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Comparative study of seismic analysis of multistory buildings with shear walls and bracing systems

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Abstract: The application of the shear wall system in reinforced concrete (RC) buildings has become widely used to minimize seismic consequences. Besides, the buildings using concentrated steel bracings system are used for the same reasons in steel structures buildings. Both of the systems have significance of the structural performance. Although both systems are used for same the reasons, their effect shows unequal variations and behaviour against seismic load. This is for the reason that the values of response factors are miscellaneous for varying structural systems. This paper contains a numerical approach to show dissimilarity between the shear wall system and steel bracing system. The new approach of this research is strengthening lateral force resisting system by using steel bracing. A gradual process has been done step by step to show comprehensible contrasts between the systems. For implicit results, East Malaysia has considered as the corresponding region. The overall analysis has been carried out using Etabs9.7 software

Keywords: *Shear Wall System, Steel Bracing System, Seismic Load*

Introduction:

Nowadays, the Earthquake disaster has become a great concern. Many damages have been caused due to earthquake in both Asia & other continent. It is very tremendous as it is unforeseeable in nature. So it is very necessary to keep in mind the hazards due to seismic effects and should adopt the necessary assumptions before design. Because structures are susceptible to severe damages due to earthquake. Different countries have a variety of provisions of providing such system with a view to dissipating the energy of earthquake. Shear wall and steel bracing systems are most effective means to adopt to add more stiffness in frames. At present, in many high rise building constructions, shear wall has been provided as lift core in case of core type shear wall or constructed as load bearing walls. Besides, the steel bracing systems are allocated in that portion of a structure where more rigidity is required. For different cases, distinct kinds of bracing systems are assumed. Though, bracings have less stiffness comparing with shear wall, there is a significant concern that is the self-weight of bracings are to a small extent comparing with concrete shear wall. As per assumptions, it is considerably regarded that less self-weight causes less story shears.

Previously, the findings of researches had almost identical outcomes to determine the effectiveness of strengthening systems. Zandi (2013) discussed on comparison between thin steel plate shear walls with dual system of steel moment frame and cross bracing or chevron with a design method based on performance levels. The study focused and discuss on the dual system comprising with thin steel plate shear wall and bracings. In addition, it is based on steel moment resisting frames and approach on performance based design has been arrogated in this research. Five (5) different frames have been taken into consideration. Thin plate shear wall, chevron bracings and cross bracings have initiated the differences between the models. For each case, five different models have been appeared with distinctive arrangements of thin plate shear wall or chevron bracings or cross bracings. The result of findings indicates that the thin plate shear wall and cross bracings have better result compared to others.

Kumar.n et al (2014) has presented a review of shear wall systems. The main focused of this research has been found that the behaviour and resistance of miscellaneous type shear wall against cyclic loads. The output of this analysis shows the suitability of inner shear walls comparing with outer shear walls.

Gowardhan et al (2015) reviewed on comparative seismic analysis of steel frame with and without bracing by using software. This research has depended upon the affectivity of steel bracings in steel structures. A comparison has been deliberated between structure with and without steel bracings resistant to seismic effects. It has been found that seismic bracings increase the stiffness against lateral loadings and it might be a good practice to use bracings as retrofitting scheme.

Parasiya et al (2013) has showed a review on comparative analysis of brace frame with conventional lateral load resisting frame in rc structure using software. It has been represented that the parameters of bracings, locations & stiffness of bracings have notable effect on the performance of a building. Kevadkar & Kodag (2013)[5] discussed on lateral load analysis of rc buildings. An illustration of non-identical buildings including bare frame, frame with shear wall & frame with steel bracings is the main key point of the exploration.

A further study was carried out by Chandurkar & Pajgade (2013)[6] on the Seismic Analysis of rc Building with and Without Shear Wall. A variation has become the comparing issue of this research and that is the consideration of differential zones. Including cost analysis was another key issue of the thesis.

Alashkar et al (2015) represents a comparative study of seismic strengthening of RC buildings by steel bracings and concrete shear walls systems. He contemplated on the retrofitting techniques for steel bracings and shear walls. It has been found that adding shear wall is efficacious as it reduces shears, displacements of frames. On the contrary, steel bracings on retrofitting system are advantageous and economic. In case of bracing systems, X-bracings have been found to be more effective. The main approach of this paper is to clarify the comparisons, performances of multi-story building frame considering shear wall and X-type steel bracings for RCC buildings.

A new view of present research is the strengthening the lateral force resisting systems by adding floor bracings. It is considerable that concrete floor system is rigid in plane. Concrete floor system can be included a mean for resisting lateral forces due to earthquake. X-type bracings have been used on floor plane to the corresponding shear wall and vertical steel bracing orientation to observe the consistency against seismic forces. Shear wall as core is spotted in both inside and the side of the building has been considered to observe the distinguished more evidently. Vertical steel bracings and floor bracings have also been positioned according to the oriented positions of shear wall. An 8-storied building has been considered for the research purpose. Shear wall at centre, shear wall at side, Vertical bracings at centre, vertical bracings at sides, floor bracings at mid position & side positions has been taken into consideration. For formal analysis, East Malaysia has been taken as the zone since the calculation of seismic forces is based on certain regions. UBC97 has been adopted as the code for analysis purpose.

Research Methodology:

Structures Systems:

Nowadays, the Structural systems for residential, commercial or any other purposes have a great diversity. It was variety depends upon a number of points such as client's choice, design consideration, architectural perspective and other factor related to the application. For conventional output, a simple shaped structure has been chosen for the research purpose. As the research deals with shear wall and steel bracing systems, the main frame has been kept same in all case. Constant height, constant area, constant exposures in all sides and materials with same properties are the main features of the considered structural frame.

For the shear wall systems, the frame structure is a reinforced concrete meanwhile the steel concentric bracings are pinned at the certain beam-column joints. A minimum size of steel tube has been appointed as bracing considering the radius of gyration to meet with the minimum slenderness ratio. The details of building frames using steel bracing are described in the table 1.

Table 1: *Properties of Multi-storied Building frame*

Structural elements	Properties
Beam Size	40x30 cm in cross section
Column size	40x40 cm in cross section
Slab Thickness	150mm
Shear wall thickness	180 mm
Bracing pipe	Pipe profile : PIPE5SCH40
Floor Height	3m
Total height of frames	24m
Plan Area	400 sq. m
Number of bays in each exposure sides	5
Length of each bay	4m

Based on the Table 1, it was observed that the relevant properties are almost same in all frames of both systems namely shear wall and steel bracing systems. A further consideration will be taken to make the analysis objective more elaborate by change the position of shear wall and shear wall system. As the building frames have symmetry to both axes, only two patterns have been considered here for each system. The selected frame has some identical characteristics. Regularity in plan, mass regularity and vertical regularity are among of them. There is a discontinuation in floor due to lift core but it is below the minimum of the requirements. Therefore, there is no diaphragm discontinuity in the selected frame.

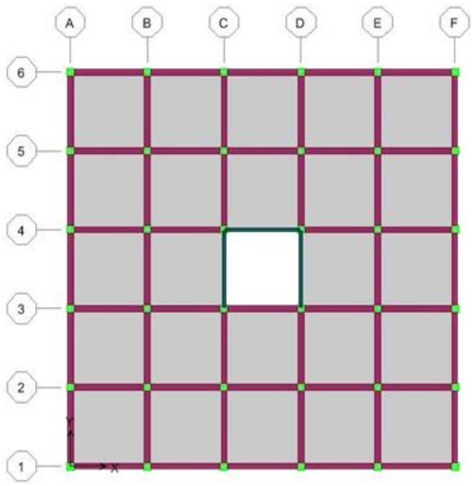

Figure 1: *Shear wall at the mid portion (Model 1)*

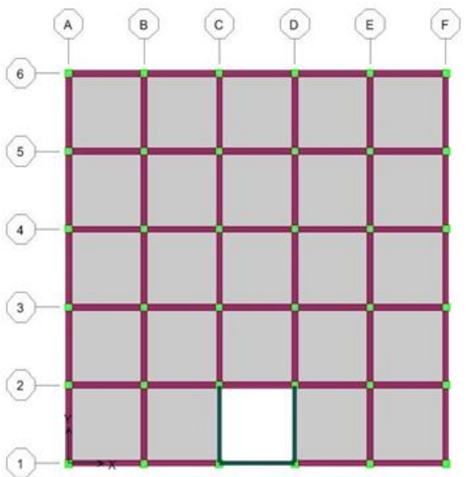

Figure 2*: Shear wall at side portion (Model 2)*

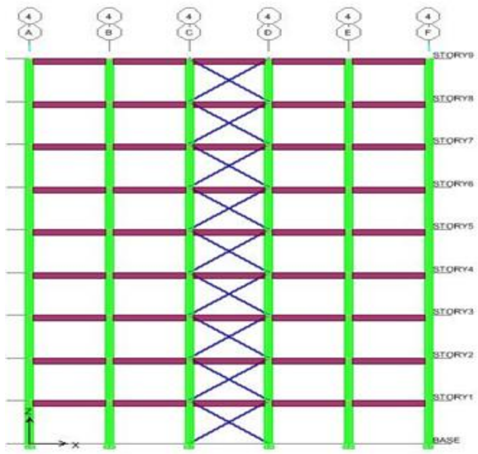

Figure 3*: Vertical bracings at mid (Model 3)*

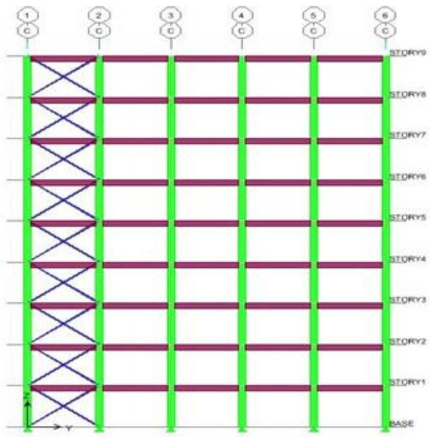

Figure 4: *Vertical bracings at side (Model 4)*

Figure 1 shows observed that the position of shear wall is at the middle portion of the building. Two shear walls along Y-direction and a single shear wall along X-direction has been provided. Meanwhile, Figure 2 shows the position is at the side portion. A little bit differences have been noted. The orientation is different with the previous model. Two shear walls are along x-direction and a shear wall along y-direction has been considered here. In case of Figure 3 and Figure 4, the placing of vertical bracings has been done following the direction of Figure 1 and Figure 2. Steel bracing has been imparted here in lieu of concrete shear wall. In Figure 5 and Figure 6, it represent clearly that the positioning of floor bracings is same as corresponding shear wall model & vertical bracing model.

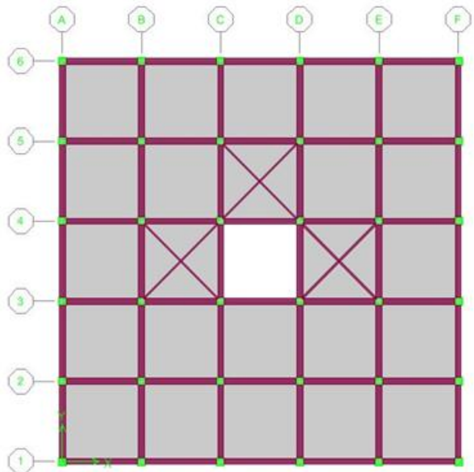

Figure 5*: Floor bracings at mid (Model 5)*

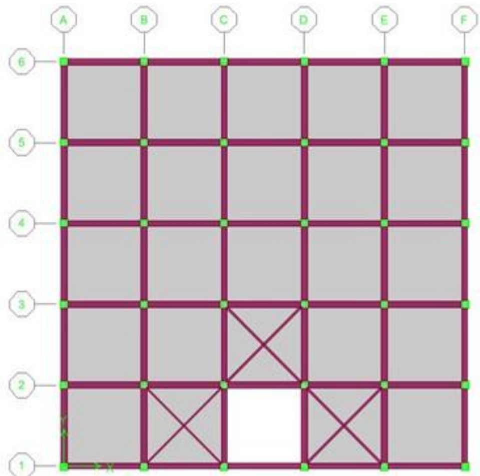

Figure 6*: Floor bracings at side (Model 6)*

Uniform Building Code (UBC) 97 code has been adopted to implement the analytical parameters study. This study focus the building behaviour against seismic forces either shears wall or steel bracing. The seismic analysis was very complicated portion in the field of structural engineering whereas it needs to adopt the exact process to analyse a certain structural frame considering its corresponding characteristics related to earthquake.

There are two types of analysis of structural are explained as below;

a. Static analysis: In this method, the seismic force is calculated in a normalized way. It is known as equivalent static force method. The total base shear is calculated from the building/frame weight. Sometimes a portion of live load is also considered with the dead loads and distributed along each story.

b. Dynamic analysis: Sometimes, equivalent static force is not enough for analysis purposes. Some specific basis indicates to assume this method. Dynamic analysis is classified into three types:
i. Response spectrum analysis
ii. Time history analysis
iii. Pushover analysis.

The response spectrum method has been adopted in present research. Though the frames are within the limit of using static analysis, a linear dynamic or response spectrum analysis has been executed in this study to obtain more accuracy result. For the execution of analysis, the response spectrum parameters has been taken form UBC97 and used in Etabs9.7 program to generate response spectrum function and response spectrum cases. The details of parameters are show in Table 2

Table 2: *Seismic Analysis parameters*

Parameters	Manipulated Value
Seismic Coefficient, Ca	0.12
Seismic Coefficient, Cv	0.12
Assumed Soil Profile	Sa
Damping Ratio	5%
Structural Importance, I	1
Scale Factor	gI/R *(Has been adjusted if needed)*
Over-strength Factor, R (Shear Wall)	5.5
Over-strength Factor, R (Braced Frame)	5.6

Shear wall system:
In structural engineering, shear wall is known as a combination of braced panels. Shear wall has better resistance against lateral loads. It is considered that shear wall has more efficiency against lateral loads. In a general point of view, shear wall is actually reinforced concrete wall or large dimensioned columns. In addition, the shear wall has an extensive meaning in the field of structural engineering and it will increase the lateral stiffness of structural frames. Shear walls can be classified into a number of divisions based on materials, construction processes, and positions. Based on material shear walls are of various types:

a. Wood studs with plywood
b. Metal studs with plywood
c. Reinforced Concrete wall
d. Reinforced CMU wall
e. Un-reinforced brick wall
f. 6 Reinforced 2-wythe brick wall
g. Party walls - double studs for 65 STC (STC = Sound Transmission Coefficient), From the above list, Concrete shear wall is used enormously. In high rise buildings, often it is provided as lift cores. Depending on the construction process, shear wall are of two types. Precast and cast in situ. Positioning of shear wall is a key aspect. Shear wall has impact on centre of mass (CoM) & centre of rigidity (CoR). It is very important to minimize the distance between centre of mass and centre of rigidity to reduce eccentricity and corresponding torsional moments. Shear walls are mainly constructed from foundation level. Maintaining a minimum thickness it is provided in maximum heights of buildings. Generally, the thickness of shear walls is approximately 150-200mm or more is provided. A little bit differences between shear wall (with vertical load) & shear wall (without vertical load). In case of heavy loaded structures, shear walls are also constructed as load bearing walls to carry vertical loads.

Steel Bracing System:
A braced frame is a structural system which is designed primarily to resist lateral loads comprising of wind and earthquake actions. Members in a braced frame are designed to work in tension and compression, similar to a truss type frame. Bracing system is much common in steel frame comparing with concrete frame. In a general, bracing frames are of two types known as concentric steel bracing and eccentric steel bracing. Concentric steel bracing is a type of bracing seems to be provided like as truss member. The method of resisting lateral force of such type bracing is mainly based on axial compression and tension. On the contrary, Eccentric braced frames (EBFs) are a relatively new lateral force resisting system implemented to resist seismic effects in a predictable manner. Another pattern has been common and that is the bracings with shear links. It is being used as it provides more stiffness to the frame. In this study, the concentric steel bracing is using for comparison between shear wall and steel bracing systems.

Finite Element Analysis
Finite element method (FEM) is a numerical method to evaluate approximate solutions of boundary value problems for partial differential equations. It assembles discretisation of a whole problem domain into small-scale parts, called finite elements, and energy methods from the calculus of variations to solve the problem by reducing a corresponding error function. This method is focussed on the Structure analysis, Solid mechanics, Dynamics, Thermal analysis, Electrical analysis, Biomaterials either in behaviour or performance the model structural elements.

Analytical Result & Discussion:
The analyses of both systems either shear wall or steel bracing systems using ETABS software analysis to determine the behaviour and performance of each of models.
Table 3 shows comprehensible difference can be observed. Minimum displacements are found in Model 1 while it is the maximum in Model 4 (along x-direction) and Model5 and Model 6 (along y-direction). Meanwhile, Table 4 shows a clear prospect of story drift ratio is obtained. The drift ratio

is not chronological at all. That is the drift is the maximum along x-direction in Model 3 & along y direction is in Model 6. In case of minimum story drift, it is the minimum in model 1 for both directions. The modal participation mass ratios can be remarked from Table 5 and Table 6. The effects of modes are less in Model 5 and Model while it is highest in Model 2. In addition, Figure 7 and Figure 8 indicate the difference of Diaphragm CoM (Centre of mass) displacement of each model with respect to height or story along both axes. It is explicit that the maximum CoM displacement prevails in Model 6 while the minimum is in Model 1.

Table 3: *Maximum Displacements of Different Models*

Axes	Along X (mm)	Along Y (mm)
Model-1	6.52	5.41
Model-2	7.5	5.59
Model-3	18.67	12.05
Model-4	19.83	10.42
Model-5	13.03	13
Model-6	14.05	13

Table 4: *Maximum Story drift ratio*

Axes	Along X	Along Y
Model-1	0.000286	0.000242
Model-2	0.000481	0.000249
Model-3	0.001011	0.000675
Model-4	0.001096	0.00522
Model-5	0.000717	0.000715
Model-6	0.000775	0.000716

Table 5: *Variation in Modal Participation mass ratio along X-axis*

Modes	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
1	15.56	54.14	49.51	63.56	81.5	81.4
2	0	0	31.69	0	0.27	0.00
3	58.43	21.93	0	17.63	0.00	0.396
4	2.16	8.24	5.82	7.96	9.88	9.84
5	11.03	2.13	4.91	0	0.01	0.00
6	0	0	0	2.69	0.00	0.05
7	3.8244	1.4102	1.5587	2.7763	3.6181	3.60
8	0.19	6.62	2.15	0	0.005	0.00
9	4.43	0.89	0	0.95	0	0.02
10	0.1193	0	0.8413	1.4462	1.93	1.9234
11	0	0.41	1.04	0	0.005	0
12	0.114	0.360	0	0.964	0	0.012

Table 6: *Variation in Modal Participation mass ratio along Y-axis*

Modes	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
1	0	0	0	0	0.27	0.00
2	71.20	70.79	0	79.56	81.6	81.8
3	0	0	80.15	0	0	0
4	0	0	0	0	0.01	0.00
5	0	0	0	12.32	9.88	9.88
6	17.26	17.59	11.83	0	0	0
7	0	0	0	0	0.005	0.000
8	0	0	0	3.906	3.618	3.623
9	0	0	3.843	0	0	0
10	0	6.23	0	0	0.005	0
11	6.178	0	0	1.889	1.93	1.93
12	0	0	1.87	0	0	0

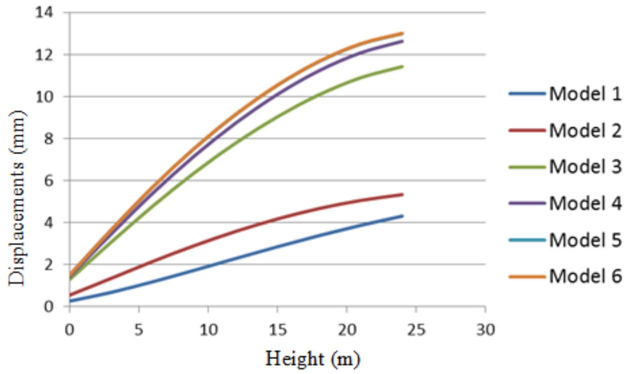

Figure. 7: *Variation of Diaphragm CoM Displacements with Height along X-axis*

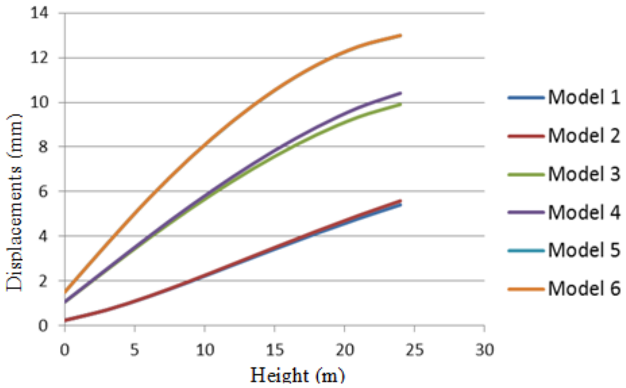

Figure 8: *Variation of Diaphragm CoM Displacements with Height along Y-axis*

Conclusion:

As conclusion, the simplified numerical analysis of reinforced concrete buildings considering shear wall and steel bracings systems at different positions and orientations. A number of arbitration can be attained from the successive analytical results.

i) Considering the displacement records, Model 1 is unassailable enough.

ii) Model 2 is in higher mode effects with respect to the other models.

iii) The gradual increase of COM movement is less along y-direction and it is same for model 5 & model 6 along corresponding axis.

As a result of analysis, it is coherent that model 1 is the safest among the 6 models assessed in the research purpose. Positioning of shear wall is a dominant point. Besides, the orientation in floor bracings is of less significant scrutinizing with the vertically oriented bracing systems. Further modification in floor bracings will accompany good formation as seismic force resisting system.

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