Study of Reinforced Concrete Beams Strengthened with Different Types of Textile Reinforced Mortar

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ABSTRACT

Reinforced concrete (RC) structures often face shear deficiencies due to various factors such as aging, design inadequacies, or changes in loading conditions. Shear strengthening techniques are crucial to enhancing the structural capacity and ensuring the safety of these elements. In recent years, textile reinforced mortar (TRM) has emerged as a promising solutionfor the shear strengthening of RC beams due to its lightweight, high tensile strength, and ease of application

This study investigates the shear strengthening of reinforced concrete(RC) beams using various types of textile reinforced mortar (TRM). The research aims to assess the effectiveness of different TRM materials in enhancing the shear capacity of RC beams. Two types of TRM, namely carbon fiber and basalt fiber, are considered for the study.The objective of this study is to investigate the effectiveness of different types of TRM systems in enhancing the shear capacity of RC beams. By analyzing the behavior of strengthened beams under various loading conditions and comparing the performance of different TRM configurations, valuable insights can be gained to optimize the design and application of TRM strengthening techniques..Finite Element Analysis (FEA) will also be employed for the validation to simulate the behavior of strengthened RC beams under different loading scenarios, allowing for a detailed examination of factors influencing shear capacity enhancement.

Keywords: **TRM (textile reinforced mortar) ,FEA (finite element analysis)**

1. INTRODUCTION

1.1 General Background

Modern infrastructure is primarily composed of Reinforced Concrete (RC) structures, which give diverse buildings and bridges solidity and support. But with time, aging, exposure to the elements, or loads that exceed the original design specifications could cause these buildings to fail. Shear failure is a crucial mode of failure in reinforced concrete buildings, particularly in beams.

When the applied load is greater than the structure's ability to withstand lateral stresses, shear failure occurs, which can cause cracks and possibly collapse. Stirrups or shear reinforcement are two common ways that shear weaknesses in RC beams are addressed. Even though they work well, these techniques frequently call for intrusive and lengthy building processes.

Alternative methods for shear strengthening RC beams that make use of Textile Reinforced Mortar (TRM) have gained traction in recent years. The tensile and flexural strength of TRM is increased by the high-strength fibers that are incorporated in a mortar matrix. This strategy has a number of benefits, such as greater durability, less interference with the current structure, and simplicity of application.

This project's main goal is to provide a thorough investigation and comparison of the various TRM types' impacts on shear strengthening in RC beams. Through performance evaluation of several TRM materials (carbon fiber,basalt fiber, etc), the goal of this study is to determine which material is most suited for increasing the shear capacity of RC beams.

Additionally, the goal of this study is to investigate how important factors like bonding methods, mortar composition, and fiber orientation affect how effective TRM strengthening is. The study intends to offer important insights into the behavior of TRM-strengthened RC beams under various loading scenarios through analytical and experimental modeling and parametric investigations. All things considered, this research project has important ramifications for the structural engineering community and presents novel approaches to reducing shear weaknesses in reinforced concrete structures. The goal of this research is to further our knowledge of TRM- based strengthening methods in order to aid in the creation of more resilient and sustainable infrastructure systems.

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1.2 Scope of the Study

The following reasons make the project on the experimental and analytical analysis of RC beam shear enhanced with various kinds of textile-reinforced mortar (TRM) necessary: RC structures are vulnerable to shear failure, which can jeopardize theirstructural integrity and safety. This is especially true of beams in RC structures. For these structures to function well and last over time, shear weaknesses must be addressed. The drawbacks of conventional strengthening techniques Adding stirrups or shear reinforcement, for example, are examples of traditional shear strengthening techniques that can be intrusive, time-consuming, and disruptive to the existing structure. Alternative methods that provide greater effectiveness, simplicity of use, and less disturbance are required.Benefits of TRM Strengthening: TRM has a number of benefits over conventional strengthening techniques, including as improved durability, simplicity of application, and adaptability to intricate geometries. For shear strengthening applications, it is necessary to methodically assess and contrast the efficiency of various TRM materials and methods. Knowledge Vapor in TRM Conduct: Although TRM is becoming more and more popular as astructural strengthening material, a thorough understanding of its behavior under shear loadingcircumstances is still required. Analytical research can assist optimize design parameters for optimal efficiency and offer insightful information about the performance of TRM- strengthened RC beams. Advances in Research and Engineering Practice: The project's conclusions can influence engineering procedures for RC structure up keep and repair.

2. LITERATURE REVIEW

2.1. GENERAL

This chapter presents the review of studies conducted on the performance and behaviour of various textile reinforced mortar .

Azadeh Parvin et al.(2022) The paper examines textile-reinforced mortar (TRM) jackets for shear-stimulated reinforced concrete (RC) beams using nonlinear finite-element analysis (FEA). A parametric research will be conducted to investigate the impacts of load distributions, beam depths, and the stacking sequences of textile mesh layers after FEA models have been built and verified against existing literature. The findings indicate that lowering the shear contribution of TRM and raising cross section depth both increase load capacity. When the load on the beams is evenly distributed, the shear impact of TRM is more pronounced. To increase shear capacity, strengthening beams with one or three layers oriented at a 45° angle isthe most efficient structure. According to the study, ply sequences had no effect on the RC beam's.

Hui Chen et al.(2022) An experimental research using textile-reinforced mortar (TRM) to strengthen pre-damaged reinforcement concrete (RC) beams is presented in this work. Eight RC beams were tested under a four-point bending monotonic load, seven of which had a U- shaped TRM jacket and one of which was a control beam. According to the study, TRM strengthening increased the pre-damaged RC beams' shear capacity by 18.32–67.45% while also fully restoring their mechanical characteristics. Nonetheless, compared to non-damaged beams with the same strengthening strategy, the pre-damaged reinforced beams exhibited a lower shear capability. The specimens' failure mode shifted from shear-compression to diagonal-tension as the sustaining load on the beams rose, lowering the shear capacity of the reinforced beams. Based on the present code, a modified model was suggested to forecast the shear capacity of beams reinforced by TRM

Rita Irmawaty et al. (2022) The application of geopolymer-mortar panels (GMPs) for shear strengthening reinforced concrete (RC) beams is examined in this work. By prefabricating a 15mm thick GMP and fastening it to the shear span of the beam using mechanical anchors, the research focuses on how well GMPs function in increasing the shear capacity of RC beams. According to the study, GMP can increase the shear capacity of RC beams by up to 34.9% to14.1% when compared to unstrengthened beams. The shear capacity of GMP-strengthened RC beams was predicted using an analytical model based on the simplified modified compression field theory, which demonstrated a respectable degree of agreement with test findings.

Andresia Cristine Hamilko Giese et al.(2021) An option for reinforcing or repairing reinforced concrete (RC) structures is textile reinforced mortar, or TRM. When compared to existing consolidated procedures, it has some benefits, but as an original solution, additional study and advancements are required. Consequently, this work is an experimental research that uses AR fiberglass cloth (TEXIGLASS AR-360-RA-04) made locally to strengthen reinforced concrete beams flexurally. The beams underwent a four point bending test and had a rectangular section that measured 1500 mm in length, 200 mm in depth, and 120 mm in width. The study program examines the effects of different textile layers (2, 3, and 4), TRM age (3, 7, and 28 days), and beam precracking level (none, 50%, and 100% of the yielding load) on the flexural strength. The following were the key findings: (a) every beam showed an increase in the ultimate load and the load at serviceability conditions (b) Variations in TRM ages and precracking levels impact the yielding and cracking loads, but have no discernible effect on the final load; (c) as anticipated, the load-carrying capacity improves with an increase in the number of textile layers. Ultimately, the

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findings suggest that there is a chance to employ the Brazilian cloth that was examined for TRM.
Sungnam Hong et al.(2020) A study tested nine specimens to analyze the strengthening efficiency of textile-reinforced mortar (TRM) and the flexural behavior of prestressed and non- prestressed TRM-strengthened concrete beams. The study found variations in flexural behavior due to the shapes of glass and carbon textiles, emphasizing the need for appropriate textile selection for structural reinforcement. The study also showed that textile prestressing enhances the uniformity in load distribution of textiles and steel reinforcement, increasing the structure's strengthening efficiency. The study provided detailed specifications for AR-glass and carbon textiles, emphasizing the importance of textile selection in structural reinforcemement

3. METHODOLOGY

The materials' properties, the work methodology, and the numerical simulation carried out at work are explained in this section
Modelling of Rc beam using ANSYS software → Modelling of RC beam ,u-wrap & full- wrap with different textile reinforced mortar → Identification of better specimen → Validation.

4.MATERIALS USED

4.1 CONCRETE (M30)

M30 concrete is a grade of concrete that indicates the characteristic compressive strength of 30 MPa (Megapascals) after 28 days of curing.

Table (1) Properties of concrete.

Unit system	Metric
Density	2400kg/m³
Concrete strength	30 MPa
Youngs modulus	27,386MPa
Poisons ratio	0.2
Thermal expansion	131/C

4.2 Carbon Fibre

Carbon fibers are a material with exceptional mechanical properties that are composed of crystalline links of carbon atoms. These fibers are renowned for their great tensile strength, stiffness, and low weight to strength ratio

Table (2) Properties of carbon fibre

Fibre orientation	Bidirectional
Ultimate tensile strength	4320 (MPa)
Young's modulus	240 (GPa)
Ultimate strain	1.80 (%)

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The properties of carbon textile are shown in table(3) (Christian Escrig et al.)

Weight	168 (g/m2)
Wide of tow	4 mm
Distance between tows	10 mm
Equivalent thickness	0.047 mm

4.3 Basalt Fibres

Basalt fibers are naturally occurring volcanic rock fibers that come from basalt, a fine-grained igneous rock formed by the rapid cooling of lava. Excellent mechanical properties of basalt fibers include tensile strength, tolerance to temperature fluctuations, and a high modulus of elasticity. Because they are chemically inert and non-corrosive, they can be utilized under challenging conditions.

Table (4) Properties of Basalt fibre

Fibre orientation	Bidirectional
Ultimate tensile strength	2990 (MPa)
Young's modulus	95 (GPa)
Ultimate strain	3.15 (%)

The properties of basalt textiles are shown in table(5)(Christian Escrig et al.)

Weight	200(g/m2)
Wide of tow	5mm
Distance between tows	15mm
Equivalent thickness	0.053mm

5. NORMAL RC C BEAM

5.1 Modelling of a Normal RCC Beam.

The dimensions for a normal rcc beaqm will be Dimension = lxbxh= 1000mmx200mmx150mm
Where,l=length, b= width, h= height and the support condition is fixed.

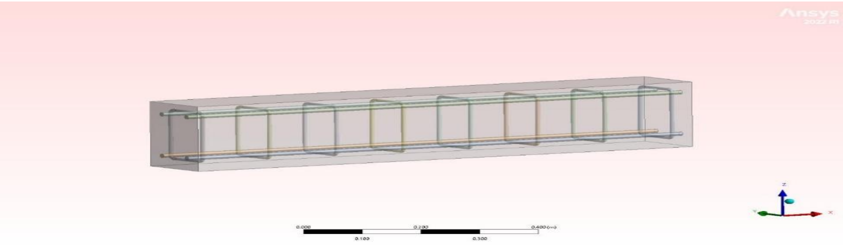

Fig (5.1) beam geometry

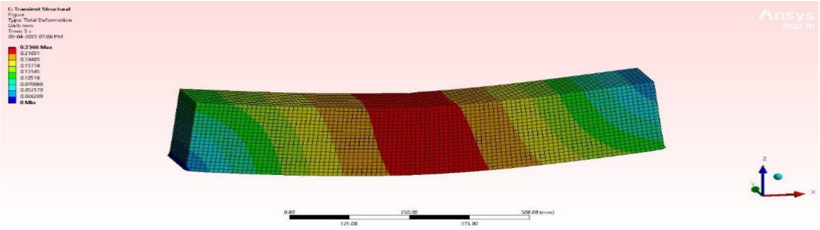

Fig (5.2) beam deformation

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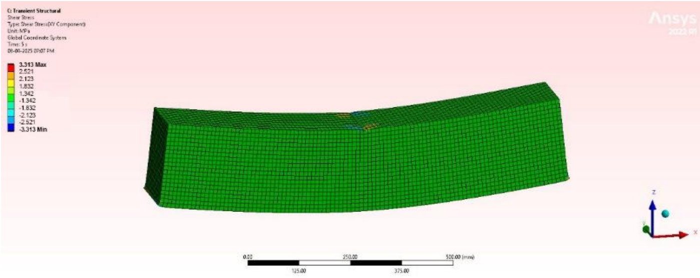

Fig (5.3) beam shear stress

The load , deflection and shearstress obtained are shown in table

Table (5.1) load , deflection, Shearstress values of normal RC beam

Load (KN)	Deflection (mm)	Shear stress (MPa)
99	0.2366	3.313

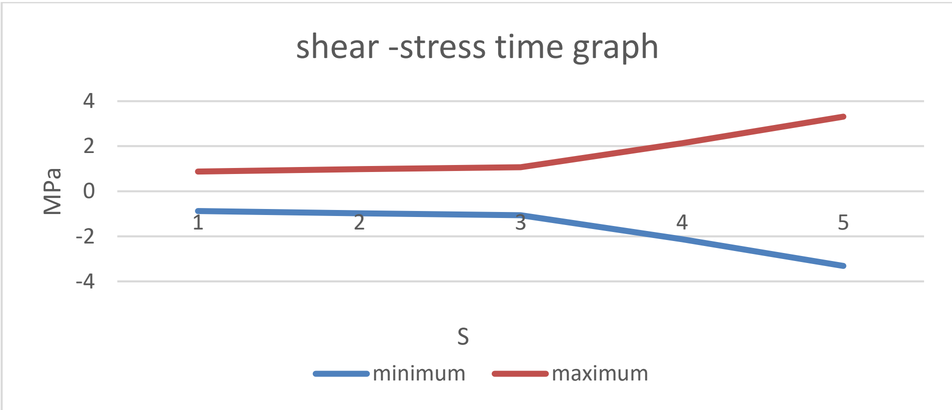

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Fig (5.4) Shear stress- time graph of Normal RC beam

6. U- WRAP OF BASALT TEXTILE

The dimensions for a normal rcc beaqm will be Dimension = lxbxh= 1000mmx200mmx150mm
Where,l=length, b= width, h= height and the support condition is fixed.

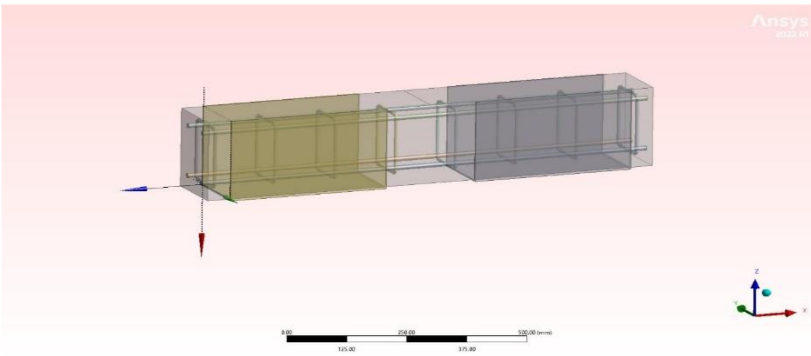

Fig (6.1) u- wrap of basalt textile

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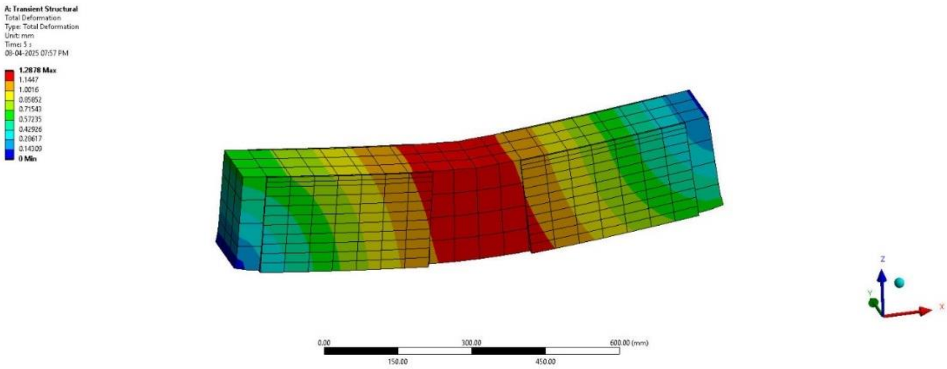

Fig (6.2) u- wrap basalt deformation

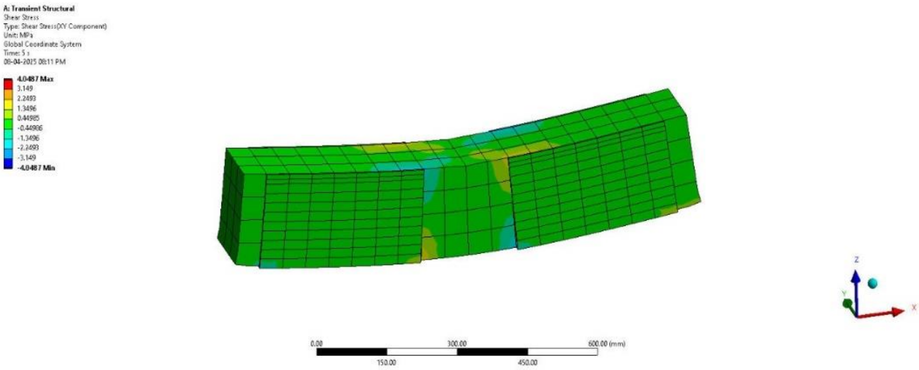

Fig (6.3) u- wrap basalt shear stress

The load , deflection and shearstress obtained are shown in table

Table (6.1)load, Deflection, Shearstress of u-wrap basalt beam

Load (KN)	Deflection (mm)	Shear stress (MPa)
121	1.2878	4.0487

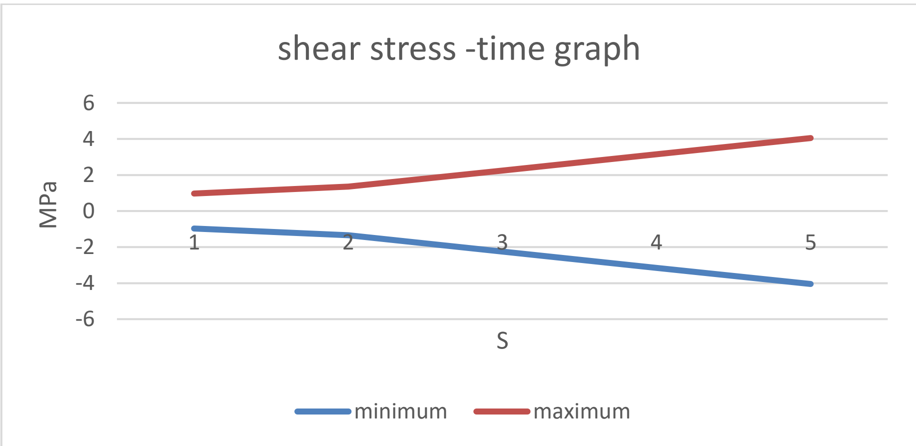

Fig (6.4) Shear stress time graph of u- wrap basalt beam

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7. FULL WRAP OF BASALT TEXTILE.

The dimensions for a normal rcc beaqm will be Dimension = lxbxh= 1000mmx200mmx150mm
Where,l=length, b= width, h= height and the support condition is fixed.

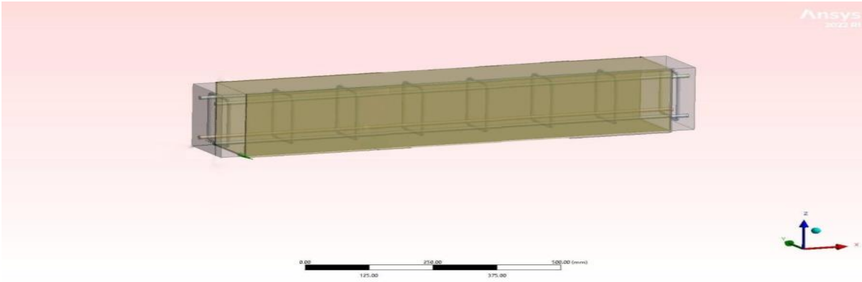

Fig (7.1) Full- wrap geometry

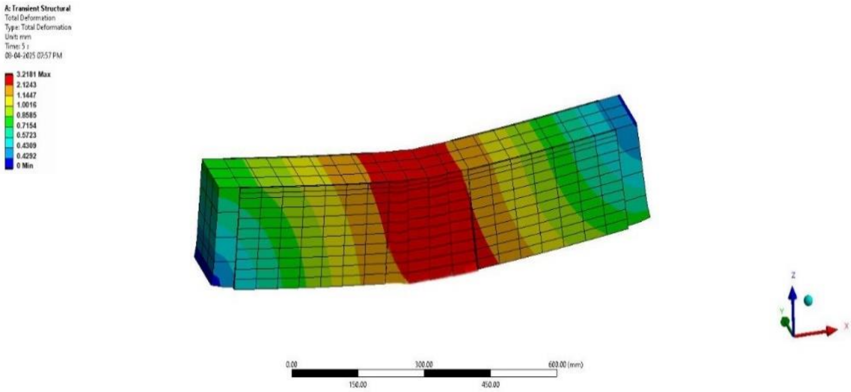

Fig (7.2) total deformation of full – wrap basalt

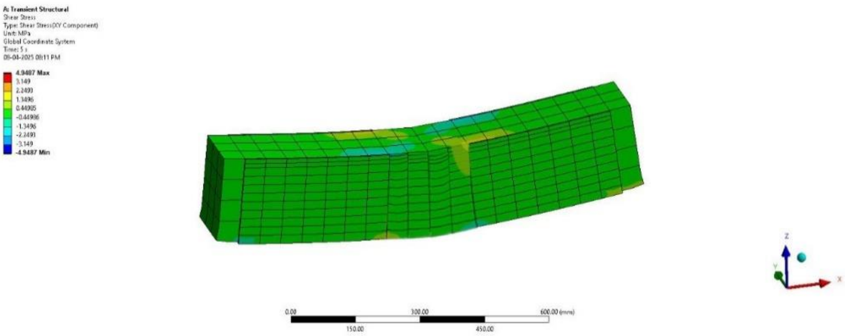

Fig (7.3) shear stress of full – wrap basalt

The load , deflection and shearstress obtained are shown in table

Table (7.1) load , deflection, Shear stress of full- wrap basalt beam

Load (KN)	Deflection (mm)	Shear stress (MPa)
143	3.2181	4.9487

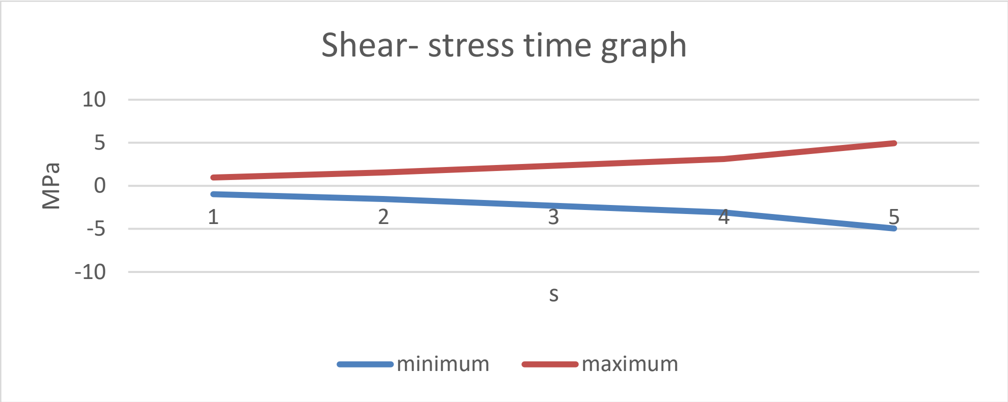

Fig (7.4) shear stress of full- wrap basalt beam

8.U- WRAP OF CARBON TEXTILE

The dimensions for a normal rcc beaqm will be Dimension = lxbxh= 1000mmx200mmx150mm
Where,l=length, b= width, h= height and the support condition is fixed.

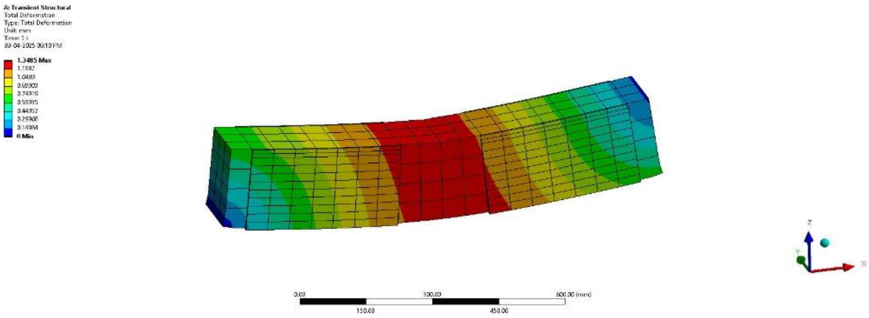

Fig (8.1) U- wrap of carbon textile.

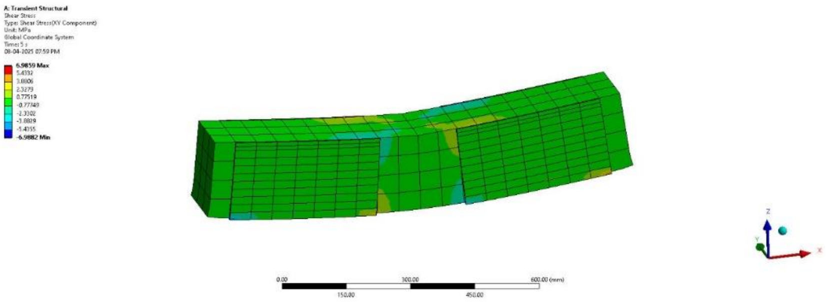

Fig (8.2) Shear stress of U- wrap carbon textile.

The load , deflection and shearstress obtained are shown in table

Table (8.1) load , deflection, shear stress of u- wrap carbon beam

Load (KN)	Deflection (mm)	Shear stress (MPa)
154	1.3485	6.9859

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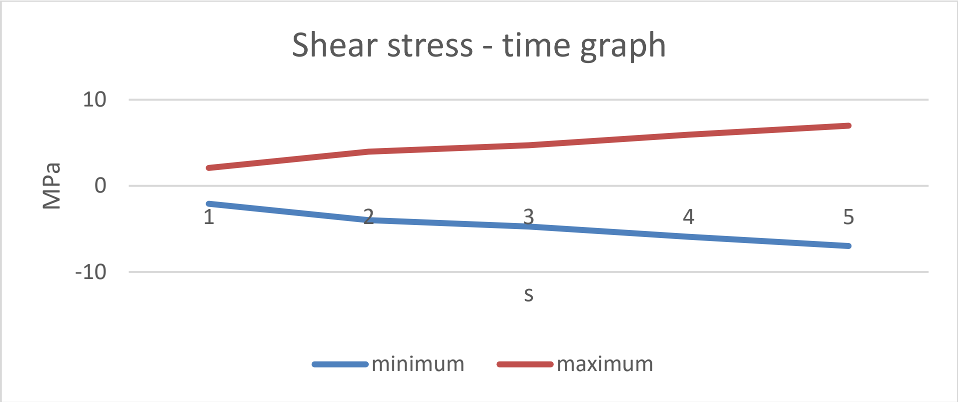

Fig (8.3) shear stress – time graph of u- wrap carbon beam

9. FULL- WRAP OF CARBON TEXTILE.

The dimensions for a normal rcc beaqm will be Dimension = lxbxh= 1000mmx200mmx150mm
Where,l=length, b= width, h= height and the support condition is fixed.

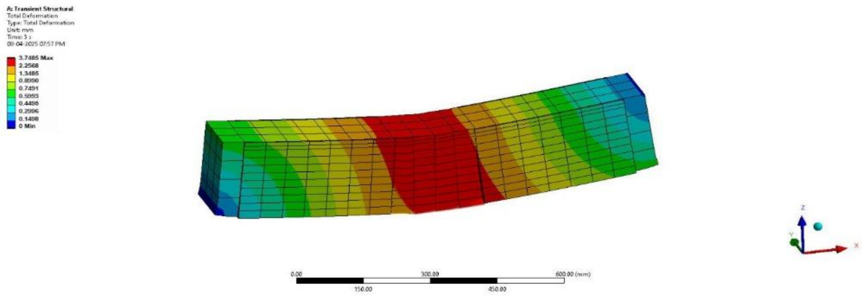

Fig (9.1) Total deformation of full- wrap carbon textile.

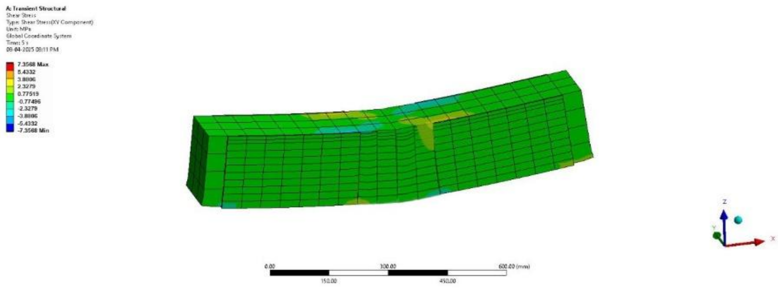

Fig (9.2) . Shear stress of full- wrap carbon textile.

The load , deflection and shearstress obtained are shown in table

Table (9.1) Load, deflection, shear stress of full- wrap carbon beam

Load (KN)	Deflection (mm)	Shear stress (MPa)
163	3.7485	7.3568

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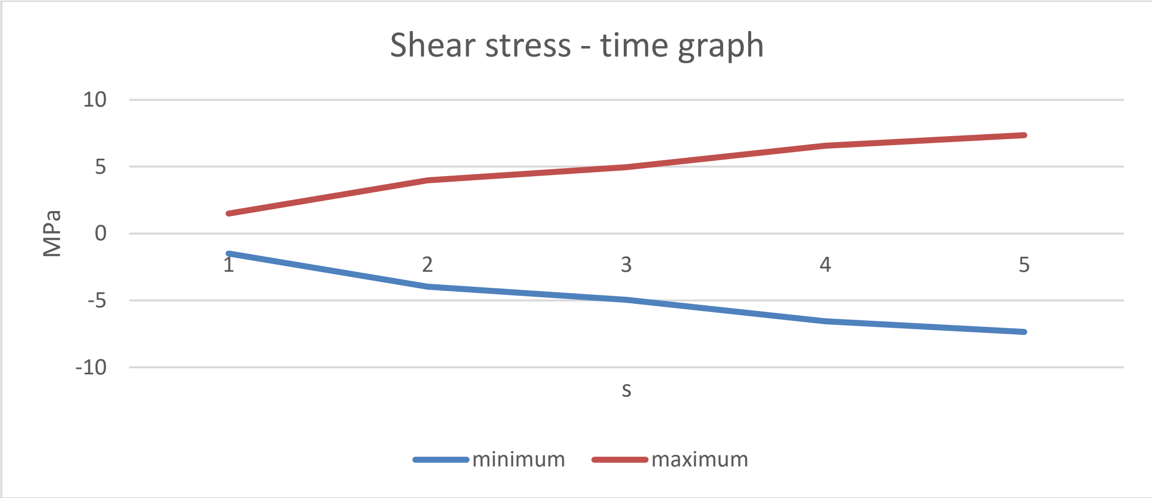

Fig (9.3) Shear stress – time graph of full- wrap carbon beam

10.RESULT AND DISCUSSION

10.1 General

An inventive and successful method for improving structural performance and extending service life is the use of textile reinforced mortar (TRM) to reinforce reinforced concrete (RC) beams. TRM systems are made up of inorganic mortar matrices, usually based on cement or lime, embedded in high-strength textile textiles, such as carbon, glass, or basalt fibers. In order to increase the flexural and shear capabilities, ductility, and crack management of existing RC beams, these systems are applied externally. While basalt and glass textiles are more affordable and appropriate for particular climatic situations, carbon textiles provide unique mechanical qualities such as high tensile strength and durability. TRM is a flexible and long-lasting option for the restoration of degraded or underperforming RC structures since the selection of the textile and mortar matrix has a substantial impact on the strengthening intervention's overall efficiency.

The results obtained as shown in table

	NormalRC beam	u-wrap basalt beam	Full-wrap basalt beam	u-wrap carbon beam	Full-wrap carbon beam
Shear stress (-ve) MPa	3.313	4.0487	4.9487	6.9859	7.3568
Shear stress (+ve) MPa	3.313	4.0487	4.9487	6.9859	7.3568
Deformation(mm)	0.2366	1.2878	3.2181	1.3485	3.7485

Table (10.1) Results

10.2 Results

Using the shear stress and deformation data for conventional reinforced concrete (RC) beams and RC beams reinforced with different types of fibers (Carbon, and Basalt) that have been given, let's review the results and discuss their implications The shear stress increases progressively from the Normal RC beam to the fully wrapped carbon beam, with the full-wrap carbon beam showing the highest shear resistance (7.36 MPa). Similarly, deformation also increases with wrapping, indicating improved ductility, where the Normal RC beam has the least deformation (0.24 mm) and the full-wrap carbon beam shows the highest deformation (3.75 mm). This suggests that both basalt and carbon fiber wrapping significantly enhance shear capacity and deformation performance, with carbon wrap being more effective

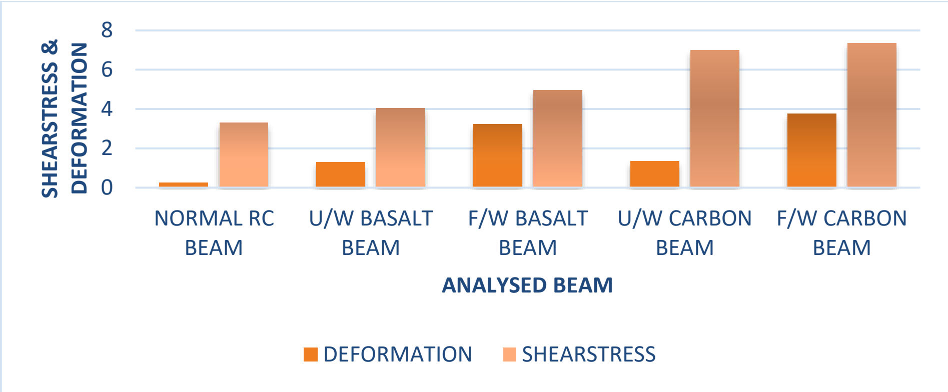

Fig (10.2) graph showing shear stress and deformation v/s analysed beam

11. CONCLUSION

Several inferences may be made based on the information supplied about shear stress and deformation in normal reinforced concrete (RC) beams and RC beams reinforced with different kinds of fibers:

The experimental results unequivocally show that using textile-reinforced mortar (TRM) to strengthen reinforced concrete (RC) beams greatly increases their shear strength and deformation capacity. The effectiveness of TRM varies depending on the type of textile (carbon or basalt) and the wrapping configuration (full-wrap or U-wrap). In terms of both shear stress (3.313 MPa) and deformation (0.2366 mm), the unstrengthened RC beam performed the worst, suggesting brittle behavior and inadequate shear resistance. Performance was significantly improved in all settings when TRM was used

Shear strength and ductility were somewhat but significantly improved by basalt-based TRM systems. The full-wrap basalt beam obtained a 49% increase in shear capacity, whereas the U-wrap basalt beam improved it by around 22%. Improved energy dissipation and crack resistance are indicated by the corresponding increases in deformation to 1.2878 mm and 3.2181 mm, respectively. These findings demonstrate that full wrapping significantly outperforms partial wrapping in terms of harnessing TRM's potential.

In every way, carbon-based TRM systems performed better than basalt. The full-wrap carbon beam peaked at 7.3568 MPa, more than tripling the shear capacity of the unstrengthened beam, whereas the U-wrap carbon beam attained a shear stress of 6.9859 MPa. Superior ductility was confirmed by the fact that carbon TRM systems had the greatest deformation levels, with the full-wrap configuration reaching 3.7485 mm. The great tensile strength and stiffness of carbon fibers, along with the continuous confinement offered by the full-wrap design, are responsible for this outstanding performance.

In conclusion, the wrapping arrangement and the textile material selection are important factors in the efficiency of TRM strengthening. Among the evaluated solutions, full-wrap carbon TRM is the most effective since it offers the greatest improvement in ductility and shear performance. Nonetheless, basalt TRM is still a practical and affordable substitute, particularly when used in full-wrap settings. All things considered, TRM systems offer a dependable, adaptable, and high-performing way to reinforce and retrofit existing RC structures.

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