Investigations on Beam Column Joint with Textile Reinforced Concrete

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Abstract- *When an earthquake hits a reinforced-concrete structure, the beam-column junctions are the most vulnerable areas. Large stresses and moments generated by severe earthquakes result in diagonal cracking and crushing of concrete in the joint area. For the design of beam-column junctions, extremely ductile materials are necessary. The purpose of the research is to analyse RCC structures for Dead load, live load, and Earthquake load in order to find Critical joints. Comparing beam column connection with RCC beam column connection and using textile reinforced concrete material in various places, performed the study in ANSYS. In comparison to non- textile reinforced concrete specimens, load bearing capability and strength improve as stress decreases, according to the research. The various textile reinforced concrete configurations or specimens were attached to the top, bottom, and lateral sides of the beams. When textile reinforced concrete material is completely wrapped around the RCC beam column connection, the results are better compared to non- textile reinforced concrete specimens.*

Keywords- Beam Column Joint, textile reinforced concrete, Non Linear Analysis, ANSYS

I. INTRODUCTION

Textile Reinforced Concrete (TRC) is a composite material consisting of cementitious matrix reinforced with textile materials such as glass, carbon, or polypropylene fibers. TRC is an innovative material that combines the advantages of conventional concrete, such as high compressive strength and durability, with the advantages of textile materials, such as high tensile strength, flexibility, and ease of handling. The textile reinforcement in TRC is typically in the form of woven or non-woven fabrics, or as grid-like structures. The textile fibers are embedded in the concrete matrix to enhance its tensile strength and provide ductility, crack resistance, and improved impact resistance. The textile fibers also help to reduce the weight of the concrete, which can be an advantage in construction applications. TRC has several advantages over traditional concrete reinforcement methods, such as steel reinforcement. TRC is lightweight, easy to handle, and can be easily shaped into complex forms. It also offers high resistance to corrosion and can be used in aggressive environments. TRC is also more sustainable than traditional concrete reinforcement methods since it requires fewer resources to produce and transport. TRC has a wide range of applications in the construction industry, including façade elements, thin shells, cladding panels, and prefabricated elements. It is also used in the rehabilitation of existing structures such as bridges, tunnels, and buildings.

One of the key advantages of TRC is its ability to resist cracking and prevent structural failure, even when subjected to high stresses. This is because the textile fibers used in TRC are highly resistant to tension and can distribute stress uniformly across the concrete matrix, reducing the risk of localized damage. Another advantage of TRC is its potential for architectural innovation. TRC allows for the creation of lightweight, thin-walled structures that are aesthetically pleasing and structurally sound. This makes it an ideal material for creating complex, curved shapes that would be difficult or impossible to achieve with traditional concrete.

TRC is also a sustainable material, as it requires less energy to produce than steel and has a lower carbon footprint. Additionally, the use of textile reinforcement can reduce the amount of cement used in the concrete matrix, further reducing the environmental impact of the material. However, there are also some challenges associated with the use of TRC. One of the main challenges is ensuring proper bonding between the textile reinforcement and the concrete matrix. This can be achieved through proper surface preparation and the use of appropriate bonding agents. Another challenge is the need for specialized design and construction techniques to ensure that the TRC structure is stable and durable. This requires expertise in both textile engineering and concrete construction. Despite these challenges, the use of TRC is expected to continue to grow in the coming years, as architects, engineers, and builders seek out sustainable, innovative materials that offer superior performance and design flexibility.

Textile Reinforced Concrete

Textile Reinforced Concrete which was first introduced in the 1990s is emerging as a valuable construction material and is being widely used in construction projects as it can take any form since it is extremely versatile. It is an innovative composite material with a combination of fine grained concrete and multi-axial mesh like textile fabrics as reinforcements. It is a cementitious material where reinforcement consists of high strength non-corrosive textile fabrics. TRC is light, stable, and sustainable. It is a composite material that takes advantage of the non-corrosive nature of fiber materials.

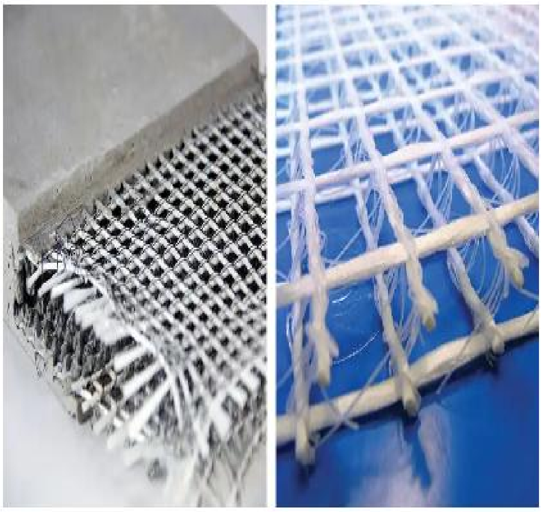


Fig 1: Textile reinforcement

Difference Between RCC, FRC and TRC

Concrete is well known for its very high compressive strength, but the high bending tensile strength which is essentially required for many structural members is provided only by reinforcing steel. If the concrete is not properly mix-designed and consolidated, the steel easily undergoes corrosion once cracks appear in concrete due to tensile forces. This problem is over come in TRC by using a textile fabric instead of using a metal cage inside concrete. Textiles replace conventional steel reinforcement and overcome the weakness of steel to corrode which is a major advantage of TRC over steel reinforced concrete. Thus, the basic difference between textile reinforced concrete and conventional reinforced cement concrete is that, the steel reinforcing bars in conventional concrete are replaced with 2D or 3D textile materials.

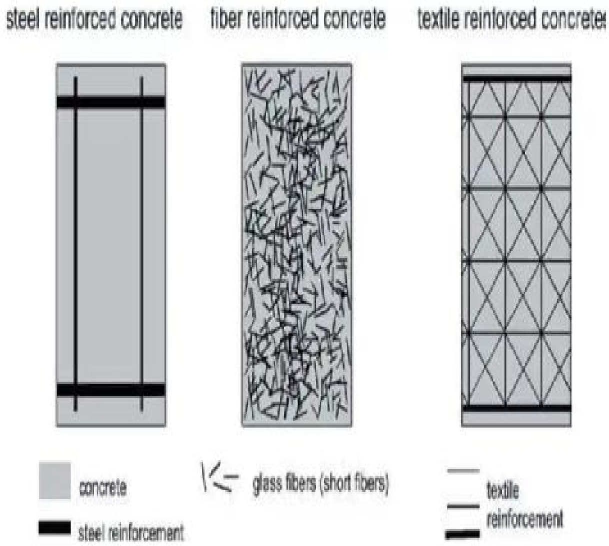


Fig 2: Stress-strain relations of TRC

Unlike fiber reinforced concrete containing short fibers, textile reinforced concrete provides a higher degree of effectiveness because the fiber bundles are arranged in the direction of the main tensile stresses. Thus, TRC overcomes the shortcomings of both conventional RCC and FRC, wherein the reinforcement bars and short-cut fibers are replaced with textile meshes to improve durability, ductility and design control. Figure 3 shows the stress-strain relations of TRC as compared with other concretes.

The TRC possess a linear plastic behaviour with strain hardening. The carbon textile reinforcement undergoes brittle failure at the ultimate limit strain.

II. LITERATURE REVIEW

Bahman Ghiassi et.al (2022) "Development of cost-effective low carbon hybrid textile reinforced concrete for structural or repair applications".

The results showed that the developed TRCs show a significantly higher flexural strength and deformation capacity while having a lower drying shrinkage, cost and environmental impact than those available in the literature. Textile reinforced concrete (TRC) is a composite material that combines the advantages of traditional concrete with the flexibility of fiber reinforcement. It consists of cement-based matrix and textile reinforcement in the form of woven or non-woven fabrics. TRC has many potential advantages, such as high strength, durability, resistance to cracking, and reduced weight. Moreover, it has a lower carbon footprint compared to conventional concrete due to the reduction in cement content. Developing cost-effective low carbon hybrid TRC for structural or repair applications requires optimizing several parameters, including the type and proportion of fibers, the type of matrix, the textile architecture, and the manufacturing process. One approach to achieve this is by using a hybrid approach, where multiple types of fibers are used to reinforce the concrete. For instance, carbon fibers can be used in combination with cheaper synthetic fibers to achieve both high strength and cost-effectiveness. Another approach is to use a low-carbon matrix material, such as geopolymers, instead of conventional Portland cement. Geopolymers are synthesized from industrial waste materials, such as fly ash and slag, and can be used as a binder for TRC. They have lower greenhouse gas emissions and require less energy to produce than conventional cement. Furthermore, the textile architecture can be optimized to reduce material waste and improve the mechanical properties of the TRC. Non-woven fabrics, such as chopped strands or continuous filaments, can be used to reduce fiber orientation and increase the interlocking between fibers and matrix.

Will Hawkins et.al (2017) "Thin-shell textile-reinforced concrete floors for sustainable buildings".

In this investigation, the performance of various shell geometries is compared using finite element analysis. A functional design is produced and found to offer reductions of 62% in embodied energy and 64% in weight compared to an equivalent flat slab. This project brings together modern developments in computational design, materials and construction to propose a novel thin-shell concrete flooring system for multi-storey buildings, creating a low embodied energy and lightweight alternative to traditional reinforced concrete flat slabs. Steel-reinforced concrete, cast in flat prismatic forms, dominates multi-storey building construction around the world. Despite the fluidity of the material, opportunities to create efficient geometries through manipulation of form are habitually overlooked, resulting in inefficient cracked sections, high steel requirements and large carbon footprints. Future work by the authors will explore and resolve further technical details, practicalities and design refinements for the proposed system. These include the effects of initial imperfections, variable section thicknesses, non-linear material behaviour, point loadings and stability loads. A programme of prototyping and physical testing is also being undertaken.

Ping Xu et.al "Flow Mechanism and Strength Characteristics of Textile Reinforced Concrete Mixed with Colloidal Nano-SiO".

Textile reinforced concrete (TRC) has the superior characteristics of crack resistance, impact resistance, and durability properties, which has been widely applied in lightweight thin-walled structures, such as large span arches, shells, and domes.The use of textile reinforced concrete (TRC) as a building material has gained increasing attention due to its unique properties such as high tensile strength, good ductility, and durability. In recent years, the incorporation of nanomaterials in TRC has been explored to further enhance its performance. This study investigates the flow mechanism and strength characteristics of TRC mixed with colloidal nano-SiO.The results indicated that the addition of colloidal nano-SiO significantly increased the mechanical properties of the TRC mix, with the compressive strength increasing by up to 22%, tensile strength increasing by up to 41%, and flexural strength increasing by up to 35%. The study also investigated the microstructure of the TRC mix using scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis. The SEM images revealed that the addition of colloidal nano-SiO improved the interfacial bond between the textile and cement matrix, leading to a more compact and uniform microstructure. XRD analysis showed that the addition of colloidal nano-SiO led to the formation of additional hydration products, which contributed to the improvement in strength characteristics.

Anjana Elsa Alexander et.al (2020) "Sustainability of Construction with Textile Reinforced Concrete- A State of the Art".

This review paper presents an evaluation of different textiles that can be used as reinforcement in TRC, their bonding behaviour, durability characteristics and applications. A comprehensive overview on TRC reveals that TRC has excellent mechanical properties and durability characteristics. TRC is applicable for constructing lightweight, thin structural elements and for strengthening or repair of damaged structural elements. Steel reinforcement in reinforced concrete structure is prone to corrosion. It has been found that a sustainable building material that can be used to replace steel from the construction industry is textile reinforcement. Textiles of high strength and fine-grained mortar are used to make a composite material termed as Textile Reinforced Concrete (TRC). In this review paper, fibers such as glass, carbon, aramid, and basalt are examined for their applicability in TRC. Carbon fibers are inert and compared to other fibers has superior characteristics in terms of tensile strength and modulus of elasticity. But carbon has high cost. Alkali Resistant glass is found to be the most cost-effective and gives satisfactory results in terms of tensile strength. Improved tensile properties, good filling in between bundles and strong bonding are observed for matrix with mineral filler composite.

C.G. Papanicolaou et.al (2016) "Applications of textile-reinforced concrete in the precast industry".

Textile-reinforced concrete (TRC) is a composite material that combines the advantages of traditional concrete with the flexibility and versatility of textiles. In recent years, TRC has gained increasing attention as a promising solution for improving the performance of precast concrete elements, especially in terms of durability, resistance to cracking, and seismic behavior. The precast industry is an ideal field for the application of TRC due to the numerous advantages it offers. TRC allows for the production of lighter and thinner precast concrete elements, which reduces transportation and installation costs. Furthermore, TRC can be easily shaped and molded, allowing for the creation of complex and aesthetically pleasing designs. TRC can be used in a variety of precast concrete elements, including façade panels, cladding elements, sandwich panels, and structural elements such as beams, columns, and slabs. The use of TRC in precast elements has been shown to improve their performance in terms of durability, resistance to cracking, and fire resistance.

III. METHODOLOGY

MIX DESIGN

To design the mix for M30 grade of Textile Reinforced Concrete (TRC) as per Indian Standard Code, the following steps need to be taken:

Preliminary Data Required for Mix Design:

Purely governed on the local conditions, were the concrete need to be applied

- **Exposure Condition:** Exposure Conditions of the structure: The general environment to which the concrete will be exposed during its service life, is categorized into five class to severity, as per IS 456.

The exposure condition limits the minimum cement content, maximum water – cement ratio and minimum grade of concrete.

As per exposure condition, you have the above data for working the first trial and arriving its mix proportion.

If you are getting desired result at a lower cement content, you need to put extra as mentioned by IS 456.

- **Minimum thickness of member:** Size of aggregate should not be more than one-fourth of the minimum thickness of member, mostly 20 mm nominal size aggregate is suitable for most works. It is always suggested to go the maximum nominal size of aggregate to save on quantity of cement per unit of concrete.
- **Cement Grade:** Cement type/grade locally available that can be made available throughout construction period
- **Workability:** Placing condition of concrete governs its workability, low – slump of 25-75 mm (lightly reinforced sections in slab, beam, column) to high – slump of 100-150 mm (slip form, pumped concrete) .

(i) Concrete Mix Design Stipulation

- Target strength: 30 MPa (N/mm2) at 28 days
- Maximum size of aggregate: 20 mm
- Exposure condition: Moderate
- Type of cement: OPC 53 grade
- Specific gravity of cement: 3.15
- Specific gravity of fine aggregate: 2.6
- Specific gravity of coarse aggregate: 2.7
- Water-cement ratio: 0.45
- Workability: Slump = 50-75 mm

Step 1: Determine the characteristic compressive strength (fck) of concrete at 28 days from the target mean strength (fck).

- For M30 grade concrete, the target mean strength is 30 MPa.
- The characteristic compressive strength of concrete at 28 days can be determined using the following formula:
- fck = fck + 1.65 x standard deviation
- Where fck = target mean strength, and standard deviation can be assumed as 5 MPa for TRC.
- Therefore, fck = 30 + 1.65 x 5 = 38.25 MPa

Step 2: Determine the water-cement ratio (W/C)

- The water-cement ratio can be determined based on the exposure conditions and the maximum size of the aggregate. For TRC, the maximum size of the aggregate is generally limited to 10mm to 12mm.
- For moderate exposure conditions and maximum size of aggregate 10mm to 12mm, the water-cement ratio can be taken as 0.45.

Step 3: Determine the cement content (c)

- The cement content can be determined using the following formula:
- c = (fck/ (w/c)) x 1000
- Where c = cement content in kg/m3, fck = characteristic compressive strength of concrete at 28 days, w/c = water-cement ratio

- Therefore, c = (38.25 / 0.45) x 1000 = 850 kg/m3

Step 4: Determine the amount of Textile Reinforcement

- The amount of textile reinforcement is typically expressed as a percentage of the cross-sectional area of the concrete. As per Indian Standard Code, the maximum percentage of textile reinforcement shall not exceed 2.5% by volume of concrete.

Step 5: Determine the amount of water

- The amount of water required for the mix can be determined using the following formula:
- w = (w/c) x c
- Where w = water content in kg/m3, w/c = water-cement ratio, c = cement content in kg/m3
- Therefore, w = 0.45 x 850 = 383 kg/m3

Step 6: Determine the amount of aggregate

- The amount of aggregate can be determined based on the desired workability and the volume of cement and water in the mix. For TRC, the aggregate size is generally limited to 10mm to 12mm.
- Assuming a slump of 50mm to 75mm, the amount of aggregate can be taken as 1165 kg/m3.
- Therefore, the final mix proportions for M30 grade Textile Reinforced Concrete are:
- Cement = 850 kg/m3
- Water = 383 kg/m3
- Aggregate = 1165 kg/m3
- Textile Reinforcement = 2.5% by volume of concrete
- Note: The mix design may need to be adjusted based on the specific properties of the textile reinforcement being used and the site conditions. It is recommended to perform trial mixes to optimize the mix design before starting production.

Step 7: Determine the superplasticizer dosage

Superplasticizers are commonly used in TRC mixes to improve workability and reduce water content. The dosage of superplasticizer can be determined by performing a slump flow test on the concrete mix with varying dosages of superplasticizer and selecting the dosage that provides the desired slump flow.

Assuming a superplasticizer dosage of 2%, the total mix proportions become:

- Cement = 850 kg/m3
- Water = 383 kg/m3
- Aggregate = 1165 kg/m3
- Superplasticizer = 2% by weight of cement
- Textile Reinforcement = 2.5% by volume of concrete

Step 8: Check for durability requirements

- In addition to strength and workability, durability is an important consideration in TRC mix design. The mix should be designed to resist the effects of weathering, freeze-thaw cycles, and other environmental factors.
- To ensure adequate durability, it is recommended to use a mix design that meets the requirements of Indian Standard Code IS 456:2000 for durability of concrete.

Step 9: Prepare trial mixes and adjust as necessary

- Once the initial mix design is determined, it is recommended to prepare trial mixes and test the properties of the concrete, including strength, workability, and durability. The mix proportions can be adjusted as necessary to optimize the properties of the concrete for the specific application.
- It is also important to consider the specific properties of the textile reinforcement being used and adjust the mix design as necessary to ensure proper bonding and performance of the reinforcement.
- Overall, the mix design for M30 grade TRC as per Indian Standard Code involves careful consideration of strength, workability, durability, and the specific properties of the textile reinforcement being used.

Step 10: Prepare and test specimens

- Once the final mix proportions have been determined, it is important to prepare and test specimens to validate the mix design. The specimens should be prepared according to standard procedures, and the testing should be conducted in accordance with Indian Standard Code IS 516:1959.
- The specimens should be tested for compressive strength, splitting tensile strength, flexural strength, and other properties as necessary to verify the performance of the mix.

Step 11: Monitor production and quality control

- To ensure consistent quality and performance of the concrete, it is important to implement a robust quality control program during production. This may include regular testing of the fresh concrete, monitoring of curing conditions, and inspection of finished products.

- Any issues or deviations from the expected performance should be addressed promptly to maintain the quality and consistency of the concrete.
- Overall, the mix design for M30 grade TRC as per Indian Standard Code requires careful consideration of a range of factors to ensure the desired strength, workability, and durability of the concrete. With proper planning, testing, and quality control, TRC can provide a high-performance and sustainable solution for a wide range of applications in construction and infrastructure.

IV. MODELLING

- Details for ANSYS Models for Textile reinforcement concrete and RCC
- Column Size – 300 x 750 mm
- Reinforcement of Column – 12Ø – 16No
- Beam Size – 230 x 450 mm
- Reinforcement of Beam – Top – 12Ø -2, Bottom- 12Ø -2, Shear – 10Ø@120 C/C
- Textile reinforcement thickness- 5mm
- Total Maximum Load – 1824 KN

ANSYS model

RCC Model

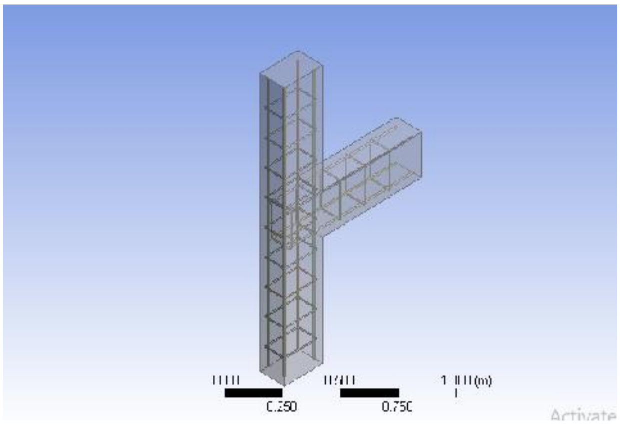


Fig 3: No wrapping model

Textile reinforcement concrete Specimen 1

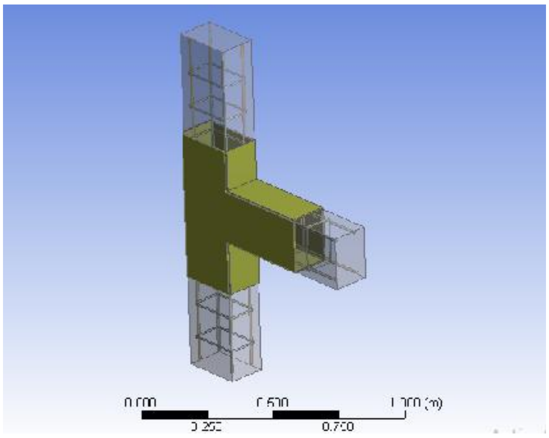


Fig 4: Total wrapping model

Textile reinforcement concrete Specimen 2

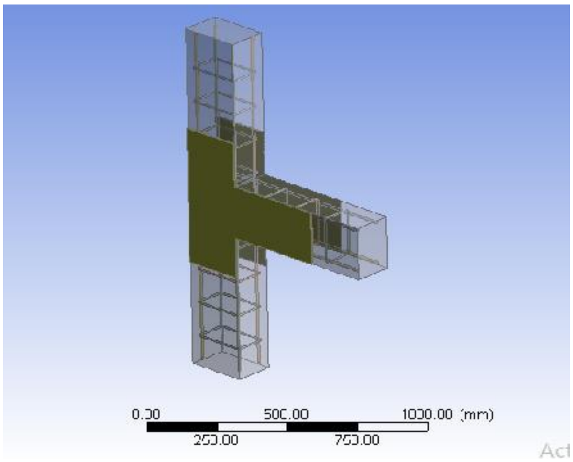


Fig 5: Side wrapping model

Textile reinforcement concrete Specimen 3

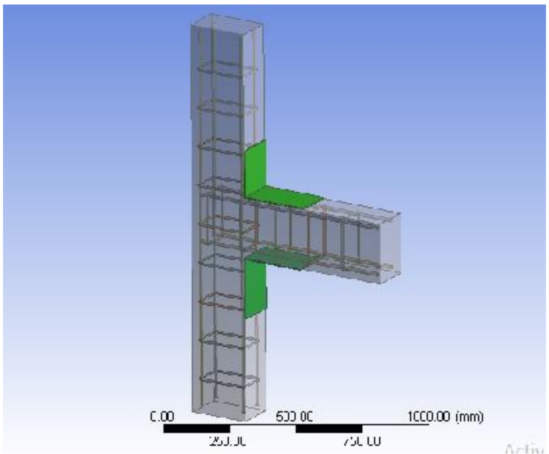


Fig 6: Top-bottom wrapping model

- Analysis of Beam-Column joint by using ANSYS Software: -
- Modeling of beam column joints in ANSYS Software

For T-Shape: -

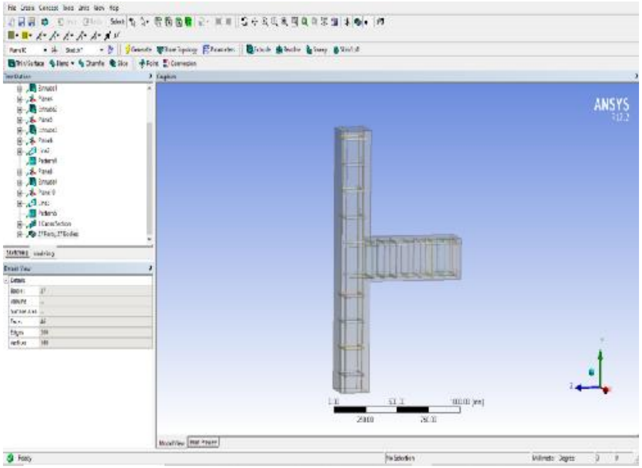
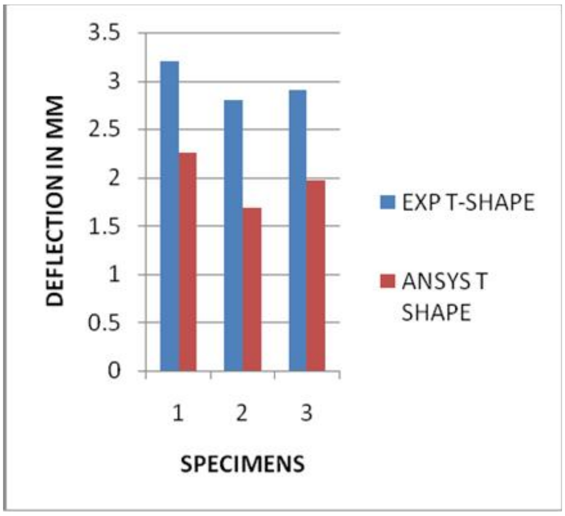


Fig 7 For T-Shape

Results of Casted Beam-Column Joints

- **Comparison of Experimental and ANSYS model**
- **For T shape**



Graph 1:For T shape

V. RESULT AND DISCUSSION

- **Analysis of Non-Textile reinforcement concrete Beam-Column Joint**

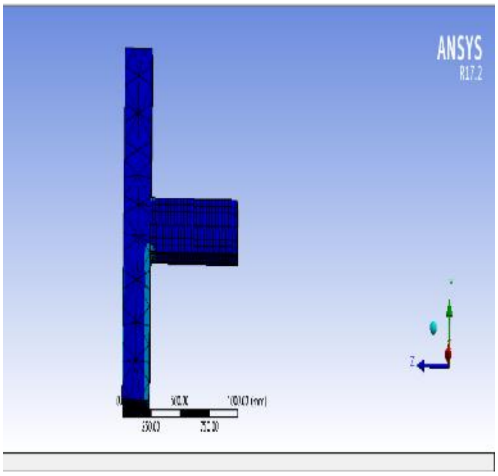
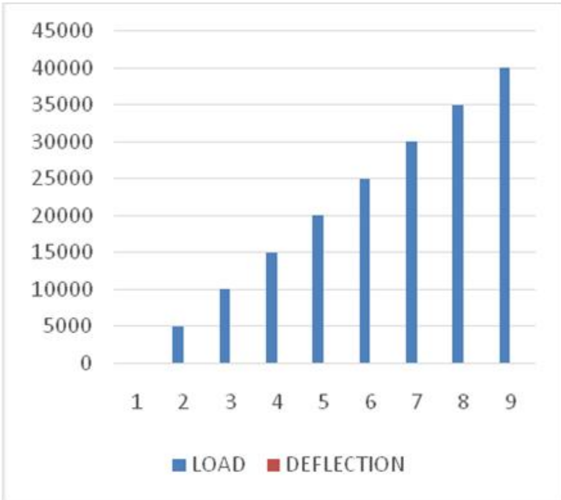


Fig 8:For T-Shape

RESULTS: -

Load vs Deflection for T Shape without Textile reinforcement concrete



Graph 2:Load vs Deflection for T Shape without Textile reinforcement concrete

As we can see in the graph, deflection is increasing as per loads are increasing. Also stress and strain and increasing when loads are increasing.

- ***Analysis of Textile reinforcement concrete Specimens***
- ***For T Shape: - Textile reinforcement concrete Specimen 1 (S1)***

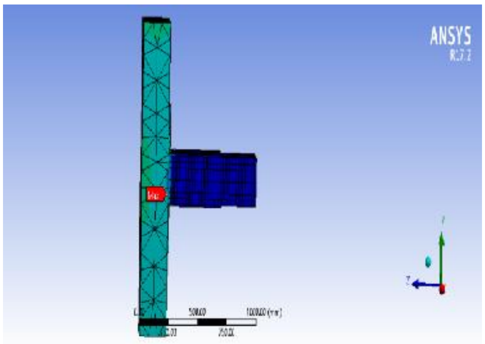
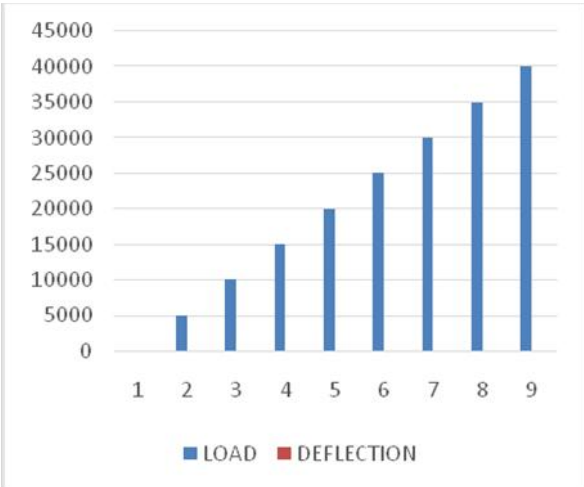


Fig no 9:Textile reinforcement concrete Specimen 1 (S1)

RESULTS

load vs Deflection for T Shape with Textile reinforcement concrete

S1



Graph 3:load vs Deflection for T Shape with Textile reinforcement concrete

S1

As we can see in the graph, deflection is increasing as per loads are increasing. Also stress and strain and increasing when loads are increasing.

Analysis of Textile reinforcement concrete Specimens

For T Shape: - Textile reinforcement concrete Specimen 2 (S2)

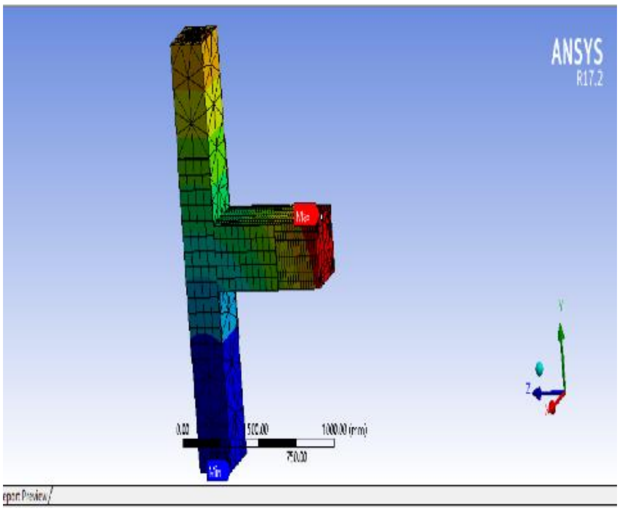
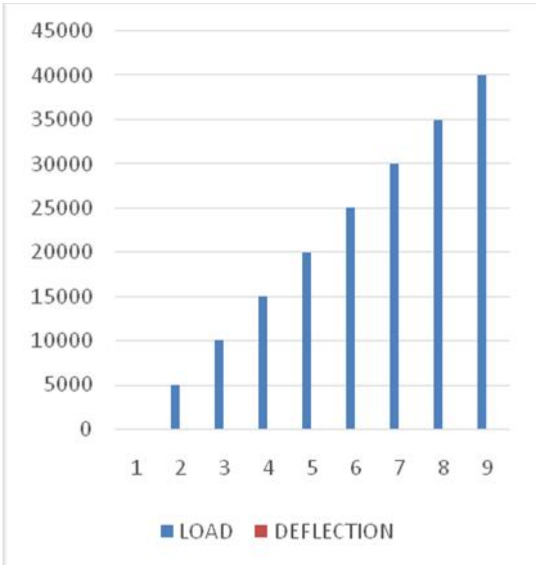


Fig 10:Textile reinforcement concrete Specimen 2 (S2)

RESULTS

load vs Deflection for T Shape with Textile reinforcement concrete S2



Graph 4:load vs Deflection for T Shape with Textile reinforcement concrete S2

As we can see in the graph, deflection is increasing as per loads are increasing. Also stress and strain and increasing when loads are increasing.

- **Analysis of Textile reinforcement concrete Specimens**
- **For T Shape: - Textile reinforcement concrete Specimen 3 (RS3)**

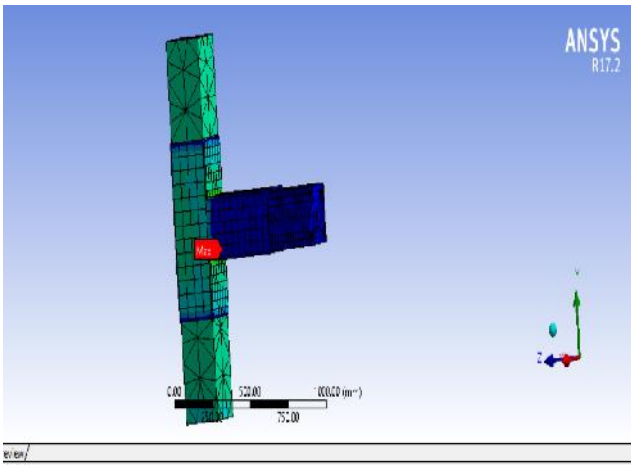
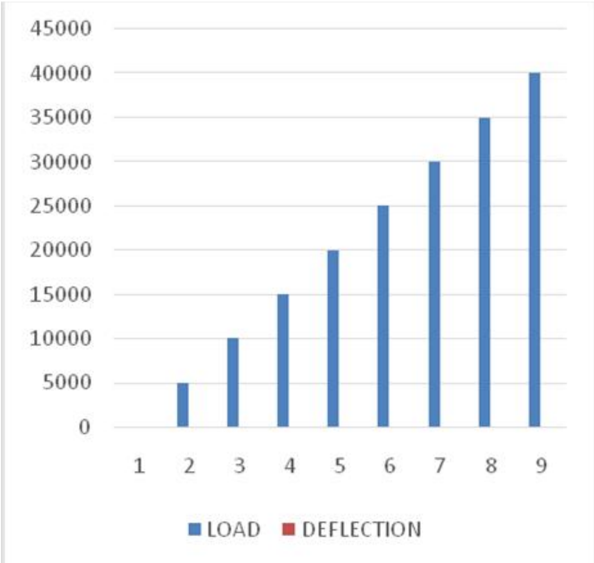


Fig 11: Textile reinforcement concrete Specimen 3 (RS3)

RESULTS: -

load vs Deflection for T Shape with Textile reinforcement concrete C3



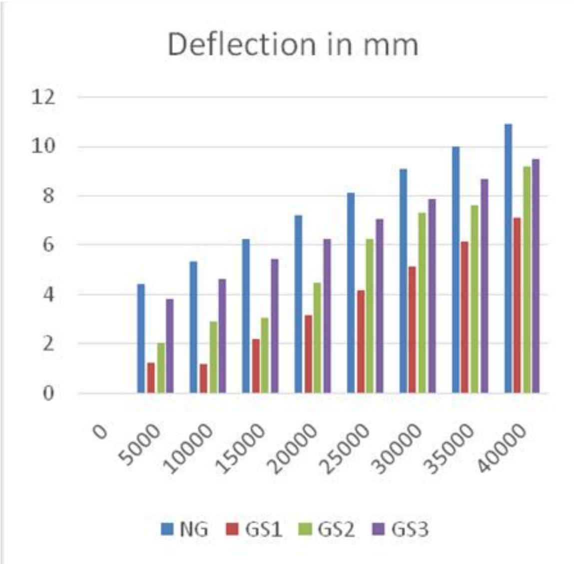
Graph 5: load vs Deflection for T Shape with Textile reinforcement concrete C3

As we can see in the graph, deflection is increasing as per loads are increasing. Also stress and strain and increasing when loads are increasing.

Comparison of Non Textile reinforcement concrete and Textile reinforcement concrete Beam-column Joints Results

For T Shape: - Load v/s Deflection Results

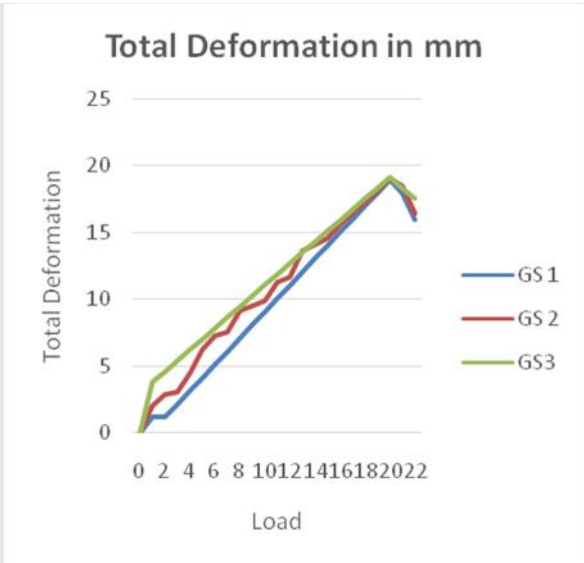
Table No. 6.5 Deflection



Graph 6:Deflection

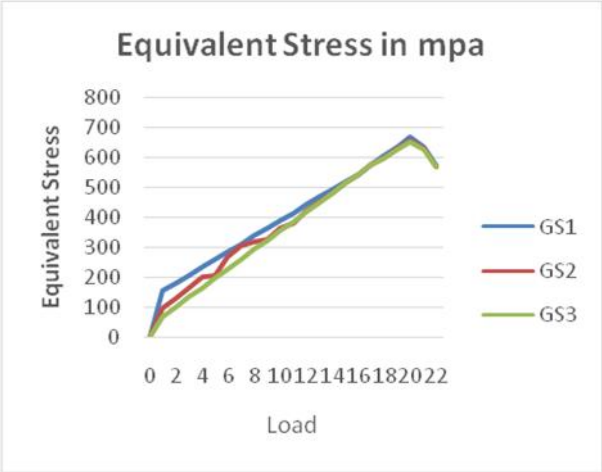
As we can see that RCC model has higher deflection than the other textile reinforcement concrete models.

T SHAPE TEXTILE REINFORCEMENT CONCRETE SPECIMEN



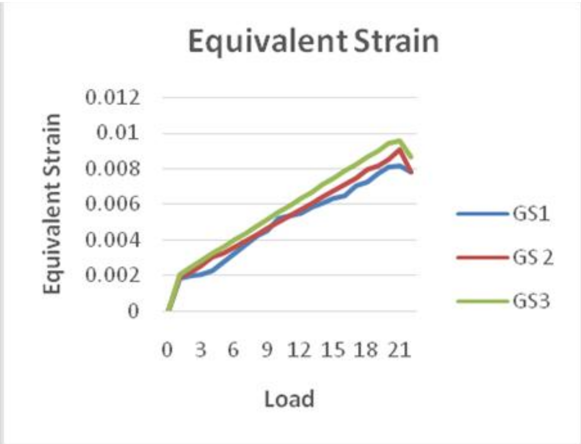
Graph 7: Total Deformation

the above graph shows total deformation for the T shape model for 3 different specimenswith using textile reinforcement concrete. as we can see that total wrapping textile reinforcement concrete model has thelower displacement which is 1.2002mm and top bottom textile reinforcement concrete wrapping model hasthe highest deformation which is 3.8184mm.



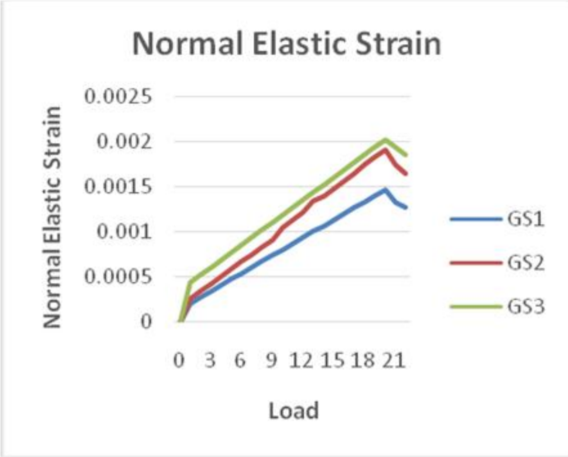
Graph 8: Equivalent Stress mpa

the above graph shows Equivalent Stress for the T shape model for 3 different specimenswith using textile reinforcement concrete. as we can see that top bottom textile reinforcement concrete model has the Highest Equivalent Stress which is 154.47 mpa and total wrapping textile reinforcement concrete wrapping modelhas the highest Equivalent Stress which is 68.617 mpa.



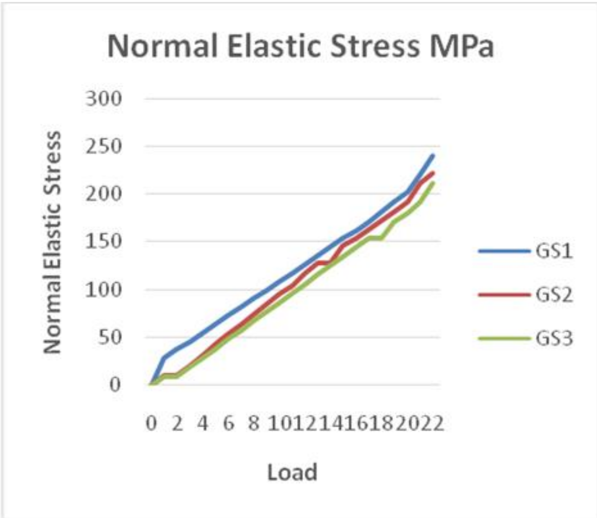
Graph 9: Equivalent Strain

the above graph shows Equivalent Strain for the T shape model for 3 different specimens with using textile reinforcement concrete. as we can see that total wrapping textile reinforcement concrete model has the lower Equivalent Strain which is 0.00185 and top bottom textile reinforcement concrete wrapping model has the higher Equivalent Strain which is 0.00205.



Graph 10: Normal Elastic Strain

The above graph shows Normal Elastic Strainfor the T shape model for 3 different specimens with using textile reinforcement concrete. as we can see that total wrapping textile reinforcement concrete model has the lower Normal Elastic Strain which is 0.00021 and top bottom textile reinforcement concrete wrapping model has the higher Normal Elastic Strain which is 0.00044.



Graph 11: Normal Elastic Stress MPa

The above graph shows Normal Elastic Stressfor the T shape model for 3 different specimens with using textile reinforcement concrete. as we can see that total wrapping textile reinforcement concrete model has the highest Normal Elastic Stress which is 28.2579 mpa and top bottom textile reinforcement concrete wrapping model has the lower Normal Elastic Stress which is 9.5008 mpa.

VI. CONCLUSIONS

- The goal of the comparison of FE analysis results with the experimental test results is ensure that the present finite-element model and analysis are capable of predicting the response of the beam-column joints.
- Cracks are developed at the joint due to shear failure. It shows the cracking pattern in beam column joint.
- If there is no textile reinforcement concrete material present, the RCC beam column connection will have a greater amount of deflection.
- Stress and strain are both increasing in value when the load is increasing.
- When compared to the side wrapping, the textile reinforcement concrete connection that is completely wrapped has a value of normal elastic stress that is 63.015 % greater and an equivalent strain that is 4.22 % Lower.
- Comparison between the Load-Stress results obtained from finite element analysis for control and Textile reinforcement concrete specimens shows that the Stress has significantly increased for the Textile reinforcement concrete specimen. The Stress of TRC specimens of T shape - S1, S2 and S3 are 63.15%, 17.04%, 13.04% Less than the Non retrofitted specimen.
- As the stress decreased the load carrying capacity and strength increases by using TRC as compared to non-Textile reinforcement concrete specimen.
- The different configurations of TRC considered or the specimens were by attaching to the top, bottom and lateral sides of beams. The results show that when textile reinforcement concrete material is totally wrapped around the RCC beam column connection will give better results as compared to non-Textile reinforcement concrete specimen.

REFERENCES

[1] Vidjeapriya, R., & Jaya, K. P. (2011), "*Behaviour of precast beam-column mechanical connections under cyclic loading"* Vol. 13, Asian journal of civil engineering (building and housing).

[2] Abdel Naser Abdel Rahim, K. (2019) "*Modelling of Reinforced Concrete Beam-column Joint for Cyclic Earthquake Loading"*Vol. 7 American Journal of Civil Engineering and Architecture, 7(2), 67–114.

[3] V.Chaudhari, S., K.A. Mukane, K. A. M., & M.A. Chakrabarti, M. A. C. (2014) *"Comparative Study on Exterior RCC Beam Column Joint Subjected to Monotonic Loading*" Volume 102 International Journal of Computer Applications, 102(3), 35–40.

[4] Patil, S. S., & Manekari, S. S. (2013) "*Analysis of Reinforced Beam-Column Joint Subjected to Monotonic Loading"* Volume 2, Issue 10International Journal of Engineering and Innovative Technology (IJEIT), 2(10), 149–158.

[5] Bidgar, S. T., & Bhattacharya, P. (2014) *"Nonlinear finite element analysis of reinforced concrete exterior beam column joint subjected to monotonic loading"*Volume 4, Issue 2Recent Trends in Civil Engineering & Technology, 4(2), 1–10.

[6] Ataei, A., & Bradford, M. A. (2013), *"Finite Element Analysis of sustainable and deconstruct able semi-rigid beam-to- column composite joints"*Volume 2, Issue 10, ICCM*1971*, 1–10.

[7] Rajaram, P., Murugesab, A., & Thirugnanam, G. (2010), *"Experimental Study on behavior of Interior RC Beam Column Joints subjected to cyclic Loading"*Volume 1, International Journal of Applied Engineering Research, 1(1), 49–59.

[8] Vidjeapriya, R., Vasanthalakshmi, V., & Jaya, K. P. (2014). "Performance of exterior precast concrete beam-column dowel connections under cyclic loading" Vol: 6 issue 4, *International Journal of Civil Engineering*, *12*(1 A), 82–94.

[9] Raj, S. D., Ganesan, N., Abraham, R., & Raju, A. (2016), "*Behavior of geopolymer and conventional concrete beam column joints under reverse cyclic loading"*Vol. 4, Advances in Concrete Construction, 4(3), 161–172.

[10] Defalla, R., El Hafez, A., Rahman, A., Ahmad, M., Khafaga, M. A., Al, F., & Refaie, Z. (2019), *"Article ID: IJCIET_10_10_043 Temperatures on Geopolymer Concrete Properties"* Volume 10, Issue 10, International Journal of Civil Engineering and Technology (IJCIET), 10(10), 448–461.

[11] Vidjeapriya, R., & Jaya, K. P. (2013), "*Experimental Study on Two Simple Mechanical Precast Beam-Column Connections under Reverse Cyclic Loading"* Vol: 3 issue 4, Journal of Performance of Constructed Facilities, 27(4), 402–414.

[12] Subramani, T., & Piruntha, M. (2018), "*Behaviour of CRP- Geopolymer Concrete Columns under Axial Loading using ANSYS*" Vol:8 International Journal of Engineering & Technology,*7*, 203–206.

[13] Priya, P. K., & Neamitha, M. (2018), *"A Comparative Study on Precast Construction and Conventional Construction"*Volume: 05 Issue: 08International Research Journal of Engineering and Technology (IRJET), 5(8), 839–842.

[14] V, C. C., & S, P. K. M. (2022), "*Performance of beam column joint with geopolymer material by nonlinear analysis*" Volume: 09 Issue: 06, International Research Journal of Engineering and Technology (IRJET) June, 2025–2032.

[15] Tran, T. T., Pham, T. M., & Hao, H. (2020), *"Effect of hybrid fibers on shear behaviour of geopolymer concrete beams reinforced by basalt fiber reinforced polymer (BFRP) bars without stirrups"* Vol: 6, issue 4, Composite Structures, 243(January), 112236.