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FE Analysis on RC frame followed by column elimination using ANSYS

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***Abstract*— A possible and economic method for changing the area is to remove the brick walls and rcc pillars from the required framed constructions. If there no further reinforcing measures are taken, completely removing columns can cause accending collapse or intolerable deformations. In this work, only the 2 storey, 2 bay RC frame is taken into account, rather than the full structure. Costs associated with labour and installation can be decreased because FRP is lightweight. Compared to other building materials, FRP is a better heat insulator and can withstand higher temperatures. In the vicinity of the deleted column, contrast a number of bracing techniques, including the X, V, inverted V, forward, and backward. to assess the steel's ability to withstand vertical cyclic loading when the column is removed. to assess how different FRP varieties, including CFRP, BFRP, and GFRP, perform when utilised on beams. to assess the overall performance of the FRP sheets and suitable bracing on the lower story column. The RC frame is retrofitted when a column is removed using a number of techniques, and seismic performance is assessed while under cyclic loads. The bracing techniques used while constructing a truss system on top of an RC frame are contrasted. The FRP sheet jacketing strengthens the beam, and different FRP materials are contrasted. examining axial seismic loads.**

Keywords – FRP Jacketting, Bracings, seismic behaviour, cyclic loading

1.INTRODUCTION

Many older structures in densely populated cities are unable to adapt to changes in use and the demand for more space as a result of societal and economic development. Removing columns and masonry walls from existing framed constructions is a practical and cost-effective way to create more space. However, removing a column could result in progressive collapse or intolerable deformations if there are no further reinforcing measures. Therefore, it is required to reinforce the upper beams and eliminate any columns that are next to the walls or adjacent columns. The stories above the removed columns can be refitted as truss systems to correct both, or the beams above the removed columns can be strengthened as underpinning beams (i.e., transfer girders). Different techniques have been developed in engineering practise to increase the flexural and shear resistance as well as the stiffness of the supporting beam, including section enlargement by increasing the RC cross section, external prestressing or post-tensioning, and adding externally bonded plates or sheets, other great steel to fiber-reinforced polymer, and now fabric. Research has advanced on a variety of materials, including reinforced cementitious matrix composites and externally bonded plates, sheets, and strips. These materials are attached to the tension sides of structural components and have a high tensile strength to increase bearing capacity. Additionally, methods of enlarging the section via RC jacketing and employing a combination of steel angles and battens are frequently used if RC columns need to be improved in terms of both strength and stiffness. The latter technique bonds four steel angles to the RC column's rounded corners, and steel battens are externally welded to the angles at predetermined intervals to provide restricting and joint action if the angles are directly loaded.

By joining existing beams and structural parts, such as by adding vertical connections to produce a verandeel truss system or steel X-bracing to construct a standard truss, stories above a removed column can be transformed into a truss system.

Qun Gao, Jun Yu, Youhua Zhu, and Fangfang Wei (2020). With strengthened beams and columns at the renovated story and steel X-bracing at the second story, the seismic behaviour of a two-story, two-bay RC frame and a corresponding renovated RC frame is experimentally investigated in this journal under cyclic loading. The findings show that the renovated frame's lateral stiffness and peak capacity are significantly higher than those of the original frame, but its final deformation capacity is lower and its energy-dissipation capacity is comparable to that of the original frame..

Analysis was done by Issa et al. (2014) to determine how reinforced concrete columns with a steel jacket or fibre composite would react to an axial load. The two stages of this research are the first stage, which consists of experimental tests, and the second stage, which consists of theoretical and numerical analysis.

SamYoung Noh, Joseph A, and Yihai Bao (2017). A computational tool for assessing structural robustness against column loss is given in this article. The application of the concept to RC frame structures, employing a reduced-order modelling strategy for three-dimensional RC framing systems that incorporate the floor slabs, serves as an illustration of the methodology. The method is validated using comparisons with high-fidelity finite element model output. The reduced-order modelling approach is utilised to perform pushdown studies of prototype structures under scenarios of column loss, and an energy-based procedure is used to account for the dynamic impacts of abrupt column loss.

Loss.Adams et al. (2013) used the finite element approach as well as computer models to conduct experiments on axially loaded RC columns strengthened by steel cages in order to validate the results. Additionally, a parametric research was carried out to examine the impact of each parameter on the performance of RC columns reinforced with steel cages. • The impact of a failed column is limited to the nearby columns and the beams attached to the column's vertical axis. The side columns in a braced storey should not have an axial compression ratio more than 0.5. It has been mathematically proven that a building frame that has been partially filled may withstand a base-column failure without causing any harm to the other members. It should be more than 0.5 for the renovated storey to braced storey elastic lateral stiffness ratio. The restored frame's lateral stiffness and peak capacity are significantly higher than those of the original frame, but its final deformation capacity is lower and its energy-dissipation capacity is comparable to that of the original frame. Although the X-bracing system is rigid, it may be utilised to design or retrofit for a damage-level earthquake but not for a collapse-level earthquake since it may diminish the ductility of the ductile frame. FRP is useful in many aspects, including its light weight and ability to save labour and installation costs. speedier development that has less of an impact on the environment. It is extremely resilient to fatigue failure. It has strong corrosion resistance. FRP structural members weigh up to 75% less and are stronger longitudinally than many steels. FRP are better heat insulators than other building materials and can endure higher temperatures.

II. OBJECTIVE OF THE STUDY

- Compare various bracing techniques, including the X, V, inverted V, forward, and backward in the location of the column removal.
- To compare seismic load analysis of various bracing techniques, such as X, V, invertedV, forward, and backward above the location of the column removal.
- To analyse the performance of the combined effect of suitable V bracing with FRP sheets onthe lower storey columns.

III.METHODOLOGY

FINITE ELEMENT METHOD: A common technique for numerically resolving differential equations that appear in engineering and mathematical modelling is the finite element method (FEM). The conventional topics of structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential are typical issue areas of interest. The FEM is a general numerical method for addressing boundary value problems involving partial differential equations in two or three spatial variables. With a variety of contact methods, temporary loading characteristics, and nonlinear material models, ANSYS makes advanced engineering analysis quick, dependable, and practical.

Ansys Workbench is useful for simulation technology and parametric CAD systems with unique automation and performance.

SOLID186 is a 3D 20-node higher-order solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes that have three degrees of freedom per node: displacement in nodal directions x, yz. The element promotes plasticity, hyperelasticity, creep, strain hardening, large deflections, and large deformation capabilities. It also has a mixed formulation capability to simulate the deformations of nearly incompressible elastoplastic materials and fully incompressible hyperelastic materials.SOLID186 is available in two forms:Homogeneous Structural Solid, Layered Structural Solid.

SOLID186 Homogeneous Structural Solid is well suited to modeling irregular meshes (such as those produced by various CAD/CAM systems). The element may have any spatial orientation.It is shown in Figure 3.1.

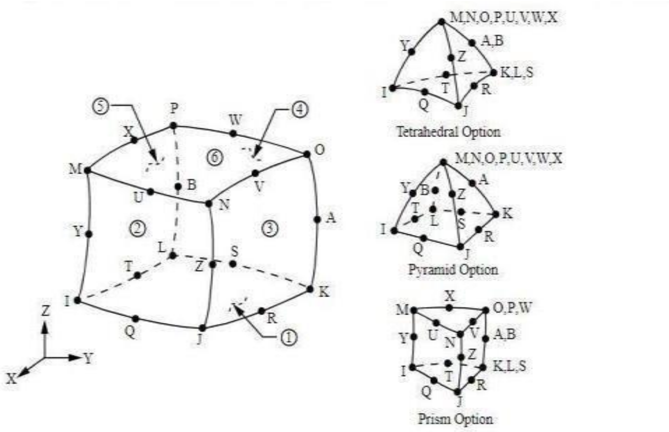

Fig.1 Solid 186 Geometry

To represent layered thick shells or solids, use the SOLID186 Layered Structural Solid. ANSYS section commands provide a definition of the stacked section. There is also a prism degeneration option. The anisotropic material attributes are part of the element input data in addition to the nodes. The layer coordinate directions, which are based on the element coordinate system, correspond to the anisotropic material directions..

SOLID 65: For 3-D modelling of solids with or without reinforcing bars, utilise SOLID65. capable of both compression and tension cracking. For instance, in concrete applications, concrete can be modelled by an element's tensile strength while reinforcement behaviour is modelled by an element's yield strength. Geological materials and reinforced composites both fall under this category. The element is defined by eight points, each of which has three degrees of freedom: translation in the point's x, y, and z directions. Concrete components are sturdy three-dimensional constructions, yet they have additional crushing and unique crushing abilities. The consideration of nonlinear material properties is the most crucial part of this component. Concrete is susceptible to creep, plastic deformation, cracking, and crushing.

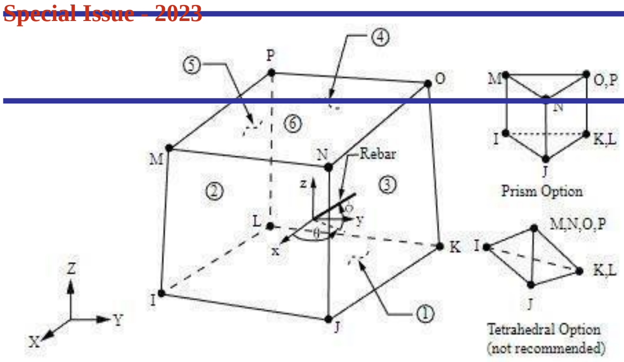

Fig 2 SOLID 65 Geometry

SHELL 181: For research on thin and medium-thickness shell structures, SHELL181 is appropriate. a four point element with rotation along the x, y, and z axes and translation along the x, y, and z axes, giving each point six degrees of freedom. The element has only translational degrees of freedom (if the membrane type is selected). Only filler elements for the mesh generation should be created using the weak triangle option. Applications requiring big rotation, huge linear, or both should use SHELL181. Nonlinear analysis takes shell thickness variations into consideration.

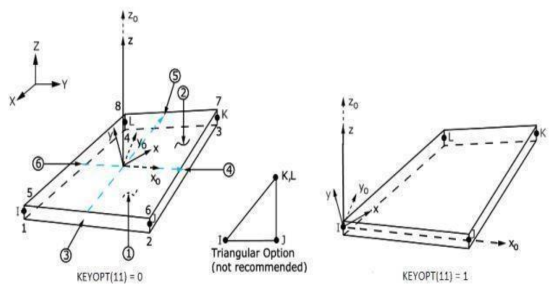

Fig 3 SHELL 181 Geometry

IV. MODELLING AND ANALYSIS

Modelling of Renovated RC frame with different bracings:

Different bracing models at the top storey of the of RC frames were constructed. ANSYS Workbench was used for modelling. The following models werecreated:

1) V
2) Inverted V
3) X bracing
4) Eccentric V bracing
5) Eccentric Inverted V bracing

The beam of the model is strengthened by steel jacketing and column of the model is strengthened by steel jacketing.

Geometry*:*

The different bracing renovated RC frames modelled in ANSYS workbench are shown below. The steel belts, steel C channel and infilled concrete were defined using element types shell 181, solid 181 and solid 65.

All dimensions of the various components such as dimensions of columns and beams, thickness of steel C channel, thickness of steel belts were adopted from the validation journal.

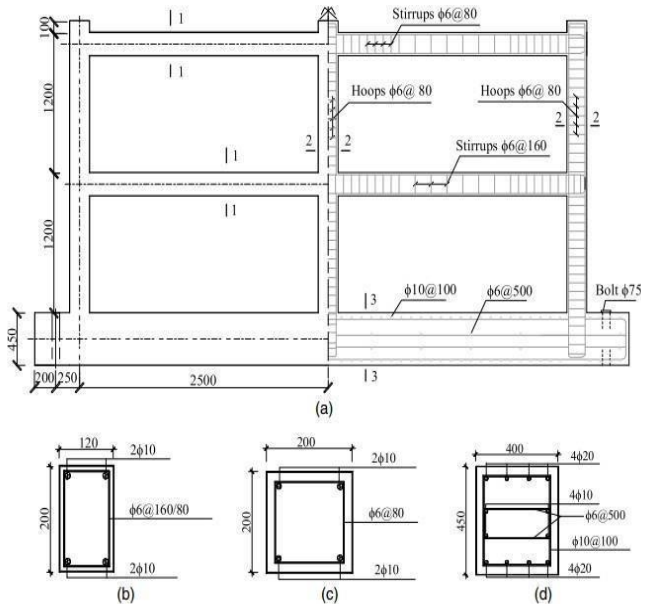

Fig 4. Geometry of the original framefrom validation journal

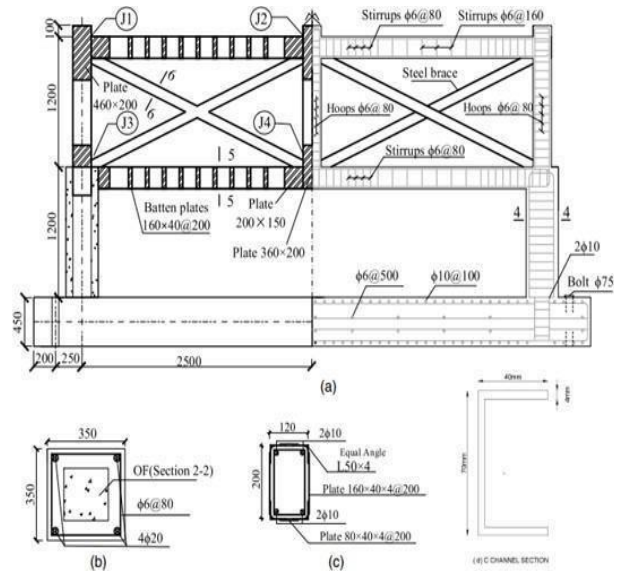

Fig 5 Geometry of renovated RC frame

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Material properties of concrete such as bulk modulus, elastic modulus, poisson's ratio and compressive strength are adopted from the validation journal. Material properties of the steel channel, reinforcement steel and steel belts are also adopted from the validation journal.

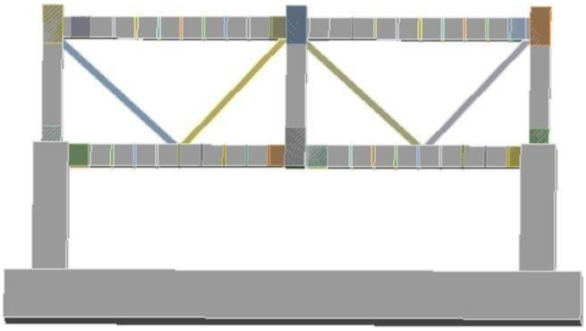

Fig. 6 Model of RC frame with Eccentric V bracing

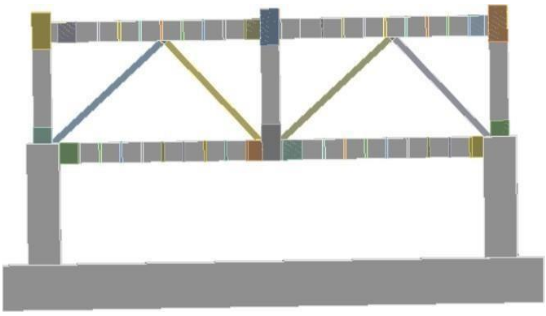

Fig. 7 Model of RC frame withEccentric inverted V bracing

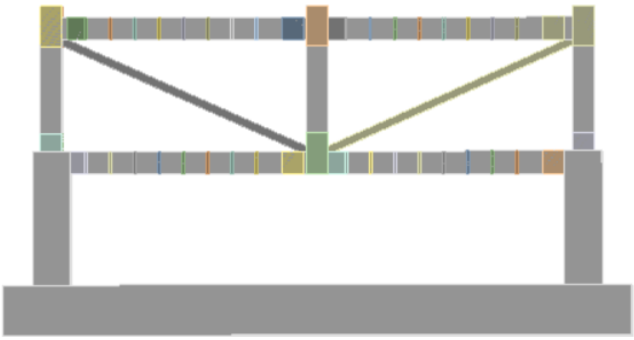

Fig.8 Model of RC frame with single V bracing

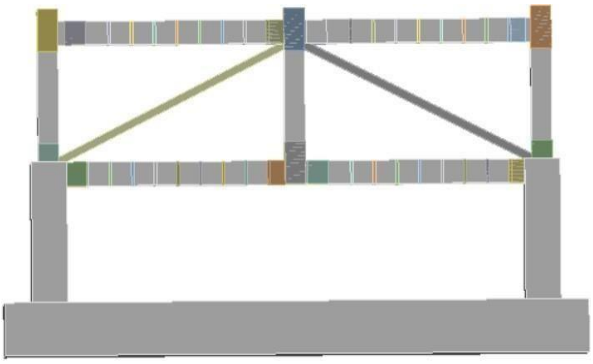

Fig 9 Model of RC frame with single IV bracing

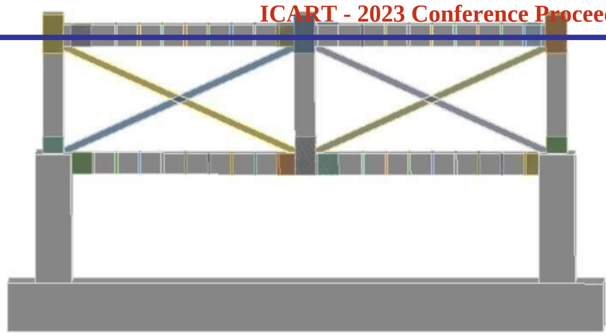

Fig 10 Model of RC frame with K bracing

Meshing*:* Meshing was done to divide into elements and nodes. Tetrahedral meshing was done in the model using ANSYS tools. The results are calculated by solving the relevant governing equations numerically at each node of the mesh.

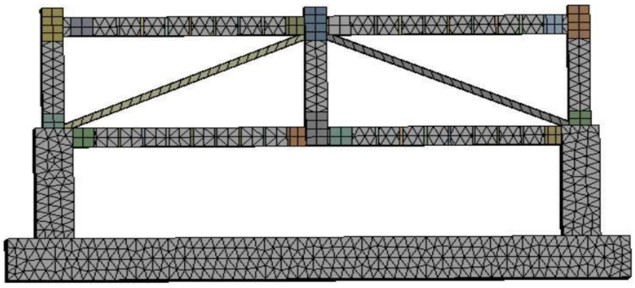

Fig 11 Meshing of RC frame with Eccentric inverted V bracing

Boundary Condition: The cyclic loading is applied from the top side of the columns, and an axial force of 84kN is applied to the top of the centre column while an axial force of 53kN is applied to the 2 end columns. The boundary condition is fixed along the column.

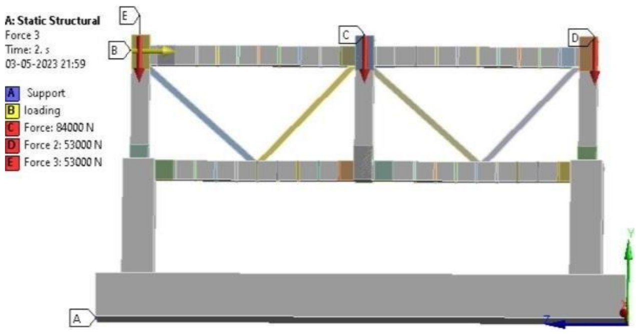

Fig.12 Boundary condition

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V. RESULTS AND DISCUSSION

All models were examined, and conclusions were drawn. Total load capacity from hysteresis curves of models are compared together with total deformation and equivalent stress diagrams.

Seismic load analysis of various bracingtechniques

a. Eccentric V bracing:

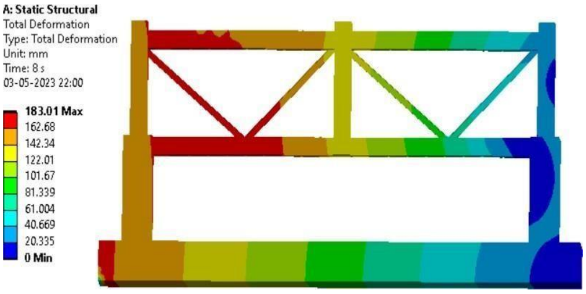

Fig 13 Total deformation of RC frame with eccentric V bracing

Fig 14 Equivalent stress of RC frame with eccentric V bracing

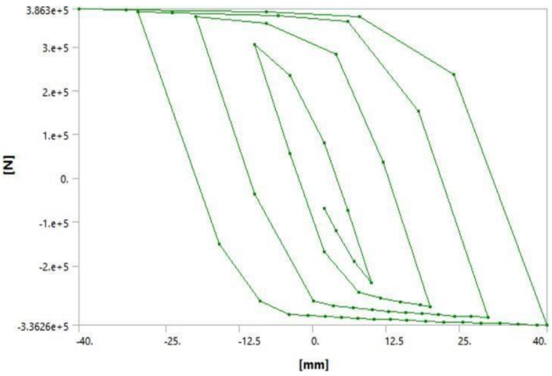

Fig 15 Force - Deflection Hysteresiscurve of RC frame with eccentric V bracing

b. Eccentric Inverted V bracing:

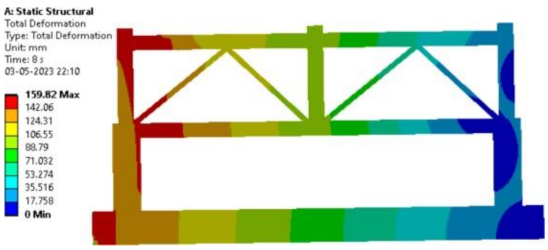

Fig 16 Total deformation of RCframe with eccentric inverted V bracing

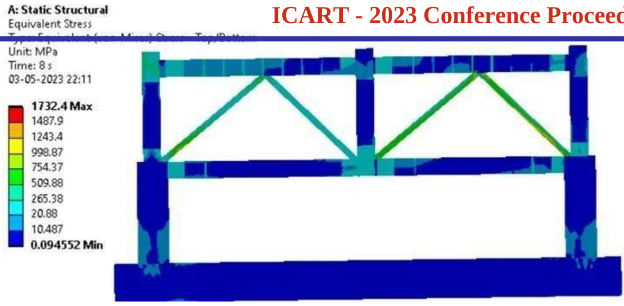

Fig 17 Equivalent stress of RC frame witheccentric inverted V bracing

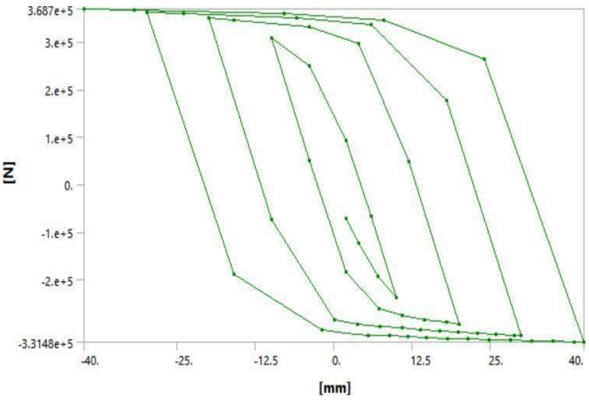

Fig 18 Force – Deflection Hysteresis curve of RC frame with eccentric inverted V bracing

c. V bracing:

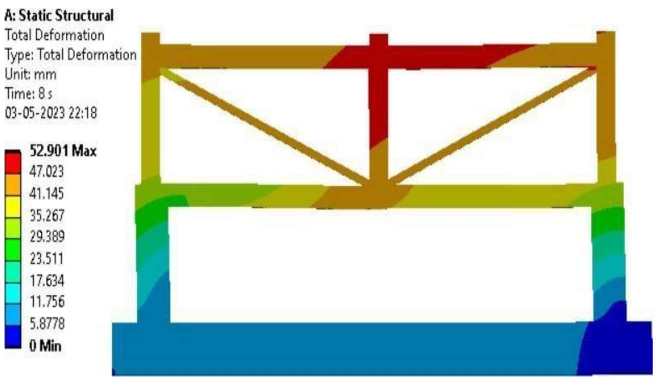

Fig 19 Total deformation of RC frame with V bracing

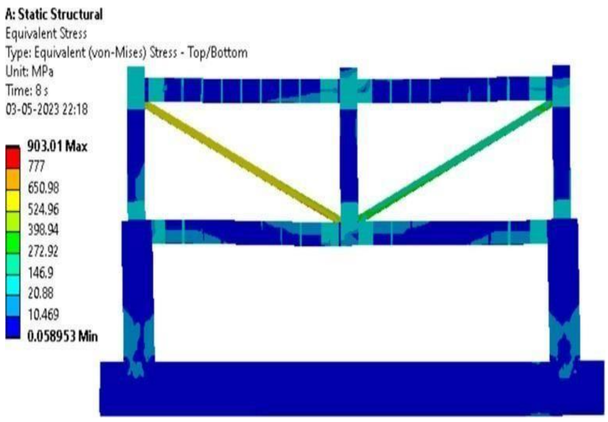

Fig 20 Equivalent stress of RC frame with V bracing

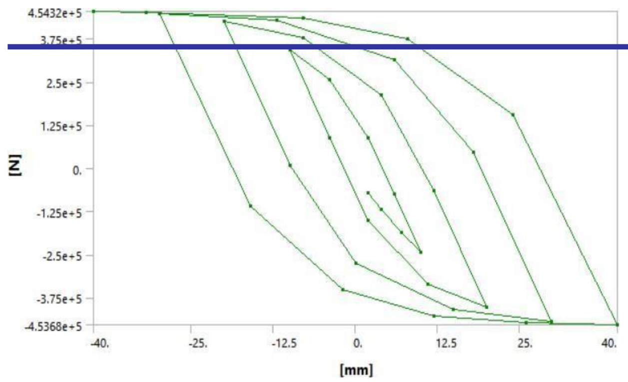

Fig 21 Force – deflection Hysteresis curve of RC frame with V bracing

d X Bracing:

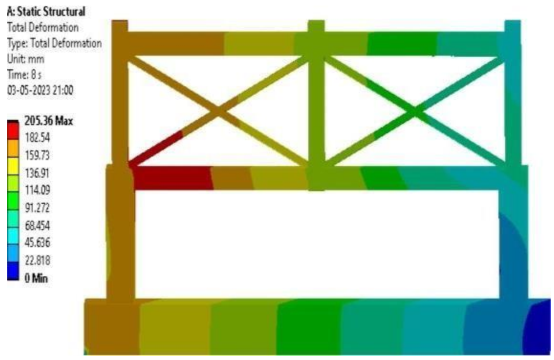

Fig 22 Total deformation of RC framewith X bracing

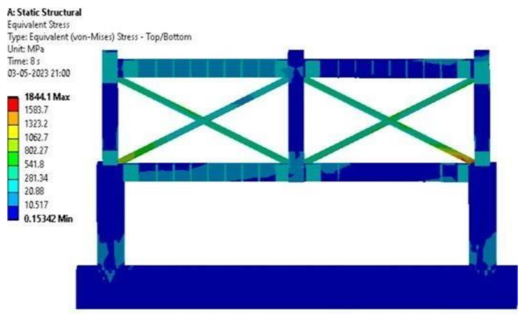

Fig 23 Equivalent stress of RC framewith X bracing

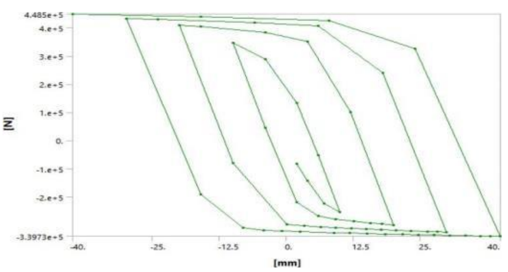

Fig 24 Force – deflection Hysteresiscurve of RC frame with X bracing

e. Inverted V Bracing:

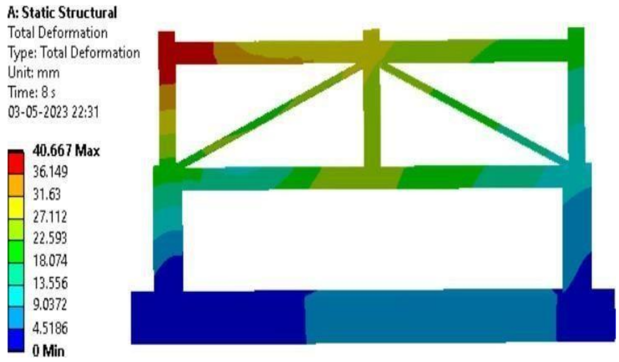

Fig 25 Total deformation of RC frame with Inverted V bracing

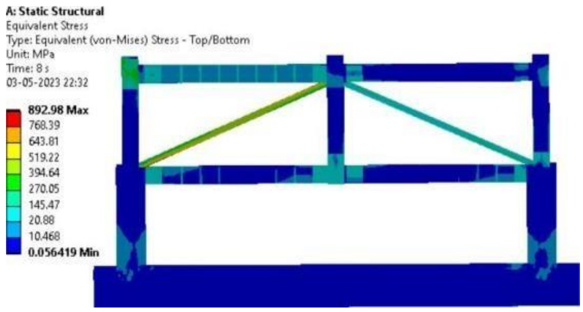

Fig 26 Equivalent stress of RC frame with Inverted V bracing

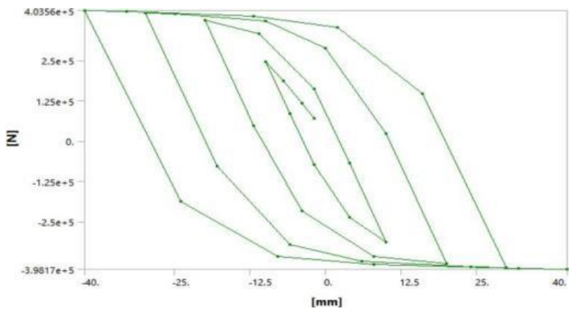

Fig 27 Force – deflection Hysteresis curve of RC frame with Inverted V bracing

VI. Comparison of Results

The Force-Deflection values obtained from ANSYS analysis of all the bracing models areplotted using hysteresis curve.

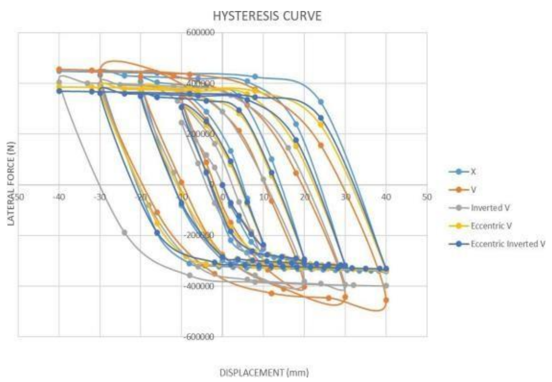

Fig 28 Combination of Force-Deflection hysteresis curve

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Total deformation values, Equivalent stressand total load capacity values of all models arecompared.

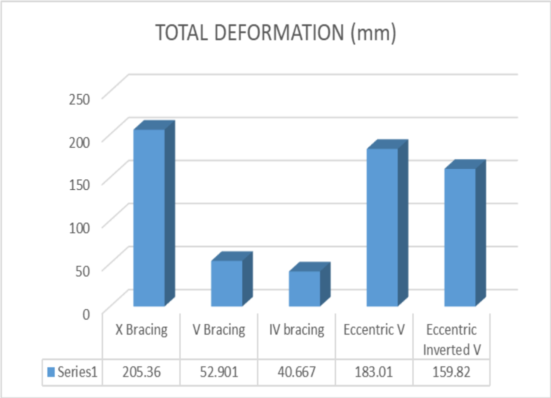

Fig 29 Graph of Total deformationvalues (mm)

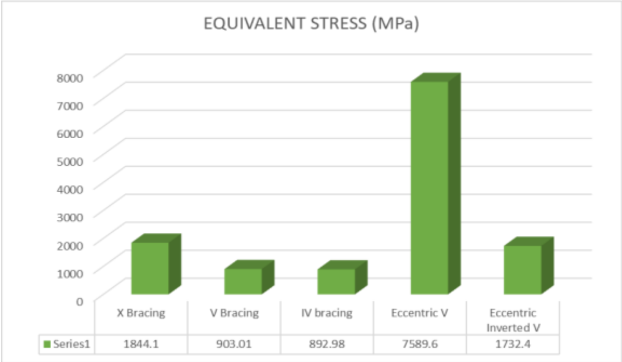

Fig 30 Graph of Equivalent stress values

Total load capacity comparison between allmodels are compared.

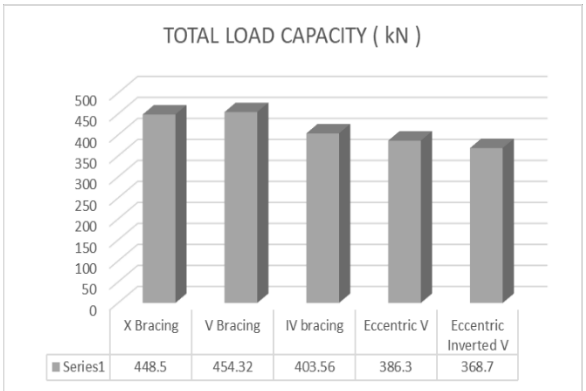

Fig 31 Graph of Total load comparison

Analysis of the force-deflection behaviour of all the models was done. As a result, in the event of column removal, we must select a model with a larger total load capacity, lower total deformation, and lower equivalent stress. According to the results of the comparison, both the Eccentric V and Inverted V bracing models exhibit high deformation values when compared to the V and Inverted V, although their respective equivalent stress values are low. X and V versions have demonstrated increased load capacities, with V bracing somewhat higher than X bracing. V bracing is determined to be ideal in all respects and has a higher overall load capacity.

VII. ANALYSIS OF RC FRAME WITH FRP SHEETS WRAPPING ONTHE BEAMS

After finding the suitable bracing in analyses, the beam is to be strengthened using FRP jacketing. FRP jacketing is a new method developing in civil engineering. FRP is about five times stronger than steel and is of less weight.

MODELING OF RC FRAME USING FRP SHEETS:

By encircling the column with FRP material sheets, the column is strengthened. The FRP sheet material is of 3 types: CFRP (CARBON FIBER REINFORCED POLYMER), BFRP (BASALT FIBER REINFORCED POLYMER), GFRP (GLASS FIBER FIBER REINFORCED POLYMER).

Different analysis models are wrapped using 3 different FRP sheets on the beams and are compared according to criteria and suitable FRP material sheet is taken for further study in this project.

Table 1 : Material properties of different FRP

Material	**Density (g/cm3)**	**Tensile strength (MPa)**	**Elastic Modulus (GPa)**	**Poissons ratio**
CFRP	1.8	3430	235	0.31
BFRP	2.1	1500	65	0.25
GFRP	2.5	1970	86	0.20
Epoxy resin	1.4	130	4.1	0.38

Total deformation, equivalent stress and total load capacity from hysteresis curve is compared to find the suitable FRP material.

Boundary Condition:

The boundary condition is fixed along the column and the cyclic loading is given from the top sideof thecolumns and axial force of 53kN is applied on the 2 end columns and axial force of 84kN is applied on top of the middle column.

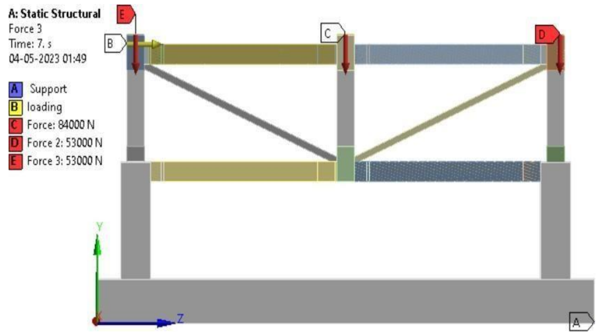

Fig 32 Boundary condition

Results:

All models were analyzed and the results were obtained. Total deformation,equivalent stressand hysteresis curves diagrams were obtained.

a. **CFRP sheet wrapping**

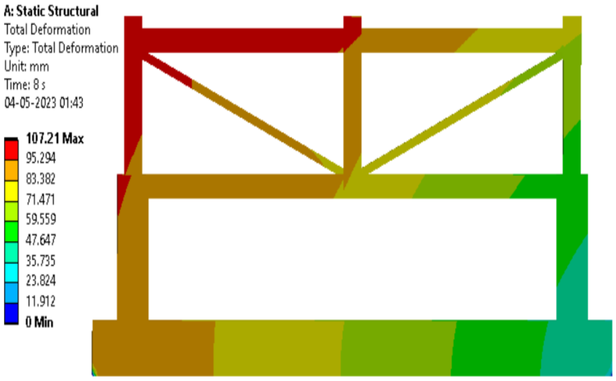

Fig 33 Total deformation

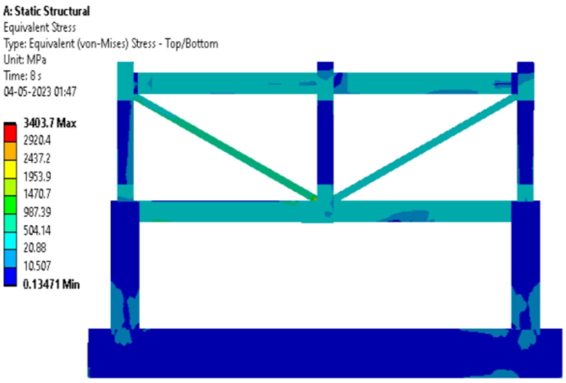

Fig 34 Equivalent stress

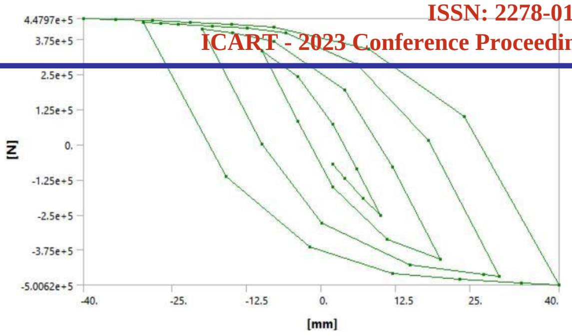

Fig 35 Force – Deflection Hysteresis curve

b. BFRP sheet wrapping

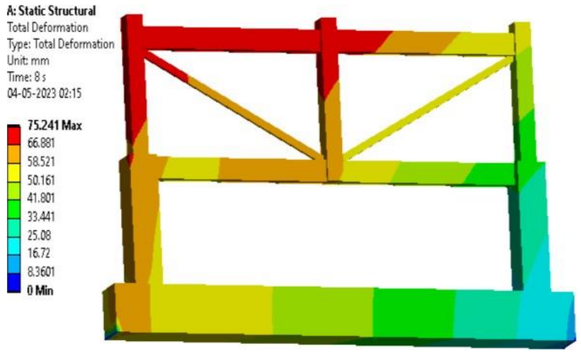

Fig 36 Total deformation

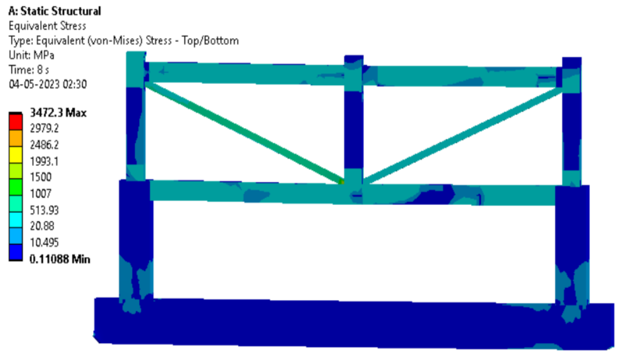

Fig. 37 Equivalent stress

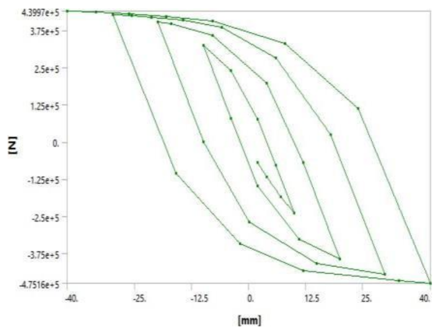

Fig. 38 Force - Deflection Hysteresis curve

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c. GFRP sheet wrapping

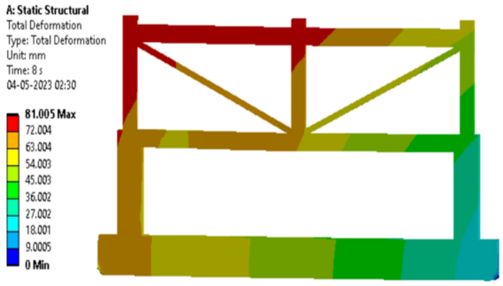

Fig. 39 Total deformation

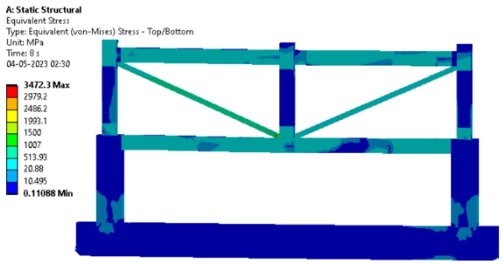

Fig. 40 Equivalent stress

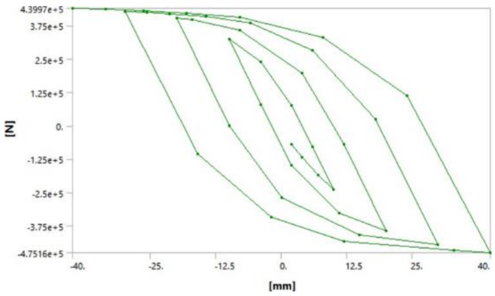

Fig. 41 Force-Deflection hysteresis curve

VIII.Comparison of Results

The Force-Deflection values obtained from ANSYS analysis of all the FRP models are plotted using hysteresis curve.

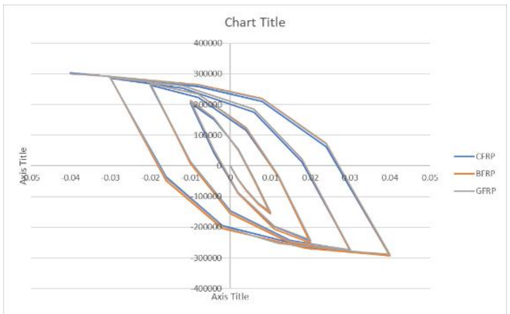

Fig 42 Graph of Force-Deflection hysteresis curve

Total load capacities from hysteresis graph of different FRP sheet wrapped model are compared to the steel jacketing model

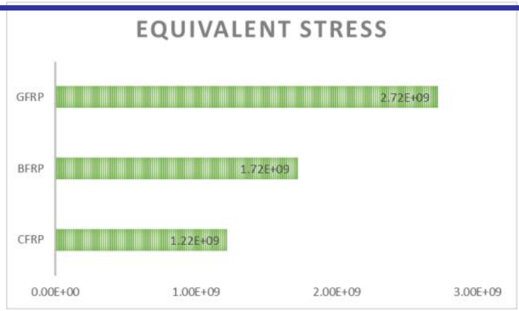

Fig. 43 Graph of equivalent stress

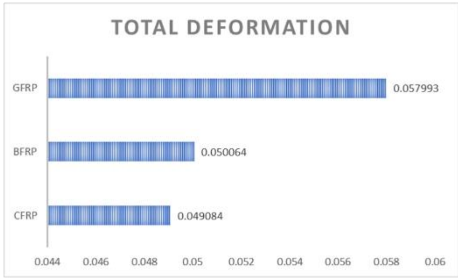

Fig. 44 Graph of total deformation

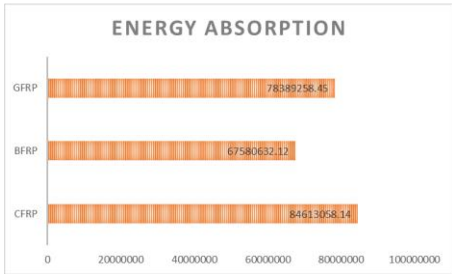

Fig. 45 Graph of energy absorption

IX. CONCLUSION

It The RC frame is retrofitted using several techniques and seismically assessed under cyclic loading in the situation of a column removal. To construct a truss system on the top storey of an RC frame, various bracing approaches are contrasted. The FRP sheet jacketing strengthens the beam, and several FRP materials are evaluated. A comparison of seismic axial loads. The conclusion are as follows: V bracing is chosen as the best bracing for the top-story truss system. As in the case of removing a column, an increase in the number of braces causes the frame to distort more. U-wrapping with FRP sheet reinforces the beam when a column is removed with less distortion. The best FRP material is chosen to be CFRP In addition to using traditional FRP for columns, steel axial seismic loading can also be employed to strengthen columns during

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X. REFERENCE

[1] Santhanam Needhidasan ⇑ , B. Ramesh, S. Joshua Richard Prabu." Experimental study on use of E-waste plastics as coarse aggregate in concrete with manufactured sand"(2019)

[2] Jun Yu, Youhua Zhu, Fangfang Wei and Qun Gao (2020), Seismic Behavior of Renovated RC Frame after Column Removal and Retrofitting with Steel X- Bracing and Jacketing. J. Perform. Constr. Facil., 2020, 34(3)

[3] Yihai Bao,Joseph A, and SamYoung Noh (2017), Evaluation of Structural Robustness against Column Loss: Methodology and Application to RC Frame Buildings, Journal of Structural Engineering, ASCE, ISSN 0733-9445

[4] Foad Mohajeri, Reza Abbasnia, Omid Rashidian ,and Nima Usefi (2017), Theoretical Resistance of RC Frames under the Column Removal Scenario Considering High Strain Rates, Journal of Performance of Constructed Facilities, ASCE, ISSN 0887-3828

[5] Serkan Sagiroglu and Mehrdad Sasani (2014), Progressive Collapse-Resisting Mechanisms of Reinforced Concrete Structures and Effects of Initial Damage Locations, J. Struct. Eng. 2014.140.

[6] Jun Yu, Youhua Zhu, Fangfang Wei and Qun Gao (2020), Seismic Behavior of Renovated RC Frame after Column Removal and Retrofitting with Steel X-Bracing and Jacketing. J. Perform. Constr. Facil., 2020, 34(3)

[7] 2. Imad Shakir Abbood , Sief aldeen Odaa b , Kamalaldin F. Hasan c , Mohammed A. Jasim(2021), Properties evaluation of fiber reinforced polymers and their constituent materials used in structures – A review, Materials Today: Proceedings 43 (2021) 1003–1008.

[8] 3. Mand Kamal Askar, Ali Falyeh Hassan b, Yaman S.S. Al-Kamaki (2022), Flexural and shear strengthening of reinforced concrete beams using FRP composites: A state of the art, Case Studies in Construction Materials 17 (2022) e01189.

[9] 4. Mahmoud F. Belal, Hatem M. Mohamed b, Sherif A. Morad (2015), Behavior of reinforced concrete columns strengthened by steel jacket, HBRC Journal (2015) 11, 201–212

[10] 5. Simone Ravasini, Beatrice Belletti, Emanuele Brunesi , Roberto Nascimbene 2 and Fulvio Parisi (2021), Nonlinear Dynamic Response of a Precast Concrete Building to Sudden Column Removal, Appl. Sci. 2021, 11, 599.

[11] Yihai Bao,Joseph A, and SamYoung Noh (2017), Evaluation of Structural Robustness against Column Loss: Methodology and Application to RC Frame Buildings, Journal of Structural Engineering, ASCE, ISSN 0733-9445

[12] Foad Mohajeri, Reza Abbasnia, Omid Rashidian ,and Nima Usefi (2017), Theoretical Resistance of RC Frames under the Column Removal Scenario Considering High Strain Rates, Journal of Performance of Constructed Facilities, ASCE, ISSN 0887-3828 8.

[13] Serkan Sagiroglu and Mehrdad Sasani (2014), Progressive Collapse-Resisting Mechanisms of Reinforced Concrete Structures and Effects of Initial Damage Locations, J. Struct. Eng. 2014.140