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Retrofitting of the Structure using Composite Material FRP

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Abstract: Retrofitting is the process of modifying existing structures in order to increase their performance and durability. Day-to-day concrete structures may require retrofitting owing to a variety of issues such as corrosion, detailing laceration, and bonding failure, among others. Fiber reinforced polymers (FRP) are a relatively recent method used in retrofitting to strengthen and repair structural damage.

The goal of this research is to go over the advantages, applications, and major challenges of employing FRP as a composite material. To begin, the paper will describe the principles of FRP composites, including the definition and description of components such as fibers and matrices.

We have collected significant information properties of composite materials and uses in retrofitting process to improve strength and durability of the structure and studying the behavior of reinforced concrete structure strengthened (retrofitted) using composite materials in this paper on Retrofitting of the Structure using Composite material FRP. Our research included a fact study and prediction analysis of key records and data connected to our research purpose, which assisted us in reaching a conclusion on Retrofitting of the Structure Using Composite Material FRP and also comparative analysis between steel retrofitting and composites materials (FRP) retrofitting of the existing structure.

Keywords: Retrofitting, FRP, Concrete reinforced, Matrix, Rehabilitation.

I. INTRODUCTION

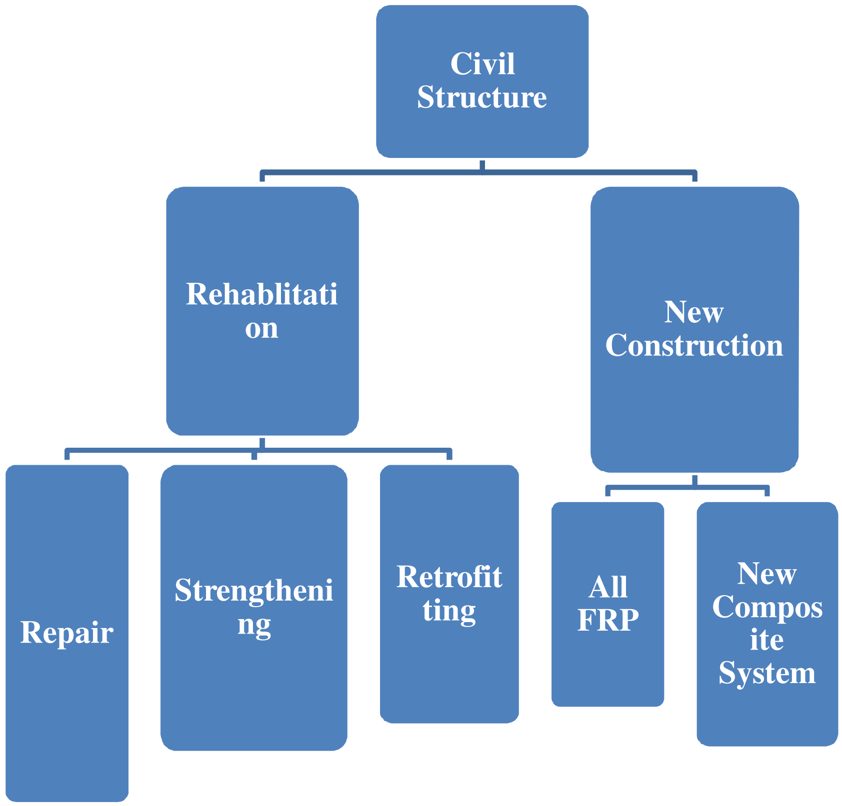
Rehabilitation and retrofitting of reinforced concrete (RC) and pre-stressed concrete (PC) structures with advanced polymer composites are now well established methods. Externally-bonded FRP composite strengthening has shown to be particularly desirable over the last three decades, with various advantages including FRP laminate light weight and strength.[1][2]Retrofitting old reinforced concrete (RC) structures has become required as a result of environmental degradation, changes in usage, and increased loading conditions.[3][4][5].

FRP have traditionally been used primarily in the aerospace and military industries, but over the last three decades.

Indeed, this class of materials has immense potential for use in Civil Engineering, both for rehabilitating existing structures and developing new ones. [6] Due to a lack of strength (flexure, shear, etc.), stiffness, ductility, or durability, a civil structure may require strengthening or rehabilitation. The following are some of the most common situations in which a structure requires reinforcement over its lifetime:

A. Seismic retrofit to meet current code standards;
B. Enhanced loading requirements;
C. Accidental and environmental damage;
D. Flaws in the initial design; and
E. Modification of usage.

FRP composites are the chosen material in many reinforcing applications because they are lightweight and straightforward to install on-site.When compared to structural steel, this material's application is mostly due to its light weight, higher tensile strength, and corrosion resistance. In most cases, up to seven days of curing time is required following application to achieve the system's full binding strength [7] [8]. FRPs come in many different shapes and sizes, including rods, grids, sheets, and winding strands. ACI Committee 440 comprises a review of the literature, as well as a wide overview of the class of materials utilized in civil construction, including FRPs [9][10].All of these issues must be solved ahead of time in order for our Research Objective to obtain a clear picture of the Retrofitting of the Structure Using Composite Material FRP on which we conducted our study



II. RETROFITTING

Retrofitting concrete members with FRP is dependent on the type of FRP used as a retrofit material and the method of retrofitting. The most common method is external retrofitting, which involves attaching or wrapping a FRP shaped sheet or plate with epoxy to the concrete surface. [11]Over the years, a range of structural up-gradation and retrofitting procedures for various structures have been developed and deployed. Other techniques of strengthening include grout injection, reinforcing steel insertion, pre-stressing, jacketing, and other surface treatments. [12]The major goal of retrofitting is to improve the resistance of adamaged building while fixing it so that it will be safer in the event of a future earthquake. This work may entail some of the following actions:-

1) Increase the lateral activity in one or both directions by increasing the number of walls and columns or the number of columns and walls.
2) Giving the structure unity by creating a good link between its
3) resisting elements, in such a way that the inertia focus generated by the building's vibration can be conveyed to the members with the ability to resist them.
4) Eliminating traits that are sources of weakness or cause stress concentrations in some members.
5) Avoiding the probability of brittle modes of failure by adequate strengthening and connections of resistant elements.

The most crucial stage in retrofitting is choosing an appropriate interference technique based on the kind of structural part.[17].

a) Examine the existing structure to be retrofitted.
b) Evaluate the structure's performance and verify that it meets performance standards based on the inspection results.

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A. *FRP (Fiber Reinforced Polymer Composites)*

Fibers are useful material reinforcements because they meet the needed conditions and transfer strength to the matrix constituents, altering and improving their properties. The length, shape, orientation, fibre composition, and mechanical properties of a fibre composite can all be used to evaluate its performance [8]. Carbon fibres, glass fibres, and aramid fibres are the most common fibre types utilized in civil engineering.[16]

1) *Merit of FRP*
   a) High strength to weight ratio
   b) Low weight
   c) Workable
   d) Formable

2) *Demerit of FRP*
   a) High manufacturing cost
   b) Brittle and non ductile failure
   c) Materials must be transported and stored in a refrigerated environment and have a limited shelf life.
   d) Because all resin matrices and certain fiber absorb moisture, the composite must be thoroughly dried before repair.[13][14][15]

The dominance of concrete as a building material, as well as the issues connected with steel reinforcing corrosion, pushed the development of fibre composites for internal use. [25] Fiber can be used in a variety of ways, with different performance according on the purpose. [20]Unidirectional composites offer the best strength and stiffness performance in one direction because the fibers are parallel and deliver their best performance in that direction.[26][27][28]There are many different fibers to choose from, each with their own set of advantages and disadvantages such as

3) *Carbon Fiber:* Anisotropic carbon fibres are found in nature. 1300oC is the temperature at which carbon fibre is created. Carbon fibres have high strength, low conductivity, low density, and a high elastic modulus. Carbon fibres have the drawback of being expensive, anisotropic, and having low compressive strength.[18]

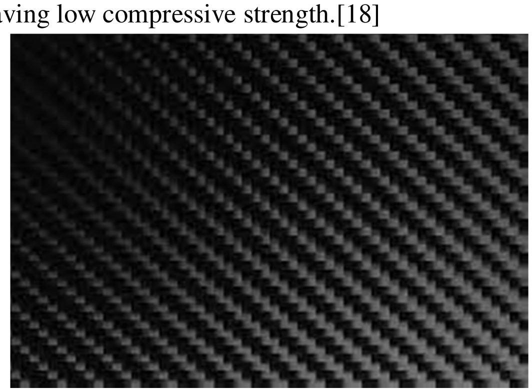

Fig1. Carbon Fiber

4) *Glass Fiber:* Because they are isotropic in nature, glass fibres are the most often used filament. Glass fibres that are often utilised include E-glass, S-glass, and C-glass. Glass fibres have high strength and low cost, as well as superior water and chemical resistance.[19]

Fig2. Glass Fiber

5) *Aramid Fibers:* Aramid fibres are also known as Kevlar fibres in the industry. Aramid fibre has an anisotropic structure and is frequently yellow in color. Aramid fibres are more expensive than glass fibres and have a moderate stiffness that is suitable for tension applications (cables and tendons) but a lower compression strength. Traditionally, these materials have been utilized to construct impact-resistant structures.[21][3]

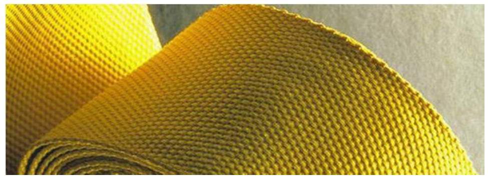

Fig3. Aramid Fiber

6) *Case Study*

a) *Wrapping of the Corporation Building and the Bridge in Fiber:* The Chennai Corporation in Tamil Nadu, India, uses fibre wrap technology to protect its historic civic structures, like as buildings and bridges, from earthquakes. The fortification tactics were implemented as a result of the city's recent seismic zone III designation. Work on the more than 150-year-old Kodambakkam Bridge and the Ripon Buildings has already begun.The new fibre wrap could endure temperature fluctuations. It was also less expensive than competing technologies. The fibre wrap was wrapped around the columns, and the original material (lime mortar or cement) was then deposited on top of it.[29]

Fig4. Wrapping the Chennai Corporation Building with Fibre

III. MATRIX MATERIAL

Matrixes, the second fundamental component of the composite material, can be categorized, as shown in Figure. The major role of the matrix is to hold the fibers together, transfer weights to the fibers, and protect the fibers from outside effects. When choosing a matrix, the moisture and dewatering properties of the material should also be addressed. The fabrication process is influenced by the matrix's physical and chemical qualities. The following are some matrix properties:[22][25]

1) Less moisture absorption
2) Excellent flow properties
3) Elasticity is required to transfer weight to fibers
4) High temperature strength
5) Low temperature capability

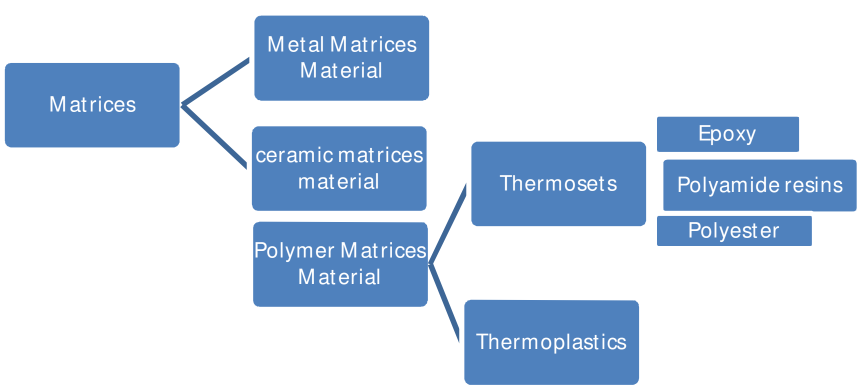

Fig5. Classification of Matrix Material

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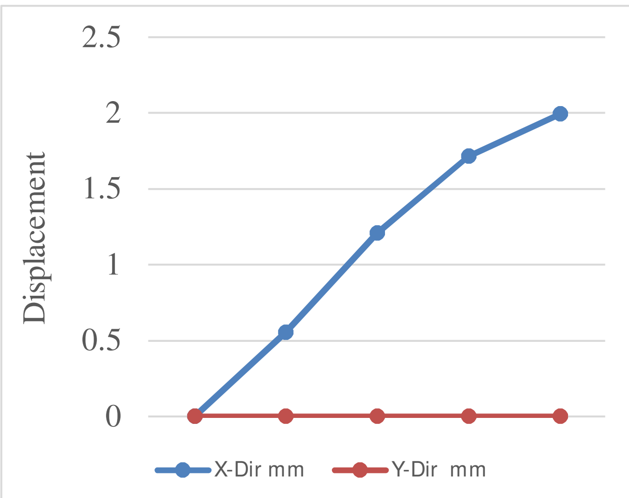
IV. REHABILITATION

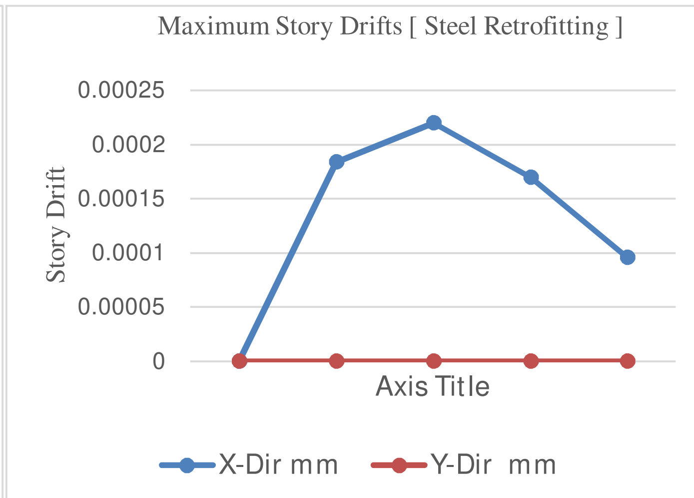
The majority of rehabilitation work involves fixing existing failing structures as well as damage caused by seismic activity and other natural disasters. As a result, over the last two decades, structural repair strengthening has received a great deal of attention all around the world. [24] Design problems, insufficient safety features, the use of lower-grade materials, and poor construction quality.[23]

1) Changes in usage, in service, notably greater safety criteria (upgrading structural design standards), modernization, resulting in stress redistribution and an increase in applied load.
2) Natural disasters, such as fires or earthquakes[16]

A. *Analysis of the Steel Retrofitting Structure Building*

Maximum Story Drifts   Maximum Story Displacement





Graph 1 and 2

B. *Story Shear*

Story	Elevation	Location	X-Direction	Y-Direction
	M		*kN*	*kN*
Base	0	Top	0	0
Story 1	3	Top	311.2775	0
Story 2	6	Top	276.8734	0
Story 3	9	Top	208.0461	0
Story 4	12	Top	110.7539	0

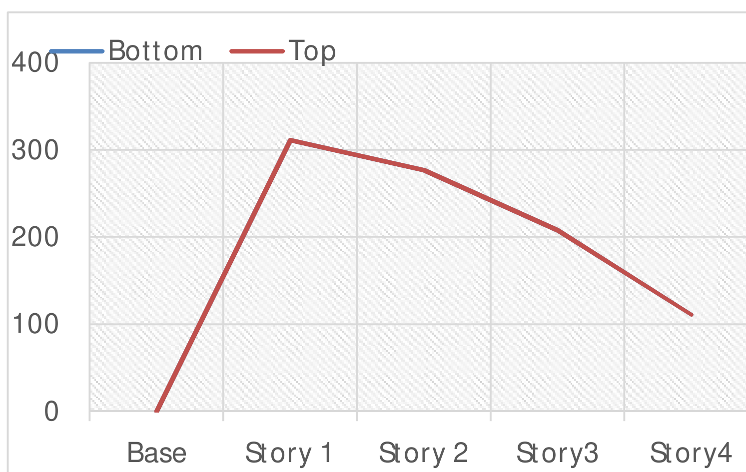


Table 1 and Graph 3

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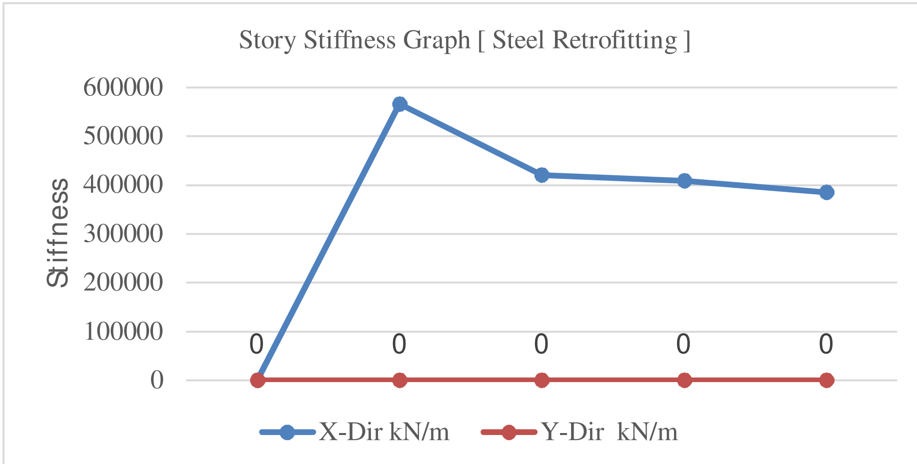
C. Story Stiffness

Graph 4

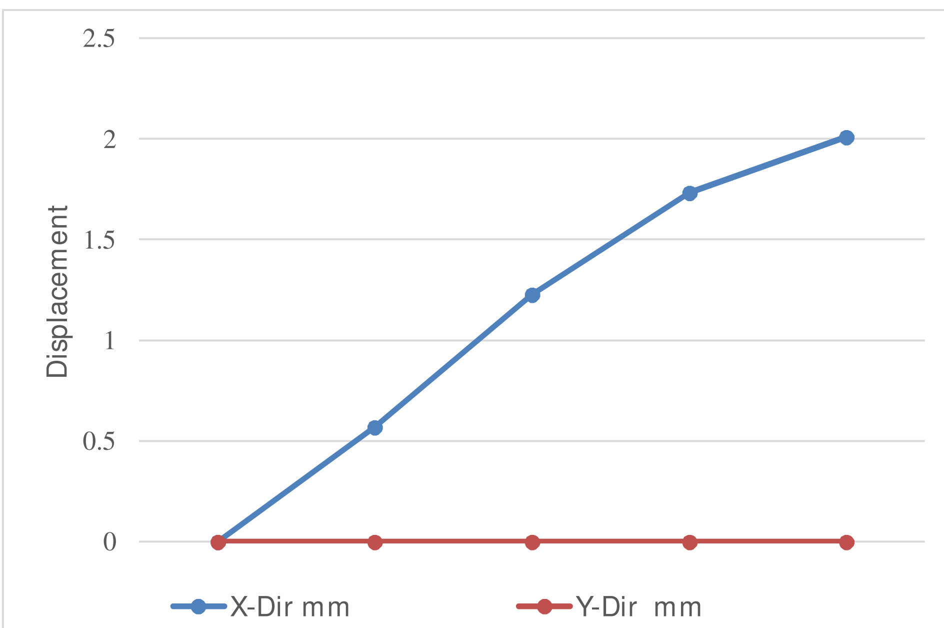


D. Analysis of the FRP Retrofitting Structure Building

Direction	Period Used (sec)	W (kN)	Vb (kN)
X	0.4	6905.2708	621.4744

Table 2

Maximum Story Displacement

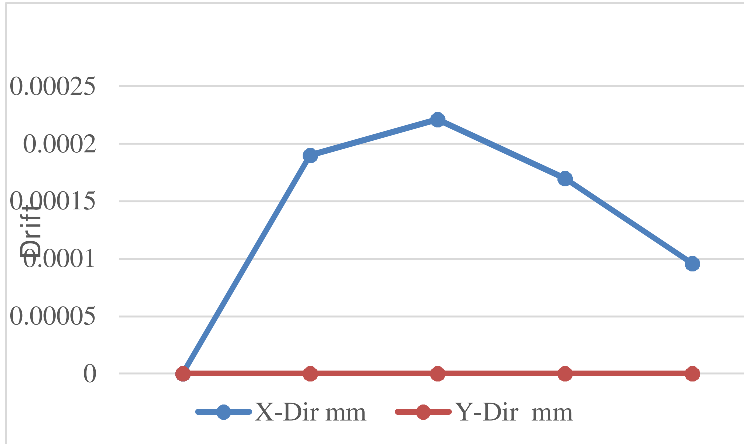


Graph 5

E. Maximum Story Drifts

Table 3 and Graph 6

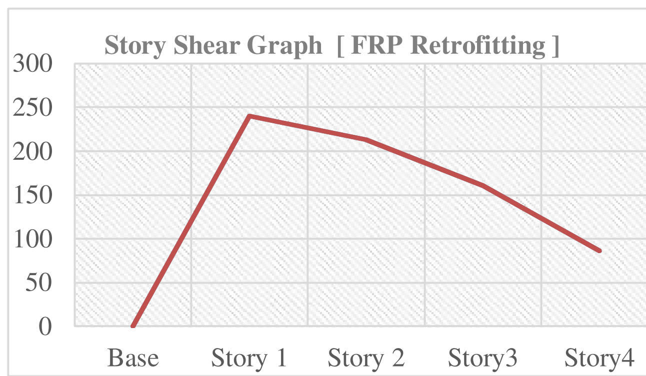
Story	Elevation	Location	X-Direction	Y-Direction
	M		*kN*	*kN*
Base	0	Top	0	0
Story 1	3	Top	240.0912	0
Story 2	6	Top	213.4152	0
Story 3	9	Top	160.6733	0
Story 4	12	Top	86.4327	0



F. Story Shear

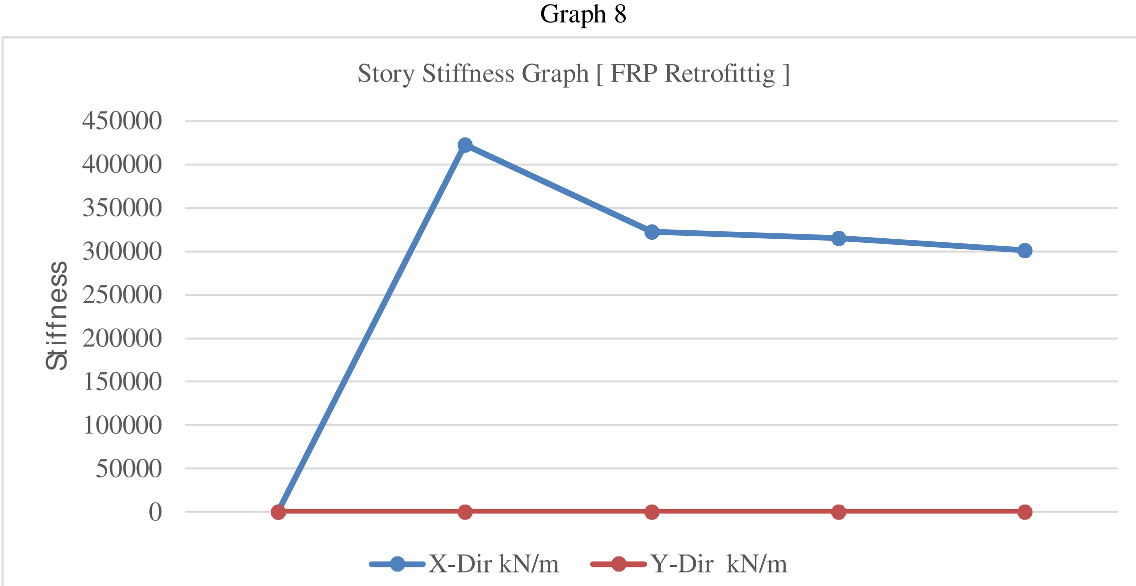
Table 4 and Graph 7

Story	Elevation	Location	X-Direction	Y- Direction
	M			
Base	0	Top	0	0
Story 1	3	Top	0.000190	2.777E-07
Story 2	6	Top	0.000221	1.069E-07
Story 3	9	Top	0.000170	1.766e-07
Story 4	12	Top	0.000096	1.608E-07



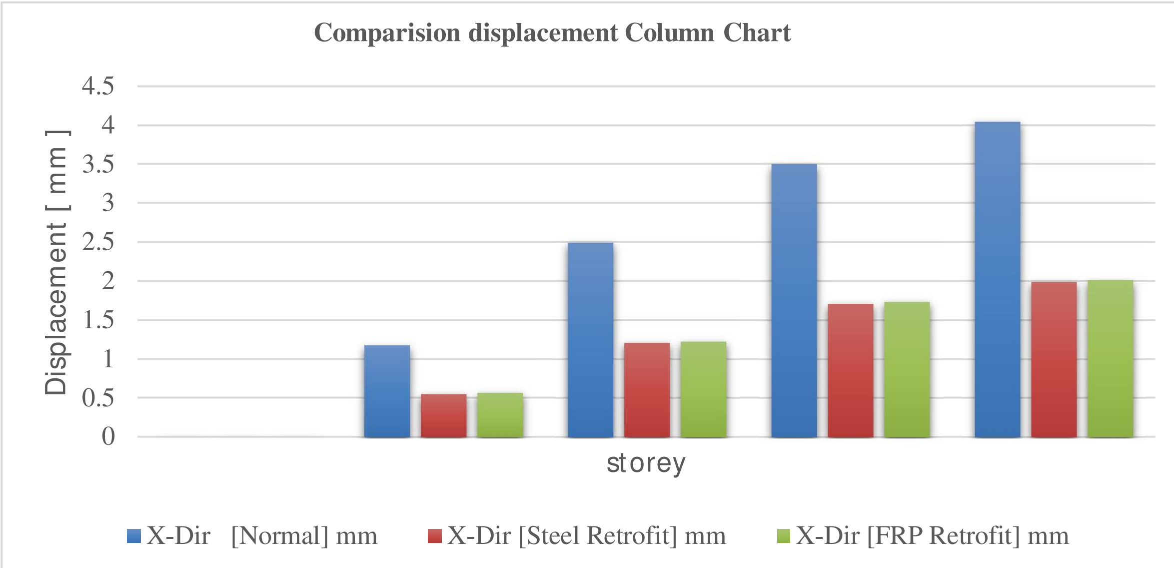
G. Story Stiffness

Graph 8

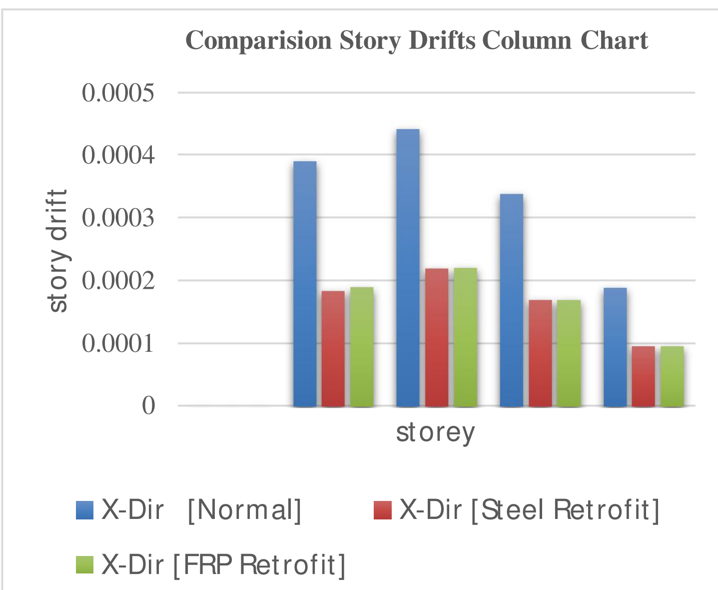


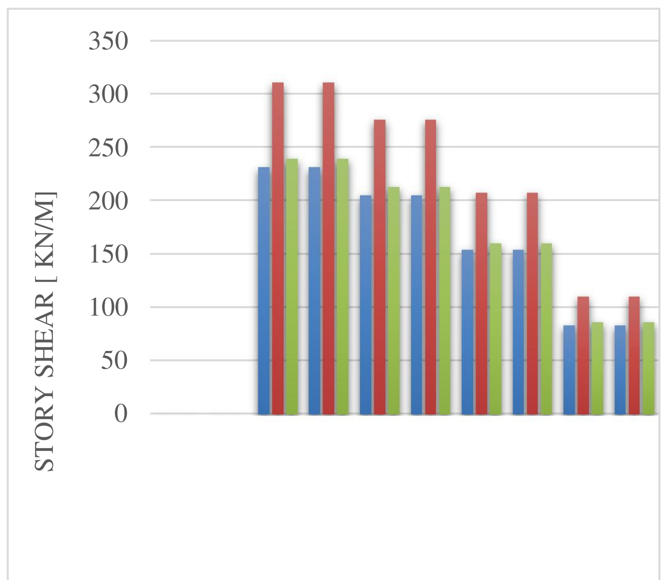
V. GRAPHICAL REPRESENTATION OF COMPARISON RESULT

A. Comparison Displacement Graph



Graph 9 Comparison Story Drifts and Shear-





Graph 10 and Graph 12

VI. COMPARSION RESULT OF STEEL AND FRP RETROFITTING

A. Percentage Variation of Results of Steel and FRP Retrofitting

Base Shear

In x-Dir and Y-Dir

Steel using - 808.6811 KN

FRP using – 621.4744 KN

Percentage variation = $\frac{808.6811-621.4744}{621.4744} \times 100$ =30.12%

B. Lateral Load

In X-Dir and Y Dir

Steel using - 411.407 KN

FRP using – 320.2807 KN

Percentage variation = $\frac{411.407-320.2807}{320.2807} \times 100 = 28.45\%$

C. Storey Displacement

Steel using – 1.993 mm

FRP using – 2.012 mm

Percentage variation = $\frac{2.012-1.993}{1..993} \times 100 = 0.9443\%$

D. Storey Drift

In X-Dir

Steel using – 0.000220

FRP using – 0.000221

Percentage variation = $\frac{0.000221-0.000220}{0.000220} \times 100 = 0.45\%$

In Y-Dir

Steel using- 7.68E-08

FRP using – 9.36E-08

Percentage variation = $\frac{9.36\times 10^{-8}-7.68\times 10^{-8}}{7.68\times 10^{-8}} \times 100 = 21.87\%$

E. Storey Shear

In X-Dir

Steel using -311 KN

FRP using -240.0912 KN

Percentage variation = $\frac{311-240.0912}{240.0912} \times 100 = 11.278\%$

In Y-Dir

Steel using-0.0001 KN

FRP using -0.0003 KN

Percentage variation = $\frac{0.0003-0.0001}{0.0001} \times 100 = 200\%$

F. Storey Stiffness

In X-Dir

Steel using -565320.887kN/m

FRP using- 422714.716kN/m

Percentage variation = $\frac{565320.887-422714.716}{422714.716} \times 100 = 33.73\%$

G. Time Period

Steel using – 0.398 sec

FRP using – 0.400 sec

Percentage variation = $\frac{0.400-0.398}{0.398} \times 100 = 0.50\%$

The time period of FRP composite material is slightly greater than steel reinforced retrofitted.

VII. RESULT

All data from steel reinforced and fibre reinforced composite materials were considered and compared. We reach a judgment based on comparison outcomes and data analysis.

A. The model with fibre reinforcement has a somewhat longer time period than the variant with steel reinforcement. We compare fibre reinforced materials to steel reinforced materials.
B. When we analyze the stiffness criteria, we tend to choose the model with the least stiffness so that the building model has flexibility and does not form cracks in the event of an Earthquake.
C. In some circumstances, storey displacements and storey drifts are slightly more in fibre reinforced polymer composite material than steel reinforced in retrofitting conditions.
D. FRP retrofitting may have a dynamic increase factor, enabling for larger FRP strains at high strain rates.
E. In some circumstances, fibre reinforced polymer composite material has substantially greater base shear lateral stresses than steel reinforcement retrofitting.
F. Fiber reinforced polymer retrofitting can improve ductility and open up design possibilities.

VIII. CONCLUSION

FRPs are increasingly being used in civil infrastructure in various European and North American countries, as well as in Japan and China. FRP is currently widely employed instrengthening existing structures as well as restoring damaged buildings and bridges, indicating that in many circumstances, both technically and economically, this approach may be a superior option to previous techniques. FRP provides several advantages over traditional materials when it comes to reinforcing and retrofitting. Because of its thinness, its use adds no weight to existing structures. It contributes to the cultural heritage preservation of massive structures. It has no corrosive properties. Lightness, structure, and ease of use are three different benefits of FRP materials. The usage of FRPs in structural engineering applications has boundless potential in the future. The Fibre optic sensor can be used to detect strain and temperature differences within the structure, providing engineers with information on the structure's short and long-term performance. Despite the fact that certain smart structures have previously been built and are being monitored in Canada, these materials are still considered novel technology. Constructions and materials that are smart will surely grow increasingly essential and prevalent.

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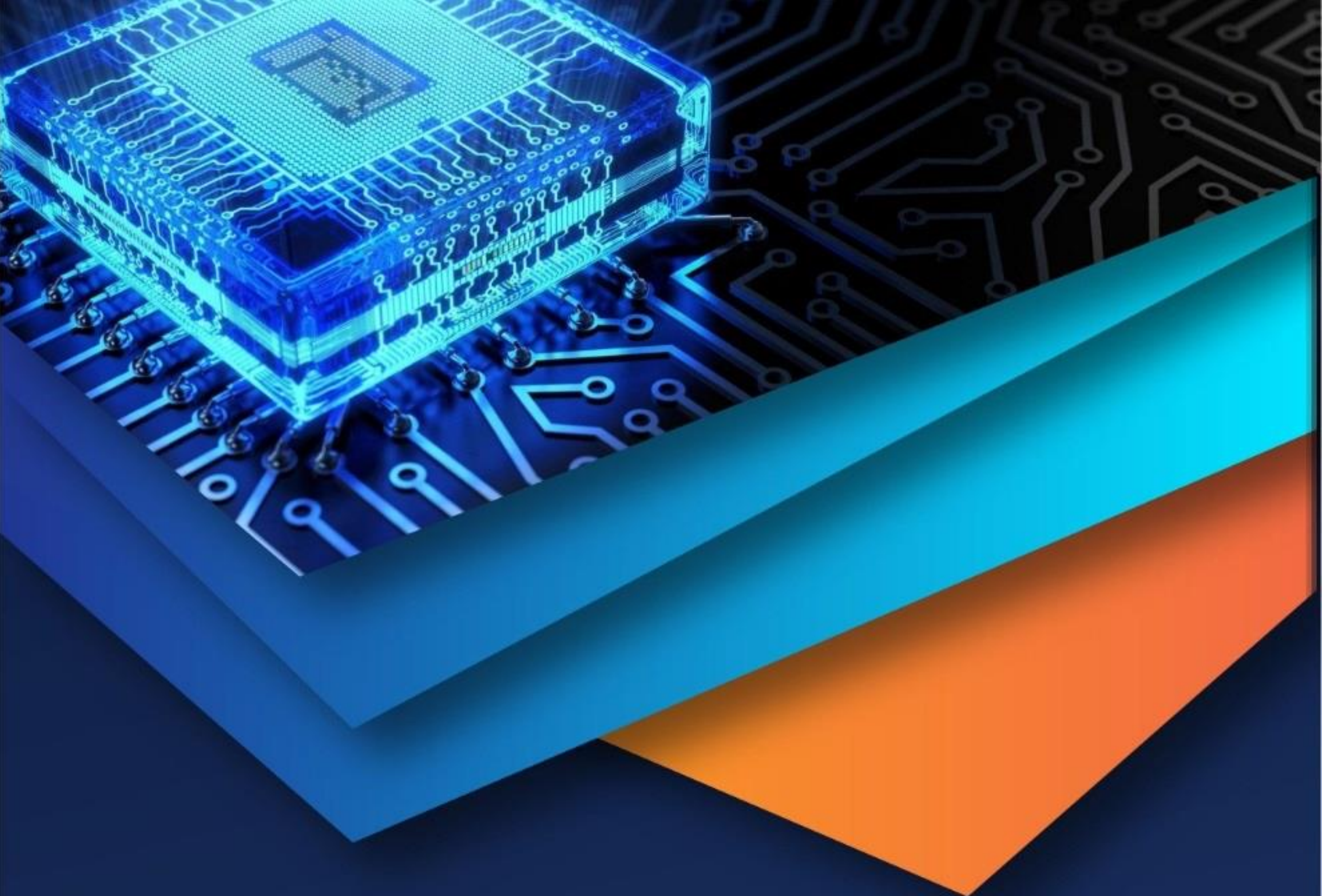

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