Seismic Behavior of Staggered Shear Wall and X- Bracing RC Structures by Nonlinear Time History Analysis

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Abstract-Shear wall and Bracing are a very important component for resisting seismic forces in multi-storey buildings.Various types of shear walls and bracing are used for multi-storey buildings. In this paper, we are usingstaggered shear wall and X Bracing to check the seismic behavior of G+9Storey residential staggered shear wall and X bracing RC Structures by nonlinear time history analysis. This study also checks frequency, base shear, fundamental time period, story drift and story displacement, of both structures and compares them by applying previous earthquake data.Nonlinear Time History analysis done by ETABS V19 software and SEISMO (SIGNAL, MATCH, and SELECT) Software are used to find out required earthquake data. The Kocaeli Turkey, 8/17/1999 earthquake ground acceleration data are used as time-history data.This analysis was carried out under IS1893:2016, IS456:2000, andIS875:1987 Part 1, 2 & 5 Codes.

Keywords-Seismic Behavior, Staggered Shear wall, Nonlinear Time History Analysis, fundamental time period, ETABS, Storey Drift, Storey displacement etc.

1. INTRODUCTION

The shear wall is the component of the structure that is the most effective at withstanding the load of the wind and earthquake. Shear walls are an extremely common component of multi-story buildings. In order to achieve this, X-bracing is also utilised for the purpose of resisting lateral loads, both with and without dampers. Therefore, various types of shear walls, such as RC Shear walls and Steel walls, as well as various types of bracing, such as X-type, V-type, inverted V-type, and so on, are utilised to improve the lateral strength of structures against horizontal forces in structures. The use of shear walls is another contributor to monolithic construction. Shear walls are utilised in order to withstand the bending moment that a building experiences 'because of horizontal forces.' The design of the shear wall must also take into account various types of architectural requirements, such as openings, the amount of reinforcement required, horizontal forces, the location of the site, and so on. In order to accomplish that, a brand-new Staggered Shear wall has been incorporated into this design. This wall eliminates the deficiencies that were present in the conventional one. For example, an extremely high self-weight and shearing-weight ratio. Therefore, in this new staggered shear wall that is utilised, it is positioned at a staggered location of the structure. Every floor has walls that are staggered with respect to one another. In addition, the configuration of the shear wall can be altered to suit the needs of the design. This type of staggered shear wall can be utilised to provide high lateral stiffness while also requiring less material for construction. In a manner analogous to this, bracing is utilised in high-rise buildings. In addition, bracings contribute to the aesthetic appeal of buildings. The use of bracings in high-rise structures is extremely beneficial for the structural stability of the building. because it is very simple to fabricate and assemble them on location. Modifications can be made to the kind of bracing used in accordance with the specifications of the design. Therefore, X-type bracing is taken into consideration in this analysis.

Members made of steel that are used in the construction of steel structures are called bracing. Bracing are also used for the purpose of providing structural stability, and this applies to both RC and steel structures. Different sizes and configurations of sections are available for bracings. In multi-story buildings, bracings can be installed to provide a structure with lateral stiffness. In order to accomplish this, X-bracing are also used for resisting lateral loads with and without dampers, etc. Bracing such as X-type, V-type, inverted V-type, etc. are used to improve the lateral strength of structures in opposition to horizontal forces in structures. In addition, bracings contribute to the aesthetic appeal of buildings. The use of bracings in high-rise structures is extremely beneficial for the structural stability of the building. because it is very simple to fabricate and assemble them on location. Modifications can be made to the kind of bracing used in accordance with the specifications of the design. Therefore, X-type bracing is taken into consideration in this analysis.

2. LITERATURE REVIEW

Jianxin and colleagues (2013) conducted a study that compared the 2-D and 3-D coupled shear wall structures in great detail. The authors took into account the influence of slab and beam connections as well as the spatial effect. In light of the findings of this study, it has become abundantly clear that the 3-D skipped floor staggered shear wall is a significantly superior alternative to the 3-D as well as the old traditional one. In addition, the 2-D staggered shear wall performs significantly better than the 2-D traditional shear wall in a variety of characteristics, such as lateral stiffness. It has many advantages, including increased space and lateral stiffness, decreased dead mass and seismic effect, increased rigidity and economic benefits, and so on. This investigation was carried out using the finite element method by ANSYS software.

Using ANSYS software, Ll et al. (2017) analyse the 28.8-meter-tall building that has a skip-floor staggered shear wall in their study. The weak part of the staggered shear wall, the performance of the walls, and the condition in which cracks develop are compared in this study using both a two-dimensional and a three-dimensional structure. In addition to this, they offer treatment recommendations for the weak parts and components of the staggered shear walls. Additionally, the investigation provides the necessary data for the promotion of the use of staggered shear walls.

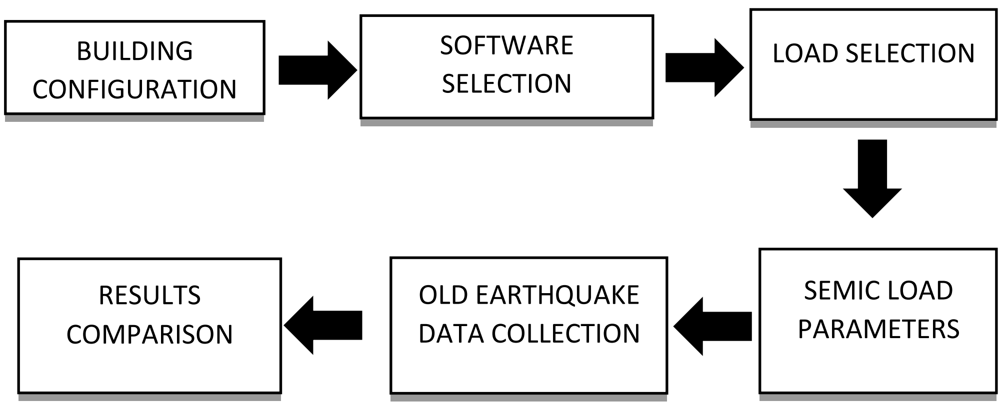
Veerni and Ch (2016) used the STADD.PRO software to conduct an in-depth study that compared the performance of multistory steel frame (G+20) buildings with and without shear walls and bracings when subjected to varying amounts of wind and seismic load. This study complies with the performance of the combination of shear walls and X bracings, which are significantly better than the combination of shear walls and v bracings in displacement, axial force shear force, etc. and the displacement and moment were minimum in both the X and V bracing model.

Khattar & K. ETABS software was utilised to perform a seismic analysis on a 15-story RC building in accordance with IS1893; 2016 part 1 codal provision for the purpose of this study (2019). In this study, a number of different kinds of bracing, including concentric (chevron, V type, and D type) and eccentrically (chevron, V type, and D type) bracing, were utilised. According to the findings of their investigation, the eccentric bracing frame exhibits a deflection that is 10% lower than that of the concentric bracing frame. A greater eccentricity is associated with a greater amount of deflection. The eccentricity of the structure is also a factor in the moment carrying capacity of the structure.

In their study, Kumar and Pandian (2016) analysed G+9, G+14, and G+19 RC buildings in seismic zone V using the ETABS software. These buildings had shear walls and bracing. The primary objective of this investigation is to determine the storey drift, storey displacement, base shear, amount of time required, and cost per panel for both structures. Their findings demonstrated that the lateral displacement of the 15 storey model is greater when compared to the G+9 and G+19 models. It has been determined that the weight of the shear wall model is significantly greater than that of a different all-type bracing model. The cost of bracing is higher than that of the shear wall panel as well.

The shear wall Structure is analysed by all of the researchers, with or without an opening in the shear wall. In addition to that, they look at the storey drift, the fundamental time period, and the storey displacement under the seismic load. The primary performance was evaluated using ANSYS's Etabs software while it was subjected to a seismic load.

3. METHODOLOGY



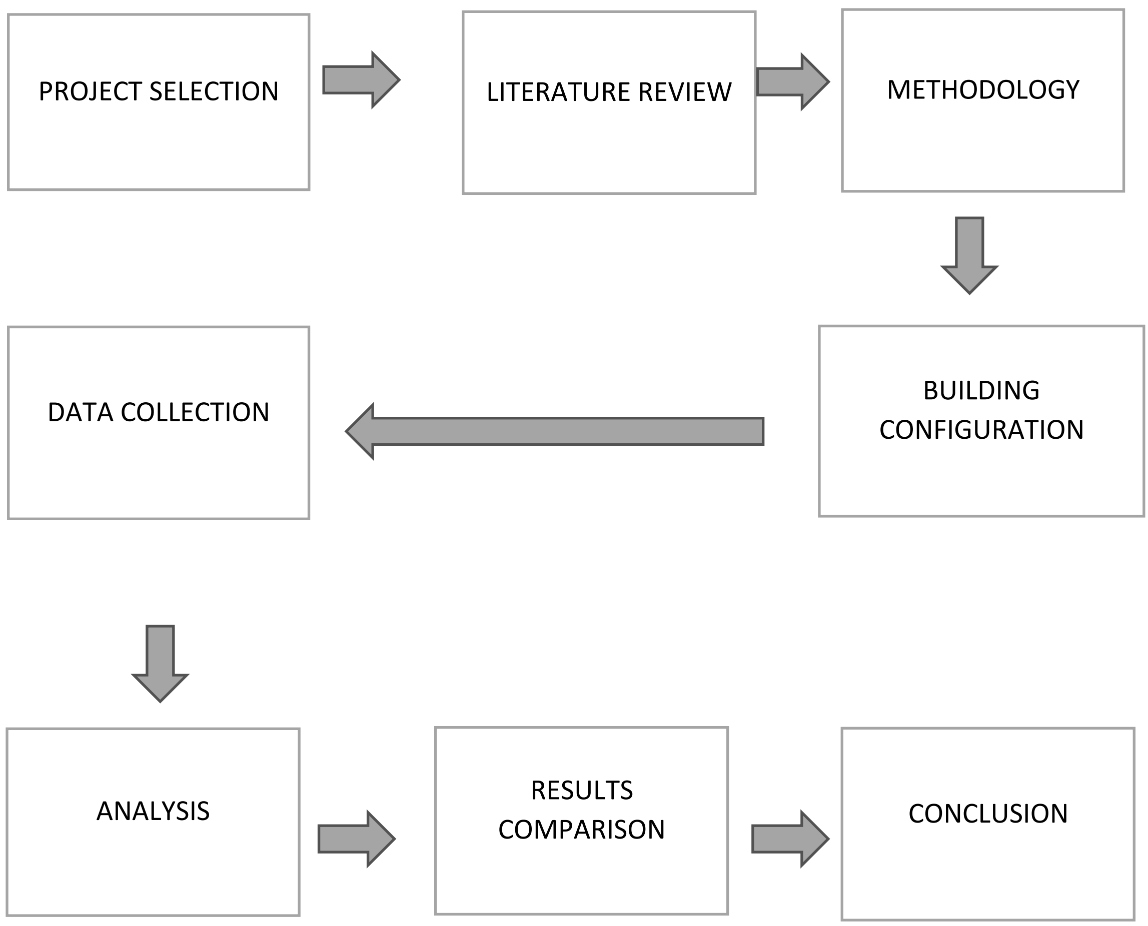
4. SCOPE & OBJECTIVES

The utilization of a nonlinear time history analysis yields accurate findings regarding the structure. The analysis is typically applied to high-rise buildings, with the results of which being used to apply lessons learned from previous earthquake acceleration to the process of seismic retrofitting;

- In order to test the effect of a staggered shear wall and X bracing while the building is under earthquake load
- In order to evaluate the performance of the staggered shear wall and the x bracing under earthquake load

The staggered shear wall is compared to the x-bracing structure.

WORK FLOW CHART



Flow Chart 1: Working Procedure

5. BUILDING MODELLING AND ANALYSIS METHOD

The analysis in this work is performed on a ten-storey RC building that has a G+ rating. Both a staggered shear wall and staggered X bracing were used in the RC buildings of the two models. In the X direction, there are 5 bays, and in the Y direction, there are 3 bays; the length of each bay is 4 metres. There are three metres between each level. Every single support has been fastened. The model plans and model elevations of both buildings are presented in the following tables, respectively:

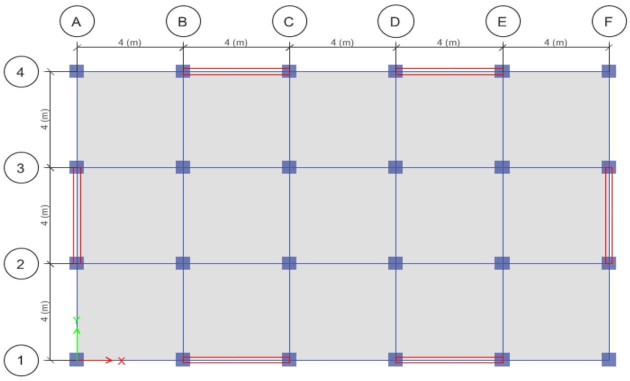
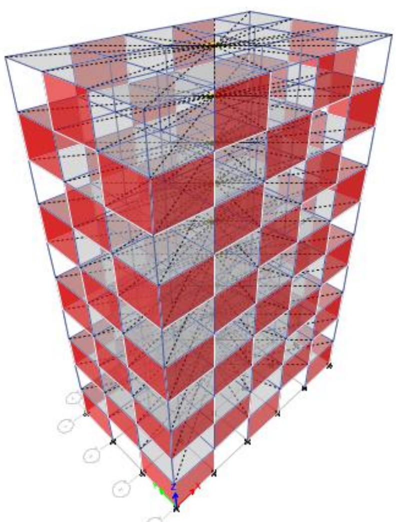
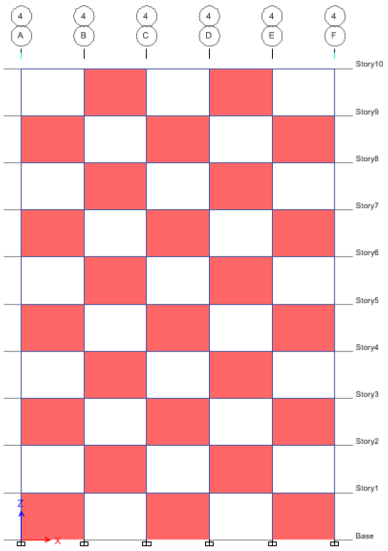


Fig. 1.Plan (Staggered Shear Wall Model)



(a)



(b)

Fig. 2. Staggered Shear Wall (a) 3D View (b) Elevation

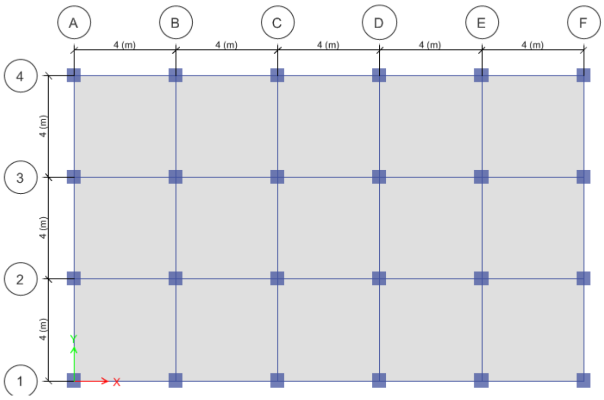
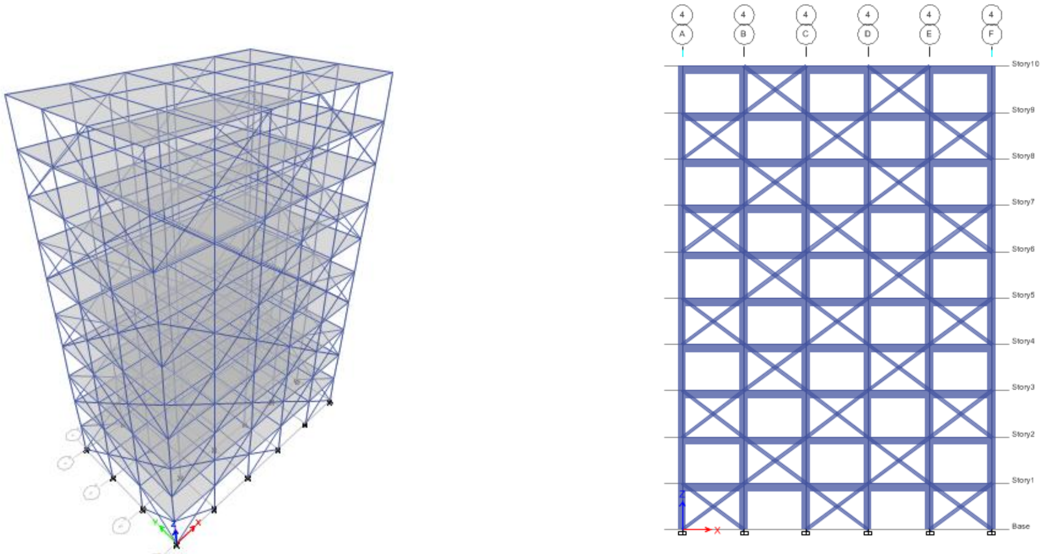


Fig. 3. Plan (Staggered X Bracing Model)



(c) (d)

Fig. 4.Staggered X Bracing Model (c) 3DView (d) Elevation

4.1 Following Software is used for analysis-

a) SEISMO SELECT - for selecting required earthquake data,

b) SEISMO MATCH – for match the earthquake data to the Target response spectrum,

c) ETABS 2019 – for model analysis,

4.2 Following codes and standard are used for desire consideration-

i. IS456:2000 – practice for plain and reinforced concrete,
ii. IS1893:2016 (part 1) – code for earthquake resistant structures,
iii. IS875:1987 (part 1) - for dead load consideration,
iv. IS875:1987 (part 2) - for imposed load consideration,
v. IS875:1987 (part 5) - for special load and combinations,

4.3 Model Configuration and Loads:-

Table 1: Building material properties

Parameters	**Standards**
Grade of steel	Fe500, Fe250
Grade of concrete	M30

*Note: all values are in N/mm^2.

Table 2: Building Description

Parameters	**Dimensions**
Beam size	500X300 millimeter
Column size	500X500 millimeter
Thickness of shear wall	250 millimeter
Thickness of slab	150 millimeter
X Bracing size	ISNB175H
Wall thickness	230mm, 115mm

Table 3: Loads

Description	**Values**
DEAD LOAD (floor finish)	1.0 kN/m^2
DEAD LOAD (water proofing)	1.5 kN/m^2
IMPOSED LOAD(floor load)	1.5 kN/m^2
IMPOSED LOAD (roof load)	3 kN/m^2
WALL LOAD (230mm)	13.248 kN/m
WALL LOAD (115mm)	6.624 kN/m

***Note: -** Dead & Imposed loads as per IS 875:1987 (Part 1 & 2).

SEISMIC LOAD PARAMETERS

Seismic load parameters are considered as per IS1893:2016 (Part 1);

Table 4: Seismic load parameters

Description	**Values**
Seismic Zone(Z)	V
Importance Factor (I)	1.2
Soil Site Type	II
Response Spectrum Factor (R)	5
Damping Ratio	5 Percent

The detail of previous earthquake ground motion data have considered as below-

Table 5: Earthquake data

Earthquake:	Kocaeli Turkey, 8/17/1999
Magnitude:	7.51
Database:	PEER NGA strong motion database record

Note: -The earthquake with a magnitude of 7.4 struck the Kocaeli region in the northwestern part of Turkey at 3:02 in the morning on August 17, 1999. An abrupt fissure in the surface of the Earth was the root cause of the earthquake. The region is Turkey's industrial and population centre, and it has a high population density. According to the government of Turkey, 17127 people have been killed, 43953 people have been injured, and 250000 people have been displaced. Approximately 121 pavilion cities were required as essential emergency housing. This earthquake caused severe damage to approximately 30,500 commercial establishments as well as 214,000 residential homes.

The above building configuration data, loads, and Kocaeli turkey earthquake ground acceleration data were utilised in order to carry out this analysis of the structure in accordance with the provisions of the IS codes. This analysis of the structure was carried out using the nonlinear time history method by the ETABS software.

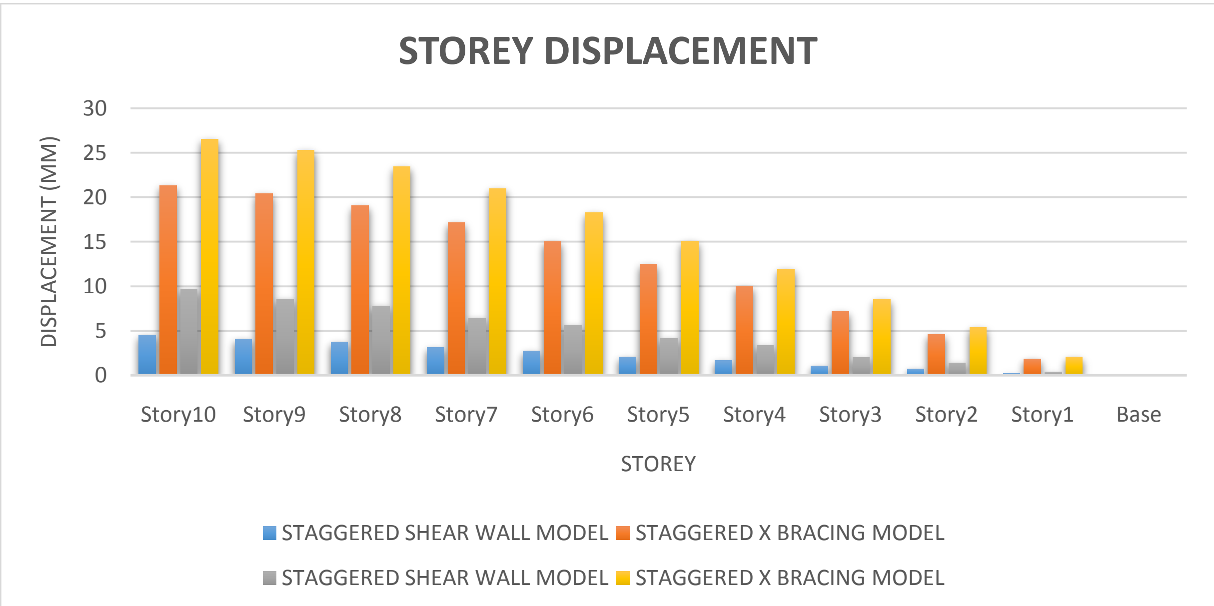
5. ANALYSIS RESULTS AND DISCUSSION

5.1. Storey Displacement

The storey displacement results of staggered shear wall and staggered X bracing model are shown in table – 6 and graph -1 respectively. The variation of storey displacement of staggered shear wall is less as compare to staggered X bracing structure both in X and Y direction.

Table 6: Storey Displacement

STOREY NO.	MODEL 1(X–dir.) (MM)	MODEL 2(X–dir.) (MM)	MODEL 1(Y–dir.) (MM)	MODEL 2(Y–dir.) (MM)
Story10	4.535	21.312	9.668	26.551
Story9	4.058	20.442	8.571	25.289
Story8	3.706	19.068	7.806	23.457
Story7	3.102	17.153	6.448	20.974
Story6	2.701	15.017	5.619	18.266
Story5	2.038	12.481	4.139	15.068
Story4	1.65	9.969	3.362	11.953
Story3	1.024	7.179	1.98	8.499
Story2	0.7	4.59	1.364	5.358
Story1	0.216	1.821	0.343	2.035
Base	0	0	0	0



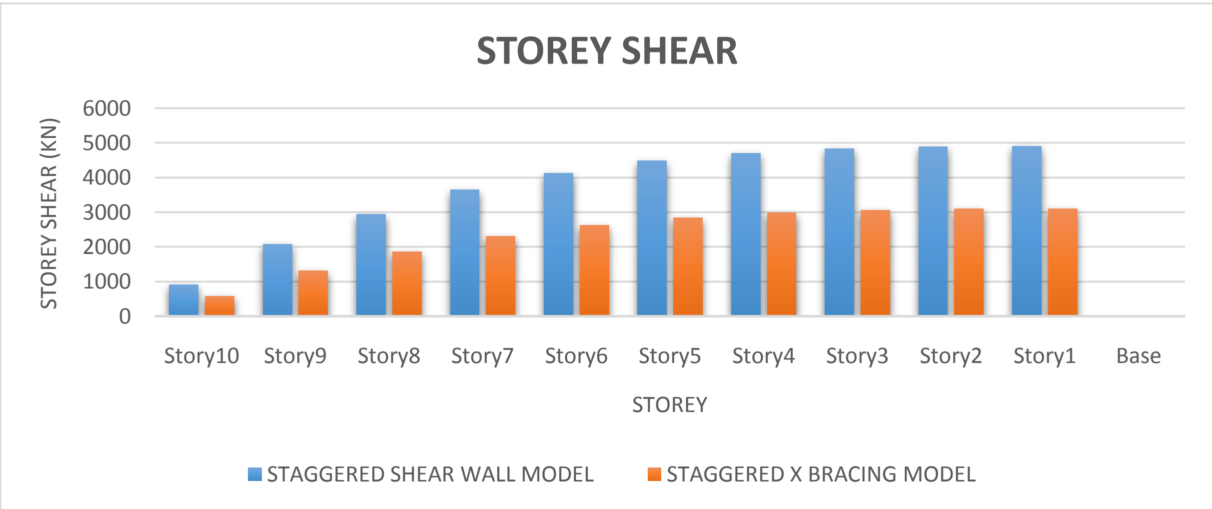
Graph 1: Storey Displacement

5.2. Storey Shear

The variation of storey shear in the staggered shear wall and staggered X bracing are shown in table- 7 and graph- 2 respectively. The storey shear of the X bracing structure is less as compared to the staggered shear wall structure.

Table 7: Storey Shear

STOREY NO.	MODEL 1(X–dir.) (KN)	MODEL2(X–dir.) (KN)
Story10	907.4155	578.8484
Story9	2085.354	1314.02
Story8	2937.678	1865.62
Story7	3650.258	2310.354
Story6	4129.69	2620.629
Story5	4493.251	2847.534
Story4	4706.332	2985.434
Story3	4837.214	3067.12
Story2	4890.484	3101.595
Story1	4905.027	3110.671
Base	0	0



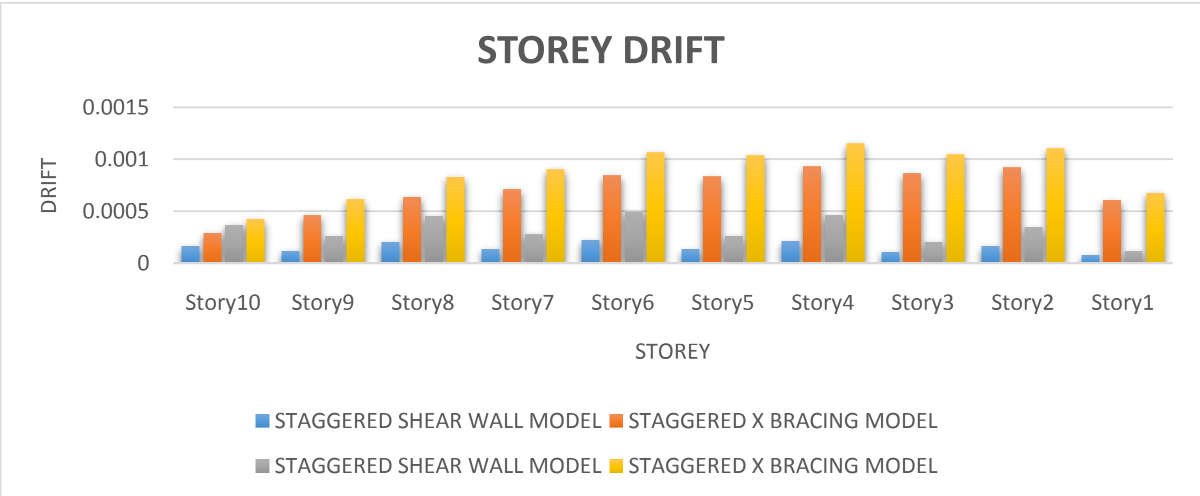
Graph 2: Storey Shear

5.3. Storey Drift

Table 8 and Graph 3 both show the variation of storey drift that occurs in the staggered shear wall and the staggered X bracing structure, respectively. When compared to a staggered X bracing structure, staggered shear walls have a storey drift that is significantly lower in both the longitudinal and transversal directions respectively.

Table 8: Storey Drift

STOREY NO.	MODEL 1(X–dir.)	MODEL 2(X–dir.)	MODEL 1(Y–dir.)	MODEL 2(Y–dir.)
Story10	0.000159	0.00029	0.000366	0.000421
Story9	0.000119	0.000458	0.000259	0.000611
Story8	0.000201	0.000638	0.000453	0.000828
Story7	0.000134	0.000712	0.000277	0.000903
Story6	0.000221	0.000845	0.000493	0.001066
Story5	0.000129	0.000837	0.000259	0.001038
Story4	0.000209	0.00093	0.000461	0.001151
Story3	0.000108	0.000863	0.000205	0.001047
Story2	0.000162	0.000923	0.000341	0.001107
Story1	7.20E-05	0.000607	0.000114	0.000678



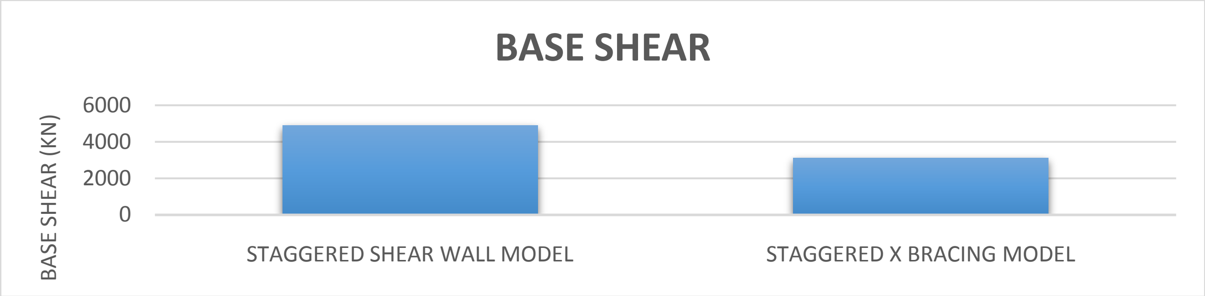
Graph 3: Storey Drift

5.4. Base Shear

The variation of base shear in the staggered shear wall and staggered X bracing structure are shown in table 9 and graph 4 respectively. The base shear of the staggered X bracing structure is less as compared to the staggered shear wall structure.

Table 9: Base Shear

STOREY NO.	MODEL 1 (KN)	MODEL2 (KN)
BASE	4905.0268	3110.671



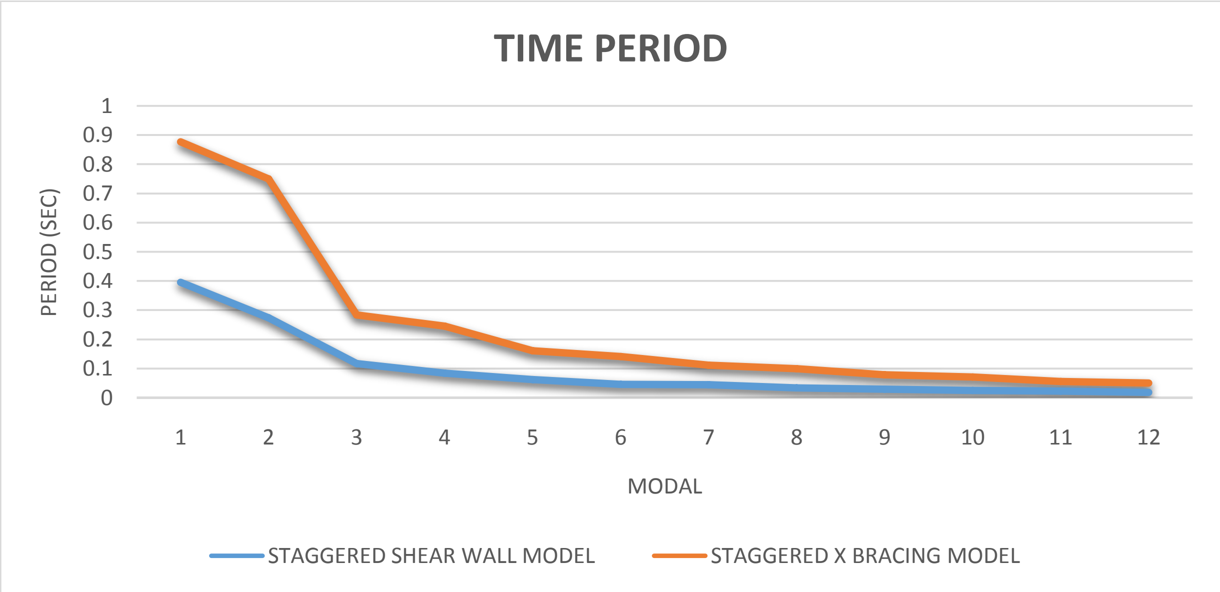
Graph 4: Base Shear

5.5. Time Period

Table 10 and graph 5 display, respectively, the variation in time period that occurs in the staggered X bracing structure and the staggered shear wall. In every mode, the structure with the staggered shear wall has a shorter time period when compared to the structure with the staggered X bracing.

Table 10: Time Period

MODAL NO.	MODEL 1 (Sec.)	MODEL2 (Sec.)
1	0.396	0.878
2	0.275	0.75
3	0.118	0.284
4	0.085	0.246
5	0.063	0.161
6	0.046	0.142
7	0.045	0.112
8	0.034	0.1
9	0.03	0.079
10	0.025	0.072
11	0.023	0.056
12	0.019	0.051



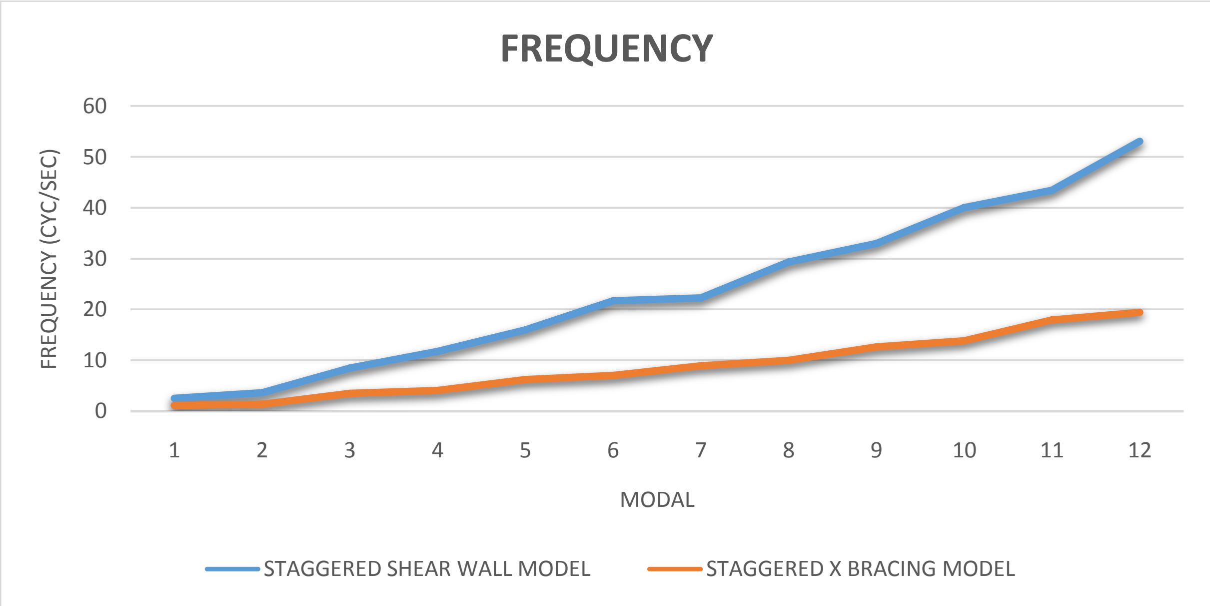
Graph 5: Time Period

5.6. Frequency

The variation of frequency in the staggered shear wall and staggered X bracing structure are shown in table- 11 and graph- 6 respectively. The frequency of staggered shear walls is higher as compare to staggered X bracing structures.

Table 11: Frequency

MODAL NO.	MODEL 1 (Cyc/Sec.)	MODEL2 (Cyc/Sec.)
1	2.525	1.139
2	3.633	1.334
3	8.472	3.515
4	11.728	4.065
5	15.998	6.212
6	21.723	7.031
7	22.312	8.942
8	29.332	10.006
9	32.985	12.635
10	40.023	13.868
11	43.425	17.964
12	53.071	19.459



Graph 6: Frequency

6. CONCLUSIONS

With the assistance of nonlinear time history analysis carried out by ETABS software, the focus of this study is on determining the seismic behaviour of staggered shear wall models and staggered X bracing models when subjected to historical earthquake data. The following conclusions follow from the analysis study that was presented earlier:

- In the X direction, the structure with staggered shear walls has a storey displacement that is 83 percent smaller than the structure with staggered X bracing, and the Y direction displacement is 71 percent smaller. The shear wall with staggered studs responds to seismic load in a much more effective manner.
- In both directions, the storey shear of staggered X bracing is 37% lower than the storey shear of staggered shear wall structure. The structure that is braced in the form of an X will be less susceptible to being damaged.
- The storey drift of the staggered shear wall is 76% less than that of the staggered X bracing structure in the X direction, and it is 61% less than that in the Y direction when subjected to seismic load. According to the recommendation provided in IS1893 part1:2016, the storey drift of both structures did not exceed the value of 0.004h.
- The base shear of the structure with staggered X bracing is 37% lower than the base shear of the structure with staggered shear walls.
- When compared to staggered X bracing structures, staggered shear walls have a fundamental time period that is 62% shorter. However, because the values are lower, the structure with staggered shear walls is stiffer. Therefore, the structure with the staggered X bracing can perform better than the structure with the staggered shear wall because of the higher value of time period.

- When compared to the staggered X bracing structure, staggered shear walls have a frequency that is 62% higher. When compared to the structure with staggered X bracing, the overall dynamic performance of the structure that has staggered shear walls is superior.

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