Study of the Behavior of Zipper Braced Frames

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Abstract: Due to the buckling of compressive brace in inverted-chevron braced frames, an unbalanced vertical force has to be applied on the intersection of braces and above beam, which will make an oversized displacement at the beam mid-span. This disparate force results in a strong beam design which is not proportionate to other members. Also, buckling of the compressive brace, results in a localization of the failure and loss of the lateral resistance. One of the ways to overcome this problem is to use a vertical structural element at the beam mid span from the second to the stories above, called zipper strut. In order to evaluate the behavior of this new system, known as the zipper braced frame, some in-plane frames with zipper struts was modeled in Open Sees, along with chevron frame system. These models were analyzed under response spectrum and their ductility, drift and internal forces of the members were compared with each other. Here the seismic response are evaluated by using equivalent static analysis, response spectrum analysis and linear time history analysis seismic analysis for the structure of 10-storey building by providing zipper bracings will be carried and compared with the inverted V type of bracings for the zone-2 & zone-5 using ETABS.

Keywords: zipper strut, chevron frame, Etabs.

I. INTRODUCTION

In the common, buckling will caused mainly due to the lateral loads acting on the structural members of the buildings. A braced frame is mainly subjected to compression load. The design procedure for bracing frames, when it is subjected to wind loads acts as tension members and the compression strength is neglected. If the design procedure of bracing is mainly depends on seismic loads then it will ask for large cyclic drifts needed to for energy dissipation, the buckling and yielding of bracings will results poor hysteretic behaviour of the bracing frame and it is normally forms a soft story mechanism, due to these disadvantages, braced frames are not considered for high seismic zones. To make these type of structures seismically strong and efficient, the buckling and yielding of bracings members must be controlled by using brace members with the low slenderness ratio. For inverted v bracings beams with large significance flexural strength are required.

The evolution of new rules for steel moment-resisting frames following the Northridge earthquake, the U.S federal emergency management agency (FEMA) adopted a performance- based seismic-resistance design approach (FEMA, 2000). The main advance in the new FEMA methodology is the misdoubt and aimless in the seismic hazard, structural response, analytical procedures and modelling, and system and member level capacities are accounted for explicitly. Based on this consistent framework, the procedure selects the confidence that the structure will maintain the specified performance level. In the case of new structure construction, accent is placed on life safety and collapse prevention. This interpretation based evaluation framework gives the comparison basis, as well as the development of new design provisions that would gives equal levels of consistant for different structural
systems, design and analysis methods, seismic causes, etc. To under take such study the seismic demands need first to be selected for various causes levels and then the structure ground motion characteristics affecting seismic demand of braced frames of braced frames are examined.

II. RELATED WORK

Acxa Kuriakose et.al., (2017) [1]: Buildings are often subjected to lateral loads like earthquake, wind etc. So it is necessary to provide additional lateral load resisting systems to them in order to ensure safety. Nowadays are prone to cause damage concentrations in single storeys resulting in ultimate collapse by soft storey mechanism. The work in this paper is the comparative study of conventional concentric X braced frame along with new systems like Zipper frame and Strong Back System. These three systems are analyzed under linear and non-linear static lateral load cases using FE software SAP2000. From the results it is clear that Strong Back system outperformed other two bracing systems.

Ali Paseban et. al., (2013) [2]: The Chevron braced frames have high hardness and resistance but show a weak buckling behavior, as the buckling of the brace in a floor brings in an unbalanced vertical force in the middle of the beam which causes the failure focus to that floor and finally destruction of the structure. For preventing this condition the zipper could be placed between the beams to connect the tip of the braces in height to transfer the produced unbalanced force to the upper floors. Such frame is called the Zipper Frame. In this investigation a comparative study has been done on the seismic behavior of Chevron and Zipper braced frames.

M. Pourbabaa et. al., (2013) [3]: In this study the Behavior of Zipper Braced Frame0 (ZBF) is investigated and compared with Concentrically Braced Frame (CBF). In order to ensure the systems behavior in a stable manner, different concentrically0 braced configuration has been studied. The analyses verify the reduction of mid-point deflections of beams in the braced system as well as improvement of ductility and response modification factor in comparison to the other concentric braces.

J. Vaseghi Amiri et. al., (2015) [4]: When structures are subjected to severe ground excitations, structural elements may be prone to yielding, and consequently experience significant levels of inelastic behavior. The effects of inelastic behavior on the distribution of peak floor loads are not explicitly accounted for in current seismic code procedures. During recent years, many studies have been conducted to develop new design procedures for different types of buildings through proposing improved design lateral load patterns. One of the most important parameters of structural damage in performance-based seismic design is to limit the extent of structural damages (maximum inter-story ductility ratio) in the system and distribute them uniformly along the height of the structures. In this paper, a practical method is developed for optimum seismic design of zipper-braced frames (ZBF) subjected to seismic excitations.

S. Naeimi et. al., (2012)[5]: Which will make an oversized displacement at the beam center span. The disparate force results in a strong beam design which is not proportionate to other members. Also, buckling of the compressive brace, results in a localization of the failure and loss of the lateral resistance. In order to overcome these effect the new type of bracing systems are adopted as zipper bracing frames and the software used for model and analysis is open sees, along with inverted v bracing is used for the study. These models were analyzed under pushover analysis to study ductility, drift and internal forces of the members were compare with each other.
Nasim Irani Sarandi et al. (2013): Inverted-V-braced frames are one type of ordinary concentrically braced frame. The behavior of this system is controlled by the buckling of the first story braces in compression, resulting in localization of failure and loss of lateral resistance. The unexpected failure of steel structures during past strong seismic excitation led to full fill adequate strength for modern structures in seismic areas. Concentrically Braced Frames (CBF) shows a concentration of damage within a single floor and tendency of strong mechanism formation. The undesired effect of the unbalanced force can be reduced by adding zipper struts which is labeled zipper frames. As a consequence, the results showed that zipper struts can improve the seismic performance of CBF system.

R. Rahimi et al. (2013): In the time of Northridge earthquake in USA in 1994, a number of variety of disaster caused in steel connections. Studying these structural disasters led to investigation or introducing new type of bracing system for seismic load resistance. This thesis investigates through numerical simulation, here zipper braced frame and suspended braced frames are considered for the study of the structures subjected to seismic loads.

III. OBJECTIVES
1. To study the behavior of structure with invert-v braced and zipper braced frames.
2. To study the lateral displacement, story drift and base shear, Story shear for the structures.
3. To study the performance point and performance level of the considered building frames using equivalent static and response spectrum method.
4. To identify the most vulnerable building among the models considered for seismic action.
5. The effect of zipper braced structure is summarized using the obtained results.

IV. METHODOLOGY
1. Steel structure is considered for the study having 5, 10 and 15 stories, each floors is considered as 3 m height.
2. The regular steel moment resisting frame of bare frame model will be taken as reference base model for 5, 10 and 15 stories.
3. With reference to base model, inverse-v brace and Zipper brace frame structure are modeled by using ETABS Software.
4. In order to get consistent results, the floor height is kept constant for all models.
5. To understand the behavior under lateral loads applied as per IS 1893: 2002 are used respectively.

V. STRUCTURAL MODELLING AND LOADING
Type of Structure – Steel Moment Resisting frame, chevron bracing, Zipper bracings.
Number of Stories – 5, 10 and 15 stories
Height of each floor - 3 m
Height of building – 15, 30 and 45 m
Building type- Office Building

Material Properties
Grade of concrete for deck  fck – M25
Grade of steel- fe -345

Material Property Design Data Section Properties
Column Sections - Built up column.
Beam Sections - ISMB 450.
Deck slab - 75 mm thick.
Bracings - ISMB 150.

Gravity and Lateral load consideration
Gravity load:
- Live load - 3 kN/m²
- Floors finish - 1.5 kN/m²
- External Glazing - 2.0 kN/m

Earthquake inputs as per IS 1893 (Part I):2002
Location of Building-Moderate intensity (Z-II) and (Z-V)
Soil type- Type II
Importance factors- 1.0
Response reduction factors – 5

List of design load combinations considered during the analysis as per 1893(Part-1):2002

<table>
<thead>
<tr>
<th>Type</th>
<th>Design Load Combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity analysis</td>
<td>1.5 (Dead Load + Live Load)</td>
</tr>
<tr>
<td>Equivalent Static Analysis</td>
<td>1.2 (Dead Load + Live Load + EQX)</td>
</tr>
<tr>
<td></td>
<td>1.2 (Dead Load + Live Load - EQX)</td>
</tr>
<tr>
<td></td>
<td>1.2 (Dead Load + Live Load + EQY)</td>
</tr>
<tr>
<td>Wind Analysis</td>
<td>1.2 (Dead Load + Live Load + WINDX)</td>
</tr>
<tr>
<td></td>
<td>1.2 (Dead Load + Live Load - WINDX)</td>
</tr>
<tr>
<td></td>
<td>1.2 (Dead Load + Live Load + WINDY)</td>
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<td>1.5 (Dead Load + WINDX)</td>
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<td>1.5 (Dead Load - WINDX)</td>
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<td></td>
<td>0.9 (Dead Load + WINDX)</td>
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<td></td>
<td>0.9(Dead Load + WINDY)</td>
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<tr>
<td></td>
<td>0.9(Dead Load - WINDY)</td>
</tr>
</tbody>
</table>
BARE FRAME STRUCTURE

INVERTED V FRAME STRUCTURE

ZIPPER BRACED FRAME STRUCTURE

3D VIEW OF STRUCTURE
VI. RESULTS AND DISCUSSIONS

In this chapter the behavior of each model is captured and the results are tabulated. The variation of systematic parameters like story lateral displacement, story drift, Storey shear, natural time period and base shear has been studied for seismic analysis. The results of all the models are observed and the most suitable model is selected by comparing the results of each model.

Story Displacement

The lateral displacements obtained for equivalent static method (EQS) and response spectrum analysis for 5, 10 and 15 storey building models of different Bracing systems for all the storey. Along both X and Y directions are listed in the tables below.
Displacement for 10 storey building in zone-5 in X direction

Displacement in mm

No of storeys

0 2 4 6 8 10 12

Displacement for 10 storey building in zone-5 in Y direction

Displacement in mm

No of storeys

0 2 4 6 8 10 12

Displacement for 15 storey building in zone-2 in X direction

Displacement in mm

No of storeys

0 10 20

Displacement for 15 storey building in zone-2 in Y direction

Displacement in mm

No of storeys

0 10 20

Displacement for 15 storey building in zone-5 in X direction

Displacement in mm

No of storeys

0 50 100

Displacement for 15 storey building in zone-5 in Y direction

Displacement in mm

No of storeys

0 20 40 60
DRIFT:
Storey drift obtained for 5, 10 and 15 storey for all building models along both X and Y directions are listed for both Equivalent static methods and response spectrum analysis as shown in the below tables.
From the comparing their values in Figure shows that displacement increases as the storey height increases. The lateral displacement depends on the storey height. In this study we can see that the 5 story buildings have less displacement compared to 10 and 15 storey buildings. From this we can say that the displacement depends on the number of stories.

The structure with bare frame gives maximum displacement value compared to inverted v bracing structure and zipper bracing structure. In equivalent static analysis and response spectrum analysis we are getting almost equal value due to the scale factor applied for the analysis.

**STOREY SHEAR:**
Storey shear for 5 storey building in zone-2 in EQY

-500 0 500

Shear value in KN

No of storeys

-500 0 500

Bare frame EQY

Bare frame RQY

Invert v braced frame EQY

Invert v braced frame RQY

Storey shear for 5 storey building in zone-5 in EQY

-2000 -1000 0 1000 2000

Shear value in KN

No of storeys

-2000 -1000 0 1000 2000

Bare frame EQY

Bare frame RQY

Invert v braced frame EQY

Invert v braced frame RQY

Storey shear for 15 storey building in zone-2 in EQX

-1000 0 1000

Shear value in KN

No of storeys

-1000 0 1000

Bare frame EQX

Bare frame RQX

Invert v braced frame EQX

Invert v braced frame RQX

Storey shear for 15 storey building in zone-5 in EQX

-4000 -2000 0 2000 4000

Shear value in KN

No of storeys

-4000 -2000 0 2000 4000

Bare frame EQX

Bare frame RQX

Invert v braced frame EQX

Invert v braced frame RQX

Storey shear for 15 storey building in zone-2 in EQY

-1000 0 1000

Shear value in KN

No of storeys

-1000 0 1000

Bare frame EQY

Bare frame RQY

Invert v braced frame EQY

Invert v braced frame EQY

Storey shear for 15 storey building in zone-5 in EQY

-4000 -2000 0 2000 4000

Shear value in KN

No of storeys

-4000 -2000 0 2000 4000

Bare frame EQY

Bare frame RQY

Invert v braced frame EQY

Invert v braced frame EQY
Generally wind load and seismic load acts on the structure in lateral direction. The storey shear is calculated for each storey and it is found from that value of storey shear attained maximum at ground storey and minimum at top storey. The values of the storey shear varies with height of building. The shear is maximum for Zone-5 compared to Zone-2 and the structure with zipper braced configuration got maximum value. From the graphs we can see that the storey shear is minimum for the bare frame structure.

**BASE SHEAR:**

It is the total amount of lateral force acting on the building at its base, which is equal to storey shear of the bottom storey.

From comparing their values indicate the variation in Base shear with respect variation in configuration of braces to the structure. The value of base shear increases with its height and configuration.

Base shear depends on the irregularity in structure, configuration and loads applied on structure. Here the zipper braced frame structure in zone-5 got more shear compared to all other models in both Equivalent and response spectrum method of analysis.
TIME PERIOD:

![Graph 1: Time period v/s modes Plot for 10 storey structure (zone-2)](image1)

![Graph 2: Time period v/s modes Plot for 10 storey structure (zone-5)](image2)

By the analysis from comparing their values in indicates the variation in Natural time period with respect to modes. Generally in ETABS software by default it will generate 12 mode shapes, among that we have to consider 3 mode shapes for analysis. Here mode-1 indicates translational motion in x direction; mode-2 is translational in Y direction. Mode-3 is rotational in Z direction.

From the results obtained in this study we can say that the bare frame structure takes maximum time to pass the considered point. Here the structure with zipper braced frame getting less time for showing the response of the structure.

VII. CONCLUSIONS

The present work is to compare structure with its behavior when it is subjected to lateral loads to due wind and earthquake. Three different Building heights are considered for the study as 5, 10 and 15 storey structures and bare frame structure is modeled and compared with adding bracing to the structures subjected to lateral loads. The various parameters is considered for the study are determining the good configuration of bracings to resist lateral loads they are lateral storey displacement, storey drift, base shear, storey shear, natural time period and storey drift. Following conclusion are given for different thickness of structures.

1. From the seismic analysis results obtained for storey displacement, it shows that we got maximum values for the bare frame structure, when we added invert v bracings there is small reduction in the displacement and for zipper bracing system we found that maximum reduction in the storey displacement.

2. From the results obtained we concluded that the steel structure with bracings can control the lateral displacement due to wind and earthquake.
3. From drift parametric study we can say that the obtained value is within the limit that is less then the value of h/250 (h=total height of the structure)

4. The drift value is maximum at the center and minimum at the top and bottom here the steel structure without bracings gives maximum drift value compared to inverted v bracing and zipper bracings.

5. From the analysis from Storey shear parametric study the shear is maximum at the base and its goes on decreases with the story height it’s depending on story weight, here the structure with zipper bracing structure gives maximum storey shear.

6. Base shear parametric study base shear is maximum for the zipper braced frame structure compared to bare frame and invert v bracing structure.

7. Time period is maximum for the 15 storey bare frame structure and minimum for the zipper frame structure in 5 storey structure.

8. From over all consideration of study we can see that the 5 story structure gives minimum results compared to 10 storey and 15 storey structure so the parameters considered for the study is depends on number of storeys.

9. In the study the zonal comparison is done for all models from zone 2 to zone 5 we can see that maximum results for zone 5 compared to zone 2 due to zone factor.

10. Here equivalent static analysis and response spectrum analysis got almost same results due to the scale factor.

11. From over all consideration zipper bracings will gives better performance for the lateral loads.

REFERENCES


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