IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 1, April 2025
Impact Factor: 7.67

Comparative Investigation of Ordinary Concrete Structure and Carbon Laminated Concrete Structure

S. M. Khedekar[1], A. R. Gupta[2], B. J. Choudhari[3], A. H. Lendave[4], Prof. P. L. Jadhav[5]
Diploma Engineering Students[1,2,3,4]
Head of Department, Civil Engineering[5]
Zeal Polytechnic, Pune, India

Abstract: *Carbon laminates, which consist of carbon fibers embedded in a polymer matrix, offer a high strength-to-weight ratio and excellent corrosion resistance when applied to concrete. This project investigates the mechanical performance of carbon-laminated beams in comparison to non-carbon-laminated beams. Carbon-laminated beams, made by embedding layers of carbon fiber in a resin matrix, are recognized for their superior strength-to-weight ratio, high stiffness, and fatigue resistance. The study explores how the inclusion of carbon fibers enhances the structural properties of the beams, such as load-bearing capacity, deflection, and overall durability, compared to traditional non-carbon-laminated beams made from materials like wood, fiberglass, or standard polymers. Experimental testing and analysis are performed to evaluate the bending strength, stiffness, and failure modes of both types of beams under various loading conditions.*

Keywords: Carbon laminate beams, non-carbon laminated beams, Mechanical performance, Bending strength, Deflection, Corrosion resistance

I. INTRODUCTION

Carbon fiber is a type of retrofitting widely used in civil works. Carbon fiber is a high-performance material made from thin strands of carbon atoms bonded together in a crystal lattice structure. The material is known for its exceptional strength, stiffness, and lightweight, making it ideal for use in industries that require high-performance materials. Carbon fiber is produced through a process known as carbonization, where precursor fibers (usually made from polyacrylonitrile, PAN) are heated to very high temperatures in an inert atmosphere, causing the carbon atoms to bond together in a tightly organized structure. Carbon laminate is made by layering carbon fiber sheets (or fabric) impregnated with resin to create a composite material. The structural performance of laminated beams has long been a critical area of study in engineering, particularly for applications requiring a balance between strength, weight, and durability. Laminated beams, which consist of multiple layers of materials bonded together, are favored for their enhanced mechanical properties and ability to distribute loads efficiently. Among these materials, carbon fiber laminates stand out due to their superior strength-to-weight ratio, high stiffness, and resistance to fatigue and environmental degradation.

These unique properties have made carbon-laminate beams increasingly popular in high-performance industries such as aerospace, automotive, and civil engineering. On the other hand, non-carbon-laminated beams, which are typically constructed using materials like wood, fiberglass, or conventional polymers, continue to be widely used due to their cost-effectiveness, ease of manufacturing, and adequate performance in many standard applications. However, as material technology advances and the demand for lighter, stronger, and more durable components increases, understanding the comparative performance of carbon and non-carbon-laminated beams has become essential for making informed material choices in engineering design. This research paper aims to conduct a comparative analysis between carbon-laminated beams and non-carbon-laminated beams. By evaluating critical mechanical properties such as load-bearing capacity, bending strength, stiffness, deflection, and failure modes under various loading conditions,

DOI: 10.48175/IJARSCT-24835

ISSN 2581-9429 IJARSCT

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 5, Issue 1, April 2025 Impact Factor: 7.67

this study seeks to highlight the advantages and limitations of both materials. The findings from this analysis will provide valuable insights into the design and application of laminated beams, contributing to the optimization of structural components in engineering projects where material selection plays a pivotal role in ensuring performance, efficiency, and sustainability. Retrofitting involves modifying or improving existing structural elements to make them more resistant to various forces such as seismic loads, wind loads, or other external factors.

The goal of retrofitting is to upgrade the performance of the structure without significantly altering its original configuration or appearance. Retrofitting of Reinforced Cement Concrete (RCC) structures involves various methods to enhance the strength, durability, and overall performance of existing buildings. It is often done to extend the lifespan of a building or structure, improve its sustainability, or ensure it meets new safety regulations without the need for complete demolition and reconstruction.

II. LITERATURE REVIEW

In this Research "Research on Tensile Properties of Carbon Fiber" Jiayi Wang et al. Conclude that, in order to study the thread tensile performance of carbon fiber composite laminates, the connection between the test piece, connecting bolts, bushings, and the composite matrix, was leveraged for loading, and combined with an ultra-sound scanning imaging system, experiments were carried out on the dynamic response to record the failure behaviour of the laminate structure of equal thickness. The effects of different pull-off loading strengths on the dynamic failure process, deformation profile, midpoint deformation, failure mode, and energy dissipation ratio of the thread were studied. The results show that (1) with the increase in pull-off strength, the response speed of mid-point deformation increases, the thread deformation mode changes from overall deformation to partial deformation, and the localizedeffect increases, accompanied by severe matrix and fiber fracture failure; (2) the thread energy dissipation ratio ascends with increasing pull-off strength and exhibits three distinct stages, i.e., elastic deformation, central fracture, and complete failure, which are directly related to the structural failure mode.

In this Research "Flexural testing on carbon fiber laminates taking into account their different behaviour under tension and compression". M C Serna Moreno et al. Conclude that, an analytical model has been derived for describing the results of three-point-bending tests in materials with different behaviour under tension and compression. The shift of the neutral plane and the damage initiation mode and its location have been defined. The validity of the equations has been reviewed by testing carbon fiber-reinforced polymers (CFRP), typically employed in different weight-critical applications. Both unidirectional and cross-ply laminates have been studied. The initial failure mode produced depends directly on the beam span thickness relation.Therefore, specimens with different thicknesses have been analysed for examining the damage initiation due to either the bending moment or the out-of-plane shear load. The experimental description of the damage initiation and evolution has been shown by means of optical microscopy.

In this Research "Use of Carbon Fiber Reinforced Polymer Laminate for strengthening reinforced concrete beams in shear" M.B.S Alferjani et al. concludes that, the use of Fiber Reinforced Polymer (FRP) is becoming a widely accepted solution for repairing and strengthening ageing in the field of civil engineering around the world. Several researches have been carried out on reinforced concrete beams strengthened with fiber reinforced polymer composite. Some of the works were focused on shear strengthening compared with flexural strengthening that had the largest share. This paper reviews 10 articles on carbon fiber reinforced polymer strengthened reinforced concrete beams. Finally, this paper attempts to address an important practical issue that is encountered in shear strengthening of beams with carbon fibre reinforced polymer laminate. This paper also proposes a simple method of applying fibre reinforced polymer for strengthening the beam with carbon fibre reinforced polymer The external bonding of high-strength Fiber Reinforced Plastics (FRP) to structural concrete members has widely gained popularity in recent years, particularly in rehabilitation works and newly builds structure.

III. PROBLEM STATEMENT

To enhance these properties, carbon fiber laminates have emerged as an innovative reinforcement technique. Carbon laminates offer high strength-to-weight ratio, corrosion resistance, and improved flexural performance, making them a promising alternative for structural strengthening.

This project aims to conduct a comparative experimental investigation between ordinary concrete structures and carbon laminated concrete structures to assess their performance in terms of :

- Flexural strength
- Durability
- Crack resistance
- Load-bearing capacity

By evaluating these parameters, the study seeks to determine whether **carbon fiber laminated concrete** provides significant advantages over conventional concrete. The results will help in understanding the feasibility, cost-effectiveness, and potential applications of carbon laminates in structural engineering.

IV. AIM AND OBJECTIVES OF PROJECT

AIM:-

To Compare the Ordinary Concrete Structure and Carbon Laminated Concrete Structure.

OBJECTIVES:-

- To cast concrete beams of M30 and M35 grade, and also casting of same grade cubes.
- Performing tests on beam and cubes.
- To compare the results of without carbon laminate on beam and with carbon laminate on beam.
- To investigate the impact of carbon laminates on the concrete structure.

V. METHODOLOGY

1.1 SELECTION OF MATERIAL

- **Ordinary Portland Cement:** -The OPC is a mixture of limestone, clay, sand, and other minerals, which are crushed, ground and blended.
- **Fine Aggregate:** -Fine aggregate helps to improve the bonding between the glass fibre wrapping and the concrete substrate. The fine aggregate particles provide a mechanical interlock, allowing the glass fibre wrapping to adhere better to the concrete.
- **Coarse Aggregate:** - In the comparative analysis of conventional concrete, the coarse aggregate used plays a crucial role in determining the mechanical properties and overall performance of the concretemixtures.
- **Water: -** The water should be fit for drinking. The water is used for mixing as well as for curing the samples.
- **CFRP Sheet**: - Atype of composite material made from carbon Fibers embedded in a polymer matrix.
- **Epoxy Resin:** - Epoxy resin is a common adhesive used to bond glass fibre sheets to various substrates. Epoxy resin has high mechanical strength, making it suitable for structural applications.
- **Hardener: -** Hardener for GFRP (Glass Fiber Reinforced Polymer) sheet is a crucial component that helps to cure and harden the resin, creating a strong and durable bond between the glass fibres and the polymer matrix.

Desired strength, durability, and workability of the concrete mix. The materials must conform to the standard guidelines such as IS 456:2000 (for general concrete design) and IS 10262:2019 (for concrete mix proportioning). Below is a detailed selection process for the materials used in casting M30 and M35 grade concrete cubes:

- Ultra Tech Cement
- Coarse Aggregate
- Crushed Sand
- Water
- Fly Ash
- Admixture

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 1, April 2025
Impact Factor: 7.67

1.2 CONCRETE MIXING PROPORTION OF M-30 & M30 GRADE:

1.	**Grade of Concrete**	M30 & M35
2.	**Type of Cement to be used**	OPC 53 Grade Conforming to IS 12269:2013
3.	**Maximum Size of Aggregate**	20mm
4.	**Maximum Water/Cement Ratio**	0.55
5.	**Crushed Sand**	150 µm – 600 µm
6.	**Fly Ash**	250 – 600 m^2/kg

Table No. 1 Concrete Mixing Proportion of M30 & M30 Grade

1.3 CASTING OF CONCRETE CUBE & BEAM: -

- Prepare Cube& Beam Mold
- Mix Concrete
- Fill Cube& Beam Mold
- Finishing

1.4 CURING OF CUBE:-

- Initial Curing
- During of cubes
- Temperature control
- Quality Assurance

1.5 CURING OF BEAM :-

- Initial Curing(24 hours)
- De-moulding& Immersion (After 24 Hours)
- Curing Duration (28 Days)
- Final Testing (After 28 Days)

1.6 COMPRESSIVE TESTING ON CUBES :-

- Testing after 7 days
- Testing after 14 days
- Testing after 28 days

1.7 WRAPPING THE CFRP SHEET ON BEAM: -

The flexure test (also called bending test) is one of the most common types of tests for beams. This test is used to evaluate the flexural strength, deflection, and behaviour of beams under loading.Testing beams, especially with and without CFRP reinforcement, provides crucial insights into their performance under load, failure modes, and material behaviour. By performing flexural tests and other evaluations, engineers can determine the strength, serviceability, and long-term durability of beams. The CFRP reinforcement can significantly enhance a beam's performance, offering higher strength, reduced deflection, and greater load-carrying capacity when compare to traditional concrete beams.

1.8 TESTING RESULT-

COMPRESSIVE STRENGTH TEST:

The compression test is one of the most fundamental tests for concrete materials, especially for evaluating the compressive strength of concrete.In concrete structures, the compression strength is critical because it helps determine the beam's capacity to withstand compressive forces during service, which is especially relevant for structural elements

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 1, April 2025
Impact Factor: 7.67

like columns or slabs. The concrete in a beam typically experiences compressive stress on the top side and tensile stress on the bottom during bending, so understanding its compressive strength is crucial.

1.9 OBSERVATION

1) Testing of Cubes of Grade M30: -

Date of Testing	Age in Days	Wt. in Kg	Load in KN	Strength in Mpa	Average Strength	Percentage	Plant
20/01/25	7	9.000	585	26	23.77	79%	Sunraj Rmc Plant
		8.860	485	21.55			
27/01/25	14	8.880	754	33.51	32.49	103%	Sunraj Rmc Plant
		8.820	708	31.47			
10/02/25	28	8.920	795	35.33	35.73	119%	Sunraj Rmc Plant
		8.860	813	36.13			

Table No. 2 Testing of cubes of grade M30

Sample calculation for M30 grade cubes of 7 days :

Area – 150X 150= 22500mm^2 = 22.5m^2.

Weight 1 – 9.000 kg**.**

Weight 2 - 8.860 kg

Load apply 1 - 585 N/mm^2.**V.**

Load apply 2 – 485 N/mm^2.

Strength in Mpa :-

I. 585/22.5 = 26 Mpa

II. 485/22.5 = 21.55 Mpa

Average Strength :-

= 26+21.55/2

= 23.77 Mpa

Average Percentage :-

= 79% after 7 days.

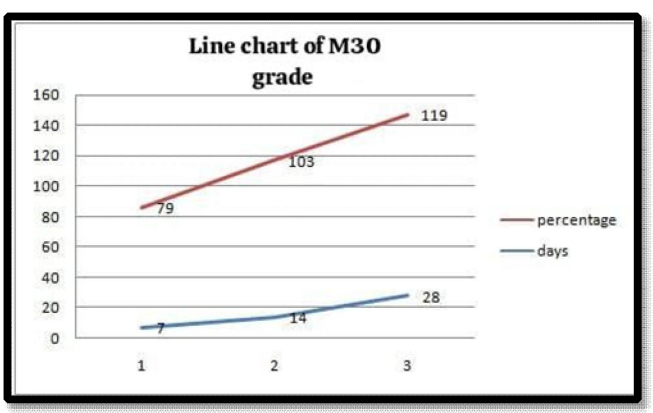

Chart No. 1 Compression Test Results of M30

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 1, April 2025
Impact Factor: 7.67

Testing of Cubes of Grade M35: -

Date of Testing	Age in Days	Wt. in Kg	Load in KN	Strength in Mpa	Average Strength	Percentage	Plant
20/01/25	7	8.720	553	24.57	26.90	17%	Sunraj Rmc Plant
		8.700	658	29.24			
27/01/25	14	8.700	804	35.79	36.22	103%	Sunraj Rmc Plant
		8.780	826	36.71			
10/2/25	28	8.960	916	40.71	40.04	115%	Sunraj Rmc Plant
		8.920	886	39.37			

Table No. 3 Testing of cubes of grade M35

Sample calculation for M35 grade cubes of 7 days :
I.Area – 150X 150= 22500mm^2 = 22.5m^2.
Weight 1 – 8.720 kg
Weight 2 - 8.700 kg
Loads applied 1 - 553 N/mm^2.**V.**
Loads applied 2 –658 N/mm^2.

Strength in Mpa :-
I. 553/22.5 = 24.5 Mpa
II. 658/22.5 = 29.2 Mpa

Average Strength :-
= 24.5+29.2/2
= 26.85Mpa
Average Percentage :-
= 17% after 7 days

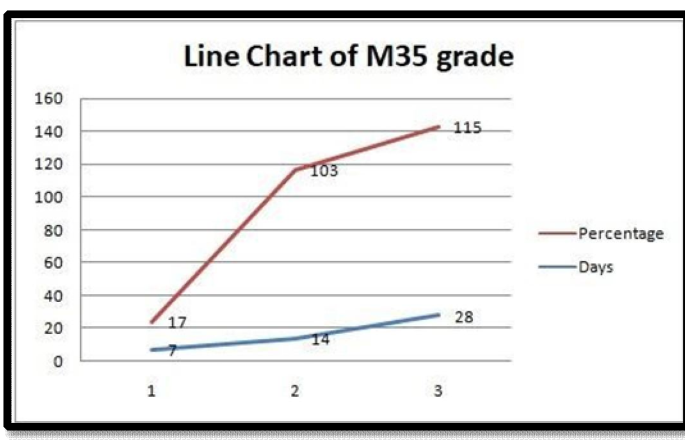

Chart No. 2 Compression Test Results of M 35

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Volume 5, Issue 1, April 2025
ISSN: 2581-9429
Impact Factor: 7.67

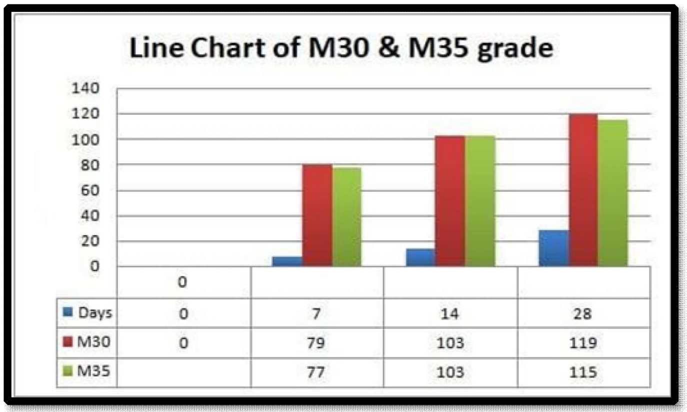

Chart No.3.Compression Test Results of M30 & M35

Testing on Beams :

The flexure test, also known as the bending test, is a critical test used to evaluate the flexural strength (bending strength) of materials, particularly concrete beams. In this test, the beam is subjected to a bending moment that causes it to bend and experience both compressive and tensile stresses. The purpose of the flexure test is to understand how well a material resists bending under load and how it behaves when it reaches failure.This test is widely used for concrete beams, especially in the construction and civil engineering fields, where structural elements like beams, slabs, and columns are often subjected to bending.

Concrete Grade	Beam ID	Carbon Laminate Thickness (mm)	Max Load (P) (kN)	Flexural Strength Without Laminate (MPa)	Flexural Strength With Laminate (MPa)	% Increase
M30	B1	1.4	12.2	3.95	5.12	**30%**
M35	B2	1.4	13.4	4.20	5.50	**31%**

Table No. 4 Testing on Beams of M30 & M35

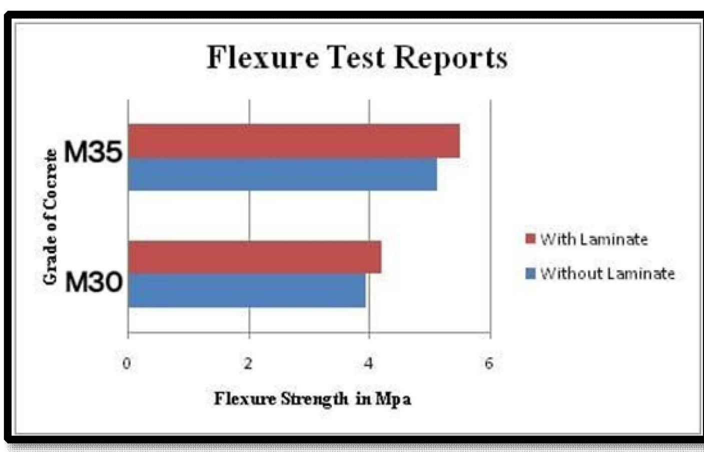

Chart No. 4 Flexure Test Reports

IV. CONCLUSION

The CFRP laminates proves to be a highly effective solution for improving the performance of concrete beams.
It enhances strength, durability, and serviceability while being a lightweight and cost-effective alternative to traditional reinforcement methods.
This makes CFRP an ideal choice for retrofitting and strengthening existing concrete beams in real-world applications.
The test results support the conclusion that CFRP laminates provide a significant advantage over unreinforced concrete beams in terms of load capacity, flexural strength, and deflection control, making them a viable option for structural rehabilitation and enhancement.

REFRENCES

[1]. Ton Peijs, Robert Kirschbaum, Pieter Jan Lemstra. *A critical review of carbon fiber and related products from an industrial perspective.* WMG, University of Warwick, Coventry, UK.

[2]. Nasif Chowdhury, GM Faysal, Tarikul Islam, Habibur Rahman, Farjana Yeasmin. *A Study on Mechanical Properties of Carbon Fiber Reinforced PolymerComposite*. Department of Textile Engineering, Anwer Khan Modern University, Dhaka-1230, Bangladesh.

[3]. Xiaosong Huang. *Fabrication and Properties of Carbon Fibres.* Chemical Sciences & Materials Systems Laboratory, General Motors Research & Development Centre.

[4]. Habibur Rahman Sobuz, Ehsan Ahmed, Noor Md. Sadiqul Hasan, Md. Alhaz Uddin. *Use of carbon fiber laminates for strengthening reinforced concrete beams in bending.* Department of Civil Engineering, Universiti Malaysia Sarawak, Sarawak, Malaysia.

[5]. Jiayi Wang, Lifeng Chen, Wei Shen and Lvtao Zhu. *Research on Tensile Properties of Carbon Fiber Composite Laminates.* Research on Tensile Properties of Carbon Fiber Composite Laminates.

[6]. Yanlei Chen, Yanbo Hui, Dengjie Zhu, Xingle Li and Hongxiao Wang. *Study on Thin Lamination of Carbon Fiber Based on Mechanical Broadening.* School of Mechanical and Electrical Engineering, Henan University of Technology, Zhengzhou 450001, China.

[7]. Yunsen Hu, Gang Han, Fei Cheng, Xiaozhi Hu. *Thickness effect on flexural strengths of laminar carbon fibre composites.* School of Materials Science and Engineering, Southwest University of Science and Technology, Mianyang 621010, China.

[8]. M C Serna Moreno, A Romero Gutiérrez and J L Martínez Vicente. *Flexural testing on carbon fibre laminates taking into account their different behaviour under tension and compression.* Universidad de Castilla-La Mancha, Instituto Investigaciones Energéticas y Aplicaciones Industriales & ETS Ingenieros Industriales, Av. Camilo José Cela s/n, 13071 Ciudad Real, Spain.

[9]. Hughes, B.P. and N.I. Fattuhi, " *Predicting the Flexural Strength of Steel and Polypropylene Fiber – Reinforced Cemented Based Beams* ", Composites, Butterworth and Co. Ltd., January, (1977).

[10]. T. Waki and T. Nakamura," *Flexural Strength and Bending Elasticity of Fiber Reinforced Composite Systems*", IADR/AADR/CADR 80th General Session, (San Dieg.), (2002).

[11]. Alsayed, S.H., Al-Salloum, Y.A., Almusallam, T.H (2002), "*Rehabilitation of the infrastructure using composite fabrics*", final report – research project no. AR-16-52. Technical report, King Abdul Aziz City for Science and Technology (KACST), Riyadh, Saudi Arabia.

[12]. Aram, M.R., Czaderski, C., Motavalli, M (2008), "*De-bonding failure modes of flexural FRP-strengthened RC beams*", Composites: Part B. 39, pp 826 841.

[13]. Barnes, R.A. Mays, G.C (1999), *"Fatigue performance of concrete beams strengthened with CFRP plates",* Journal of Composites for Construction, 3(2), pp 63-72.

[14]. Meier, U., Kaiser, H (1991), "*Strengthening of structures with CFRP laminates*", advanced composites materials in civil engineering structures, ASCE, New York, pp 224–232.

[15]. Sobuz, H.R. Ahmed, E (2011), *"Flexural Performance of RC Beams Strengthened with Different Reinforcement Ratios of CFRP Laminates",* Key Engineering Materials, Trans Tech Publications, Vols. 471-472, pp 79-84.

[16]. Liu, Q.; Guo, B.; Liu, W. *Mechanical response analysis of carbon fiber composite laminates under low velocity impact.* Sci. Technol. Eng. 2019, 19, 97–102.

[17]. Yogesh R. Suryawanshi, Amar G. Kadam, Sagar S. Ghogare, Ramrao G. Ingale, Priyanka L. Patil. *Experimental Study on Compressive Strength of Concrete by Using Metakaolin.* Associate Professor, Department of Civil

[18]. Engineering, JSPM's ICOER, Pune, Maharashtra, India.

[19]. Reba Iram, P. O. Modani. *Literature Review on Prediction of Compressive Strength of Concrete Using Artificial Neural Network,* Student M.E Structure, Dept. of Civil Engineering, PLITMS Buldana.

[20]. Paulina Spanu, Cristian-Vasile Doicin, Mihaela-Elena Ulmeanu, Florin Baciu. *Analyzing the Tensile Strength of Carbon Fiber-Reinforced Epoxy Composites Using LabVIEW Virtual Instrument.* National University of Science and Technology Politehnica Bucharest, Faculty of Industrial Engineering and Robotics, 313.

[21]. Hatta, H., Aoi, T., Kawahara, I., Kogo, Y.*, Tensile Strength Of Carbon– Carbon Composites:* II – Effect of Heat Treatment Temperature. J. Compos. Mater., 2004, 38, 1685–1699, doi:10.1177/0021998304044764.

[22]. Galos, J. *Thin-ply composite laminates: A review*. Compos. Struct. 2020, 236, 111920.

[23]. Scott, A.E.; Mavrogordato, M.; Wright, P.; Sinclair, I.; Spearing, S.M. *In situ fibre fracture measurement in carbon–epoxy laminates using high resolution computed tomography.* Compos. Sci. Technol. 2011, 71, 1471– 1477.

[24]. Zsolt R'ACZ, "*Analyzing the Flexural Strength Properties of Unidirectional Carbon / Epoxy Composites",* Hungarian Scientific Research Fund, (2002).

[25]. Hatta, H., Goto, K., Ikegaki, S., Kawahara, I., Aly-Hassan, M.S., Hamada, H., *Tensile Strength and Fiber/Matrix Interfacial Properties of 2D- and 3D-Carbon/Carbon Composites.* J. Eur. Ceram. Soc. 2005, 25, 535–542, doi:10.1016/j.jeurceramsoc.2004.02.014.

[26]. Spadea, G., Bencardino, F. and Swamy, R.N (1998), "*Structural behavior of composite RC beams with externally bonded CFRP",* J. Compos. Constr, 2(3), pp 132–137.