use of a box impactor and a central impact position leads to increased beam deformation. The study also suggests that Finite Element Modeling can be used in accurately predicting the behavior of concrete beams under impact loads at an early design stage.

“Modelling and simulation of flexural behaviour for reinforced concrete beams using ANSYS” (2023), Mohamed et.al -In this study, a numerical model is developed using ANSYS 2022R2 software, to simulate flexural behaviour of RC beam. To examine the influence of reinforcement steel ratio and compressive strength of concrete on the flexural strength of the model, it is tested under four-point testing. Results conclude that, there is a considerable effect on the load deflection capacity with the increase in the tensile steel reinforcement ratio. The load-deflection behaviour of the numerical models was considerably affected with the increase in the concrete compressive strength. And also, the structural stiffness of the numerical model has a minor impact.

“Flexural behaviour of hybrid FRP-recycled aggregate concrete-steel hollow beams” (2023), Liwen Zhang - This paper presents the findings from an experimental program examining the flexural behaviour of hybrid FCS hollow beams with a rectangular hollow cross-section. Hybrid fiber reinforced polymer (FRP)-concrete-steel (FCS) hollow members are new type of structural elements known for their superior mechanical properties and long-term durability. Recycled aggregate concrete (RAC) was employed to tackle the pressing issue of construction waste today, while leveraging the benefits of FRP confinement to enhance RAC performance. The test results showed that these hybrid FCS hollow beams exhibit high ductility, with the shear connectors playing a crucial role in their behaviour. Finally, a theoretical beam model was proposed

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based on conventional section analysis, to predict the results of the test hybrid FCS hollow beams.

"Evaluating dynamic behaviour of a concrete dam using modal analysis" (2023), Surabhi Saxena and Mahesh Patel- This study examines the Shahpurkandi Dam, a 55.5-meter-tall concrete gravity dam, to investigate its dynamic properties through the finite element software ANSYS. Additionally, a case of the full reservoir is considered to evaluate the dam's modal response to explicitly model structure-acoustic interaction. By using a direct solver with the block Lanczos method, the first six mode shapes are extracted, and total displacement is recorded through numerical simulations. This study indicates that, at the first fundamental natural frequency, the maximum deformation, measuring 0.0039 mm, occurs at the dam's crest. Here, a comparison of the natural frequencies for both full and empty reservoir scenarios is demonstrated.

"Soil–pipe interaction and structural response under static and seismic loading for geopolymer concrete pipes" (2024), Kong Fah Tee and Sayedali Mostofizadeh – This study uses Solid 185 and Pipe 288 elements of ANSYS, to thoroughly investigate the nonlinear behavior of soil and geopolymer concrete (GPC) pipes. To evaluate the critical role of SPI parameters, 43 static and dynamic analyses are conducted and primarily focusing on optimal vertical displacement in the middle span of geopolymer concrete (GPC) pipes. Soil density is highlighted as the he most significant factor in both static and dynamic scenarios, showing that its impact under seismic loading is approximately 46% higher than under static conditions. This knowledge helps us in understanding the behavior of underground concrete pipes during seismic events. In enhancing the resilience and efficiency of underground concrete pipe systems, this study provides a valuable foundation.

"Numerical analysis of high-strength centrifugal precast RC hollow pipe columns using grouted corrugated duct connection: Confinement effect and ductility evaluation" (2024), Sibo Su et.al- This study explores the confinement effect and ductility of hollow columns using finite element analysis. The constitutive relationship of the core concrete is assessed by a modified model. Results shows that the confinement effect is sensitive to the wall thickness ratio; as the wall thickness ratio decreases, the ultimate strain of the core concrete significantly reduces, although strength remains relatively unaffected. To ensure both strength and ductility, a wall thickness ratio greater than 0.2 is recommended, and the peak load increases by 16.7% by increasing the ratio from 0.1 to 0.2. To support the preliminary ductile design of HSCP hollow columns, the study also introduces a ductility evaluation method and a design example.

"A comprehensive review of ultra-high-performance concrete (UHPC) behavior under blast loads" (2024), Jian Liu et.al- This paper presents a comprehensive overview of recent progress in ultra-high-performance concrete (UHPC) structural members—such as slabs, beams, and columns—as well as UHPC-based composite structures like mesh-reinforced UHPC, UHPC-filled steel tubes, and UHPC strengthening of normal reinforced concrete (NRC) structures for their ability to withstand blast loads. The exceptional material and structural dynamic performance of UHPC is highlighted here. The paper also offers recommendations for future research directions to resist blast loads, including the exploration of eco-friendly UHPC, the integration of 3D printing technology, and employing machine learning analytical methods.

"Dynamic mechanical behavior of steel fiber reinforced-recycled aggregate concrete subjected to uniaxial loading" (2024), Ping Li et.al – In this study, investigation of the dynamic mechanical performance of steel fiber reinforced-recycled aggregate concrete (SFRAC) under uniaxial loading is carried out. For this purpose, 22 groups of cylindrical samples of size 100mm x 200mm, were tested for uniaxial compression. The results indicate that incorporating steel and PVA fibers improves the integrity of fractured samples and modifies failure modes, with maximum increases in uniaxial compressive strength due to strain rate is 15.0%, Vsf is 23.57% and Vpf is 8.57 %. Although recycled aggregates did not significantly affect failure modes, the compressive strength was reduced by up to 16.34%.

"The Numerical and Experimental Analysis of the Utilization of Used Glass Fibre Reinforced Polymer (Gfrp) Strip on Reinforced Concrete (Rc) Slab Exposed to Impact Force" (2024), S.M Mubin et.al- In this study, cracks in reinforced concrete slabs is subjected to both low and high-velocity impacts, using recovered glass fiber reinforced polymer (GFRP) strips arranged in the configurations 0°, 45°, 0°-90°, and -45°-45°. First, by using a Universal Test Machine (UTM), the tensile properties of the used GFRP strips were obtained. By using ANSYS, 6 arrangements of GFRP strip were created and to assess the impact resistance, explicit dynamic analysis is done. Optimal performance was observed at the diagonal arrangement -45° and 45°, with total deformation of 56.03 mm and von Mises stress value of 67.07 MPa. When compared to the control beam, impact strength was improved by 33.2% in deformation and 10.6% in stress. Experimental results for the optimal GFRP strips showed differences of 3.9% and 9.4% between the numerical and experimental models, ensuring the reliability of the developed model.

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"Numerical simulation of projectile impact on reinforced concrete structures: a study of slab performance under varying projectile velocities using ANSYS" (2024), Abhishek Minhas and Seema- In this paper, a comprehensive study on the behavior of reinforced concrete slabs is conducted when they are subjected to varying projectile impact velocities. This study examines the dynamics of projectile impacts on reinforced concrete slabs using numerical simulations in ANSYS. Models replicate impacts on a standardized slab of 200 mm thickness, using a Steel 4340 ogive-nosed projectile, investigating different projectile velocities and geometries to understand their effects on internal stresses and deformations. For full penetration, this study identifies a critical velocity of 313m/s and evaluates how reinforcement spacing, diameter, and layers affects the slab performance. In optimizing the design guidelines and protective measures for the structures facing projectile impacts, this study makes a substantial contribution.

"Dynamic performance of fiber-reinforced ultra-high toughness cementitious composites: A comprehensive review from materials to structural applications" (2024), Liangming Sun et.al –A comprehensive review of the dynamic properties and damage mechanism of ultra-high toughness cementitious composite (UHTCC) reinforced with various fibers under different dynamic loading conditions is conducted in this study. The loading conditions include unidirectional, cyclic, instantaneous penetration, and seismic loading. The analysis discuses the numerical simulations that show UHTCC provides greater deformation capacity and energy dissipation compared to conventional concrete. Without significantly affecting its strain-hardening properties, the combination of steel and synthetic fibers enhances the dynamic strength of UHTCC. UHTCC demonstrates a longer service life under cyclic and fatigue forces, preserving structural integrity during projectile impacts, blasts, and seismic events, which helps reducing the risk of potential injuries.

"Dynamic behavior of ultra-high performance concrete beams with rectangular openings subjected to impact loads" (2024), Jian Liu et.al – By utilizing numerical simulations in ANSYS/LS-DYNA, the dynamic response of ultra-high-performance concrete (UHPC) beams with rectangular openings under low-velocity impact is examined. By using quasi-static four-point loading tests on UHPC beams with openings, the Continuous Surface Cap (CSC) model is validated. After that, to analyze the behavior of these beams, drop hammer impact simulations are conducted. Additionally, parametric investigations are conducted to evaluate the impact response of UHPC beams with varying opening sizes and positions, stirrup quantity and UHPC strength level.

"Three dimensional simulations of FRC beams and panels with explicit definition of fibres-concrete interaction" (2024), I. Marzec et.al- This paper aims to create a new and efficient mesoscale modeling approach for steel fiber-reinforced high-performance concrete (HPC). This approach involves fully 3D modeling that explicitly takes into account the distribution and orientation of the steel fibers. The results from numerical simulations is compared with data from an experimental campaign involving beams and panels made from high-performance concrete with different sizes and dosages of steel fibers, to validate and calibrate the finite element model.

III. METHODOLOGY

3.1 GENERAL

Simply supported hollow steel fiber reinforced beams of length 3000mm are modelled and analyzed using ANSYS. The beams of different cross section and thickness are modelled. It is analyzed by applying varying velocities. Initially, a velocity of 5000mm/sec is applied to the beam and gradually increased since the significant deflection in solid reinforced beam was observed at velocity 5000mm/sec onwards. But in case of hollow section, the deflection was more than permissible limit in most of them. Consequently, the velocity was gradually reduced until the beam was within safe operational parameters.

Table 3.1: Details of the beams modelled for the analysis

Sl. No	Dimensions (mm)	Thickness (mm)	Velocity (mm/sec)
1	100X100X3000	2	2000
			3000
			4000
			5000
			8000
			11000
		4	2000
			3000
			4000
			5000
			8000
			11000
		8	2000
			3000
			4000
			5000
			8000
			11000
2	200X300X3000	2	2000
			3000
			4000
			5000
			8000
			11000
		4	2000
			3000
			4000
			5000
			8000

			11000
			2000
		8	3000
			4000
			5000
			8000
			11000
3	300X350X3000	2	2000
			3000
			4000
			5000
			8000
			11000
		4	2000
			3000
			4000
			5000
			8000
			11000
		8	2000
			3000
			4000
			5000
			8000
			11000
4	400X450X3000	2	2000
			3000
			4000
			5000
			8000
			11000
		4	2000
			3000
			4000
			5000
			8000
			11000
		8	2000
			3000
			4000
			5000
			8000
			11000

3.2 WORKING WITH ANSYS

The beams are modelled and analyzed using ANSYS Explicit Dynamics. An Explicit Dynamics analysis is used to determine how a structure responds dynamically to stress wave propagation, impact or rapidly changing time-dependent loads. Important aspect of this type of analysis is exchange of momentum between moving bodies and the effects of inertia. This Analysis is particularly effective for events with time scales of less than 1 second, usually around one millisecond. The steps involved the analysis are as follows:

3.2.1: Create an analysis system

Open ANSYS software. From the tool box drag in explicit dynamics to the project Schematic.

3.2.2: Define Engineering Data

Open engineering data and define the material and material properties of the beam to be modelled. Material used here is Concrete. Here we have the option for deriving the results using combination of different data. In this analysis Youngs modulus and Poisson’s ratio is used for this analysis.

Table 3.2: Engineering Data Entries

Sl. No.	Material Property	value
1	Youngs modulus	30GPa
2	Poisson’s Ratio	0.25
3	Density	2500kg/m^3

3.2.3: Geometry

The geometry of the model is created in ANSYS Design Modeler. First, the sketch is created by selecting a plane along with proper dimensions, then it is extruded to form a solid 3-dimensional parametric model.

3.2.4: Material Assignment

Once the geometry is modelled, go to model. Ansys Mechanical tab will open. Here, the material assigned to the parts and bodies of the model can be changed.

3.2.4: Define Connections

After assigning the material, the connections to the bodies in the model should be applied. Ansys Explicit dybnamics automatically creates the contacts ann body interactions. We are keeping it as program controlled.

3.2.5: Generate Mesh

Meshing is the process where the geometry is spatially discretized into elements and nodes. To mathematically represent the stiffness and mass distribution of the structure, the mesh is used. To generate mesh, select mesh in the outline. In the detail view, select the physics preferance as explicit, element order as linear and element size as 15mm. The element used is SOLID185. A linear hexahedral mesh is generated. A linear hexahedran has 8 nodes. For the beam size 100mm x 100mm x 3000mm, the number of elements geneared is 11788 and number of nodes generated is 23472.

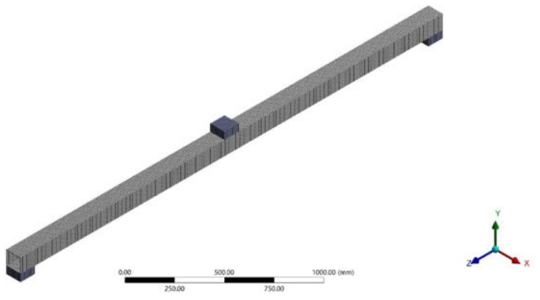

Fig 3.1: Generate mesh

3.2.6: Defining Initial Conditions

Defining Initial conditions is determined by the selected type of analysis. For an Explicit Dynamics analysis, utilize the Initial Conditions object to define Velocity, Angular Velocity, and Drop Height. These values can be applied to specific parts of the geometry. In this analysis velocity is applied.

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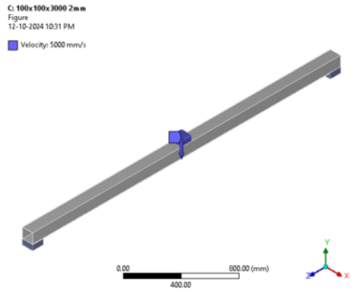

Fig 3.2: Initial Conditions - Velocity

3.2.7: Defining Boundary Conditions

Boundary conditions are frequent called "loads" or "supports". In this analysis, ‘fixed support’ is used. It is applied to the two bottom faces of the supports provided in the model, making it a simply supported beam.

3.2.8: Establish Analysis Settings

Each analysis type in ANSYS includes a group of analysis settings that allow you to tailor the solution options customized to the specific analysis type.

3.2.9: Perform Solution

The parameters to be calculated must be selected. In this analysis total deformation of the beam is calculated. In the outline, right click on solution, go to insert and select total deformation. After selecting, right click on Solution and select Solve. Solution progress for synchronous solutions is monitored by a ‘Solution Status’ window in the mechanical application.in this window conventional progress bars are displayed, along with a ‘Stop Solution’ and an ‘Interrupt Solution’ button.

IV. RESULT AND DISCUSSION

The analysis of various hollow steel fiber reinforced concrete beams of varying cross- sections (D1, D2, D3, D4), under different velocities and thicknesses is carried out.

5.1 Total deformation of hollow FRC beam of dimension 100X 100X3000mm (D1)

5.1.1: Thickness =2mm, Velocity=2000mm/s (D1)

The total deformation v/s time graph is plotted for the hollow beam (D1) of thickness 2mm, when subjected to a velocity of 2000mm/sec.

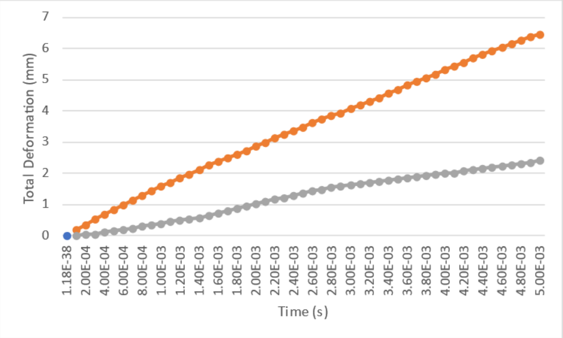

Fig 5.1.1: Total deformation v/s time graph, beam(D1), 2mm thickness, v=2000mm/s

From the above graph, the maximum deflection observed is 6.4784mm. According to IS 1343 1980, the maximum permissible deflection for the beam of size 3000mm is limited to 12mm. Since the observed deflection is within the permissible limit, we can conclude that, the beam is structurally safe when subjected to a velocity of 2000mm/sec.

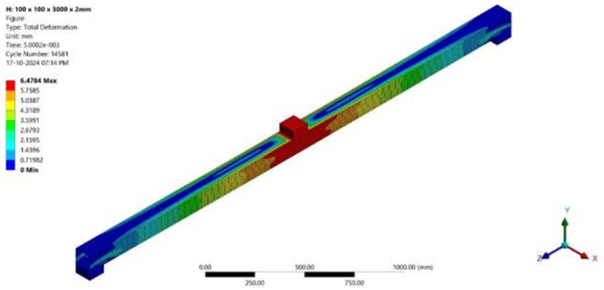

Fig 5.1.2: Total deformation v/s time graph, beam(D1), 2mm thickness, v=2000mm/s

5.1.2: Thickness =2mm, Velocity=3000mm/s (D1)

The total deformation v/s time graph is plotted for the hollow beam (D1) of thickness 2mm, when subjected to a velocity of 3000mm/sec.

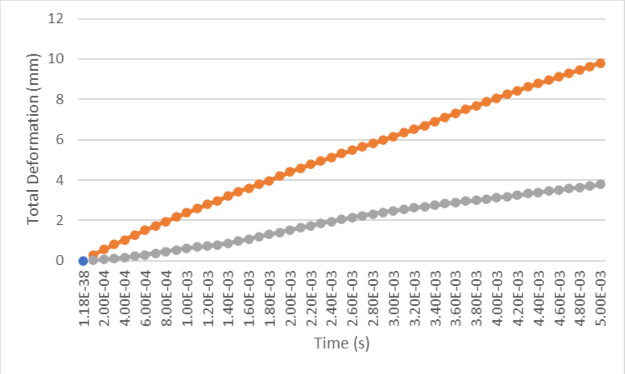

Fig 5.1.3: Total deformation v/s time graph, beam(D1), 2mm thickness, v= 3000mm/s

From the above graph, the maximum deflection observed is 9.797mm. According to IS 1343 1980, the maximum permissible deflection for the beam of size 3000mm is limited to 12mm. Since the observed deflection is within the permissible limit, we can conclude that, the beam is structurally safe when subjected to a velocity of 3000mm/sec.

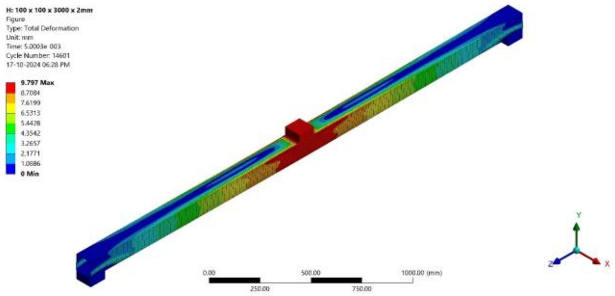

Fig 5.1.4: Total deformation of beam(D1), 2mm thickness, v= 3000mm/s

5.1.3: Thickness =2mm, Velocity=4000mm/s (D1)

The total deformation v/s time graph is plotted for the hollow beam (D1) of thickness 2mm, when subjected to a velocity of 4000mm/sec.

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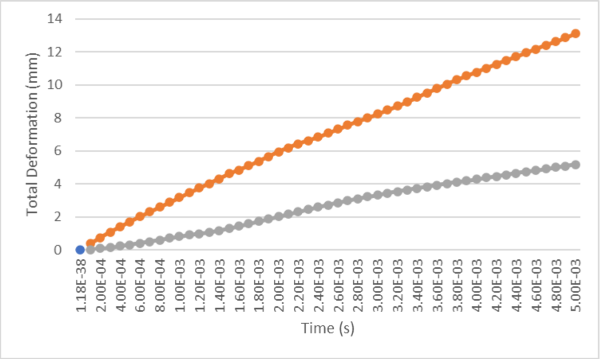

Fig 5.1.5: Total deformation v/s time graph, beam(D1), 2mm thickness, v= 4000mm/s

From the above graph, the maximum deflection observed is 13.115mm. According to IS 1343 1980, the maximum permissible deflection for the beam of size 3000mm is limited to 12mm. Since the observed deflection exceeds the permissible limit, we can conclude that, the beam is structurally unsafe when subjected to a velocity of 4000mm/sec.

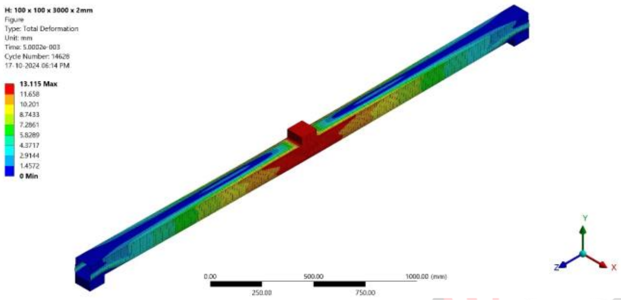

Fig 5.1.6: Total deformation of beam(D1), 2mm thickness, v= 4000mm/s

5.1.4: Thickness =2mm, Velocity=5000mm/s (D1) The total deformation v/s time graph is plotted for the hollow beam (D1) of thickness 2mm, when subjected to a velocity of 5000mm/sec.

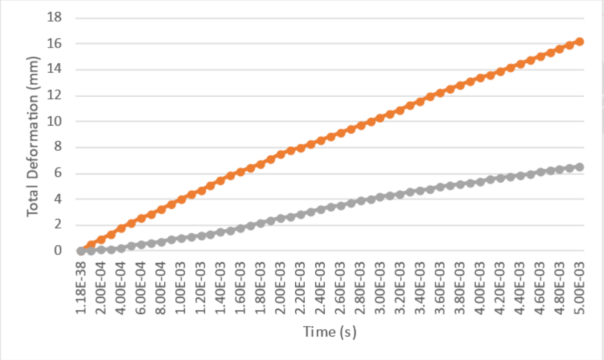

Fig 5.1.7: Total deformation v/s time graph, beam(D1), 2mm thickness, v= 5000mm/s

From the above graph, the maximum deflection observed is 16.246mm. According to IS 1343 1980, the maximum permissible deflection for the beam of size 3000mm is limited to 12mm. Since the observed deflection exceeds the permissible limit, we can conclude that, the beam is structurally unsafe when subjected to a velocity of 5000mm/sec.

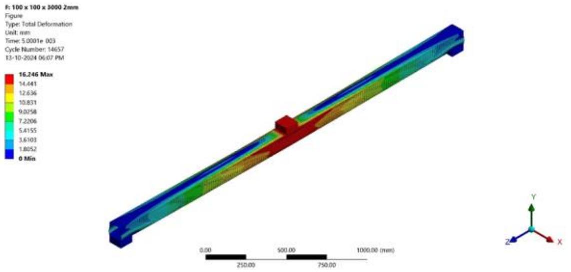

Fig 5.1.8: Total deformation of beam(D1), 2mm thickness, v= 5000mm/s

5.1.5: Thickness =2mm, Velocity=8000mm/s (D1)

The total deformation v/s time graph is plotted for the hollow beam (D1) of thickness 2mm, when subjected to a velocity of 8000mm/sec.

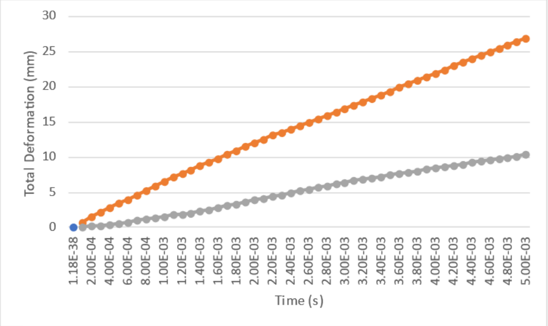

Fig 5.1.9: Total deformation v/s time graph, beam(D1), 2mm thickness, v= 8000mm/s

From the above graph, the maximum deflection observed is 26.823mm. According to IS 1343 1980, the maximum permissible deflection for the beam of size 3000mm is limited to 12mm. Since the observed deflection exceeds the permissible limit, we can conclude that, the beam is structurally unsafe when subjected to a velocity of 8000mm/sec.

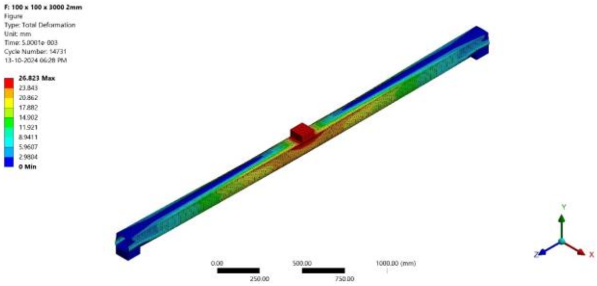

Fig 5.1.10: Total deformation of beam(D1), 2mm thickness, v= 8000mm/s

5.1.6: Thickness =2mm, Velocity=11000mm/s (D1)

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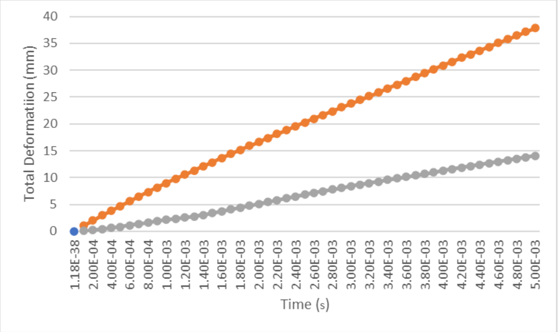

Fig 5.1.11: Total deformation v/s time graph, beam(D1), 2mm thickness, v= 11000mm/s

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From the above graph, the maximum deflection observed is 37.825mm. It is noted that, the deflection of the beam increases with the increase in velocity. According to IS 1343 1980, the maximum permissible deflection for the beam of size 3000mm is limited to 12mm. Since the observed deflection exceeds the permissible limit, we can conclude that, the beam is structurally unsafe when subjected to a velocity of 11000mm/sec.

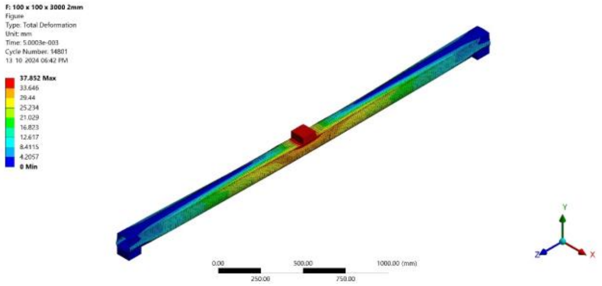

Fig 5.1.12: Total deformation of beam(D1), 2mm thickness, v= 11000mm/s

Similarly, for the thickness 4mm and 8mm, these velocities are applied and analyzed. This is done for cross sections D2, D3 and D4 also.

5.2: Comparison of deformation in the beams D1, D2, D3 and D4.

5.2.1: 100 X 100X 3000mm (D1)

Comparison of deformation in Beam D1 is graphically represented by plotting the total deformation v/s velocity graph for thickness 2mm, 4mm and 8mm, when subjected to varying velocity.

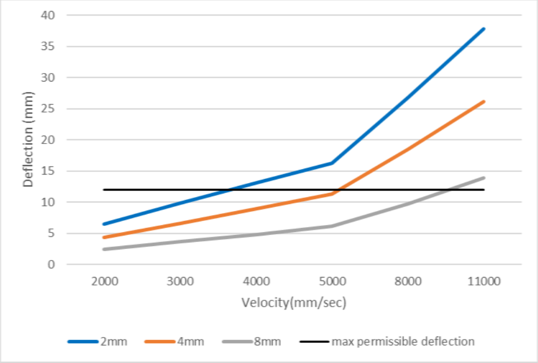

Fig 5.2.1: Comparison of deformation in Beam D1

From the above graph, it is observed that for the beam 100X100X3000mm, when the thickness is 2mm and 4mm, the beam is structurally safe at lower velocities and becomes unsafe at higher velocities. Whereas the beam of thickness 8mm remains safe till velocity of 8000mm/sec.

5.2.2: 200 X 300X 3000mm (D2)

Comparison of deformation in Beam D2 is graphically represented by plotting the total deformation v/s velocity graph for thickness 2mm, 4mm and 8mm, when subjected to varying velocity.

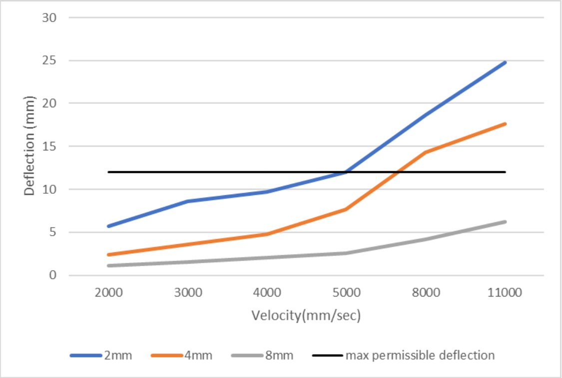

Fig 5.2.2: Comparison of deformation in Beam D2

From the above graph, it is observed that for the beam 200X300X3000mm, when the thickness is 2mm and 4mm, the beam is structurally safe at lower velocities at 4000mm/sec and 5000mm/sec respectively, and becomes unsafe at higher velocities. Whereas the beam of thickness 8mm remains safe even at velocity of 11000mm/sec.

5.2.3: 300 X 350X 3000mm (D3)

Comparison of deformation in Beam D3 is graphically represented by plotting the total deformation v/s velocity graph for thickness 2mm, 4mm and 8mm, when subjected to varying velocity.

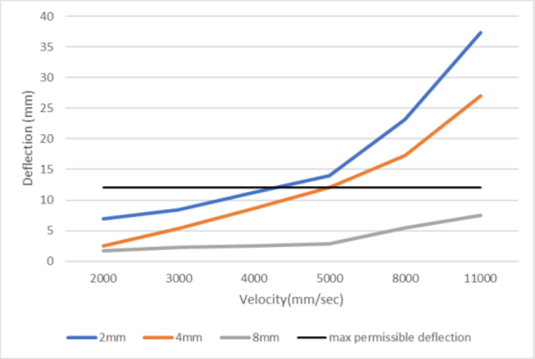

Fig 5.2.3: Comparison of deformation in Beam D3

From the above graph, it is observed that for the beam 300X350X3000mm, when the thickness is 2mm and 4mm, the beam is structurally safe at lower velocities at 4000mm/sec and 5000mm/sec respectively, and becomes unsafe at higher velocities. Whereas the beam of thickness 8mm remains safe even at velocity of 11000mm/sec.

5.2.4: 400 X 450X 3000mm (D4)

Comparison of deformation in Beam D4 is graphically represented by plotting the total deformation v/s velocity graph for thickness 2mm, 4mm and 8mm, when subjected to varying velocity.

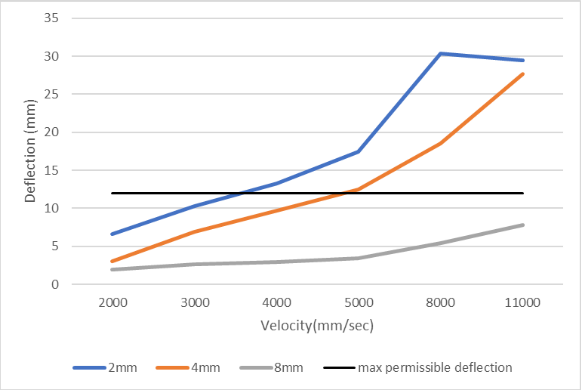

Fig 5.2.4: Comparison of deformation in Beam D4

From the above graph, it is observed that for the beam 400X450X3000mm, when the thickness is 2mm and 4mm, the beam is structurally safe at lower velocities at 3000mm/sec and 4000mm/sec respectively, and becomes unsafe at higher velocities. Whereas the beam of thickness 8mm remains safe even at velocity of 11000mm/sec.

V. CONCLUSION

The analysis evaluated the structural performance of various hollow steel fiber reinforced concrete beams of varying cross- sections (D1, D2, D3, D4), under different velocities and thicknesses. According to IS 1343 1980, the maximum permissible deflection for the beam of size 3000mm is limited to 12mm. Initially, a velocity of 5000mm/sec is applied to the beam and gradually increased since the significant deflection in solid reinforced beam was observed at velocity 5000mm/sec onwards. But in case of hollow section, the deflection was more than permissible limit in most of them. Consequently, the velocity was gradually reduced until the beam was within safe operational parameters.

In the study [11], the flexural behavior of hybrid fiber reinforced beams with longitudinal openings is highlighted primarily focusing on the static loading conditions, and the dynamic response of these structures is not considered. In our study, this gap is addressed by incorporating finite element analysis and providing a deeper understanding of the dynamic behavior and load-bearing capacity of hollow steel fiber-reinforced beams. This is an important factor as real-world applications frequently involve dynamic loads including impacts and vibrations.

It is noted from the analysis that, the deflection of hollow beams increases with velocity and decreases with thickness. While beams with 2mm and 4mm thickness are structurally safe at lower velocities, they become unsafe at higher speeds. Thicker beams (8mm) consistently show reduced deflection, enhancing stability. Overall, the results highlight that by increasing the thickness of hollow sections, decreases the deflection consistently and enhances the structural stability of the beams, validating the significance of material properties in design considerations.

REFERENCES

[1] T. Menouillard, A. D. Tzenkov & M.V. Schwager (2020) "Dynamic Analysis of Pine Flat Concrete Dam: Acoustic Fluid-Structural Interaction with ANSYS Workbench", Lecture Notes in Civil Engineering, vol. 91, pp 161–174, DOI: 10.1007/978-3-030-51085-5_6.

[2] A. Sahu, N. Pradhan, S.K. Sarangi. (2020), “Static and Dynamic Analysis of Smart Functionally Graded Beams”, Materials Today: Proceedings, Volume 24, Part 2, 1618-1625, Doi.org/10.1016/j.matpr.2020.04.483.

[3] Shubham Tiwari & Dr. Rakesk Patel (2020), “Crack Identification and Analysis of Rcc Beam Using Ansys”, International Journal of Scientific Research & Engineering Trends, Volume 6, Issue 3.

[4] Rafea F. Hassan, Muna H. Jaber, Nabeel H. Al-Salim, Husam H. Hussein (2020), “Experimental research on torsional strength of synthetic/steel fiber-reinforced hollow concrete beam”, Engineering Structures, vol. 220, Doi.org/10.1016/j.engstruct.2020.110948.

[5] Indrajeet Singh, Nirendra Dev, Shilpa Pal & Talakokula Visalakshi, (2021), “Finite Element Analysis of Impact Load on Reinforced Concrete”, Lecture Notes in Civil Engineering, vol. 203, pp 265–274, Doi.org/10.1007/978-981-16-7160-9_26.

[6] Nagavinothini Ravichandran, Daniele Losanno & Fulvio Parisi. (2021). “Comparative assessment of finite element macro-modelling approaches for seismic analysis of non-engineered masonry constructions”, Bulletin of Earthquake Engineering, vol. 19, Part 2, pp.5565–5607, doi.org/10.1 007/s10518-021-01180-3.

[7] Dhiraj Ahiwale, Harshada Madake, Nikita Phadtare, Amit Jarande, Deepak Jambhale, (2022), “Modal analysis of cracked cantilever beam using ANSYS software”, Materials Today: Proceedings, 56(Part 1), 165-170, Doi.org/10 .1016/j.matpr.2022.01.055.

[8] A.K. Gantayat, M.K. Sutar, J.R. Mohanty, (2022), “Dynamic characteristic of graphene reinforced axial functionally graded beam using finite element analysis”, Materials Today: Proceedings, 56(Part 1), 5923-5927, Doi.org/10.1016/j.matpr.2022.04.636.

[9] Janhavi Singh and Shilpa Pal, (2022), “Analysis of Blended Concrete Cubes under Impact loading using ANSYS”, IOP Conference Series: Earth and Environmental Science, Doi:10.1088/1755-1315/1084/1/012067.

[10] Asmaa Said, Mahmoud Elsayed, Ahmed Abd El-Azim, Fadi Althoey, Bassam A. Tayeh, (2022), “Using ultra-high performance fiber reinforced concrete in improvement shear strength of reinforced concrete beams”, Case Studies in Construction Materials, vol. 16,

doi.org/10.1016/ j.cscm.2022.e01009.

[11] V. Anuradha, T. Ch. Madhavi (2022), "Behaviour of self-compacting concrete hybrid fiber reinforced hollow beams". Structures, vol. 35, Pages 990-1001, doi.org/10.1016/j.istruc.2021.11.058.

[12] Saeed Ahmed Asiri, (2022). "Dynamic, fatigue and harmonic analysis of a beam to beam system with various cross-sections under impact load", Heliyon, vol. 8, doi.org/10.1016/j.heliyon. 2022.e10466.

[13] Arya Sajith & Shilpa Pal, (2022), "Finite Element Analysis and Parametric Study of Concrete Beams Under Impact Loading", Lecture Notes in Civil Engineering, vol.284, 2366-2565, Doi.org/10.1007/978-3-031-12011-4_20.

[14] Mohamed Khalifa Bneni and Samir Hasuna Ashour, (2023), "Modelling and simulation of flexural behavior for reinforced concrete beams using ANSYS", Al-Mukhtar Journal of Engineering Research, 07 (1): 43-56, DOI:10.54172/mx8n6k70.

[15] Liwen Zhang, Junjie Zhang, Guangming Chen, Guan Lin, (2023), "Flexural behavior of hybrid FRP-recycled aggregate concrete-steel hollow beams", Journal of Constructional Steel Research, vol 200, doi.org/10.1016/j.jcsr.2022.107650.

[16] Surabhi Saxena, Mahesh Patel (2023), "Evaluating dynamic behaviour of a concrete dam using modal analysis", Materials Today: Proceedings, 93(Part 3), pages 296-301, Doi.org/10.1016/j.matpr.2023.07.259.

[17] Kong Fah Tee & Sayedali Mostofizadeh (2024), "Soil–pipe interaction and structural response under static and seismic loading for geopolymer concrete pipes", Innovative Infrastructure Solutions, Volume 9, article number 49, https://doi.org/10.1007/s41062-023-01357-6.

[18] Sibo Su, Guangda Zhang, Qiang Han, Jiexin Yu, Xianzhuo Jia and Xiuli Du (2024), "Numerical analysis of high-strength centrifugal precast RC hollow pipe columns using grouted corrugated duct connection: Confinement effect and ductility evaluation", Engineering Structures, Volume 301, 15 February 2024, https://doi.org/10.1016/j.engstruct.2023.117326.

[19] Jian Liu, Jie Wei, Jun Li, Yu Su and Chengqing Wu (2024), "A comprehensive review of ultra-high-performance concrete (UHPC) behaviour under blast loads", Cement and Concrete Composites, Volume 148, April 2024, 105449, https://doi.org/10.1016/j.cemconcomp.2024.105449.

[20] Ping Li, Yuhong Yan, Enming Liu, Shan Li, Yiyan Lu, and Caiwang Tai (2024), "Dynamic mechanical behavior of steel fiber reinforced-recycled aggregate concrete subjected to uniaxial loading", Journal of Building Engineering, Volume 90, 1 August 2024, https://doi.org/10.1016/j.jobe.2024.109385.

[21] S. M. Mubin, Agusril Syamsir, Daud Mohamad, A.B.M Supian, Muhammad Najeeb, Z. Itam, and Vivi Anggraini (2024), "The Numerical and Experimental Analysis of the Utilization of Used Glass Fibre Reinforced Polymer (Gfrp) Strip on Reinforced Concrete (Rc) Slab Exposed to Impact Force". SSRN: https://ssrn.com/abstract=4764134 or http://dx.doi.org/10.2139/ssrn.4764134.

[22] Abhishek Minhas and Seema (2024), "Numerical simulation of projectile impact on reinforced concrete structures: a study of slab performance under varying projectile velocities using ANSYS", Innovative Infrastructure Solutions, 9, 372. https://doi.org/10.1007/s41062-024-01671-7.

[23] Liangming Sun, Shuguang Liu, Hanbing Zhao, Umar Muhammad, Da Chen and Wengui Li (2024), "Dynamic performance of fiber-reinforced ultra-high toughness cementitious composites: A comprehensive review from materials to structural applications", Engineering Structures, Volume 317, 15 October 2024, https://doi.org/10.1016/j.engstruct.2024.118647.

[24] Jian Liu, Sen Lu, Jie Wei and Shenchun Xu (2024), "Dynamic behaviour of ultra-high performance concrete beams with rectangular openings subjected to impact loads", Structures, Volume 69, 107362, https://doi.org/10.1016/j.istruc.2024.107362.

[25] I. Marzec , J. Suchorzewski and J. Bobiński (2024), "Three dimensional simulations of FRC beams and panels with explicit definition of fibres-concrete interaction, Engineering Structures 319 (2024), https://doi.org/10.1016/j.engstruct.2024.118856

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