Evaluation of the Performance of Special Eccentrically Braced Frames against Seismic Progressive Collapse under Pulse-type Near-field Earthquakes

Navid Siahpolo[1*], Seyed Abdonnabi Razavi[2], Mostafa Jalili[1]

[1]Department of Civil Engineering, Institute for Higher Education ACECR, Khouzestan, Iran
[2]Department of Civil Engineering, Abadan Branch, Islamic Azad University, Abadan, Iran

ABSTRACT

In the event of progressive seismic collapse, the entire columns are not removed and can weaken in a time-dependent manner. For example, the possibility of reducing the carrying capacity of a column is higher in the maximum acceleration of the ground. Therefore, since earthquakes have different parameters such as frequency content, maximum acceleration, effective vibration duration and other things, they can subject a structure to different effects. This is the special distinction of this phenomenon in contrast to progressive failure under gravity loads, which multiplies its importance. In this article, the ductility of simple and bending frames with special divergent bracing against progressive collapse is evaluated from a seismic point of view. The analysis used is non-linear time history analysis, according to 14 acceleration maps of the near-pulse area of FEMA P695 and non-linear static analysis, which was performed in SAP2000 software. The results showed that the maximum demand for the floor drift angle and rotation of the floor connecting beam in the two scenarios of removing the first and fourth floors for the special bending frame with special eccentrically bracing is 50% of the values of the simple frame with special eccentrically bracing. Except for the bending beam, in the scenario of removing the fourth floor, the maximum values of the floor drift angle for both frames were 0.024 radians and for the maximum rotation of the floor beam, 0.056 and 0.061 radians, respectively.

KEYWORDS

Seismic design, seismic progressive collapse, special eccentrically steel frame, near field earthquake, pulse type.

[*] Corresponding Author: Dr. Navid Siahpolo, Email: n_siahpolo@yahoo.com

1. Introduction

Those types of progressive failures that occur under the effect of earthquakes are called progressive seismic failures. Starusk has classified progressive collapse into 4 groups and 6 types [1]. He investigated the possible mechanisms of progressive collapse in structures. By carefully studying the mechanism of progressive collapse and types of collapses, it was determined that some types of progressive collapse will occur during an earthquake. This phenomenon can occur as a result of factors such as sudden rupture between the frame, the presence of short columns, twisting in the building, or weakness in design and implementation. Also, in severe earthquakes, some specific members may be damaged early and cause load redistribution and the beginning of progressive collapse [2].

The existing methods to analyze and apply the column removal mode in the progressive collapse are mostly for the gravity and explosive progressive collapse mode in which the column or member is completely removed, but in the progressive seismic failure, seismic loads and the column removal process are both dynamic identities and They are non-linear and due to an earthquake, the columns are not removed completely, and the column can be weakened depending on the time. For example, the possibility of reducing the bearing capacity of a column is higher at the maximum acceleration of the earth. Therefore, since earthquakes have non-identical components such as frequency content, the maximum acceleration, duration of effective vibration and other things can subject a structure to different effects. Therefore, in progressive seismic collapse, instead of removing the member completely, the desired column or member will be weakened [3].

Considering the major focus of researchers on the investigation of structures under progressive failure, it is necessary, considering the importance of the topic of researchers in the subject of progressive seismic collapse, to try to create a bridge between the series of previous researches in order to overlap research and gain insight. Right from the concepts and clarifying the ambiguous things, the result of these results can be provided in the form of guides and instructions and finally used for use in the industry and creating resistant structures against this phenomenon.

2. Methodology

In this article, the evaluation of the progressive collapse under earthquake was discussed with regard to the earthquake near the pulse-type area, and in that simple and special bending steel models with special divergent bracing and three types of yield behavior of the connecting beam including shear behavior, bending behavior and bending-shear behavior. They were subjected to seismic progressive collapse analysis under different modes.

To evaluate and investigate progressive seismic collapse, two-dimensional models were made with simple and bending steel frames with special eccentrically bracing. The number of floors is 8 and the height is 3.3 meters. The number of openings of the frame is 4 openings in length of 5 and 8 meters, which have eccentrically bracing in the side openings of the frame. The bracing connection in both bending and simple frames is hinged, and the support conditions for connecting the column to the foundation are considered in the hinged bending frame and the hinged simple frame.

3. Examining the responses with a 5-meter span under nonlinear time history analysis

In order to evaluate the progressive seismic damage of the models under 14 accelerometers of the near-pulse area, nonlinear time history analysis was performed, then the average values were obtained to extract the graphs. In the following, the results of the nonlinear time history analysis in progressive seismic collapse are examined and compared.

In the process of removing the column and bracing in the first floor, although the frames with bending connection experience a lower amount than the connections with shear and shear-bending performance in terms of the distribution of the relative lateral displacement angle in the floors; But the links with shearing behavior have a uniform distribution and the values of relative lateral displacement angle in special bending frames with shear link beams in the first and fourth floor removal cases are 0.017 and 0.014 radians, respectively, from the maximum value of the lateral displacement angle. The allowed ratio of 0.02 does not exceed the 2800 standard.

The absolute displacement demand of the floors in Figure 1 shows that in the case of removing the first floor for both simple and special bending frames, the frames with shear-bending beams have the highest absolute displacement demand equal to 0.548 and 0.456 meters, respectively. and the frames with bending links with the maximum values of absolute displacement demand of 0.409 and 0.362 meters have the lowest values relative to the other two link beams.

In the case of removal on the fourth floor, the special bending frame with shear beam, with the maximum value of absolute displacement demand equal to 0.262 meters, has the lowest value in the roof height, and the simple frame with bending beam with the value of 0.362 meters has the lowest displacement. It has a roof.

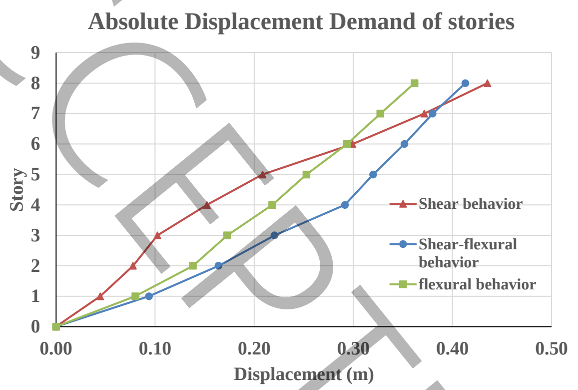

Figure 1: Demand for changing the absolute displacement with special eccentrically bracing

In this article, after investigating the progressive damage due to the earthquake in the area near the fault in steel structures with divergent bracing, it has been tried to show that when the initial failure caused by an earthquake occurs in a member of a steel structure with special eccentrically bracing, what is the structure like? It will show a performance and what is the effect of increasing the span length on the behavior of steel frames with special eccentrically brace under progressive seismic failure affected by the earthquake near the pulse-type fault. Although in terms of the distribution of the angle of relative lateral displacement in the floors, the special bending frame with special divergent bracing and the bending beam experiences lower values, but the shear beam has a better uniform distribution and the maximum demand of the angle of relative lateral displacement of the shear beam is in The 5-meter opening was 0.017 and 0.014 radians for the removal mode in the first and fourth floors, respectively, which does not exceed the permissible limits of the relative lateral displacement angle of 0.02 radians. While the maximum values in the bending beam are equal to 0.02 and 0.024 radians, and for the shear-bending beam are equal to 0.021 and 0.016 radians. The minimum and maximum demand of the relative lateral displacement angle of the simple frame is experienced by the shear and shear-bending beam of 0.028 radians, which occurs in the case of removing the fourth floor column and brace.

In this way, the evaluation of steel frames with special eccentrically bracing under the progressive seismic collapse affected by the earthquake in the area near Pulse showed that the special bending frame with special bracing in terms of floor displacement demand, connection beam rotation and permanent floor displacement is much better than the frame. It is simple and dynamic instability was observed in the simple frame with special eccentrically bracing. Also, in the investigation and effect of the length of the connecting beam in the evaluation of the progressive seismic damage caused by the earthquake in the area near the pulse type, it was found that in the special bending frame with special eccentrically bracing, the best performance of the connecting beam is related to the connecting beam with shear performance, shear- It is bending and finally bending. In simple terms, due to the instability of the demands, it had exceeded the permissible limits of the regulation.

4. References

[1] U. Starossek, Progressive collapse of structures, Thomas Telford London, 2009.
[2] Y. Tian, K. Lin, L. Zhang, X. Lu, H. Xue, Novel seismic–progressive collapse resilient super-tall building system, Journal of Building Engineering, 41 (2021) 102790.
[3] S. Karimiyan, Collapse distribution scenario in seismic progressive collapse of RC buildings caused by internal column elimination, Iranian Journal of Science and Technology, Transactions of Civil Engineering, 44 (2020) 241-252.