FINITE ELEMENT INVESTIGATION ON RETROFITTING OF CONVENTIONAL BEAM USING STARCRETE VS TRADITIONAL CONCRETE.

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Abstract— This research work aimed a finite element investigation into the structural behavior of conventional reinforced concrete beams with varying span lengths. And to investigate and comprise the performance of starcrete vs traditional concrete for retrofitting a beam of length 1.3 m and 1,5m length. The grade of concrete is M20 and the grade of steel is Fe415. The beam is subjected under two-point concentrated load to enable a better understanding of the effects of shear span–depth ratio, for this investigation ANSYS FEA numerical software was used. The dimension of test specimens 1300mm x 150mm x 150 mm. and span of 1500mm x 150mm x 150mm. The deflection at mid-span, the failure mode and the load deflection deformation curve were examined.

Index Terms— conventional beam, Retrofitting, starcrete, Traditional concrete, ABAQUS, Mid span deflection, Span-depth ratio, Numerical Modelling.

I. INTRODUCTION

The concept of retrofitting dates back to the early 20th century when engineers and architects began to explore ways to reinforce older buildings to cope with evolving standards, especially after observing the devastating impacts of natural disasters like earthquakes and fires During the 1970s and 1980s, energy crises and environmental concerns further pushed the adoption of retrofitting in HVAC systems and insulation for energy efficiency. Retrofitting is the process of upgrading or modifying existing systems, structures, or equipment to meet new standards, improve performance, enhance safety, or extend their useful life. Unlike new construction, retrofitting focuses on improving the functionality of already-built environments.

Retrofitting a beam involves strengthening or modifying an existing beam to improve its load-carrying capacity, restore its structural integrity, or adapt it to new loading requirements. This is especially necessary in aging structures, after damage due to environmental conditions or overloading Beams are critical load-bearing elements in structural systems. Any failure or weakness in a beam can compromise the stability of the entire structure, making retrofitting a vital process for safety and durability. Beams are essential structural members that resist bending and transfer loads from slabs to columns and foundations. Over time, due to increased loading demands, material degradation, or design deficiencies, beams may require strengthening.

The finite element method (FEM) is a popular method for numerically solving differential equations arising in engineering and mathematical modelling. The present study undertakes a modelling and analytical exploration of the conventional beam using ABAQUS FEA. It is a software application used for both the modelling and analysis of components and assembling and visualizing the finite element analysis result. It involves a process of pre-processing simulation, and post processing. It involves the section is created and material properties like poisons ratio young's modulus should be determined and further design steps should follow to get the finite element analysis result.

II. LITERATURE REVIEW

1) Ahmed Hassen, et.al (2019): This study focused retrofitting is essential for restoring the structural capacity of RC beams after exposure to high temperatures. Self-Compacting Concrete (SCC) outperformed both NC and HSC in terms of thermal resistance and retrofitting efficiency, making it a suitable choice for fire-prone structures. Reinforced Concrete Jacketing (RCJ) proved to be the most universally effective retrofitting method, particularly for heavily deteriorated beams, while CFRP laminates and bonded steel plates were highly effective for moderately damaged SCC and HSC beams. The effectiveness of retrofitting techniques is strongly influenced by the type of concrete, temperature exposure, and retrofitting material properties.

2) A. Ramachandra Murthy, et.al (2019): The reviewed paper provides an in-depth examination of various techniques used to strengthen reinforced concrete (RC) beams, which play a fundamental role in the overall performance of structural systems. Over time, factors such as aging infrastructure, environmental exposure, and increased loading demands can significantly compromise the integrity of these elements. As a result, implementing effective strengthening strategies becomes essential to ensure safety and extend service life. Traditional approaches such as steel plate bonding and concrete jacketing continue to demonstrate effectiveness, though their application must be carefully considered within the broader framework of structural needs and constraints.

3) Dr Aled Roberts, et.al (2023): Researchers at the University of Manchester have developed an innovative material known as starcrete, composed of simulated Martian soil, potato starch, and a small amount of salt. This bio-based composite has demonstrated a remarkable compressive strength of 72 MPa, which is more than twice that of conventional concrete (typically around 32 MPa), and significantly stronger than earlier extraterrestrial construction materials. These characteristics position starcrete as a promising alternative to traditional concrete, which contributes approximately 8% of global CO_2 emissions. Recognizing its potential for both extraterrestrial and terrestrial use, the research team has launched a startup to explore commercial applications of the materials.

4) S. Scruton, et.al (2023): This study introduces starcrete, a novel bio-based composite material designed for extraterrestrial construction, made from potato starch, simulated Martian soil, magnesium chloride, and water. The use of starch as a renewable binder results in compressive strengths significantly higher than traditional concrete and any other bio-composite previously proposed for space use. starcrete offers key advantages such as low-energy production and material simplicity, making it highly practical for off-world manufacturing. Additionally, it presents a sustainable alternative to conventional concrete on Earth, which is responsible for about 8% of global CO_2 emissions. Tests revealed that high-viscosity starches contribute to greater strength, though the moisture sensitivity of the binder remains a challenge. This research marks a step forward in eco-friendly construction solutions for both planetary and terrestrial applications.

5) Mohammad Aghaei, et.al (2012): This study employs the ABAQUS finite element software to model the nonlinear flexural behavior of reinforced concrete (RC) beams using the Concrete Damaged Plasticity (CDP) model. The model was validated against experimental results it involving a full-scale RC beam under two-point loading. The simulation accurately captured load-deflection response, tensile strain in reinforcement, compressive strain in concrete, and crack development patterns. Initial flexural cracks at mid-span evolved into diagonal cracks, matching experimental observations. The validated model offers a reliable tool for analyzing RC structures, especially in design stages where physical testing is limited. This demonstrates ABAQUS's potential for accurate, efficient structural analysis when paired with proper material modeling and mesh refinement.

III. STARCRETE AND CONVENTIONAL BEAM

starcrete is an innovative material developed for building infrastructure on extraterrestrial surfaces like the Moon and Mars. It is a space-grade concrete alternative designed to be made from materials readily available on those planetary bodies, reducing the need to transport construction materials from Earth. starcrete is a revolutionary bio composite material developed for constructing buildings and infrastructure on extraterrestrial surfaces, such as Mars and the Moon. It's essentially a concrete-like material made from simulated extraterrestrial regolith (dust) and a starch binder, such as potato starch, with a pinch of salt. The concrete made with potato starch is twice as strong as previous versions, and even more so than traditional concrete.

The composition of starcrete is both innovative and practical, designed specifically for extraterrestrial construction using materials that are either already present on planetary surfaces or can be sustainably sourced during space missions. The primary component of starcrete is regolith simulant, which mimics the soil found on the Moon or Mars. To bind the regolith particles together, potato starch is used as the central adhesive agent. A small amount of sodium chloride (common salt) is often added to the mixture to enhance the strength and stability of the binder by improving intermolecular bonding within the starch.

A conventional beam is a fundamental structural element used extensively in construction and engineering to support loads and resist bending. Typically horizontal, conventional beams transfer applied loads primarily through bending moments and shear forces to supporting structures such as columns or walls. These beams are designed using classical beam theory, which assumes that the material behaves elastically under loading conditions. They are designed based on our requirement such as size, shape etc. Common materials used in conventional beams include reinforced concrete, steel, and wood, depending on the application and load requirements. They are classified based on their support conditions (simply supported, cantilever, fixed, continuous), cross sectional shapes (rectangular, I-beam, T-beam), and materials.

IV. DIMENSIONS

The conventional beam has been designed for the length of 1500mm and width of 150mm and breadth of 150mm and 1300mm and width of 150mm and breadth of 150mm with Two-point loading condition. The support condition is fixed for both cases. The effective depth is calculated by l/3 ratio. The above specified beam is modelled in Abaqus CEA software and the deformation is noted

V. REINFORCEMENT DETAILING

Two reinforced concrete beam specimens, designated as B1 and B2, were prepared and tested under fixed-end conditions. Beam B1 had dimensions of 1300 mm × 150 mm × 150 mm, while beam B2 measured 1500 mm × 150 mm × 150 mm. Both beams had a clear span of 1175 mm with an effective cover of 25 mm. Beam B1 was reinforced longitudinally with four 10 mm diameter bars, while beam B2 used four 12 mm diameter bars. For shear reinforcement, both beams were provided with 8 mm diameter two-legged stirrups spaced at 150 mm center-to-center along the span. The reinforcement detailing and dimensions were selected to ensure comparable conditions for evaluating the structural performance under similar loading and support constraints.

FIG 1: REINFORCEMENT DETAIL OF B1

FIG 2: REINFORCEMENT DETAIL OF B2

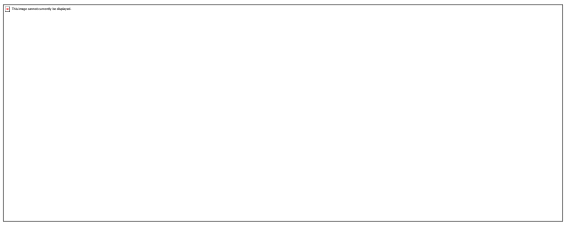
VI.NUMERICAL ANALYSIS

The Finite Element Method (FEM) is a widely used numerical technique for solving differential equations commonly encountered in engineering and scientific modeling, particularly in the field of structural analysis. The core idea behind FEM is to break down a complex structure into a finite number of smaller, manageable elements connected at discrete points known as nodes. This approach simplifies the analysis of structures that would otherwise involve an infinite number of variables. Abaqus, a powerful FEM-based software, is well-suited for analyzing both static and dynamic problems. In a typical finite element model within Abaqus, the process involves several key steps: defining the part module, assigning material properties, creating instances of parts, discretizing the model into elements (meshing), setting up interactions and boundary conditions, and finally applying loads. This structured approach enables accurate and efficient analysis of structural behavior under various loading conditions.

VII.RESULTS

The results obtained from the numerical and finite element analyses of the conventional beam provides a mid-span deflection for B1 and B2 the simulation is done on ABAQUS. it reveals that the well-detailed detail about the conventional beam. The ABAQUS module clearly shows the maximum deflection and maximum shear for the conventional beam B1 and B2. For both beam the failure occurs at midspan. The numerical analysis shows that the Deflection occurs at load of 64kN for 1.3 m length B1.the ABAQUS modelling result for beam (B1) are represented as maximum deflection and maximum shear.

FIG 3: MODEL FOR B1



Breadth:150mm, depth :150mm, length: 1300mm

FIG 4: SHEAR REPRESENTATION OF BEAM(B1)

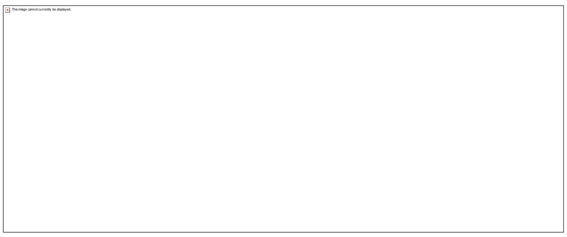


FIG 5: DEFLCTION OF BEAM (B1)

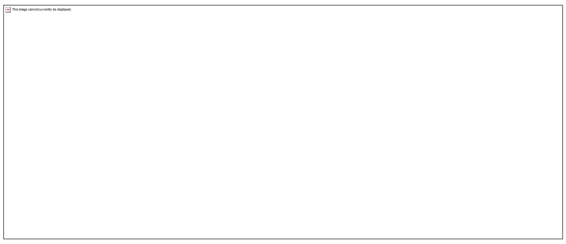
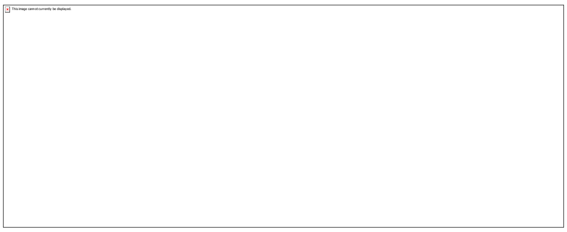


FIG 6: GRAPHICAL REPRESENTATION OF BEAM (B1)

The ABAQUS module for beam (B2). The failure occurs at midspan. The numerical analysis shows that the Deflection occurs at load of 21kN for 1.5 m length B2. the ABAQUS modelling result for beam (B2) are represented as maximum deflection and maximum shear.

FIG 7: MODEL FOR B2



Breadth:150mm, depth:150mm, length:1500mm

FIG 8: SHEAR REPRESENTATION OF BEAM(B2)

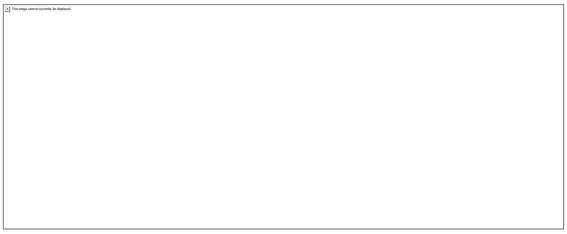


FIG 9 : DEFLECTION OF BEAM (B2)

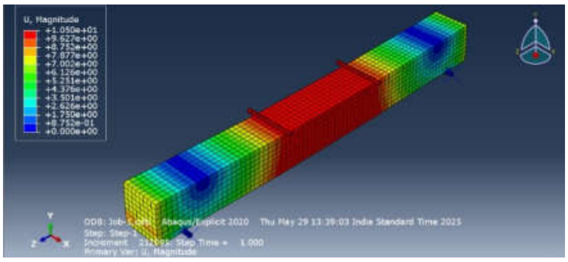
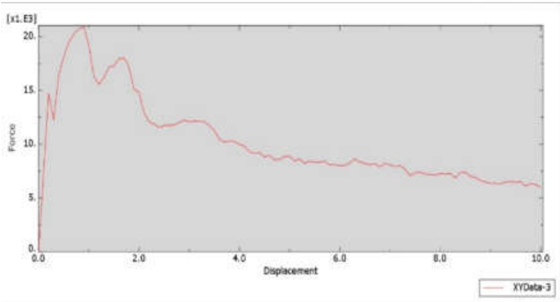


FIG 10: GRAPHICAL REPRESNETATION OF BEAM (B2)



VIII.CONCLUSION

The numerical analysis carried out using Abaqus/CEA software provides clear insight into the behaviour of conventional beams under loading. The study showed that the beam with a 1.3 m span (B1) could carry up to 64 kN before significant deflection occurred, while the longer 1.5 m beam (B2) showed deflection at a much lower load of 21 kN. After reaching these peak values, the load-carrying capacity dropped gradually, indicating the onset of structural weakening. These results highlight how increasing the span length leads to greater deflection and reduced stiffness, ultimately lowering the beam's ability to carry loads. The Load vs. Displacement graph further illustrates this trend, emphasizing the impact of span length on structural performance. Overall, the findings underscore the importance of considering span length in the design of conventional beams, as even small increases can lead to notable reductions in strength and stability. This study serves as a baseline for further investigation into retrofitting techniques using starcrete in the subsequent stages of the project.

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REFERENCES

1. Abaqus Analysis User Manual Version 6.11, Dassault Systems Similia Corp., Providence, RI, US, 2011.
2. Simonsen LC, Nealy JE. Radiation Protection for Human Missions to the Moon and Mars. NASA Tech Rep Serv; 1991. June 12, 2022).
3. Moses RW, Bushnell DM. Frontier in-situ resource utilization for enabling sustained human presence on mars. NASA Sci. Tech. June 12, 2022).
4. Design Code for Concrete Structures; GB50010–2010; China Construction Industry Press: Beijing, China, 2010.
5. Prem, P.R., Murthy, A.R.C., Gopal, R. and Bharathkumar, B.H. (2014), "Flexural behavior of damaged RC beams strengthened with ultra-high-performance concrete", Adv. Struct. Eng.,
6. Tahsiri, H., Sedehi, O., Khaloo, A. and Raisi, E.M. (2015), "Experimental study of RC jacketed and CFRP strengthened RC beams",
7. SP 34: 1987, Handbook on Concrete Reinforcement And Detailing, Bureau of Indian Standards, New Delhi.
8. Tejaswini T. and Rama Raju M.V. Analysis of RCC Beams using ABAQUS. International Journal of Innovations in Engineering and Technology Abaqus Analysis User's Guide (6.14), 2019.
9. Balciunas G, Vejelis S, Vaitkus S, Kairyte A. Physical properties and structure of composite made by using hemp hurds and different binding materials. Procedia Eng. 2013.
10. IS 456:2000,'Indian Standard plain and reinforcement concrete – code of practice', Bureau of Indian Standards, New Delhi, India, 2000.