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The Impact of Using Glass Fibers Affected the Reinforced Concrete Beams under Dynamic Loads

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Abstract
With the development of construction engineering and construction structures, whether buildings, roads, bridges, or bridges, reliance on these beams has increased in modern architectural and engineering designs, and research and studies that seek to achieve sustainability in the building and construction engineering sector have become a priority. Developing design strategies for developing concrete structures and beams has become an important requirement. To many engineers, clients and contracting companies. Through this study, which aims to enhance the performance of concrete beams? Reinforced by adding fiberglass rods through a methodology based on numerical verification and laboratory verification of the performance of these concrete beams when adding fiberglass rods . The results indicate that the use of fiberglass rods in reinforced concrete beams leads to an increase in the beams' tolerance to stresses, especially the bending stress, by a percentage ranging from 16 to 20%, but Reduces the stiffness of beams It also reduces the strains resulting from stresses by a percentage ranging from 8 to 15%, but these percentages vary according to the factors affecting the performance of the concrete cameras, such as the diameter of the bars, the method of attaching the bars to the concrete, the surrounding weather factors, as well as the type of loads.

Keywords:(fiberglass bars , performance of concrete beams. tension and pressure, Stresses., displacement, Strain, and Flexibility)

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تأثير استخدام الألياف الزجاجية على الكمرات الخرسانية المسلحة تحت الأحمال الديناميكية

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الملخص

مع تطور هندسة البناء والهياكل الإنشائية، سواء كانت المباني، الطرق، الجسور، ازداد الاعتماد على هذه الأعمدة في التصاميم المعمارية والهندسية الحديثة، وأصبحت الأبحاث والدراسات التي تسعى لتحقيق الاستدامة في قطاع هندسة البناء والتشييد ذات أولوية. أصبح تطوير استراتيجيات التصميم لتطوير الهياكل والأعمدة الخرسانية مطلبًا هامًا لعديد من المهندسين والعملاء وشركات المقاولات. من خلال هذه الدراسة، التي تهدف إلى تعزيز أداء الأعمدة الخرسانية؟ المسلحة بإضافة قضبان الألياف الزجاجية من خلال منهجية تعتمد على التحقق العددي والتحقق المخبري لأداء هذه الأعمدة الخرسانية عند إضافة قضبان الألياف الزجاجية. تشير النتائج إلى أن استخدام قضبان الألياف الزجاجية في الأعمدة الخرسانية المسلحة يؤدي إلى زيادة في تحمل الأعمدة للإجهادات، خاصةً إجهاد الانحناء، بنسبة تتراوح بين 16 إلى 20٪، لكنه يقلل من صلابة الأعمدة كما يخفض الإجهادات الناتجة عن الإجهادات بنسبة تتراوح بين 8 إلى 15٪، غير أن هذه النسب تختلف حسب العوامل المؤثرة في أداء الأعمدة الخرسانية، مثل قطر القضبان، طريقة تثبيت القضبان بالخرسانة، عوامل الطقس المحيطة، فضلاً عن نوع الأحمال.

الكلمات الدالة: (قضبان الألياف الزجاجية، أداء العتبات الخرسانية، الشد والضغط، الإجهادات، الإزاحة، الانفعال، المرونة)

1. Introduction

In recent years, with the development of modern technology in the field of building and structural engineering, the design and rehabilitation of facilities, whether metal facilities or concrete facilities, and their basic comparisons, have become one of the most important pivotal points, especially in recent years with the advancement of engineering and design sciences *(Faridmehr, I , et*

http://www.doi.org/10.62341/aamg2904

, al , 2022) . This is due to a group of different environmental, technical and economic factors. What is the change in loads resulting from operating conditions or the occurrence of emergency loads resulting from earthquakes or any different environmental conditions? Whereas sometimes the unsatisfactory performance of any facility may raise major concerns related to security and safety, and at the same time many old buildings may need to undergo restoration and maintenance operations due to their inability to adhere to the loading restrictions of the road, which raises some fears of the collapse of these facilities. Therefore, it was necessary to conduct visions, strategies, and rehabilitation plans for these facilities *(Julio, F ,et,al,2003)* . Especially in light of the trend of all sectors and governmental and non-governmental institutions to achieve what is called sustainability, and sustainability in its general concept means preserving the rights of current generations from the existing environmental and economic resources without prejudice to the rights of generations. The future of these resources . This is achieved by achieving environmental sustainability, social sustainability, and economic sustainability, which are three axes that are completely and partially linked to each other, as sustainability cannot be achieved without achieving one of these three axes. These axes work with each other, respectively and in parallel, to achieve what is called total sustainability (*Raza, M . ,et,al, 2019).* The management of facilities and buildings, like other sectors, is moving towards achieving this sustainability through several axes, including the use of modern technologies in construction operations. The use of recycled materials in construction operations as well, as well as the development of materials used in construction, whether concrete or rebar, or adding new materials to these materials would enhance the behavior of concrete and make it withstand more work, while at the same time being lightweight and inexpensive Therefore, developing design strategies for the development of concrete structures and beams has been an important requirement for many engineers, clients and contracting companies A set of practices have been developed to improve them. Some of them are effective, some are more effective, and some are practices with limited effectiveness (*Kog, C,et ,al, 2004).*

Despite the many improvement techniques and practices, there are many challenges and absolute drawbacks in structures and beams made of concrete and heavy steel, especially when loads increase and the lengths of these beams increase. Therefore, we find that

http://www.doi.org/10.62341/aamg2904

there is a general requirement, which is to modify the structural rigidity and reduce the weights of concrete structures, and traditional methods are no longer possible. It meets most of the needs in this topic. I may have security and safety considerations, steel corrosion considerations, or even stresses on the concrete in the beams. Since most structures and facilities, whether in construction projects or even in infrastructure projects such as roads, bridges and bridges, rely on steel-reinforced concrete, or so-called reinforced concrete, it was necessary to find new ways to develop these structures(*Debard, G,et,al,2019).*

This study aims to enhance the properties of reinforced concrete by adding fiberglass rods to the reinforced concrete and studying the effect of this addition on enhancing the properties of concrete in terms of position, flexibility and strength, as adding fiberglass rods to concrete enhances the flexibility and strength of the concrete in addition to contributing to reducing the weight of the concrete. Concrete is light and the cost is considered economical for this The process is relatively acceptable compared to the advantages that we can obtain through the use of fiberglass bars to reinforce reinforced concrete beams (*Fawzy, K,et,al,2024).* Through a methodology that relied on more different methodologies, such as the descriptive methodology in describing the data and variables that affect the performance of concrete beams reinforced with fiberglass bars, the analytical methodology in analyzing the effect of adding these bars to reinforced concrete and concrete beams, and the scientific and quantitative methodology in collecting and analyzing data and conducting verification operations. Numerical and experimental analysis on wire-reinforced concrete beams Fiberglass as well as the comparative methodology to compare the results and study the extent of the effect of fiberglass bars on reinforced concrete beams (*Molodtsov, M,et,al,2020).*

2. Theoretical background and basic concepts

In this part, the most important basic concepts and theoretical background of the study will be presented, as presenting the basic concepts is one of the most important points through which the reader can develop an insightful viewpoint, understanding, and awareness of the objectives of the study and its applied and theoretical stages, as well as the most important results reached by the study.

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Overview
Concrete beams are an essential element in modern construction, as they are used to distribute loads and resist stresses resulting from static and dynamic loads. Their use has evolved throughout the ages, starting with the use of wood and stone in bridges and arches in ancient times, through the Romans' creativity in using a mixture of water, gravel, and volcanic ash to build strong structures.
With the discovery of iron and its use in strengthening structures, the era of reinforced concrete began in the nineteenth century with the emergence of cement and the adoption of iron to enhance the strength of concrete. Technologies developed in the 20th century, such as prestressed concrete and high-strength concrete, with the introduction of fibers to enhance performance and reduce weight.
In the twenty-first century, digital technology and 3D printing have contributed to improving the design and analysis of concrete beams accurately and efficiently, leading to the production of smart concrete capable of resisting cracks and self-repair (*Devi, C,et,al,2010).*

Basic concepts
The basic concepts related to the study on enhancing mechanical behavior in high-strength concrete through the addition of glass fibers in the study include methods of numerical analysis and experimental verification. As well as a definition of shear, bending, tensile and compressive stresses, glass fibers and their types, factors affecting their physical and chemical properties, as well as the most important static and static loads to which reinforced concrete beams can be exposed .
Dynamic and static loads
Static loads:
These are loads arising from the weights of the structure and the tools, contents, equipment, etc., and they are what can be called fixed loads or dead loads. This type of load can be considered the main load that must be studied and tested well, taking into account all design factors and standards when calculating it, and taking further security and safety measures when designing reinforced concrete structures. It also results in many stresses, such as bending, torsion, and shear stresses (*Huang, G,et,al,2021).*
Dynamic loads: These are the loads resulting from surrounding Environmental factors , such as wind forces, earthquakes, volcanoes, and loads resulting from operations in concrete

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structures, especially those structures related to manufacturing and production operations. These loads change depending on the surrounding environmental factors. It results in dynamic stresses such as bending, torsion, shear stresses, etc .

Tensile and compressive stresses

Tensile and compressive stresses are stresses resulting from a force that works to tighten or compress a material. In reinforced concrete beams, this force pushes the concrete particles and the iron used in the reinforcement away from each other, thus causing stresses on the reinforced concrete. The reasons for the occurrence of these statements can be explained as follows:

•External loads: These are the so-called loads that include the weight of the building, foundations, equipment, people, and moving loads such as cars(*Ranaivomanana, N.,,et,al,2013).*

•Changes Environmental changes: such as changes in temperature that lead to expansion or contraction of concrete when falling, which generates stresses called compressive stresses.

•Chemical interactions: As a result of some interactions, this leads to a change in the volume of concrete and the occurrence of compressive stresses. These interactions are between the components of the concrete itself or between the components of the concrete and any other materials that have been added. Fig (1) shows the tensile and compressive stresses in concrete beams.

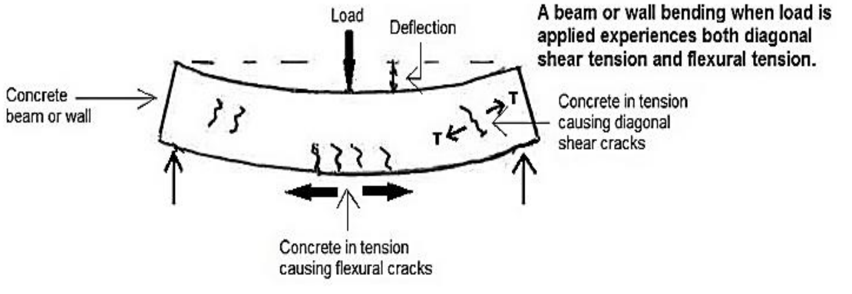

Figure 1: Tensile and compressive stresses in concrete beams

Stress and torsional moment

When anybody is subjected to a torsional moment, complex stresses arise within it, not only tensile and compressive stresses, but also shear and bending stresses. The importance of studying torsional torque is that it enables engineers to take safety and security factors into consideration during design processes, which enhances the resistance of reinforced concrete structures and increases the safety factor. Fig. (2) shows the torsional torque stress.

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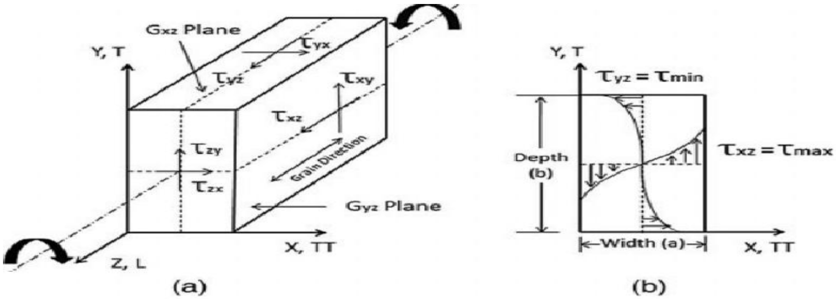

Figure 2: Shows the torsional stress

Torsional torque can be defined as the torque resulting from a force rotating around a specific longitudinal axis. In reinforced concrete beams, especially beams with wide spans and small sections, these beams are subjected to torsional moments. As a result of the concrete's resistance to these moments, oblique cracks may occur at an angle ranging from 30 to 45 degrees with respect to the axis of the structural member (*Mohaisen, S,et,al,2016).*
The ability of a concrete member to resist torsional torque depends on several factors, the most important of which are:
•Reinforcement ratio: The higher the reinforcement ratio, the greater the ability of the element to resist torsional torque.
•Distribution of reinforcement: Distributing reinforcement in a balanced and appropriate manner enhances the member's ability to resist torsional torque.
•Dimensions: Elements with larger dimensions and spans are more resistant to torsional moments.
•Type of concrete: High-strength concrete is more able to withstand stresses resulting from torsional torque.

Bending stress

Bending stress is a type of internal stress that is generated in an object, such as a concrete beam, when it is subjected to a load that causes it to bend. An illustration of bending stress is shown in Fig.(3). As with other stresses, the main cause of bending stress is external loads that include the weight of the building, foundations, and people present and moving objects. In addition, a group of moments that form around a certain point in a reinforced concrete element, especially concrete beams, plays an important role in creating this stress(*Bakar, M,et,al,2022).*

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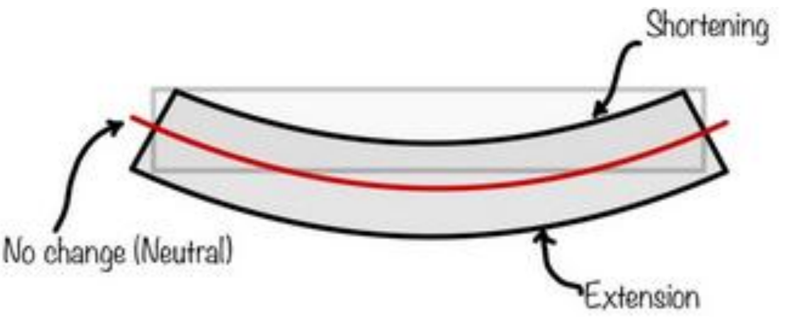

Figure 3: shows the bending stress in reinforced concrete beams.

Shear stresses

When a body is exposed to the presence of two forces of equal magnitude and opposite directions, this causes a stress on the body called shear stress as a result of the body's layers rubbing against each other. This stress leads to the occurrence of cracks and fissures, especially if the material is weakly resistant to shear stress, such as reinforced concrete. Fig. (4) shows the shear stress. One of the most important occurrences of shear stress is the presence of inclined loads that may result from operating loads or dynamic actions, such as dynamic loads resulting from earthquake forces or wind force, which makes the stresses concentrated in certain places and transportation *(Hu, B., & Wu, Y. F. 2017).*

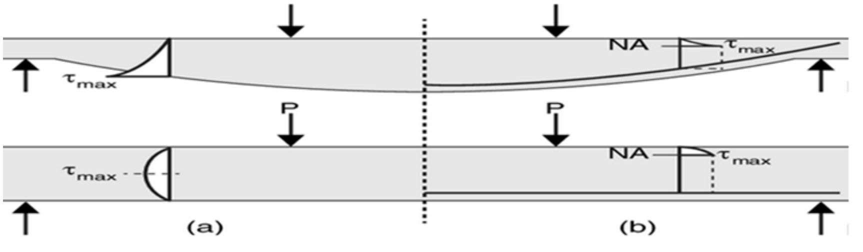

Figure 4: shows the shear stresses in reinforced concrete beams

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Factors affecting the performance of reinforced concrete beams.

The performance of reinforced concrete beams depends on a group of factors that must be carefully taken into consideration. These factors include the mechanical and physical properties of materials, some engineering factors such as design, and other factors such as

http://www.doi.org/10.62341/aamg2904

the type and duration of loading and environmental factors such as wind forces and earthquakes. the most important of these factors, which are as follows:

1. Properties of materials: In this part, the three most important materials related to the subject of the study will be presented:

- ***Concrete***: Concrete is one of the most important elements used in reinforced concrete structures, as its properties play a major role in determining the performance of reinforced concrete beams. These beams are affected in terms of their ability to bear loads, deflections or displacements resulting from stresses, as well as their estimated lifespan. The most prominent of these features are:
  - Compressive strength: The greater the compressive strength of the concrete, the greater the ability of the beams to bear loads, especially compressive loads. This in turn reduces the possibility of collapse of beams due to compressive stresses or compressions.
  - Modulus of elasticity: The modulus of elasticity is related to the hardness of concrete; The higher the modulus of elasticity, the less the beams deflect when subjected to loads.
  - Shrinkage of concrete: Shrinkage of concrete leads to the appearance of cracks, especially in areas subjected to large tensile stresses. These areas are usually the lower parts of the beams, which negatively affects the durability of the beams.
- ***Iron***: Reinforcing steel is the second basic element in reinforced concrete structures. It is what gives concrete its strength and durability and increases its ability to withstand various stresses, especially those resulting from tension. In short, it can be said that rebar is the backbone that gives concrete its strength and ability to resist loads. The main factors that affect the properties of reinforcement steel and its performance in beams are the following:
  - Withdrawal strength: Withdrawal strength expresses the ability of steel to resist pulling from concrete. The greater this strength, the greater the beam’s ability to resist cracks and the less likely slippage occurs between the steel and the concrete.
  - Flexibility of iron: The flexibility of iron refers to its ability to bend without breaking or failing. The greater the flexibility of

http://www.doi.org/10.62341/aamg2904

the steel, the more consistent it can work with the concrete, which enhances the beam's ability to withstand bending

- Steel diameter: The diameter of the reinforcing steel bars is one of the factors affecting the performance of reinforced concrete beams. The larger the diameter of the steel, the greater the beam’s ability to withstand the loads and stresses resulting from it.
- Type of steel: Types of rebar vary based on their mechanical properties. The appropriate type of steel is selected based on the type of expected loads and environmental conditions.
- Bonding between iron and concrete: The bonding between iron and concrete is considered one of the most important determining factors in the performance of beams. Good bonding ensures effective transmission of stresses between the concrete and steel, which enhances the strength of the beam.

- ***Polymeric fiberglass***

- Glass fibers are considered one of the important modern materials and elements in the field of concrete reinforcement due to their excellent mechanical and physical properties that make them excellent and effective in enhancing the performance of concrete beams. It has a higher tensile strength amplitude, a smaller range of allowable strain, and a lower modulus of elasticity. The following can be used to summarize the reasons why composites are increasingly being used as reinforcing materials for reinforced concrete elements: Low weight (about a quarter of the weight of steel), which makes it easy to apply in limited spaces, eliminates the need for scaffolding, and reduces labor costs; Hardness that can be customized to design requirements; Very high and long-lasting static tensile strength for some types of items FRP, high ability to deform; And almost endless availability in sizes, shapes and dimensions FRP(*Pham, T,et,al,2021).*
- Glass fibers are thin threads made of glass characterized by high tensile strength and light weight. These materials are used in the manufacture of fiber-reinforced materials and polymers, as they can be used in the manufacture of fiber-reinforced

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concrete. It is characterized by many characteristics that enhance the performance of concrete beams, including:

- High tensile strength: Glass fibers have a high tensile strength that makes them bear much more loads.
- Corrosion resistance: Glass fibers are characterized by their ability to resist corrosion, which extends the life of concrete beams and is not affected by the effects of the surrounding environment..
- Light weight: It is characterized by its light weight, which reduces the weight of the overall structure.
- Flexibility: Glass fiber is characterized by high flexibility, which makes it work to absorb energy resulting from earthquakes and loads and thus reduce the damage to which the reinforced concrete structure may be exposed..
- Fatigue resistance: Glass fiber is characterized by its ability to resist stress and fatigue, which makes it able to withstand repeated loads without losing its advantages and ability to resist.
- Electrical and heat insulation: Fiberglass is characterized by excellent electrical and thermal properties, as it is not a good conductor of heat or electricity, which makes it an ideal tool in the performance and operation of reinforced concrete beams
- Glass fibers are used to strengthen concrete beams by the following mechanism, as shown in Fig. (5).

Figure 5: shows the use of fiberglass in reinforced beams**.**

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2. The importance of using fiberglass is due to the following:

•Increased tensile strength: Glass fiber is added to the concrete mixture or in the form of outer layers to increase the tensile resistance of the beams, which reduces the risk of cracking.

•Improving bending resistance: Fiberglass helps improve the beams' resistance to bending, which increases their ability to bear loads.

•Weight reduction: The use of fiberglass reduces the weight of the beams, which reduces the loads on the overall structure.

•Increased structural durability: Fiberglass increases the durability of the structure and its resistance to damage resulting from environmental factors and corrosion.•

•Increased service life: Thanks to its excellent properties, fiberglass helps increase the service life of concrete beams.

•The most important characteristic of the glass fibers used to strengthen and enhance the performance of reinforced concrete is that they are diverse and can be divided into several types as follows,

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- Increased structural durability: Fiberglass increases the durability of the structure and its resistance to damage resulting from environmental factors and corrosion.
- Increased service life: Thanks to its excellent properties, fiberglass helps increase the service life of concrete beams.
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Mechanics of materials: elasticity theory, plasticity theory, and stress-strain analysis.

The theories of elasticity and ductility are among the most prominent engineering theories used in studying the behavior of materials under the influence of loads. These two theories play a crucial role in the design of various engineering structures, such as buildings and bridges, to ensure their safety and ability to bear the expected loads.

Laws of static equilibrium:

Static equilibrium occurs when the body is at rest and is not moving, that is, the body is in balance without any acceleration. To achieve static equilibrium, the following conditions must be met:

$$\sum Fx = 0 \;, \quad \sum Fy = 0 \;, \quad \sum Fz = 0 \qquad Eq.(1)$$

$$\sum Mx = 0 \;, \quad \sum My = 0 \;, \quad \sum Mz = 0 \qquad Eq(2)$$

where :

- $\sum$ Fx: The sum of the forces acting in the horizontal direction, (x direction)
- $\sum$ Fy : is the sum of the forces acting in the vertical direction (y direction)
- $\sum$ Fz: is the sum of the forces acting in the vertical direction. (z direction)
- $\sum$ Mx: is the sum of the moments about the **x** axis

http://www.doi.org/10.62341/aamg2904

- $\sum$ My: is the sum of the moments about the **y** axis.
- $\sum$ Mz: is the sum of the moments about the **z** axis.

In this case, the object is moving at a constant speed, so there is no change in velocity (i.e., no acceleration). This means that the sum of the forces is zero, but the body is not at rest [19].
The sum of the moments about any point equals zero:

Newton's laws of equilibrium:

$$\sum \vec{\tau} = \sum \tau = 0 \quad Eq(3)$$

$$\vec{F} = m\vec{a} \quad \text{Eq}(4)$$

Newton's First Law (also known as the Law of Inertia): “A body remains at rest or in motion at a constant speed in a straight line unless acted upon by an external force that changes its state.”
Newton's Second Law: "The acceleration acquired by an object is directly proportional to the force acting on it and inversely proportional to its mass." It is expressed by the equation:
where :

F: resultant force, **m**: mass, and **a**: The wheel acceleration

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Elasticity Theory:

Elasticity theory focuses on studying the behavior of solid materials when they are subjected to external loads, with the assumption that the material returns to its original shape after the load is removed, which means it has high elasticity *(Zhao, W., & Ye, J. (2020).*

Plasticity theory:

Plasticity theory focuses on studying the behavior of materials when they exceed the limits of elasticity and enter the plastic region, where the material does not return to its original shape after the load is removed *Jensen,(B. C., & Lapko, A. (2009).*

Theory of static and dynamic analysis

Static equilibrium is that equilibrium that is subject to the laws of statics, which state that a body remains stationary and balanced if the resultant of the forces acting on it at a certain point equals zero, and the sum of the moments around any point on this body equals zero. And according to Newton's first and second laws of motion, which state that the body A stationary or moving object remains in its state unless an external force acts on it. The resultant force acting on a moving body is equal to its mass times the acceleration with which it moves(*Arruda, M,et,al,2024).*

Where the laws of balance are divided into two main types: static balance (static stability) and dynamic balance (kinetic stability). Both types are based on Newton's laws of motion, but each relates to a different state of motion or immobility.

Nonlinear analysis theory

The theory of nonlinear structural analysis is an advanced method for studying the behavior of structures under complex loads beyond linear material behavior. Unlike linear analysis, it considers non-proportional relationships between stress and deformation, accounting for large deformations, material instability, and potential collapse. It also evaluates dynamic effects like earthquakes and wind, enabling the study of nonlinear relationships, structural lifespan, and collapse scenarios *(Kurrer, K. E. (2018).*

Seismic analysis theory

Seismic analysis theory is used to study the effect of earthquakes on offshore platforms, especially in seismically active areas. It focuses on analyzing the platform's response to seismic movements, including the absorption of shocks and seismic waves that may affect its stability. This theory is an important tool for evaluating the impact of potential earthquakes on reinforced concrete structures. To understand them in depth, basic concepts must be studied such

http://www.doi.org/10.62341/aamg2904

as the nature of earthquakes, which are defined as the release of excess energy due to cracks in the Earth's crust, as well as seismic waves measured on the Richter
scale *Carpinteri, A. (2017).*

Finite element analysis, FEA

Finite element analysis (FEA) is a powerful and effective tool used in analyzing structural structures. This theory is based on dividing the structure into small parts called "elements" for detailed analysis of each of them, which allows stresses and strains to be studied at specific points, whether the loads are constant or variable. To understand this theory, the structure is divided into small elements such as triangles or squares, and the properties of each element are analyzed individually. These properties include bending, strain, tensile modulus, and fracture, in addition to other physical properties. Equilibrium equations are then applied to each point of the reinforced concrete structures (*Suprobo, P.,,et,al,2022).*

Verification and numerical analysis

Numerical verification and analysis is a mathematical method used to solve complex engineering problems using computers. In the field of civil engineering, numerical analysis is used to analyze the behavior of materials and structures under various loads, such as loading fiber-reinforced concrete. Verification is the process of comparing the results obtained from numerical analysis with experimental results obtained from laboratory or field tests. The goal of verification is to ensure the validity of the models used in the numerical analysis and their accuracy in representing the actual behavior of the material.

Factors affecting the performance of reinforced concrete beams reinforced with glass fiber .

Reinforcing reinforced concrete beams using fiberglass is one of the best solutions to improve the performance of concrete structures, especially in areas exposed to high stresses. To ensure effective reinforcement, several factors that affect the performance of fiberglass-reinforced beams must be taken into account:

- Type and percentage of glass fiber: Affects strength, flexibility, and wear resistance *(Dwibedy, S., & Panigrahi, S. K. (2023).*
- Properties of concrete: Such as creep, strength, and water-cement ratio.
- Properties of iron: Such as hardness, durability, and diameter.
- Fiber distribution method: To avoid discrepancy in charact

http://www.doi.org/10.62341/aamg2904

•Fiber routing: To improve the resistance of the beam in the desired direction (*Hsu,. T. (2017).*

Methods of bonding between fibers and concrete:

•Mechanical connection: Using fiber networks or woven fibers(*Hawileh, R,et,al,2014)*

•Chemical bonding: Using chemical binders.

Method of design and implementation:

•Choosing the appropriate design (maximum limits, power, flexibility).

•Improving the distribution of fibers and their bond with concrete.

•Protecting the beam from environmental factors.

•Monitoring the quality of implementation to ensure optimal performance.

•Improving performance requires selecting appropriate fibers, using high-quality concrete, and good design to withstand the expected loads (*Boyd, A. J. (2000).*

3. Method methodology

The study methodology was to use descriptive, analytical, and comparative methods to study the effect of using fiberglass bars on the performance of reinforced concrete beams. The experiments included the manufacture of three samples with a length of 3 meters and a section of 25 x 50 cm, where the first was completely reinforced with iron, and the second with completely fiberglass, and was tested using a hydraulic press to reach the collapse load, with the results compared to simulations of the "Abacus
" program.

Applied framework

the applied framework included the steps of collecting data, conducting laboratory and simulation tests, and analyzing the results statistically using tests such as ANOVA and linear regression to determine the strength of the relationships between elasticity, tensile and compressive stress, and the performance of beams. The influence of various factors, such as the type of loads and methods of bonding between concrete and reinforcement, was clarified, to provide recommendations on improving the performance of reinforced beams using fiberglass as shown in Fig (6).

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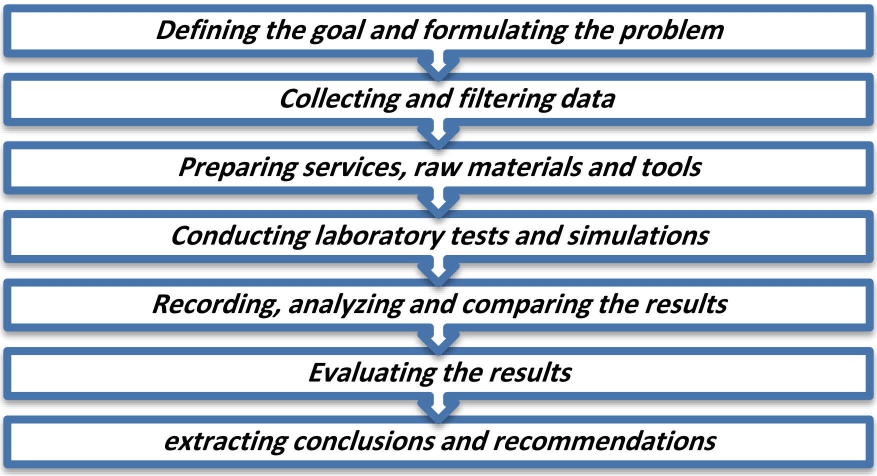

Figure 6: The applied framework of the study.

The previous figure illustrates the applied framework of the study, starting with defining the objective of the study, formulating the title, formulating the research problem, identifying obstacles and restrictions, then collecting data related to the topic, identifying the tools, materials and devices used in the study, then starting the laboratory testing procedures and simulation procedures, passing through recording and analyzing the results and comparing the laboratory testing results with the simulation results. Then evaluating these results , drawing conclusions and presenting recommendations (*Moawad, M. S., & Fawzi, A. (2021).*

Materials, tools and equipment

The materials and tools used in the study were divided into three categories:

Materials:

Steel bars and fiberglass bars with specific specifications and diameters.

High-stress concrete and additional materials such as tie wires.

3.2.2.Data and software:

- •Data on the properties of the materials used (reinforcing bars and concrete.(
- •Ambient environmental conditions (temperature and humidity.(
- •Simulation programs (such as Abaqus) and statistical analysis programs (such as SPSS) and some engineering software such as MATLAB.

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Tools and equipment:

- •Hydraulic presses, measuring and monitoring devices, and installation and lifting tools.
- •High-spec computers (16-64 GB RAM, 1 TB SSD storage, and advanced graphics cards.(

Procedures

Defining the goal and method:

Adopting various analysis methods such as stress and deformation analysis, dynamics, vibration, and fatigue, taking into account the factors affecting the analysis method.

Data collection:

- •Collect information on material properties (iron bars, fiberglass, and concrete), available loads, restraint conditions, and characteristics of software and tools used.
- •Sources included previous studies, databases, and opinions of experts and supervisors.

Preparation of materials and equipment:

- •Preparation of raw materials such as reinforcing bars and high-stress concrete.
- •Preparation of laboratory equipment such as casting and fixing tools, and measuring devices.
- •Implementation of the design and casting of reinforced concrete beams, as shown in Figures (7) and (8)

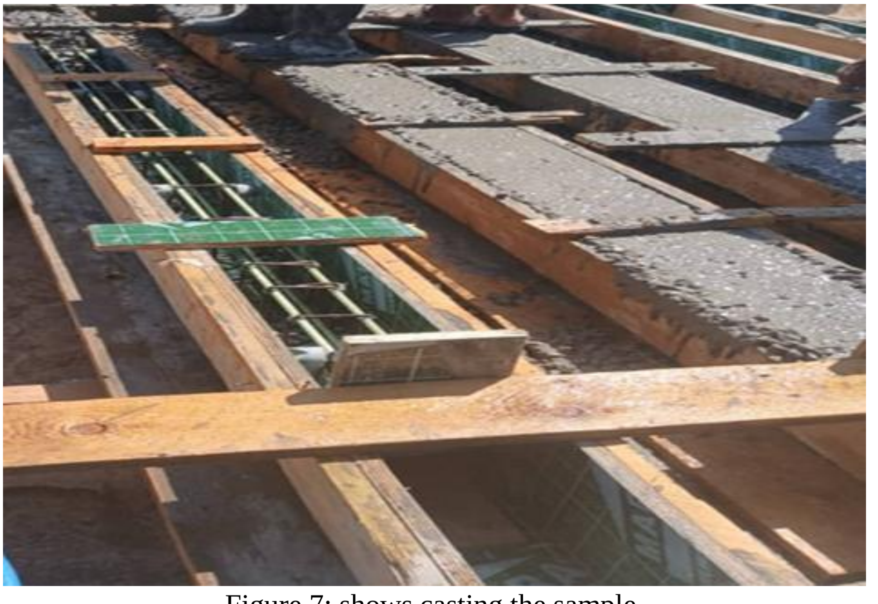

Figure 7: shows casting the sample**.**

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Figure 8: shows casting cubes

Laboratory Testing Phase

A hydraulic press was used to test stresses (tensile, fracture, and compression) in addition to elasticity and plasticity measurements for the concrete beams under study as show in Fig.(9)

Sample Details:

Fully reinforced with 14 mm diameter steel bars .

- Total length: 3 meters, effective length: 2.8 meters.
- Cross section: 25 x 50 cm.
- Reinforcement: 2 lower bars and 2 upper.
- Tie the bars using mechanical tie wires.

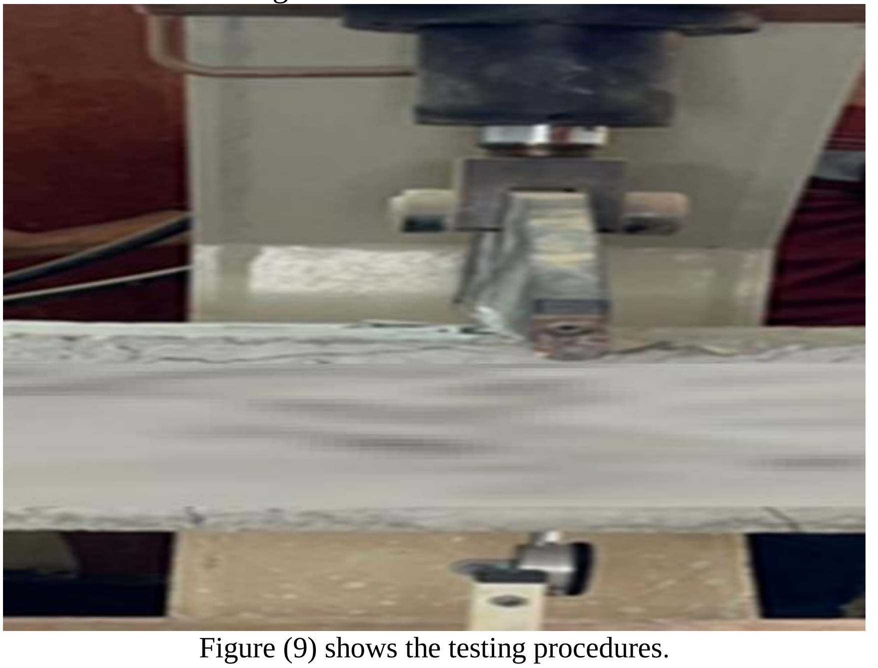

Figure (9) shows the testing procedures.

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Simulation Phase

The simulation was carried out using Abaqus program to analyze the effect of adding fiberglass bars to the reinforced concrete beam.

3.4.1Simulation Steps:

- Identification of important nodes:
- Ultimate stress nodes:
- Center area (middle of the beam.(
- Ends (at support points.(
- Contact nodes:
- Between concrete and fiberglass bars.
- **Supporting nodes:**

Study reaction forces.

- Analysis tools in Abaqus as shown in Fig. 10
- Contour Plots: Analysis of stress distribution along the beam.
- Path Analysis: Draw a path to determine the distribution of stresses and strains.
- Partitioning: Dividing the model to determine the nodes associated with the fiberglass reinforcement *(Lee, Set,al,2020).*
-

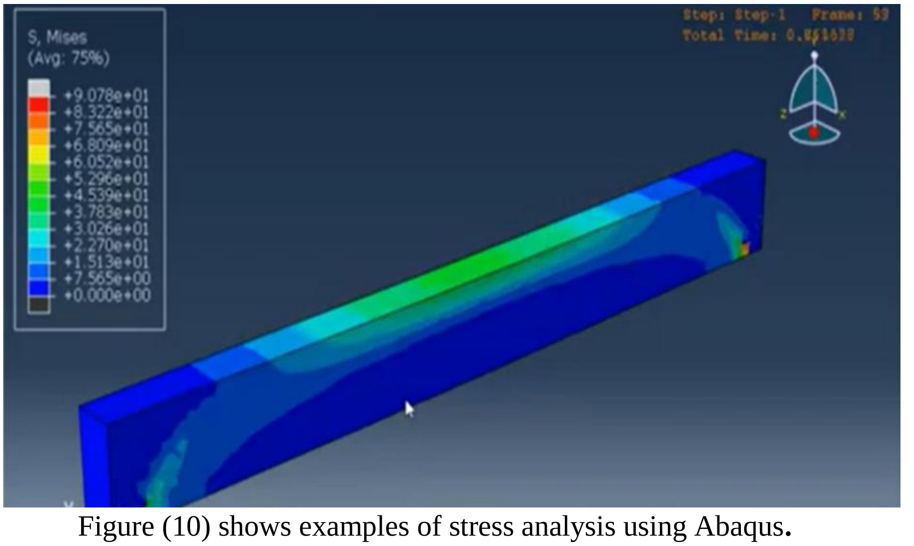

Figure (10) shows examples of stress analysis using Abaqus**.**

4. Results and discussion.

In this section, the laboratory results performed in the laboratory as well as the simulation results using the Backus program will be presented and discussed.

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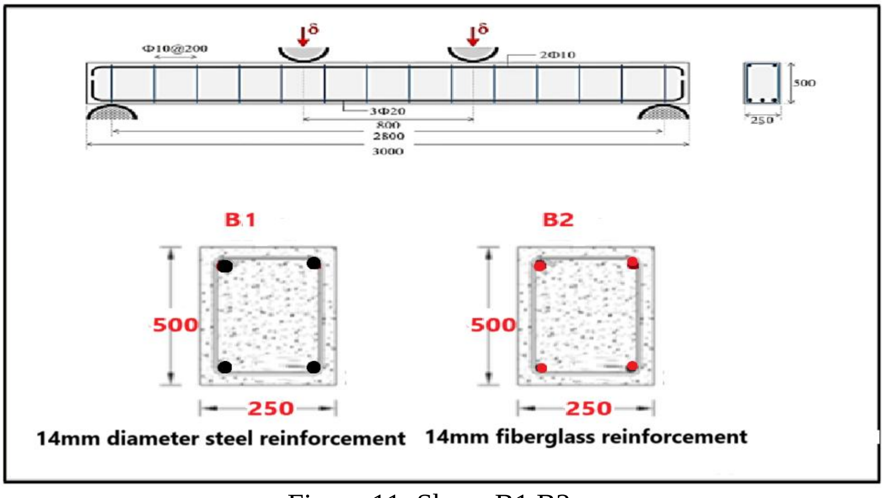

Figure 11: ShowsB1,B2

The previous Fig.11 shows the specifications of sample B1 and B2, the reinforcement method and the dimensions, where the length and width of the concrete are 3 meters, its height is 50 cm, its width is 25 cm, the upper reinforcement is 2 bars and the lower reinforcement is 2 bars. The first sample B1 is a complete repair of iron with a diameter of 14 mm, and the second sample is completely reinforced with fiberglass with a diameter of 14 mm.

Table 1: Shows the properties of GFRP and steel reinforcement used in the experiment.

Fracture stress (%)	Tensile strength fu (MPa)	factor of elasticity Ef (GPa)	Diameter (mm)	Reinforcing bar type Reinforcing bar
3	1200	50	14	GFRP
1.5	600	200	14	Steel

Experimental results

Table 2: Experimental results

BEAM	Δm	εMAX	JI	JR
			(N.sec)	(N.sec)
B1	4.5	0.022	500	490
B2	7.4	0.033	400	390

Shows the results of testing some concrete beams B1 and B2 under load . The Table1 and Table2 shows the following:

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➢ *strain*

- As for the maximum strain, we find that beam B1 reached 0.022, and it is the beam with the least reaction, followed by B2, where the strain value reached 0.036 s.

➢ *The inertia coefficients JI and JR*

- *J* &*JR* Inertia or force coefficients applied due to errors (N.sec):, where JI and JR represent the force coefficients of the beam or inertia with respect to the resulting curvature.
- As the values of *JI* and *JR* decrease, the beam stiffness decreases, B1 is the highest value (490 and 500), which indicates that the energy consumption under load decreases and equals the beam stiffness. Low values of B2 (390 and 400) indicate a slight decrease in energy efficiency due to boost input *(Sadraie, H.,et,al,2019).*

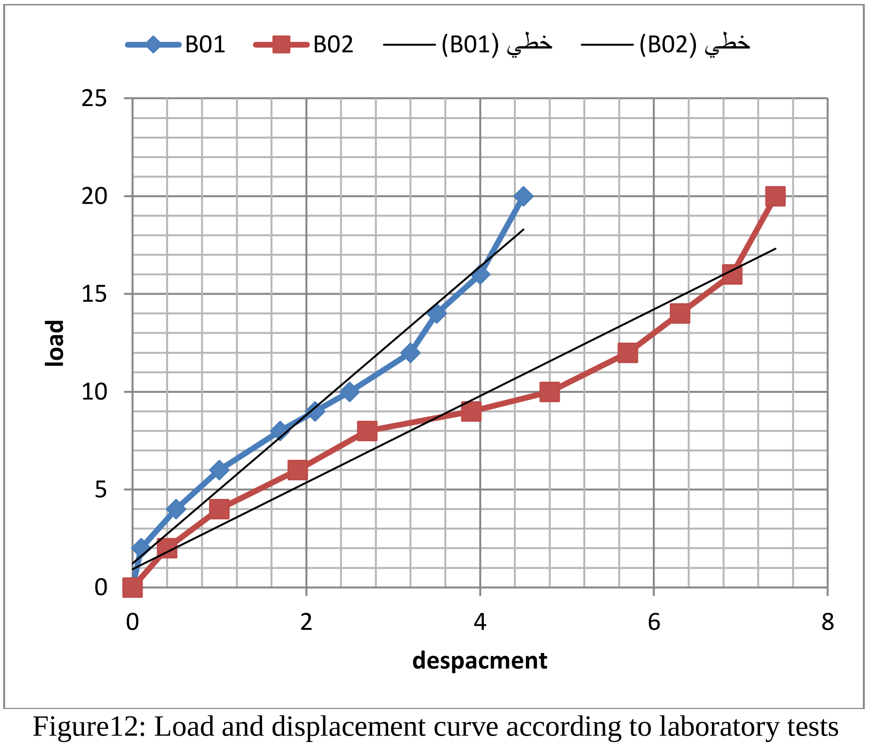

Figure12: Load and displacement curve according to laboratory tests

According to the previous Fig.12, which shows the curve of the relationship between load and displacement, we find that each point on the curve: represents a specific value for the load and the measured displacement for a specific sample. We find that when the load value is zero, the displacement is zero for all beams. This is

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normal in the initial state without load. With the gradual increase in load, the displacement begins to increase. The first beam B1 shows slight increases in displacement with each load, while the second beam B2 shows relatively higher displacements compared to the first beam. The difference between the samples, as each sample (B1, B2,) has its own curve, indicating that each material responds differently to the load. Some samples are stiffer than others, and some are more flexible (*Abdul-Jawad, H. M. (2018)*

Numerical verification results

Table 3: Numerical results

beam	Δm	ε	*JI*	*JR*
	(mm)		*(N.sec)*	*(N.sec)*
B1	*4.2*	*0.02*	*500*	*480*
B2	*7.2*	*0.036*	*400*	*380*

- *Strain:*
- Beam B1 recorded the lowest strain value (0.022), indicating its high resistance to deformation as shown in **Table3**
- Beam B2 achieved a strain value of 0.036, which is slightly higher than B01
- *The inertia coefficients JI and JR*
- B1 recorded the highest values (490 and 470), indicating low energy consumption under load and high beam stiffness.
- B2 showed lower values (390 and 370), indicating a slight decrease in energy efficiency due to the boost input.
-

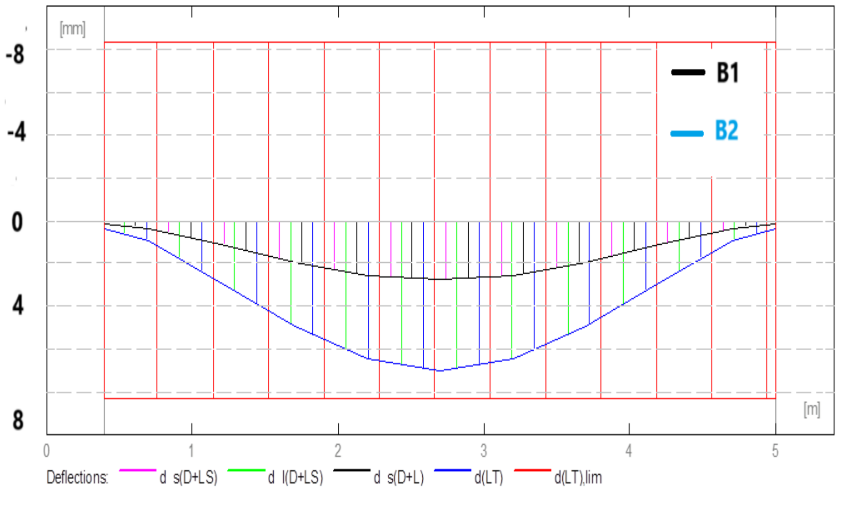

Figure12: Load and displacement curve according to laboratory tests

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Deflection (Δm):

- Beam B1 has very low deflection (4.2mm), which indicates high stability and great resistance to deformations.
- Beam B2 has a slightly higher deflection (7.2mm), showing slightly lower rigidity than B1 as shown in Fig14.

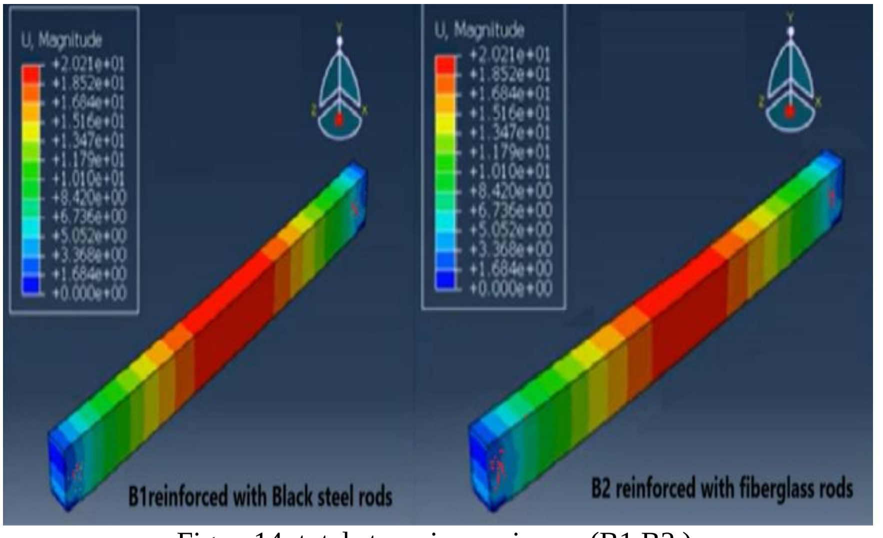

Figure14: total stress in specimens (B1,B2,)

The above figure shows the results of the performance analysis of three different types of reinforced concrete beams, allowing an understanding of how these beams interact in terms of different materials and the amount of stress in the beam. The different colors represent the stress levels in each part of the specimen; warm colors (such as red and orange) indicate areas of high stress, while cool colors (such as blue) indicate areas of low stress.

5. Recommendations and conclusions

Conclusion :

- Beam B1 recorded the lowest strain value (0.022), indicating its high resistance to deformation. Beam B2 achieved a strain value of 0.036, which is slightly higher than B1. In both laboratory testing and numerical testing and verification.
- Beam B1 recorded the lowest displacement value, which indicates its high resistance to deformation. Beam B2 achieved a displacement value that was slightly higher than B1. In both laboratory testing and numerical testing and verification.

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- Beam B2 is considered a suitable choice for applications that require a balance between rigidity and flexibility, while withstanding some deformation. Beam B1, however, is thinner and less flexible, so it can be used in applications that require greater strength and rigidity to resist greater loads *Yang, W.,et,al,2024).*
- The displacement values for widths B1 and B2 in the laboratory tests were 4.5 mm and 7.4 mm in the laboratory results, while in the numerical investigation results they were 4.2 and 7.2 mm. This indicates that the simulation results can be more accurate than the laboratory results, as some steps and laboratory results may show errors. Simple and imprecise.

Recommendations

Expanding studies on fiber types, mixing ratios, shapes, distribution methods, and their integration with concrete is crucial for advancing reinforced concrete performance. This effort supports sustainability in construction by enhancing the strength, durability, and lightweight design of concrete beams.

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