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"Double Steel Tube with Infill Concrete Frame Strengthened With Composite Steel Concrete Shear Wall (Cs)"

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ABSTRACT

The Double steel tube with infill concrete (CDST) frame is a lateral load resisting system in building. Some research paper also suggested system to strength above system. In this study composite steel concrete shear wall (CSP) is used to strengthen CDST frame. Both systems are connected by beam only connection to improve performance of system suggested by Hu et al. Numerical model is developed in this study by using finite element (FE) tool, ANSYS/ETABS for given system. And comparative study is done between CDST and Double steel tube with infill concrete frame strengthened with composite steel concrete shear wall (CS). Both numerical models are validated by comparing these models with experimental models results (Hu et al. [2020]). Results show that numerical models are in good agreement with experimental models. And CSP increase 22.49% energy dissipation capacity of CDST frame. Also, this composite system is providing in midrise building and linear analysis is done on given building.

Keywords: Double steel tube with infill concrete strengthened with composite steel concrete shear wall (CS); cyclic loading; Steel faceplate; ANSYS/ETABS.

I. INTRODUCTION

Earthquake is the shaking of earth crust resulting from release of energy from earth's lithosphere in the form of waves. It is unpredictable in nature. It can have damaged extremely to buildings. Hence analysis of building should be proper under the action of these load. During earthquake, ground is excited severely due to which building member may go under inelastic deformation and also large energy dissipate in building. So, for seismic region earthquake resisting building are needed. It has been recognized that for safe and economic structure in that region, engineers should have considered proper structural system. There are several factors while selecting structural system. It need experience, relevant literature to arrive at the best possible solution in each particular case. Although there are many software's are used for precise design of building, but this software's cannot give safe and economical structural system for different cases.

Now a day, generally reinforced concrete(RC) shear wall is providing to building system as a lateral force resisting system. It is better than building with frame system as far as non-structural elements are concerned. It is necessary to analyse building with shear wall to predict performance of building with shear wall at given site conditions. Building system with RC shear wall can significantly reduce lateral displacement and damage as compared to building with frame system. For strength and ductile behaviour of structural system, proper reinforcement detailing is required. During earthquake ductile behaviour of structural system is required to avoided sudden collapse of building.

As a result, significant development in RC shear wall. But, after earthquake RC shear wall get non-recoverable damage. Edge columns are damage due to lack of confinement of core and also longitudinal bars are buckled. To tackle this problem many steel plates shear wall and composite steel plate shear wall are developed. These walls can easily replace after earthquake damage. Also, to minimise forces on column different types of connections are suggest to connect shear wall with frame system. Hu et al. propose beam only connected connection to connect composite steel plate (CSP) shear wall with double steel tube with infill concrete (CDST) column (CS). This system is analytically analysed in this study and also effect on midrise building with this system is studied.

1.1 COMPOSITE SHEAR WALL

There are numbers of composite shear wall developed and code provisions also mentioned in different code for these composite shear wall. In this study composite steel plate (CSP) shear wall consist of steel plate shear wall with concrete panel at one side to restrained buckling of steel plate shear wall. Steel plate shear wall is failed due to diagonal tension field action. In CSP shear wall, steel plate is failed due to pure shear action due to restrained of concrete panel, resulting increase in ultimate capacity of system. And also, fabrication technic can have used to form this system suggested by Hue et al.

1.2 DOUBLE STEEL TUBE WITH INFILL CONCRETE (CDST) FRAME SYSTEM

CDST frame system consist of CDST columns and I-section as a beam. It has greater lateral stiffness and strength than H-section and concrete field steel tube (CST) column. And also, it has lesser weight and greater ultimate load carrying capacity than CST column. In CDST column inner and outer steel tube bulking restrained by infilled concrete and steel tubes provide confinement to infill concrete. It has greater fire resistance capacity. In this study, system consist of CDST frame system with beam only connected CSP shear wall is numerically analyse by using Finite element tool and also this system with mid-rise building is analyse for seismic loads.

II. LITERATURE REVIEW

Kim et al. (2005): In high rise buildings to resist lateral load generally shear wall are provided. In Asian region box system is used for high rise building in which shear wall with slab are used for construction. For functional purpose shear walls are provide with openings. This structure if finely meshed in finite element tools, it required long time and big size of memory for analysis. In this study to counteract above problem some method was suggested for finite element analysis. In this method super elements, substructures and fictitious beams are used. Static and dynamic analysis were performed on given structure to evaluate accuracy and efficiency of given model. Results show that propose method of analysis required lesser time and memory and gives good results.

Guo et al. (2011): Shear wall is generally used in high rise buildings as a lateral load resisting system. Composite steel plate shear wall is increasingly using with steel structures. Because it has greater ductility, energy dissipation capacity and lateral load bearing capacity. There are two 1/3 scaled specimens are tested of steel plate shear wall (SPSW) system and composite steel plate shear wall (CSPSW) system. Each system consists of concrete filled steel tube column (CHS) with I-section as beam and SPSW or CSPSW. In SPSW system, SPSW resists lateral load by diagonal tension field action and CSPSW consist of SPSW with concrete panels at both sides resist lateral load by composite action. Results show that both system has good energy dissipation capacity and good ductility. CSPSW system has greater lateral load carrying capacity and energy dissipation capacity than SPSW system.

Hassanein and Kharoob (2014): In this study concrete field double skin steel tube (CFDST) column is numerically analyse by using finite element tool ANSYS/ETABSunder axial loading. It consists of inner steel tube and outer tube of lean duplex stainless steel with infill concrete in between them. To verify numerical model, its results compared with experimental model results. Some parameters are studied such as slenderness ratio, hollow ratio, thickness ratio and concrete confinement effect. And compressive strength for different parameters is calculated. This ultimate strength is compared with design strength calculated by using American and European specification. However, it is found that ultimate strength suggested by American and European specification are overestimated compressive strength of CFDST column and it not satisfy safety considerations. Some method is suggested by author to calculate accurately ultimate strength of CFDST column.

Chen et al. (2015): In this study novel composite steel plate (DSP–HSCW) shear wall is suggested consist of double steel plate with infill high performance concrete in between them connected with concrete filled steel tube (CFST) columns. High performance concrete gives strength and stiffness and ductility by steel plate to given system. This system is tested under reverse cyclic loading. Some parameters are studied such as axial load ratio and ratio of tie rod spacing to steel plate thickness. Results show that DSP-HSCW has greater lateral strength and ductility than conventional system. Results show that axial load ratio has significant effect on properties of this system. By reducing ratio of tie bar spacing to steel plate thickness resulting increase in deformation capacity of given system.

Dey et al. (2016): In this study non-linear analysis is done on 4-storey and 6-storey model with composite steel plate shear wall (C-PSW). For non-linear analysis both material and geometrical non-linearity is considered for given finite element model. Results show that C-PSW behave stable and ductile manner

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under seismic loading. Both analytical and theoretical results are in good agreement with each other such as axial load and moment on boundary columns. Both concrete panel and boundary column are subjected to significant amount of shear force which is not considered in design of C-PSW in AISC 341-10. And also, time period predicted by given code is greater than time period calculates by analytical results. Author proposed some formula to calculate shear stud spacing and thickness of concrete panel of C-PSW. And also suggest formulae to calculate fundamental period of given system by using result of finite element analysis.

Ghomi et al. (2016): In this paper partial interaction theory is used to analyse and design of composite steel plate shear wall subjected to out of plane loading. In this method interaction between steel plate and concrete is considered. Composite steel plate shear walls under out of plane loading can be considered as slab under distributed loading. So, for analysis and design this wall can be considered strip beam slab. For connection of steel plate with concrete panel shear connectors are used. And for calculation of out of plane loading conventional method is used. Concrete panel in this system restrained buckling of steel plate shear wall as well as it performs vital role in out of plane loading. In this study two cases are studied, steel plate with and without concrete panel. And analyse with the help of finite element tool ANSYS/ETABS. To find the accuracy of given models, these models results are compared with theoretical results. Results show that proposed method is capable to find good results such as deformation and stress distribution of given system.

Rahnavard et al. (2016): In this study numerical model of composite steel plate shear is developed to study behaviour of composite steel plate shear wall under reverse cyclic loading. Finite element tool ANSYS/ETABS is used to create five type of three dimensional numerical models. Model results are verified by using experimental data. Result show that concrete panel attached at one side of steel plate shear wall can dissipated more energy than other system. By varying distance between connectors and thickness of concrete cover there is no increase in lateral stiffness.

Fahjan et al. (2010): Generally, shear wall is used to resist lateral load in building system. For static and dynamic analysis proper modelling of shear wall in structural system should be made. For linear analysis shear wall is modelled by using shell element and frame element in building system. For non-linear analysis non-linear material model is used with mid pier approach. Which is based on plastic hinge concept provide along length of member. For non-linear analysis of shell elements, non-linear material model of shell elements is used. For concrete material and reinforced material different shell elements are used in layers. In this study, different approaches are used to modelled shear wall in structural system. And results are compared by comparing different models of building systems.

Shafaei et al. (2016): In this study concrete stiffened steel plate shear wall (CSPSW) with steel frame is analytically analyse. In which concrete panel is used to restrained buckling of steel plate shear. Concrete panel is providing at one side of steel plate shear wall. Steel plate welded to boundary steel frame and there is gap in between steel frame and concrete panel. Results are carried out on variety of thickness of steel plate and concrete panel. Results show that by providing concrete panel to steel plate shear wall (SPSW), there is significant change in behaviour of steel plate shear wall. SPSW resist lateral load by tension field action and CSPSW resist lateral load by pure shear yielding. Thickness of concrete panel and steel plate directly effluence ultimate strength of CSPSW. Initial stiffness, shear capacity, ultimate strength of CSPSW is greater than SPSW. And also, energy dissipation capacity and ductility improve by providing concrete panel to SPSW.

Guo et al. (2017): In this study new type of steel plate shear wall system is suggested. This system is consisting of concrete filled steel tube (CFST) columns with beam only connected steel plate shear wall. There are three two storey system seismically analyse. This system varied by providing reinforced concrete (RC) panel to steel plate to restrained buckling of steel plate shear wall. Results show that RC panel can increase strength of given system but decrease ductility. Both systems have same energy dissipation capacity and stable hysteresis curve.

Nguyen et al. (2017): In this study numerical analysis is done by using ANSYS/ETABS on composite steel plate shear wall consists of outer steel plates, infill concrete in between them, shear studs, tie rods, steel base plate to connect wall to reinforced concrete (RC) foundation. Models are subjected to reverse cyclic loading. All models are verifying by comparing it with experimental model of given system with aspect ratio 1. Some parameters are study such as reinforcement ratio, connector type, faceplate slenderness ratio. Both experimental and analytical results are match such as Load-displacement response, damaged to infill concrete, behaviour of steel plate, connector behaviour, shear force contribution. Analytical results show that steel plate can contributed 20 to 70% in total shear resistance of given system depending on reinforcement ratio, face plate dimensions, storey drift and level of damage to infill concrete.

Ren et al. (2018): In this study new type of composite shear wall is present consist of reinforced concrete shear wall with square concrete filled steel tube (CFST) boundary columns incorporating with carbon fibre reinforced polymer. Reverse cyclic loading is applied on given model for seismic analysis. In this study four type of shear wall are tested under reverse cyclic loading 1) Ordinary shear wall, 2) Shear wall with CFST boundary column, 3) Shear wall with double skin CFST boundary column and forth is proposed wall. Energy dissipation capacity, ductility, stiffness degradation etc. compared of each wall. Results show that proposed shear wall has greater ductility and energy dissipation capacity than other walls.

Wang et al. (2018): In this study novel composite steel plate shear wall (SPSW) is proposed. Which consist of in cased steel plate in middle of reinforced concrete (RC) shear wall. In cased steel plate improved seismic behaviour of RC shear wall and RC shear wall restrained buckling of steel plate and also protect it from fire and corrosion resistance. In this study 16 SPSW and 3 traditional RC shear wall are tested under cyclic loading to study failure mechanism, energy dissipation capacity, ultimate load carrying capacity etc. Some parameters are studied such as aspect ratio, thickness of wall and steel plate, structural detailing. Based on test results hysteresis curve are developed and proposed some formula to calculate shear capacity of given wall.

Wu et al. (2018): In this study novel type of Precast reinforced concrete shear wall is proposed. In which instead of using reinforcement at boundary of shear wall, concrete filled steel tubes (CFSTs) are used. To connect reinforcement with CFSTs sleeve filled with high strength mortar is used. For seismic analysis of given system, seven 1/3 scaled specimen are tested under reverse cyclic loading. Varying axial load and loading rate are provided on each specimen. Results show that CFSTs improve lateral load and deformation capacity of given system. Increasing axial load ratio reduce drift ratio of given system. And also loading rate influence energy dissipation capacity of given model.

Orlando et al. (2019): In this paper monumental masonry building assessment of structural behaviour and retrofitting of structure is present. In first stage geometric configuration and condition of building is assessed. In second stage finite element analysis is done by using relevant software to assessed seismic capacity and load bearing capacity of building. In third stage retrofitting is suggested to strengthen building for both seismically and for static load.

Ansari et al. (2020): In this study rib stiffener is used to connect steel beam with concrete filled steel tube (CFT) column. In this connection rib stiffener is gone through CFT column and connected to steel beam. Finite element analysis is done by using ANSYS/ETABS. This connection is analysed under cyclic loading. Accuracy of given model is examined through by comparing it with experimental model. Parametric study is done on twenty-four models of given connection. Parameter are used such as stiffener’s height, length and thickness and in CFT column thickness and diameter of tube. Effect of these parameters on failure mode and ultimate moment carrying capacity is investigated. Result show that rib stiffener height can improved buckling behaviour and moment carrying capacity of CFT column by 8%. And by using thicker and longer rib stiffener shift plastic hinge of beam away from CFT column.

Hu et al. (2020): In this study fully, prefabricated concrete filled double skin steel tube frame with beam only connected steel plate shear wall (CFDS-SPSW) system is proposed. High strength bolts are used for prefabrication. Here beam only connected connections are used to connect steel plate shear wall (SPSW) to concrete filled double skin steel tube frame (CFDS) to eliminate additional forces on column. To know the seismic behaviour of this system, reverse cyclic loading is applied on given model. Two
½ scaled specimens are tested in this work. Results show that by providing beam only connected SPSW enhance the performance of CFDS. By providing SPSW to CFDS, CFDS can tolerated more than 5% storey drift in given system. And also, SPSW can improved initial stiffness, lateral resistance, ductility of CFDS significantly in given system.

Hu et al. (2020): Concrete filled double skin steel tube (CFDST) frame is recommended as lateral load resisting system in high rise building. Because CFDST columns has significant advantages over concrete filled steel tube (CFST) column and H-section. In this study, CFDST frame is strengthen with beam only connected composite steel plate shear wall (BF-BCW). Three ½ scaled specimen are tested of given system under reverse cyclic loading. Result show that composite steel plate shear wall (BCW) can significantly improve lateral strength and lateral stiffness of CFDST frame. Then theoretical model is proposing to calculate ultimate capacity of given system and results are verified by using test results.

Zhang et al. (2020): In this paper novel composite shear wall proposed, which consist of high strength concrete with steel rebar and concrete filled steel tube columns embedded at boundary of given system. Reverse cyclic loading is provided on given system to carry out seismic behaviour of given system. For seismic analysis, four wall with shear span ratio 2.2 are developed and tested. Some parameters are studied such as type of longitudinal reinforcement, axial load ratio and steel fibres. Results show that by using ultra high strength rebar's at boundary columns can decrease residual deformation and improved reparability. And steel fibres improve deformation capacity of given system. To calculate lateral load carrying capacity some method is proposed and validated by comparing with experimental results.

OBJECTIVE

1. Formulation of problem statement, development of methodology, and possible validation with high quality research article.
2. To carry out comparative study of bare concrete-filled double-skin steel tube (CDST) frame and concrete-filled double-skin steel tube frame with beam-only- connected composite steel plate shear wall (CS).
3. To carry out comparative study of seismic responses of midrise building with CDST and CS system.

III. PROBLEM STATEMENT

In this study, CDST frame consist of CDST column and I-section as beam strengthen with beam only connected composite steel plate shear wall is numerically analyse with suitable software. Experimental study shows that, composite steel plate shear walls can effectively enhance lateral resistance and lateral stiffness of CDST frame and also given system has less weight than conventional system. These characteristics are required in high rise buildings. This study suggested numerical model of given system. Finite element program ANSYS/ETABS is used to analyse effect of composite steel plate shear wall in strengthening given frame system. And also, midrise building with given system is analyse under seismic loading condition by using relevant software .

Model Details

Content	Description
No. of storeys	15
Typical storey height	3 m
Plan dimension	30m × 16m
Grade of steel	Fe415
Floor finish	1.5 kN/m^2
Live load	3 kN/m^2
Slab thickness	150 mm
Column size	500mm × 500mm
Beam size	230mm × 450mm
Composite system	CDST column with I-section as beam with CSP shear wall
Earthquake zone	V (0.36)
Importance factor	1.2
Soil type	II

IV. MODELLING

Model	Configuration
Model 1	CDST system at corners
Model 2	CDST system symmetrically placed at periphery

International Journal of Advances in Engineering and Management (IJAEM)
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Model 3	CDST system symmetrically placed at centre
Model 4	CS system at corners
Model 5	CS system symmetrically placed at periphery
Model 6	CS system symmetrically placed at centre

MODELLING

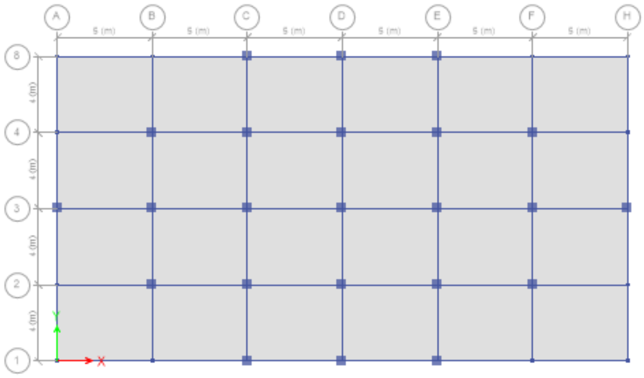

Fig: Plan view of CDST system at corners Model

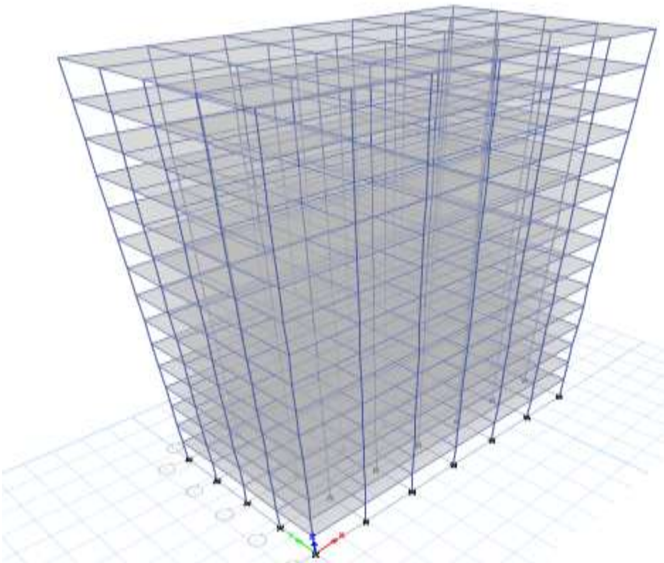

Fig: 3D view of CDST system at corners Model

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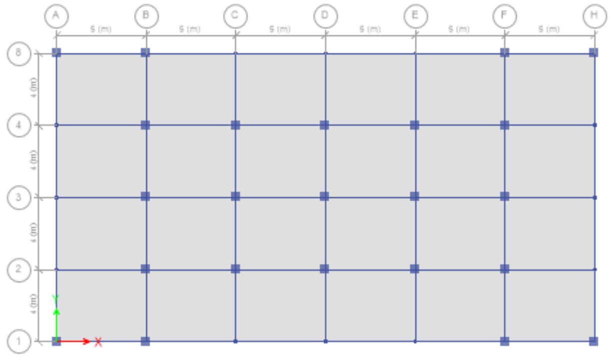

Fig: Plan view of CDST system symmetrically placed at periphery

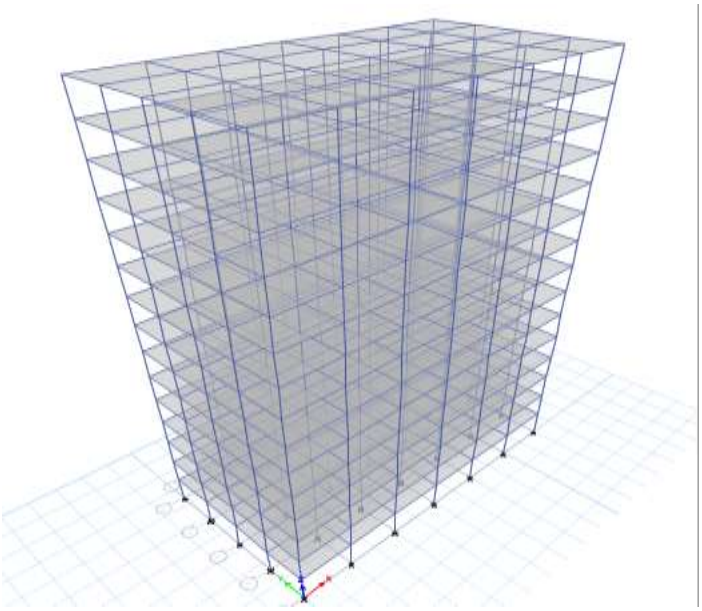

Fig: 3D view of CDST system symmetrically placed at periphery

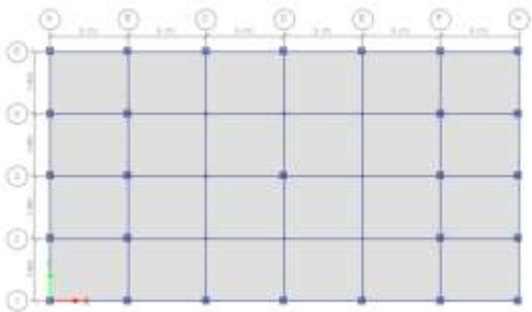

Fig: Plan view of CDST system symmetrically placed at centre

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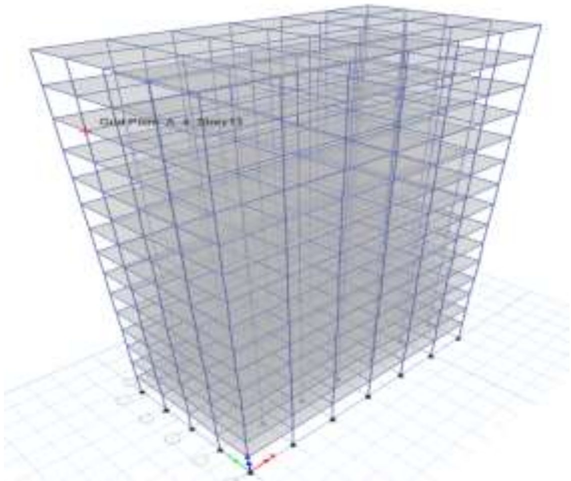

Fig: 3D view of CDST system symmetrically placed at centre

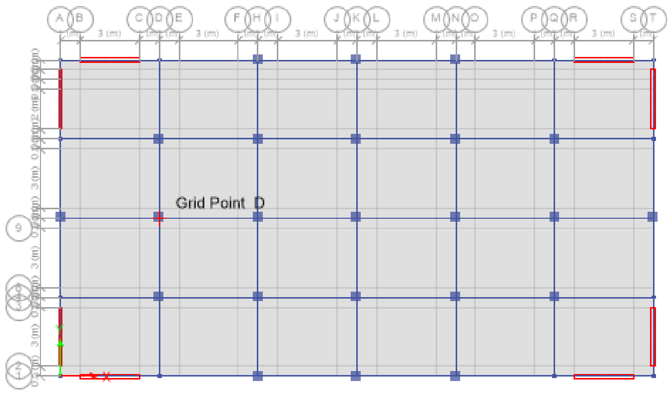

Fig: Plan view of CS system at corners

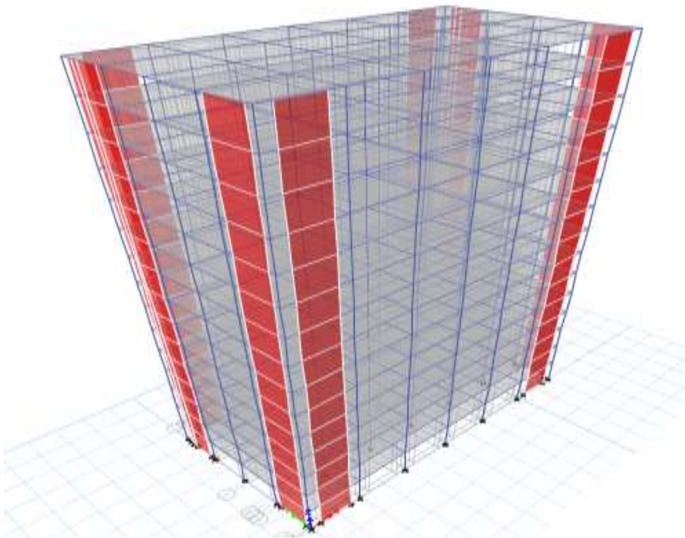

Fig: 3D view of CS system at corners

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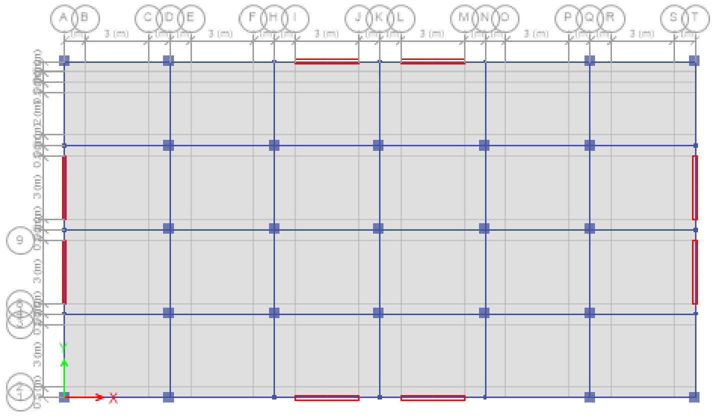

Fig: Plan view of CS system symmetrically placed at periphery

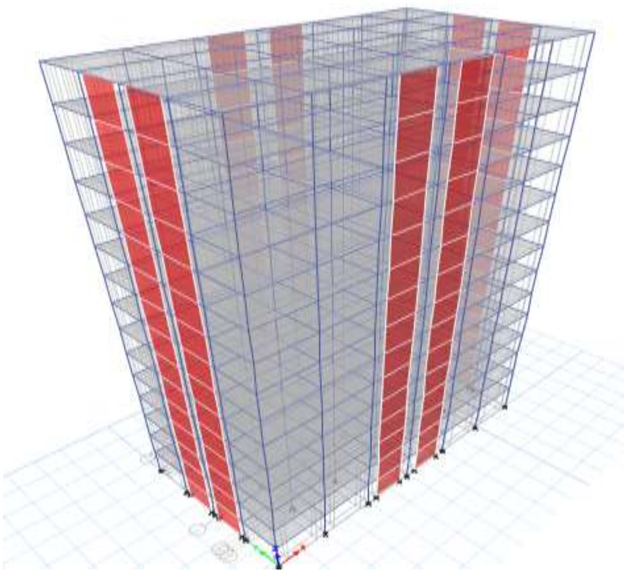

Fig: 3D view of CS system symmetrically placed at periphery

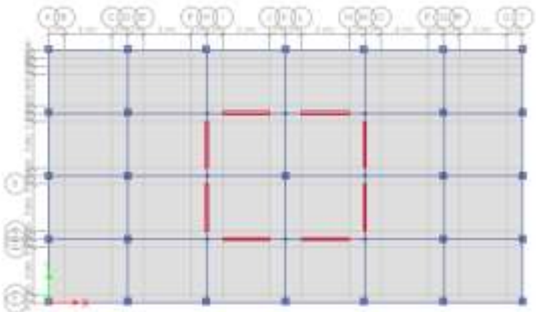

Fig: Plan view of CS system symmetrically placed at centre

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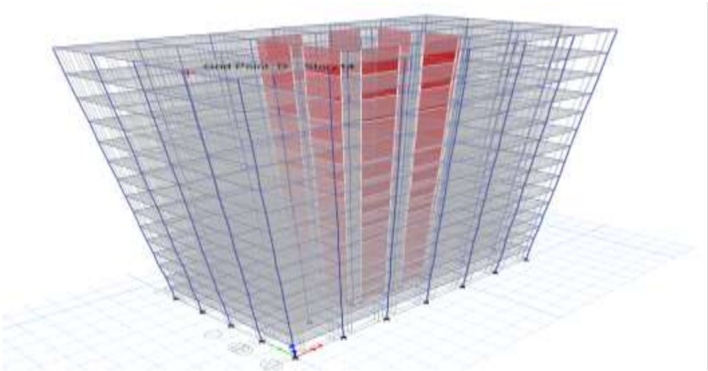
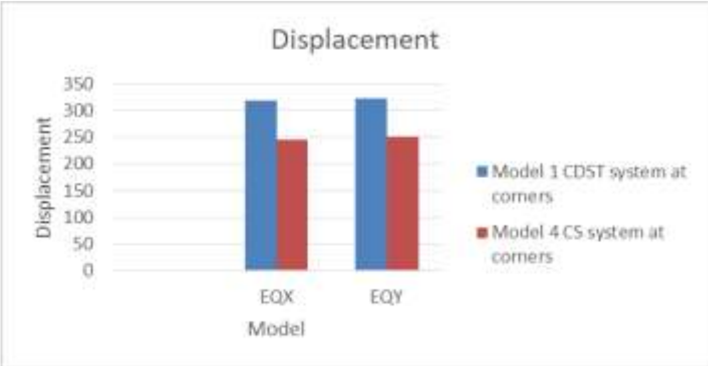


Fig: 3D view of CS system symmetrically placed at centre

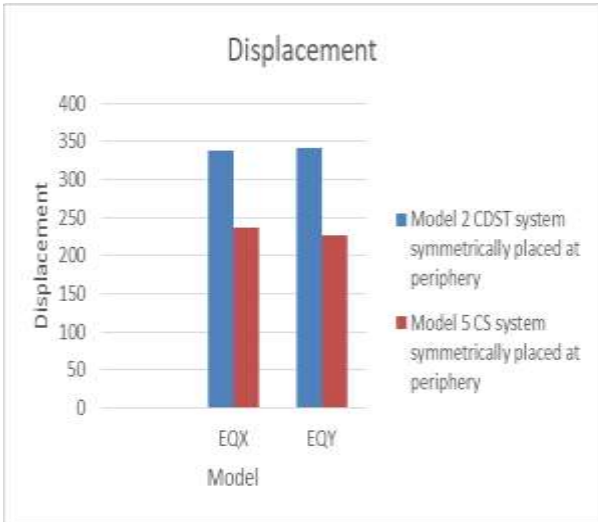
Model 1 and 4



The above graph shows displacement in X – direction for structural system, Model 1 CDST system at corners, Model 4 CS system at corners. Model 4 CS system at corners has lower displacement than Model 1 CDST system at corners by 22.96 %,

The above graph shows displacement in Y – direction for structural system, Model 1 CDST system at corners, Model 4 CS system at corners. Model 4 CS system at corners has lower displacement than Model 1 CDST system at corners by 21.82 %

Model 2 and 5

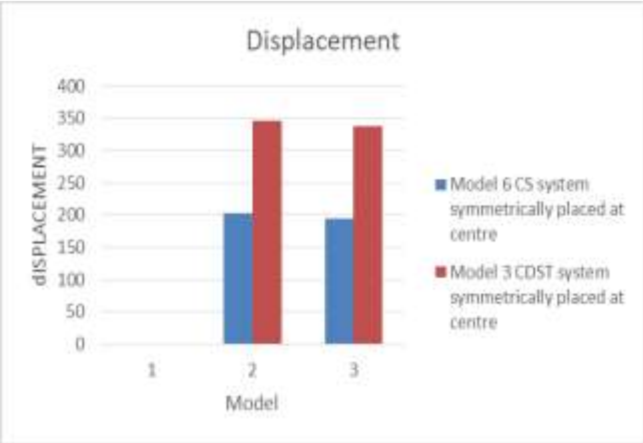


The above graph shows displacement in X – direction for structural system, Model 2 CDST system symmetrically placed at periphery, Model 5 CS system symmetrically placed at periphery. Model 5 CS system symmetrically placed at periphery has

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 686-700 www.ijaem.net ISSN: 2395-5252

lower displacement than Model 1 CDST system at corners by 30.13 %,
The above graph shows displacement in Y –direction for structural system, Model 2 CDST system symmetrically placed at periphery, Model 5 CS system symmetrically placed at periphery. Model 5 CS system symmetrically placed at periphery has lower displacement than Model 1 CDST system at corners by 30.13 %

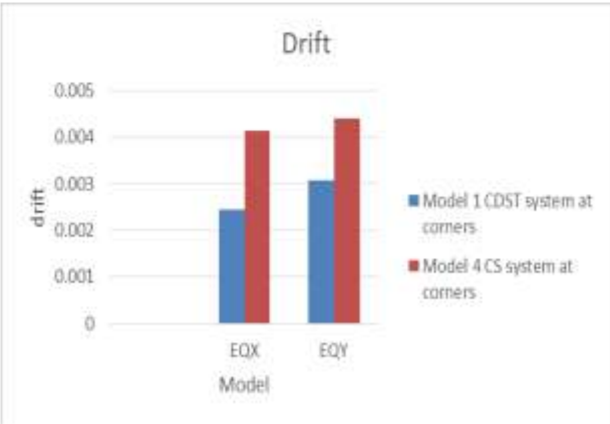
Model 6 and 3



The above graph shows displacement in X –direction for structural system, Model 6 CS system symmetrically placed at center, Model 3 CDST system symmetrically placed at center. Model 6 CS system symmetrically placed at center has lower displacement than Model 3 CDST system symmetrically placed at center 41.40 %,

The above graph shows displacement in Y–direction for structural system, Model 6 CS system symmetrically placed at center, Model 3 CDST system symmetrically placed at center. Model 6 CS system symmetrically placed at center has lower displacement than Model 3 CDST system symmetrically placed at center 42.49 %

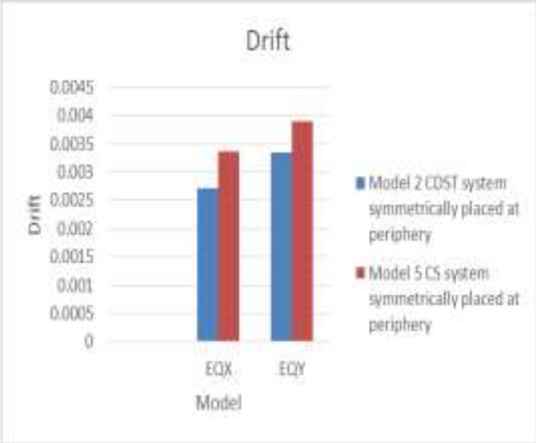
Model 1 and 4



The above graph shows Drift in X –direction for structural system, Model 1 CDST system at corners, Model 4 CS system at corners. Model 4 CS system at corners has lower Drift than Model 1 CDST system at corners by 83.06 %,

The above graph shows Drift in Y –direction for structural system, Model 1 CDST system at corners, Model 4 CS system at corners. Model 4 CS system at corners has lower Drift than Model 1 CDST system at corners by 30.15 %,

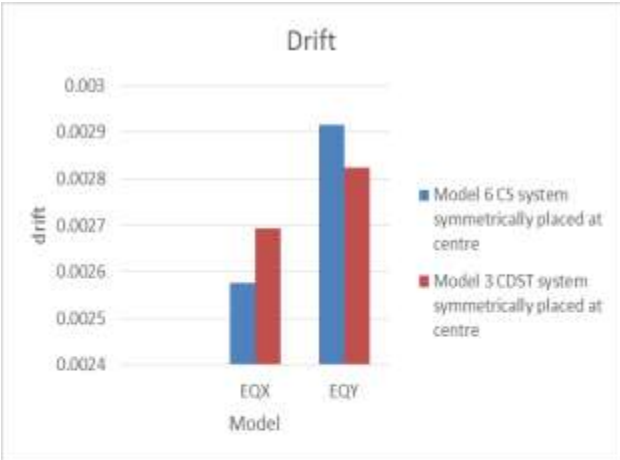
Model 2 and 5



The above graph shows Drift in X –direction for structural system, Model 2 CDST system symmetrically placed at periphery, Model 5 CS system symmetrically placed at periphery. Model 5 CS system symmetrically placed at periphery has lower Drift than Model 1 CDST system at corners by 18.86 %,

The above graph shows Drift in Y –direction for structural system, Model 2 CDST system symmetrically placed at periphery, Model 5 CS system symmetrically placed at periphery. Model 5 CS system symmetrically placed at periphery has lower Drift than Model 1 CDST system at corners by 3.18 %

Model 6 and 3



The above graph shows Drift in X –direction for structural system, Model 6 CS system symmetrically placed at center, Model 3 CDST system symmetrically placed at center. Model 6 CS system symmetrically placed at center has lower Drift than Model 3 CDST system symmetrically placed at center 4.30 %,

The above graph shows Drift in Y –direction for structural system, Model 6 CS system symmetrically placed at center, Model 3 CDST system symmetrically placed at center. Model 6 CS system symmetrically placed at center has lower Drift than Model 3 CDST system symmetrically placed at center 3.18 %.

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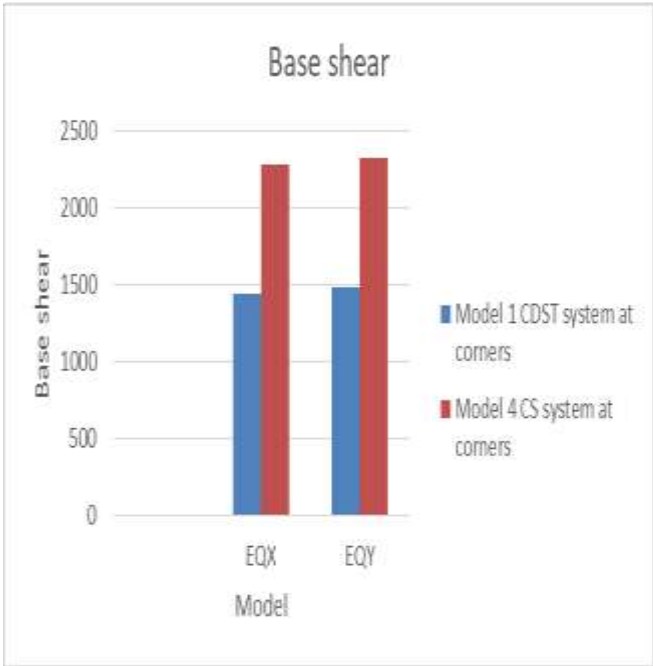
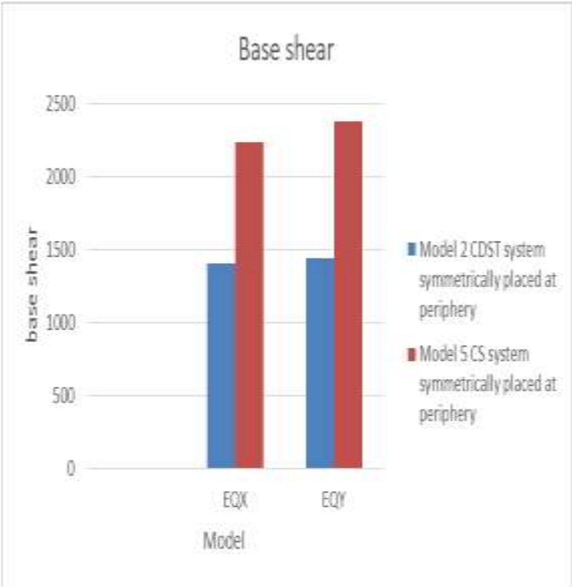
Model 1 and 4



The above graph shows Base shear in X – direction for structural system, Model 1 CDST system at corners, Model 4 CS system at corners. Model 4 CS system at corners has lower Base shear than Model 1 CDST system at corners by 36.84 %,

The above graph shows Base shear in Y – direction for structural system, Model 1 CDST system at corners, Model 4 CS system at corners. Model 4 CS system at corners has lower Base shear than Model 1 CDST system at corners by 36.04 %,

Model 2 and 5



The above graph shows Base shear in X – direction for structural system, Model 2 CDST system symmetrically placed at periphery, Model 5 CS system symmetrically placed at periphery. Model 5 CS system symmetrically placed at periphery has lower Base shear than Model 1 CDST system at corners by 37.29 %,

The above graph shows Base shear in Y – direction for structural system, Model 2 CDST system symmetrically placed at periphery, Model 5 CS

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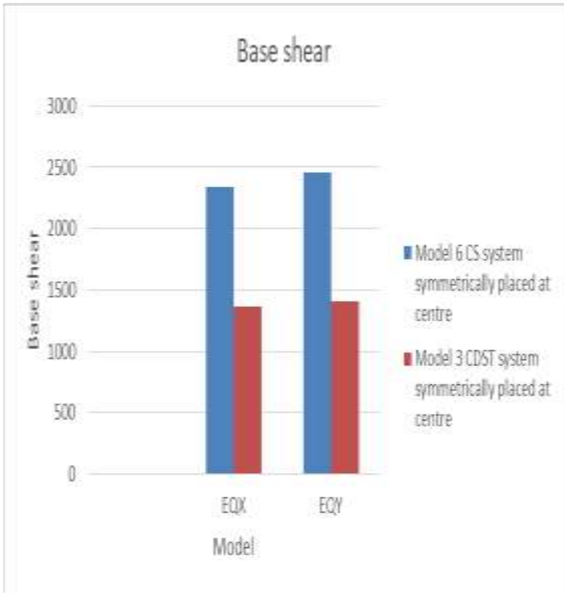
system symmetrically placed at periphery. Model 5 CS system symmetrically placed at periphery has lower Base shear than Model 1 CDST system at corners by 39.17 %

Model 6 and 3



The above graph shows Base shear in X – direction for structural system, Model 6 CS system symmetrically placed at center, Model 3 CDST system symmetrically placed at center. Model 6 CS system symmetrically placed at center has lower Base shear than Model 3 CDST system symmetrically placed at center 41.41 %,

The above graph shows displacement in Y – direction for structural system, Model 6 CS system symmetrically placed at center, Model 3 CDST system symmetrically placed at center. Model 6 CS system symmetrically placed at center has lower Base shear than Model 3 CDST system symmetrically placed at center 42.67 %.

V. CONCLUSION

10.1 NUMERICAL MODELS

In this study buildout of analytical modelling of CDST and CS system subjected to in-plane reversed cyclic loading by using finite element software ANSYS/ETABS. Conclusions derived are as follows,

1. By providing composite steel plate shear wall to CDST system, there is significant increase in average ultimate strength, energy dissipation capacity, elastic stiffness etc.
2. Concrete panel significantly increase ultimate capacity of steel plate shear wall.
3. Due to concrete panel steel plate shear wall is fail by pure shear yield action.

10.2 MID-RISE BUILDING WITH DIFFERENT SYSTEM

1. Spectral acceleration is less in case of Building with CS system than Building with CDST system.
2. Building with CS system resist more forces than CDST system. In case of CS system at corner, at periphery and at core of building resists 2.85 %, 4.705 %,38.78 % respectively in X direction respectively and 2.74 %, 1.87 %, 31.71%respectively in Y direction than Building with CDST system.
3. Also, in case of building with CS system has less top storey displacement than building with CDST system.
4. In both system interstorey drift is within limit as per IS code.
5. CS system configuration at core of building gives Significant result than other configuration.

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