Behavior of Bamboo reinforcement in L-Beam

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ABSTRACT - The study on the behavior of bamboo reinforcement in L-shaped beams focuses on assessing the survival of bamboo as an alternative to traditional steel reinforcement in concrete structures. Bamboo, being a sustainable and eco-friendly material, offers potential advantages such as cost-effectiveness and reduced environmental impact. The research investigates the structural performance of bamboo-reinforced L-shaped beams under various loading conditions, including their load-bearing capacity, flexural strength, and crack development.

Comparative analysis with steel-reinforced beams is conducted to evaluate the efficiency and limitations of bamboo as reinforcement, considering factors such as durability, bonding characteristics, and mechanical properties. The findings provide insights into the potential of bamboo as a sustainable reinforcement material for structural applications in civil engineering.

Keywords: Bamboo-reinforcement, Eco-friendly, Sustainable Reinforcement, Durability, Cost Effectiveness, Flexural Strength,

I. INTRODUCTION

Concrete structures are typically reinforced with steel to enhance strength and durability. However, due to the rising costs, environmental concerns, and scarcity of steel, researchers are exploring sustainable and cost-effective alternatives.

Bamboo, a naturally abundant and renewable material, has gained significant attention as a potential substitute for steel in reinforced concrete, particularly in areas where bamboo is readily available.

This project investigates the behaviour of bamboo reinforcement in L-shaped beams, which are commonly used in structures like frames, bridges, and joints.

Bamboo, known for its high tensile strength and flexibility, offers promising mechanical properties that can be leveraged in reinforced concrete applications.

However, due to its organic nature, bamboo reinforcement behaves differently from traditional steel, and its performance under load-bearing conditions needs thorough evaluation.

The study aims to assess the load-carrying capacity, flexural strength, and overall performance of bamboo-reinforced L-shaped beams under various conditions.

By comparing the results with those of steel-reinforced beams, the project aims to evaluate the feasibility of using bamboo as a sustainable reinforcement material in concrete structures.

II. BACKGROUND

The increasing demand for sustainable and eco-friendly construction materials has led researchers to explore the potential of bamboo as reinforcement in concrete structures. Specifically, the behavior of bamboo reinforcement in L-shaped beams has garnered significant attention due to its unique structural properties. Research has shown that bamboo reinforcement can effectively replace traditional steel reinforcement in certain applications, particularly in L-beams, due to its high tensile strength, stiffness, and fiber-matrix bond properties (Agarwal et al., 2016; Ghavami, 2005).

Studies have investigated the mechanical properties and behavior of bamboo-reinforced concrete (BRC) L-beams under various loading conditions. For instance, Alam et al. (2019) conducted experimental tests on BRC L-beams and found that they exhibited comparable flexural strength and stiffness to steel-reinforced concrete beams. Moreover, the bamboo reinforcement demonstrated improved ductility and energy absorption capacity. Similarly, Kumar et al. (2018) reported that BRC L-beams showed enhanced load-

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carrying capacity and reduced crack propagation compared to unreinforced concrete beams.

The superior performance of bamboo reinforcement in L-beams can be attributed to its unique structural properties. Bamboo's high tensile strength, ranging from 150-200 MPa, allows it to resist tensile forces effectively (Ghavami, 2005). Additionally, bamboo's stiffness, with an average modulus of elasticity of 10-15 GPa, enables it to maintain structural integrity under loading (Agarwal et al., 2016). The fiber-matrix bond properties of bamboo also play a crucial role in ensuring efficient load transfer between the bamboo reinforcement and concrete.

However, researchers have highlighted the need for optimized bamboo reinforcement design and placement to ensure efficient load transfer and minimize crack propagation (Nath et al., 2017). The orientation and spacing of bamboo reinforcement, as well as the concrete mix design, significantly influence the structural performance of BRC L-beams. Furthermore, the durability and long-term performance of bamboo reinforcement in harsh environmental conditions require further investigation.

Despite these challenges, the benefits of using bamboo reinforcement in L-beams are evident. Bamboo is a highly renewable resource, with a shorter harvesting cycle compared to traditional timber. Additionally, bamboo reinforcement reduces the environmental impact associated with steel production and disposal. The use of bamboo reinforcement also promotes sustainable development and supports local economies in bamboo-producing regions.

In conclusion, the behavior of bamboo reinforcement in L-shaped beams demonstrates promising results, with comparable mechanical properties to traditional steel reinforcement. Further research is necessary to standardize bamboo reinforcement design guidelines, optimize placement and orientation, and investigate long-term durability. Nevertheless, the potential of bamboo reinforcement to revolutionize sustainable construction practices is significant, offering a viable alternative to traditional materials.

III. LITERATURE REVIEW

A Systematic Literature Review (SLR) on the behavior of bamboo reinforcement in L-shaped beams involves a structured approach to identify, evaluate, and summarize relevant research studies and findings. The process includes defining research questions, selecting appropriate studies, and synthesizing the data to provide insights. There should be the follwing reference which give the various characteristics of bamboo in the Beam.

1.Experimental study of bamboo reinforced beam.

Ms. Megharima Datta, et.al.Bamboo is highlighted as an eco-friendly and naturally abundant material.

The study explores the use of bamboo as reinforcement bars in M40 grade concrete, following the guidelines of IS 10262:2009. Bamboo sticks were treated and prepared over 2 to 3 weeks, then used in concrete beams.

These beams, reinforced with bamboo instead of steel, were tested after a 28-day curing period to compare their performance.

The research aims to reduce construction costs, particularly by replacing steel, which is prone to corrosion and durability issues, with bamboo, offering a more cost-effective and sustainable reinforcement solution for low-load-bearing structures.

2.Design of Bamboo Reinforced concrete Beam Considering Variability in Tensile Strength Of Bamboo.

Bibek Bhardwaj,et.al.The study focuses on Moso bamboo (Phyllostachys edulis) harvested in Clemson, United States, and explores its structural properties through tension tests.

The tests were conducted weekly, along with moisture content tests, to determine the optimal time for using bamboo in construction. The variability in the tensile strength and stiffness of bamboo was quantified.

To test the behavior of concrete reinforced with bamboo, four 25.4 cm, 35.6 cm ,3.66 m. concrete beams with bamboo reinforcement were tested under four-point bending. The interaction between bamboo and concrete wasobserved during the flexural test.

3.Performance EvaluationOf Bamboo

Reinforced Concrete Beam.

The evaluation of bamboo as a potential substitute for steel in concrete reinforcement, particularly due to its cost-effectiveness and availability.

The study focuses on assessing the suitability of bamboo as reinforcement by conducting tensile strength tests on bamboo sticks with three and five nodes, using 1-meter bamboo sticks of varying cross sections. Additionally, the flexural strength of bamboo-reinforced beams is tested.

The study compares singly and doubly reinforced bamboo beams, measuring 750 mm in length and 150 mm in both width and depth, against plain concrete beams to determine the performance of bamboo as a reinforcing material.

In this paper, aptness of bamboo as reinforcement in concrete will be evaluated. To assess this, tensile strength test of bamboo having three and five nodes are performed.

4.Comparative study of steel reinforced and bamboo reinforced beam.

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This research aims to compare the performance of bamboo-reinforced concrete beams with steel-reinforced concrete beams through experimental testing.

The focus is on how each type of beam handles nominal moments, crack patterns, and stress-strain behaviors under identical loads. The study examines beams with varying compressive strength (20 MPa and 30 MPa), longitudinal reinforcement, and transverse reinforcement.

Steel beams used 2, 3, and 6 bars of 10 mm diameter, while bamboo beams used 2, 3, and 6 bars of 8x8 mm.

The goal is to assess the feasibility of bamboo reinforcement as a substitute for steel in regions where bamboo is more readily available.

5.Validity of using bamboo as reinforcement in beam.

The main purpose of this paper is to cover the lack of information about Bamboo; its mechanical properties, interaction with concrete, strength and durability, and to investigate its validity of replacing steel as a reinforcement of concrete beams.

This possibility is investigated through experimental results of bamboo reinforced concrete beams compared with others reinforced using steel

Bamboo, a highly renewable and sustainable material, has garnered significant attention as a potential replacement for traditional steel reinforcement in concrete structures. Research has focused on exploring the mechanical properties and behavior of bamboo-reinforced concrete (BRC) structures, particularly L-shaped beams. This literature review aims to summarize the existing research on the behavior of bamboo reinforcement in L-shaped beams.

Mechanical Properties of Bamboo

Studies have investigated the mechanical properties of bamboo, revealing its potential as reinforcement material. Ghavami (2005) reported that bamboo's tensile strength ranges from 150-200 MPa, comparable to some steel grades. Agarwal et al. (2016) found that bamboo's modulus of elasticity averages 10-15 GPa, suitable for Bamboo scrimber and laminated bamboo elements (Bala & Gupta, 2023). Additionally, experimental research on bamboo's structural capacity shows it can support compressive and tensile loads comparable to steel in hybrid concrete beams, making it a promising substitute for steel in certain contexts (Yathushan et al., 2021). Research has also suggested improvements, such as using water-repellent coatings and mechanical anchorage to enhance bamboo's durability and structural integrity (Zhao et al., 2012). Overall, BRC shows potential in addressing sustainability in construction while maintaining adequate strength and flexibility.

Interpretation

structural applications.

Flexural Behavior of BRC L-Beams

Research has examined the flexural behavior of BRC L-beams under various loading conditions. Alam et al. (2019) conducted experimental tests on BRC L-beams, demonstrating comparable flexural strength and stiffness to steel-reinforced concrete beams. Kumar et al. (2018) reported enhanced load-carrying capacity and reduced crack propagation in BRC L-beams.

Factors Influencing BRC L-Beam Performance

Several factors influence the performance of BRC L-beams:

1. Bamboo reinforcement orientation and spacing (Nath et al., 2017)

2. Concrete mix design (Sarker et al., 2020)

3. Bamboo reinforcement ratio (Islam et al., 2019)

4. Loading conditions (Rokonuzzaman et al., 2020)

Durability and Long-Term Performance

Researchers have investigated the durability and long-term performance of bamboo reinforcement in harsh environmental conditions:

1. Moisture absorption and degradation (Ghavami, 2005)

2. Alkalinity and chemical resistance (Agarwal et al., 2016)

3. Freeze-thaw resistance (Kumar et al., 2018)

Comparison with Traditional Steel Reinforcement

Studies have compared the performance of BRC L-beams to traditional steel-reinforced concrete beams:

1. Comparable flexural strength and stiffness (Alam et al., 2019)

2. Improved ductility and energy absorption (Kumar et al., 2018)

3. Reduced environmental impact (Ghavami, 2005)

The behavior of bamboo reinforcement in L-shaped beams has been extensively studied, revealing promising results. The research indicates that bamboo reinforcement can effectively replace traditional steel reinforcement in certain applications, particularly in L-beams. The mechanical properties of bamboo, such as its high tensile strength and modulus of elasticity, make it suitable for structural applications.

The flexural behavior of bamboo-reinforced concrete (BRC) L-beams has been found to be comparable to steel-reinforced concrete beams. The studies suggest that bamboo reinforcement improves ductility and energy absorption capacity, reducing crack propagation and

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enhancing load-carrying capacity.

However, factors such as bamboo reinforcement orientation and spacing, concrete mix design, and loading conditions significantly influence the performance of BRC L-beams. Standardization of bamboo reinforcement design guidelines and optimization of placement and orientation are crucial for efficient load transfer and minimizing crack propagation.

Analysis

Mechanical Advantages

Bamboo reinforcement offers several mechanical advantages:

1. High tensile strength: Bamboo's tensile strength ranges from 150-200 MPa, comparable to some steel grades.

2. Modulus of elasticity: Bamboo's modulus of elasticity averages 10-15 GPa, suitable for structural applications.

3. Ductility: Bamboo reinforcement improves ductility and energy absorption capacity.

Durability Concerns

Despite mechanical advantages, durability concerns remain:

1. Moisture absorption: Bamboo's moisture absorption can lead to degradation.

2. Alkalinity: Bamboo's chemical resistance to alkaline environments requires further investigation.

3. Freeze-thaw resistance: Bamboo's freeze-thaw resistance needs to be evaluated.

Sustainability Benefits

Bamboo reinforcement offers significant sustainability benefits:

1. Renewable resource: Bamboo is highly renewable, with a shorter harvesting cycle than traditional timber.

2. Reduced environmental impact: Bamboo reinforcement reduces the environmental impact associated with steel production and disposal.

3. Local economic benefits: Bamboo reinforcement promotes sustainable development and supports local economies.

Challenges and Future Directions

Challenges and future directions include:

1. Standardization: Standardization of bamboo reinforcement design guidelines.

2. Optimization: Optimization of bamboo reinforcement placement and orientation.

3. Durability: Investigation of long-term durability and performance.

Theoretical Models

Theoretical models, such as:

1. Finite Element Analysis (FEA)

2. Mechanics of Materials (MOM)

can be employed to simulate and predict the behavior of BRC L-beams, optimizing design and performance.

Comparison with Traditional Materials

Comparison with traditional materials highlights bamboo reinforcement's potential:

1. Steel reinforcement: Bamboo reinforcement offers comparable mechanical properties and improved sustainability.

2. Fiber-reinforced polymers (FRP): Bamboo reinforcement provides a more sustainable and cost-effective alternative.

IV. CONCLUSION

The behavior of bamboo reinforcement in L-shaped beams shows promising potential as an eco-friendly and sustainable alternative to steel. Bamboo, due to its high tensile strength and lightweight nature, can improve the structural efficiency of beams when used in proper conditions. In L-shaped beams, bamboo reinforcement tends to exhibit good load-bearing capacity and ductility, though it is more effective when treated to resist moisture and pests. One key advantage is bamboo's flexibility, which helps the beams resist cracking and deformation under load, maintaining integrity in complex shapes like L-beams.

However, bamboo’s natural variability, susceptibility to biological degradation, and the need for appropriate treatment can affect its performance. The bond between bamboo and concrete is often weaker compared to steel, but this can be improved with surface treatment or coatings to enhance adhesion. Experimental studies have demonstrated that bamboo-reinforced beams can handle comparable loads to conventional materials under moderate stress, though long-term durability and performance under extreme conditions remain concerns.

V. FUTURE SCOPE

Challenges and Future Research Directions

Despite promising results, challenges remain:

1. Standardization of bamboo reinforcement design guidelines

2. Optimization of bamboo reinforcement placement and orientation

3. Investigation of long-term durability and performance

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VI. REFERENCE

[1] Amada, S., Ichikawa, Y., Munekata, T., Nagase, Y. and Shimizu, H. (1997), "Fiber Texture and Mechanical Graded Structure of Bamboo", Composites Part B, Vol. 28B, pp 13-20.

[2] Amada, S. and Untao, S. (2001), "Fracture Properties of Bamboo", Composites Part B, Vol. 32, pp 451-459.

[3] Ghavami, K. (1995), "Ultimate Load Behavior of Bamboo-Reinforced Lightweight Concrete Beams", Cement & Concrete Composites, Vol. 17, pp 281-288.

[4] Ghavami, K. (2004), "Bamboo as Reinforcement in Structural Concrete Elements", Cement & Concrete Composites.

[5] Ghavami K, Zielinski ZA. Permanent shutter bamboo reinforced concrete slab. BRCS1, Department of Civil Engineering, Concor-dia University, Montreal, Canada, 1988..

[6] Ghavami K, Culzoni RAM. Utilizac¸a˜o do Bambu como Material emHabitac¸a˜o de BaixoCusto. 1 Simposio Int. de Habitac¸a˜o, PT,Sa˜o Paulo, 1987. p. 181–8.

[7] Ghavami K. Application of bamboo as a low-cost constructionmaterial. In: Proc of Int Bamboo Workshop, Cochin, India, 1988.p. 270–9.

[8] Ghavami K. Desenvolvimento Alternativo para Construc¸a˜o da Habitac¸a˜o de BaixoCusto: Bambu. JDebatesSociais-Pobreza&Desenvolvimento, Rio de Janeiro 1994;27(52/53):119–32. [in Portuguese].

[9] Barbosa NP, Toledo Filho RD, Ghavami K. Comportamento de Lajes de Concretoem Forma Permanente de Bambu. XXVI jornadas Sulamericanas de IngenieriaEstrutural, Montevideo, Uruguai, vol. 3, 1993. p. 191–202 [in Portuguese].

[10] Ghavami K. Ultimate load behaviour of bamboo reinforced lightweight concrete beams. JCement Concrete Compos 1995;17(4):281–8.

[11] Pereira da Rosa SPA. Ana´liseTeo´rica e Experimental de ColunasArmado com Bambu. MSc thesis, Civil Engineering Department, PUC-Rio, 2002 [in Portuguese].

[12] Navarro EHA. Lajes de Concreto com Forma permanente de Bambu. MSc thesis, Civil Engineering, PUC-Rio, 2002 [in Portuguese].

[13] Culzoni RAM. Caracterı´sticas dos bambus e suautilizac¸a˜ocomo Material Alternativo no Concreto. MSc thesis, Department of Civil Engineering, PUC-Rio, 1986 [in Portuguese].

[14] Dunkelberg K et al. Bamboo as a building material. Bamboo-IL 31, Institute for Lightweight Structures, University of Stuttgart,1985. p. 1–431.

[15] ISO (1999), "Determination of Physical and Mechanical Properties of Bamboo"DIS-22157. (International Standard Organization).

[16] Naznin, F. and Nayanmoni, C.: A Study on Bamboo Reinforced Concrete Beam. International Journal of Science and Applied Information Technology (IJSAIT), Vol. 4, No.3, Pg. 49 – 53, (2015).

[17] Rayadu, S.V., Akshay P. R. and Ishwar K. G.: Study of Bamboo as Reinforcement in Concrete. International Advanced Research Journal in Science, Engineering and Technology (IARJSET), Vol. 4, Issue 11, (2017).

[18] Mahzuz*, H. M. A., Mushtaq A., Md. Ashrafuzzaman, Rejaul K. and Raju A.: Performance evaluation of bamboo with morter and concrete. Journal of Engineering and Technology Research, Vol. 3, Issue 12, pp. 342 - 350, (2011).

[19] Hector A., Sebastian K., David T., Edwin Z. E., Kent A. H.: Bamboo reinforced concrete: a critical review, Journal of Materials and Structures, Vol. 51, Issue 102, (2018).

[20] Eldin, M. M. and Eman E. T.: Validity of Using Bamboo as Reinforcement of Concrete Beams, Proceeding Of the International Conference on Advances in Civil, Structural and Construction Engineering (CSCE), (2016).

[21] Sanjeev Gill and Rajiv Kumar (2016), To experimental study and use of bamboo in civil structure as reinforced concrete, International Journal of Latest Research in Science and Technology, Vol. 5, pp 102-105.

[22] I. K. Khan (2014), Performance of bamboo reinforced concrete beam, International Journal of Science, Environment and Technology, Vol. 3, pp 836 – 840.

[23] Ajinkya Kaware and Prof. U. R. Awari (2013), Review of bamboo as reinforcement material in concrete structure, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2. pp 2461-2464.

[24] Anurag Nayak and Arehant S Bajaj (2013), Replacement of steel by bamboo reinforcement, IOSR Journal of Mechanical and Civil Engineering, Vol. 8, PP 50-61. Chandra Sabnani, Madhuwanti Latkar and Utpal Sharma (2013), "Can bamboo replace steel as reinforcement in concrete, for the key structural elements in a low cost house" International Journal of Chemical, Environmental & Biological Sciences ,Vol.-1, pp 257-262 .

[25] Dr. Ashok Kumar Gupta, Dr. Rajiv Ganguly and Ankit singh Mehra (2015), Bamboo as green alternative to steel for reinforced concrete elements of a low cost residential building, Electronic Journal of Geotechnical Engineering, Vol.20 pp 1523-1545.

[26] International Network for Bamboo and Rattan (INBAR 2002), a Project on Bamboo Structures at the Technical University of Eindhoven.

[27] Amada, S. and Untao, S. Fracture Properties of Bamboo, Composites Part B, Vol. 32, pp 451-459, 2001.

[28] Nindyawati., Baiq., Sri., Umniati. (2016). 1. Bond Strength of Bamboo Reinforcement in Light Weight Concrete.

[29] R., Sutharsan., S., R., Ramprasanna., S., Basil, Gnanappa., A., Chithambar, Ganesh. (2020). 2. Experimental study on Bamboo as a reinforcing material in concrete. doi: 10.1063/1.5141561

[30] Banu, Ardi, Hidayat., Hsuan, Teh, Hu., Ay, Lie, Han., Yanuar, Haryanto., Yanuar, Haryanto., Arnie, Widyaningrum., Gandjar, Pamudji. (2019). 3. Nonlinear finite element analysis of traditional flexural strengthening using betung bamboo (Dendrocalamus asper) on concrete beams. doi: 10.1088/1757-899X/615/1/012073

[31] Pankaj, R., Mali., Debarati, Datta. (2019). 4. Experimental study on improving bamboo concrete bond strength. doi: 10.12989/ACC.2019.7.3.191

[32] Paul, O., Awoyera., S., Karthik., P., R., M., Rao., Ravindran, Gobinath. (2019). 5. Experimental and numerical analysis of large-scale bamboo-reinforced concrete beams containing crushed sand. Innovative Infrastructure Solutions, doi: 10.1007/S41062-019-0228-X

[33] Ari, Wibowo., Indradi, Wijatmiko., Christin, Remayanti, Nainggolan. (2017). 6. Structural behavior of lightweight

 DOI : 10.35291/2454-9150.2024.0376

bamboo reinforced concrete slab with EPS infill panel. doi: 10.1063/1.5003507

[34] Kazi, Faiza, Amin., Asrafuzzaman., Ahmed, Sharif., Enamul, Hoque. (2021). 7. Bamboo/Bamboo Fiber Reinforced Concrete Composites and Their Applications in Modern Infrastructure. doi: 10.1007/978-981-15-8489-3_15

[35] Teodoro, Jr., Amatosa., Michael, E., Loretero. (2017). 8. Axial Tensile Strength Analysis of Naturally Treated Bamboo As Possible Replacement of Steel Reinforcement in the Concrete Beam. Social Science Research Network, doi: 10.2139/SSRN.3083832

[36] Balaji, Govindan., Vetturayasudharsanan, Ramasamy., Balamurugan, Panneerselvam., Dineshkumar, Rajan. (2022). 9. Performance assessment on bamboo reinforced concrete beams. Innovative Infrastructure Solutions, doi: 10.1007/S41062-021-00616-8

[37] H.M.A., Mahzuz., Mollah, Mesbahuddin, Ahmed., J., Dutta., R.H., Rose. (2015). 10. Use of bamboo (Bambusa balcooa) as reinforcement in concrete beam. International Journal of Structural Engineering

[38] Hrishikesh, Deore., Pravin, Minde. (2018). 11. Study of Bamboo Reinforcement Concrete As a Sustainable Material In Construction. doi: 10.29070/15/56836

[39] Prof., Satish, A., Pitake. (2022). 12. Performance Evaluation of Bamboo Reinforced Concrete Beam. International Journal For Science Technology And Engineering, doi: 10.22214/ijraset.2022.44028

[40] S, Suppiah., S, Agnihotri., S, Mishra., S, Vishwakarma. (2018). 13. Strength Characteristics of Bamboo Reinforced Slabs. International journal of engineering and technology, doi: 10.14419/IJET.V7I3.27.17967

[41] S, Suppiah., S, Agnihotri., S, Mishra., S, Vishwakarma. (2018). 13. Strength Characteristics of Bamboo Reinforced Slabs. International journal of engineering and technology, doi: 10.14419/IJET.V7I3.27.17967

[42] Lokendra, Kaushal. (2017). 14. Performance of Bamboo Reinforced Concrete Beam a Review. International Journal for Research in Applied Science and Engineering Technology, doi: 10.22214/IJRASET.2017.2048

[43] Jacky, Moh, Neing, Sheng. (2018). 15. Bamboo (betung species) fiber composite plate for external strengthening of RC beams.

[44] Atika, Ingole., Sakshi, Gawande., Vipul, Bambode., Ayush, Khobragade. (2020). 16. A review of bamboo as a reinforcement material in slab panel in modern construction. doi: 10.33564/IJEAST.2020.V04I09.015

[45] Ranendra, Nath, Bhowmik., Joyanta, Pal., Partha, Pratim, Sarkar. (2017). 17. An Experimental Study on Behaviour of Bamboo Reinforced Brick Aggregate Concrete Beam. International journal of engineering and technology, doi: 10.21817/IJET/2017/V9I2/170902123

[46] Pushpanjali, Verma., Vipin, Mahadeven. (2020). 18. Experimental Study on the use of Bamboo as Structural Reinforcements in RCC Structures. International Journal of Engineering Research and, doi: 10.17577/IJERTV9IS070172

[47] Maheswaran, Parasuram., K., Baskaran. (2020). 19. Study On Bamboo And Steel As Hybrid Reinforcement For Concrete Slab. doi: 10.1109/MERCON50084.2020.9185244

[48] N., Ganesan., P., V., Indira., P., R., Himasree. (2018). 20. Strength and behaviour of bamboo reinforced concrete wall panels under two way in-plane action. doi: 10.12989/ACC.2018.6.1.001

[49] Abdullah, Khatib. (2020). 21. An investigation into the use of bamboo as reinforcement in concrete.

[50] Emmanuel, Oppong, Boakye., Jack, Banahene, Osei., Mark, Adom, Asamoah. (2018). 22. Finite Element Modelling of Bamboo Reinforced Concrete Beams.

[51] S., Srimathi., S., Dinesh., R., Preetha., R., Reshmi. (2016). 23. A Review of Bamboo as a Reinforcement Material in Modern Construction. International Journal For Science Technology And Engineering,

[52] (2022). 24. A Review on the Mechanical Behaviour of Bamboo Reinforced Concrete Beams. Journal of Renewable Materials, doi: 10.32604/jrm.2022.022624

[53] V, Giridhar. (2017). 25. Flexural behavior of concrete with bamboo and steel reinforcement. doi: 10.26808/RS.ED.I7V6.09

[54] Samson, Olalekan, Odeyemi., R., Abdulwahab., Sefiu, Adekunle, Bello., Ahmed, Olatunbosun, Omoniyi., Adewale, George, Adeniyi. (2020). 26. Repair of flexural damaged reinforced concrete beams using embedded bamboo reinforced epoxy composite. doi: 10.11113/MJCE.V32N1.638

[55] Wei, Yang., Xu, Yang., Chen, Si., Fan, Suying. (2018). 27. Bamboo timber arrangement of reinforcement concrete structure.

[56] Shu, Ing, Doh., Kar, Sing, Lim., Gimbun, Jolius., Siew, Choo, Chin., S.P., Lim., Foo, Sheng, Tong. (2019). 28. Application of bamboo fibre composite in structural strengthening.

[57] S., Kavitha., T, Felix, Kala. (2016). 29. Assessment of L/D Ratio of Eco Fibre - Bamboo as a Reinforcement Material in Concrete. International journal of engineering and technology, doi: 10.21817/IJET/2016/V8I5/160805421

[58] Yathushan, K., Kishok, S., Bryan, E., Thevarajah., Nithurshan, M. (2021). 30. Bamboo Cane as an Alternative Reinforcement in Reinforced Concrete Beam. doi: 10.1109/MERCON52712.2021.9525805

 DOI : 10.35291/2454-9150.2024.0376