NUMERICAL INVESTIGATION ON CONCRETE BEAM WITH PROSOPIS JULIFLORA ASH AND BASALT FIBER REINFORCEMENT

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Abstract - This research work is aimed to investigate the strength and durability characteristics of concrete beam with partial replacement of cement with Prosopis juliflora ash and Basalt fiber reinforcement and compare it with conventional reinforced concrete beam. The grade of concrete is M30 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 span–depth ratio. For this investigation ANSYS FEA numerical software was used. The dimension of test specimens are 1000 mm x150 mm x 150 mm. The deflection of mid-span, the characteristics of the full process of stress-strain relationship, the failure mode and the load deflection deformation curve were examined. The numerical analysis results showed that the failure mode of Basalt Fiber Reinforced Concrete (BFRC) beam with partial replacement of cement with Prosopis juliflora ash differed from that of the conventional reinforced concrete beam, exhibiting enhanced crack resistance and delayed failure due to improved ductility and bond strength. From this numerical analysis the deformation is maximum at midspan for both conventional reinforced concrete beam and BFRC beam and minimum at edges. The stress and strain were maximum at the edges.

1. INTRODUCTION

Global warming has emerged as one of the most critical environmental challenges of the 21st century. Among the major contributors to anthropogenic greenhouse gas emissions is the cement industry, which is responsible for approximately 8% of global carbon dioxide (CO_2) emissions. In response to growing environmental concerns and the global push toward sustainable development, there is an increasing focus on identifying and incorporating alternative materials that can partially or wholly replace conventional cement in construction. Sustainable construction practices are guided by three primary pillars: environmental sustainability, economic feasibility, and social responsibility. Within

this context, the present study investigates the **partial replacement of cement with *Prosopis juliflora ash***, a biomass-derived waste material, and the incorporation of ***basalt fiber as a reinforcing agent*** in concrete. *Prosopis juliflora*, often considered an invasive species, offers potential for value-added utilization when processed into ash, thus contributing to waste management and sustainability goals.

The objective of this research is to evaluate the mechanical performance and environmental benefits of concrete modified with Prosopis juliflora ash and basalt fiber, with the aim of promoting innovative and sustainable practices in civil engineering materials.

1.1 LITERATURE REVIEW

[1] "Effective Management of Prosopis juliflora in Southern Districts of Tamil Nadu", by Tamil Nadu State Land Use Research Board, State Planning Commission(March 2024) - **Tmt. Sudha S IFS, Member Secretary, State Planning Commission , Prof. Narasimman (Retd), Madras Christian College, Tamil Nadu Agricultural University & Research Institute, Madurai, Thiru. S. Govindaraju, Planning Officer, Land Use Division, SPC, Tmt. Durgadevi J, Technical Assistant**. They are very hardy, tolerating wide range of temperature, water, soil, and atmospheric humidity. They have fast growing ability, dormant of seeds and attractive taste of pods for many live stocks, seed maintaining viability in the livestock and wild animals droppings, it resistance to browsing and high ability of re-growth. They are highly allelopathic in nature, and it produces certain alleleo chemicals to discourage the nearby plants, which grows around them.

[2] "An experimental study flexural behaviour Prosopis juliflora ash concrete", Govindsamy. S, Professor & Head, Department of Civil Engineering, Vel Tech High Tech, Dr Rangarajan, Dr Sakunthala Engineering College, Chennai, India, MONISH RAJ. N. R Assistant Professor, Department of Civil Engineering, Vel Tech High Tech Dr Rangarajan Dr Sakunthala Engineering College, Chennai, India, ANJU. M S. The use of Prosopis juliflora ash (PJA) provides a sustainable method for managing this invasive species, turning an ecological threat into a construction asset. It aligns with *green construction* goals by reducing the carbon footprint of cement production. The flexural strength peaked at **2.5% replacement**, indicating that PJA acts as a micro-filler, improving bond strength and reducing micro-cracks—enhancing the overall ductility and performance of concrete under bending. Replacement levels above 2.5% resulted in

reduced strength properties, likely due to a lack of sufficient cementitious compounds for proper hydration. This shows there's a **threshold** after which PJA starts acting more like a filler than a reactive pozzolan. PJA shows mild pozzolanic properties. Its silica content reacts with calcium hydroxide in concrete, forming additional C–S–H (calcium silicate hydrate), which is responsible for increased strength at optimal dosages.

[3] "FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE BEAM USING BASALT FIBER" October 2020, **Manibalan P., SRM Institute of Science and Technology, Baskar Rajaram Annamalai University, Pannirselvam Narayanan, SRM Institute of Science and Technology**. The flexural behaviour of controlled concrete beam and fiber reinforced concrete beam has been analysed in this paper. The crack pattern, load carrying capacity, mid-span deflection, moment and curvature were predicted experimentally. The following are the conclusions drawn from the above results: Incorporating basalt fiber on to the concrete will arrest the crack than the controlled concrete shown by its crack pattern. The first cracking load for basalt fiber concrete beams is 21.27% higher than the control concrete beam.

1.2 Prosopis Juliflora Ash

Given its high silica and mineral content upon combustion, Prosopis juliflora ash (PJA) has shown promising potential as a supplementary cementitious material (SCM). When finely ground, the ash may exhibit pozzolanic properties, contributing to the strength and durability of concrete. Integrating PJA in partial cement replacement could reduce carbon footprint of construction. Utilization of waste material by turning an invasive species into a resource. It enhances mechanical properties when used in combination with reinforcements like basalt fiber.

Though often viewed as an ecological menace, Prosopis juliflora, when utilized thoughtfully, can serve as a resource for green construction solutions. By converting its ash into a cement alternative, we can address two major global challenges simultaneously—reducing cement-induced CO_2 emissions and managing invasive species. This aligns perfectly with the principles of sustainable development, wherein environmental, social, and economic goals intersect for the betterment of future generation.

1.3 BFR Rebars

Basalt fiber is revered for its exceptional **mechanical, thermal, and chemical properties,** which make it a competitive alternative to traditional reinforcement materials like steel and fiberglass. This contributes to reduced structural weight, easier handling, and lower transportation costs, especially beneficial in aerospace, automotive, and modern construction applications where lightweight materials are essential.

1.3.1 Density- 2700 kg/m3
1.3.2 Modulus of elasticity- 89-110 Gpa
1.3.3 Tensile strength- >2800 Mpa
1.3.4 Average lifespan- >100 years

Figure 1 BFR Rebars

2 NUMERICAL ANALYSIS USING ANSYS SOFTWARE

ANSYS is a powerful software suite used for engineering simulation and analysis. It offers a wide range of tools and capabilities for various engineering disciplines, including structural analysis, fluid dynamics, electromagnetic simulations, and more. ANSYS enables engineers to virtual1y prototype and test their designs, helping them optimize performance, reliability, and safety while reducing development costs and time. The model of 1000mm long with a cross section of 150 mm x 150 mm is fabricated.

PROCESSING STAGE

Pre-processing: In this stage the model of the physical problem is defined and an ANSYS input file was created.

Simulation: ANSYS simulation offers complete and powerful solutions for routine and sophisticated engineering problems.

Post processing: The results can be evaluated once the simulation has been completed and the displacements, stresses, or other fundamental variables have been calculated. The evaluation is generally done interactively using the visualization module.

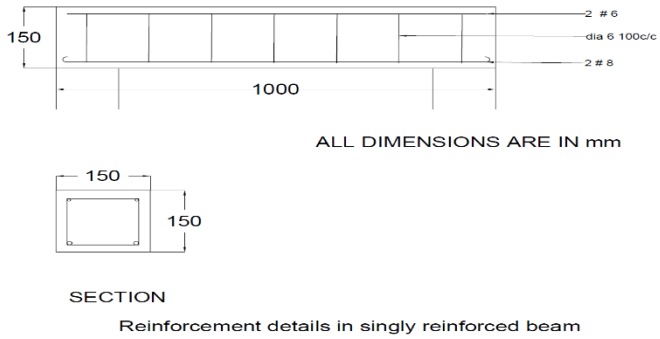

Fig. 2 Beam cross section

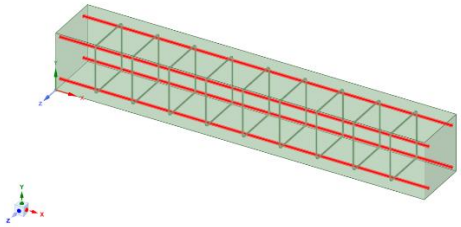

Fig. 3 Spaceclaim model

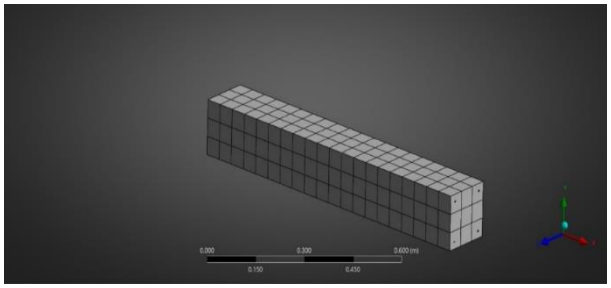

Figure 4 Geometry meshing model

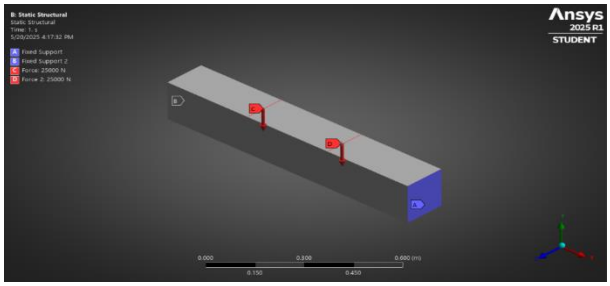

Figure 5 Two point loading on beam

3 PROCEDURE FOR ANALYSIS

Analysis procedure:

- The section was created based on the center line dimensions. The material properties like Young's modulus, Poisson's ratio, and Yield stress were defined and assigned to the sections.
- Then sections were assembled together using part instance.
- The section was converted into a finite element model by using mesh module.
- The reference points and constraints were created at both the ends. Then the boundary conditions were defined at both the ends based on the support condition.
- Unit loads were applied at reference points.
- Then the Eigen value buckling analysis was performed and deformed mode shape was obtained. Geometrical (local) imperfection was considered for this deformed shape and fed as

an input for the non-linear analysis.

- Then the non-linear analysis was performed and a graph was plotted between the load-deformation and stress-strain.
- From this graph the ultimate moment capacity (in kN-m) of the section and its corresponding results were obtained.

4. RESULTS AND DISCUSSION

The analysis is based on gradually applying loads on the beam. Load applied on the beam is between 50 to 400 kN and their corresponding deformation, stress and strain values are noted for each of the applied loads.

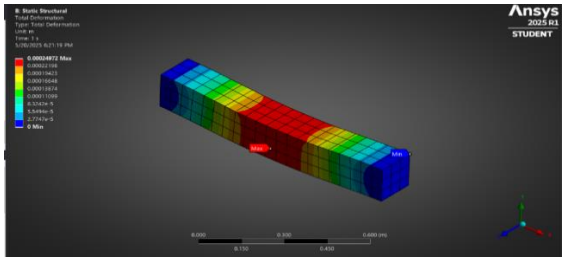

Figure 6 Total deformation

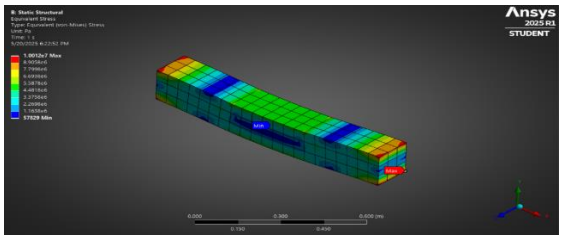

Figure 7 Total stress

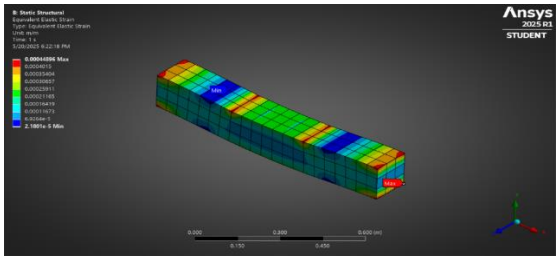

Figure 8 Total strain

S.NO	LOAD (kN)	DEFORMATION (mm)	STRESS(N/mm2)	STRAIN
1.	0	0	0	0
2.	50	0.25	10.012	0.00045
3.	100	0.40778	20.021	0.00090
4.	150	0.54651	30.026	0.00135
5.	200	0.66695	40.028	0.00179
6.	250	0.81493	50.027	0.00224
7.	300	0.98290	60.022	0.00269
8.	350	1.3256	70.013	0.00314
9.	400	1.6494	80.001	0.00359

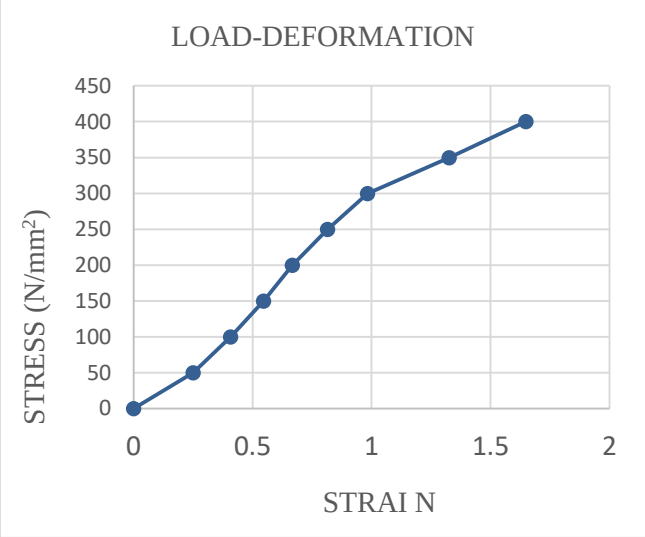

Fig 9 Load deformation graph

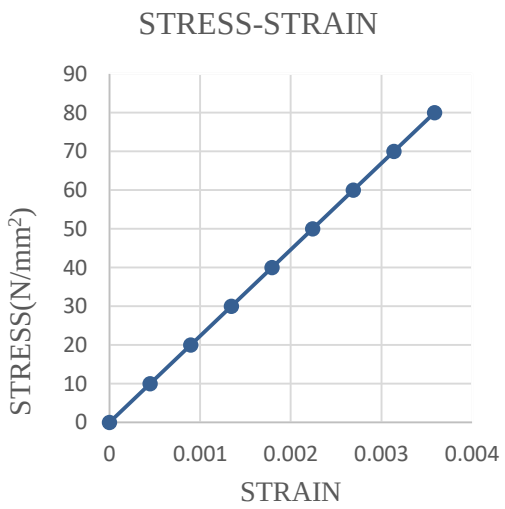

Fig 10 Stress strain graph

5. CONCLUSIONS

- This project effectively demonstrates the potential of incorporating Prosopis Juliflora ash and basalt fibers into concrete to enhance both environmental sustainability and structural performance.
- The ANSYS simulation results clearly illustrate the superior performance of basalt fiber reinforced concrete (BFRC) beams over conventional ones. Under increasing load conditions (50–400 KN), BFRC beams exhibited gradual deformation, linear stress-strain behaviour, and higher tolerance

indicating enhanced structural integrity and ductility. The stress distribution and crack resistance patterns from ANSYS images confirm that BFRC beams sustain higher loads with reduced strain concentrations.

- Overall, this study confirms that the combined use of Prosopis Juliflora ash and basalt fibers in concrete offers an eco-friendly, cost-effective, and structurally superior alternative for modern construction needs.

6. REFERENCES

1. "Effective Management of Prosopis juliflora in Southern Districts of Tamil Nadu", by Tamil Nadu State Land Use Research Board, State Planning Commission(March 2024) Tmt. Sudha S IFS, Member Secretary, State Planning Commission , Prof. Narasimman (Retd), Madras Christian College, Tamil Nadu Agricultural University & Research Institute, Madurai, Thiru. S. Govindaraju, Planning Officer, Land Use Division, SPC, Tmt. Durgadevi J, Technical AssistantACI Committee 318, Building Code Requirements for Structural Concrete (318- 95) and Commentary, American Concrete Institute, Farmington Hills, MI,1995.

2. "Impact of the Invasive Prosopis juliflora on Terrestrial Ecosystems, Sustainable Agriculture", M. Iftikhar Hussain, Ross Shackleton, Ali El-Keblawy, Luís González & M. Mar Trigo.

3. Abbas AM, Soliman WS, Mansour A et□al (2016) Predicting the spatial spread of invasive Prosopisjuliflora (SW.) D.C along environmental gradients in Gabel Elba National Park, Egypt. Int JSci Eng Res 7:596–599.

4. "An experimental study flexural behaviour Prosopis juliflora ash concrete", Govindsamy. S, Professor & Head, Department of Civil Engineering, Vel Tech High Tech, Dr Rangarajan, Dr Sakunthala Engineering College, Chennai, India, MONISH RAJ. N. R Assistant Professor, Department of Civil Engineering, Vel Tech High Tech Dr Rangarajan Dr Sakunthala Engineering College, Chennai, India, ANJU. M S.

5. "Influence of utilizing Prosopis juliflora ash as cement on mechanical properties of cement mortar and concrete" by Karthikeyan G.1*, Leema Margret A.1, Muruganantham R.1 and Harshani R.2 1Department of Civil Engineering, Ramco Institute of Technology, Rajapalayam–

626117, Tamilnadu, India 2Department of Civil Engineering, National Engineering College, Kovilpatti–628503, Tamilnadu, IndiaDeep Beam Group.

6. "Influence of Prosopis juliflora ash in mechanical properties of concrete", Author links open overlay panel Sridhar Jayaprakash , Vivek Deivasigamani , Gobinath RavindranJ.I. Enem, J.C. Ezech, M.S.W. Mbagiorgu, D.O. Onwuka, Analysis of deep beam using finite element method, *Int. Jour. Of Applied Sciences and Engineering Research,1(2),* 2012, 1-9.

7. "Experimental study on basic mechanical properties of basalt fiber reinforced concrete", H Zhou, B Jia, H Huang, Y Mou - Materials, 2020 - mdpi.com.Qian, G.L. Experimental study on reinforced concrete simply supported deep beams. J. Wuhan Inst. Water Resour. Electr. Power 1980, 4, 25–34.

8. "Experimental study on direct tensile fatigue performance of basalt fiber reinforced concrete", Xutao Zhang, Chao Lou & Xikuan Lyu. The European Standard EN 1992–1–1:2004, Eurocode 2, Design of Concrete Structures; British Standards Institution: Brussels, Belgium, 2004.

9. "Flexural behaviour of reinforced concrete beam using basalt fiber" - October 2020, Manibalan P., SRM Institute of Science and Technology, Baskar Rajaram Annamalai University, Pannirselvam Narayanan, SRM Institute of Science and Technology.

10. "Investigation on Concrete Beams Reinforced with Basalt Rebars as an Effective Alternative of Conventional R/C Structures, Author links open overlay panel Marek Urbanski Andrzej Lapko b, Andrzej Garbacz.

11. "Performance of concrete beams reinforced with basalt fibre composite rebar". Author links open overlay panelJason Duic ,, Sara Kenno b, Sreekanta Das.

12. International Journal of Civil Engineering and Technology (IJCIET). Volume 8, Issue 3, March 2017, pp. 1103–1111 Article ID: IJCIET_08_03_113. "Modelling and analysis of Rc beam under flexure using Ansys". Diyyala Naga Moulika, B. Tech Student, Department of Civil Engineering, KL University, Vaddeswaram, Andhra Pradesh, India, Reshma Vasireddy, B. Tech Student, Department of Civil Engineering, KL University, Vaddeswaram, Andhra Pradesh, India, P. Polu Raju, Associate Professor, Department of Civil Engineering, KL University,, Vaddeswaram,

Andhra Pradesh, India.

13. Asian journal of Civil Engineering (BHRC) VOL. 14, NO. 4 (2013) “Finite element analysis of FRC strengthened RC beam using Ansys , P. Jayajothi, * R. Kumutha and K. Vijai, Department of Civil Engineering (PG), Sona College of Technology, Salem, India. Received: 10 October 2012; Accepted: 8 February 2013.

14. “Finite Element Modeling and Simulation with ANSYS Workbench”, Second Edition, ByXiaolin Chen, Yijun Liu.