IJE TRANSACTIONS B: Applications Vol. 26, No. 2, (February 2013) 143-152

International Journal of Engineering

Journal Homepage: www.ije.ir

The Effect of Local Damage on Energy Absorption of Steel Frame Buildings During Earthquake

N. Parsaeifard[*], F. Nateghi-A

International Institute of Earthquake Engineering and Seismology, Tehran, Iran

PAPER INFO

Paper history:
Received 24 July 2012
Accepted in revised form 18 October 2012

Keywords:
Seismic Progressive Collapse
Failure Pattern
Nonlinear Dynamic Analysis
Steel Structure

ABSTRACT

Progressive collapse is a kind of failure in which whole or large part of a structure collapses when a local damage occurs and distributes to other parts. Earthquake inspections indicate that structural element can be damaged during earthquakes and this initial damage distributes to the other parts, so seismic progressive collapse is proposed as a research issue. As the earthquake induced progressive collapse could occur in any building independent of the number of stories, in this work, seismic progressive collapse of a one-story steel building was investigated. The effect of variation in the number and length of spans in both directions was also studied. Based on the obtained results, by decreasing the spans length and number in the direction of lateral loading compared with its perpendicular direction, the behavior of the structure becomes more critical. Furthermore, failure pattern of the structure under seismic progressive collapse was investigated. The results showed that collapse pattern is in a way that the damaged frame as well as the nearby frames has the most participation in supporting lateral deformations, and by distancing away from the damaged frame, deformation of the frames decreases. At the end, non-linear dynamic column removal analysis was carried out and the obtained results showed differences between the behavior of the structure under seismic progressive collapse and sudden column removal analyses.

doi: *10.5829/idosi.ije.2013.26.02b.05*

1. INTRODUCTION

Progressive collapse is defined as the spread of an initial local damage from element to element eventually causing in the collapse of whole or large part of a structure. Initial damage can occur due to various events such as vehicle impact, blast and fire. Many researchers focus on the column removal analysis and study of the structure behavior under gravity loads. In all cases, after removing the damaged element, behavior of the structure is investigated under the effects of gravity loads. Sasani and Saghiroglu [1] investigated progressive collapse resistance of a six-story reinforced concrete structure after removal of two adjacent exterior columns. Then the structure behavior was evaluated. Marjanishvili and Agnew [2] analyzed a nine-story steel moment resistant frame building using various analytical procedures and the findings showed that the nonlinear dynamic analysis method gives more accurate results. In addition, it is also easy to carry out to investigate the progressive collapse potential of structures. Kim and Kim [3] investigated the progressive collapse potential of steel moment frames using alternate path methods. Both linear static and nonlinear dynamic analysis procedures were used for comparison. It was shown that the nonlinear dynamic analysis provides larger structural responses, and variables such as applied load, location of column removal or number of building story affect the results.

Kim and Park [4] evaluated the progressive collapse potential of two special moment resisting frames by two analysis procedures: nonlinear static and nonlinear dynamic. The results indicated that the structures, which are designed only for normal loads, have higher progressive collapse potential whereas the structures designed by plastic designed concept satisfy the GSA [5] guideline acceptance criteria. Kim et al. [6] evaluated the sensitivity of design variables of steel buildings subjected to progressive collapse. The results showed that beam yield strength is the most significant design parameter in the dual system buildings.

Fu [7] built a 3-D model to analyze the progressive collapse of a twenty-story building and the finite element model represented the global 3-D behavior of

---

[*]Corresponding Author Email: n.parsaei@iiees.ac.ir (N. Parsaeifard)

the building under sudden column removal. The effect of variation in the strength of structural steel, concrete and reinforcement mesh size on the structure behavior was also investigated. Kwasniewski [8] evaluated the progressive collapse potential of a steel frame structure subjected to column removal scenario using nonlinear dynamic finite element model based on the GSA guidelines and, finally, the modeling parameters affecting the results were identified. Khandelwal et al. [9] assessed the progressive collapse resistance of seismically designed steel braced frames. Two systems were considered to analyze: special concentrically braced frames and eccentrically braced frames. The capability of structure to absorb member loss was studied by removing critical columns and adjacent braces. Asteneh et al. [10] investigated the strength of a typical steel structure to resist progressive collapse subjected to column removal via analytical and experimental studies. The tests indicated that after removal of the middle perimeter column, due to catenary action of steel deck and girders, the design loads of the floor could be resisted and the floor was not expected to collapse in the event of removal of the column. Also, the effect of steel catenary cables in enhancing the strength of steel structure subjected to progressive collapse was investigated [11]. The results indicated that catenary cables enhance the steel structure behavior in the case of column removal.

In some cases, failure occurs in one or more structural elements during a quake [12]. In such cases, the failed element load is redistributed by the neighboring elements; then the structure behavior is totally different from what was expected [13]. Although, many researches have been done on the behavior of structures under seismic loads [14, 15], little attention has been paid to seismic progressive collapse. Since this kind of collapse can occur in any structure with any story numbers [16], in this research, one-story building behavior under seismic progressive collapse was investigated. It is noticeable that the findings of this research are related to one-story steel building, and investigation of seismic progressive collapse of tall buildings is proposed as future research issue.

Not all buildings collapse just due to progressive collapse during a quake; rather such a collapse occurs mainly due to local deficiency in a part of the structure. In this research, in order to investigate the behavior of the structure under seismic progressive collapse, a local damage was created in a part of the structure by weakening a column intentionally. Therefore, the initial damage was navigated toward a part of the structure. After applying the gravity loads, the lateral loads were applied to the model to evaluate the structure behavior under seismic progressive collapse. Then in order to identify the effect of variation in the length and number of spans in both directions, different models were studied using nonlinear static analysis. Finally, failure pattern of the structure under seismic progressive collapse was obtained. Although progressive collapse due to sudden column removal mostly occurs in tall buildings, sudden column removal analysis was also carried out just to compare the structure behavior under seismic progressive collapse and progressive collapse under gravity loads.

The first model of this study is a one-story steel structure, with the height of 3 meters, and has 4 spans each 5 meters in both directions. The structure is located at a zone with high earthquake risk, and special moment resisting system was used as lateral load resisting system. All beams and columns were made of box profiles. Table 1 shows the properties of materials used in the model. Elements with linear behavior were used to model the columns and beams, and deformation-controlled frame hinge properties, representing only the plastic behavior of the elements, were used to define the non-linear behavior of the elements. The elastic behavior of the frame elements was determined by the material properties of the element sections assigned to them. The behavior of the hinges was defined based on FEMA 356 [17] provisions.

TABLE 1. Properties of Material Used in the Models.

Material	Modules of Elasticity [Gpa]	Yielding Stress Mpa]	Ultimate Stress [Mpa]
Steel	200	250	407.7

2. 3-D FINITE ELEMENT MODEL

Analytical study was carried out in two parts: First, seismic progressive collapse of the steel building was studied. Then the structure behavior under sudden column removal was investigated.

2. 1. Seismic Progressive Collapse In order to navigate the initial damage toward a part of the structure, one of the columns was intentionally designed weaker than required. The live load and dead load (including the weight of elements) were assumed to be 150kgf/m^2 and 550kgf/m^2, respectively and distributed uniformly on the beams.

GSA progressive collapse guidelines apply the following load combination while evaluating progressive collapse potential of the structures:

$$w = (DL + 0.25LL) \quad (1)$$

where, DL and LL are the dead and live loads, respectively. The load combination, recommended by GSA, was applied. Then the push-over analysis was performed to simulate the behavior of the structure under seismic progressive collapse. The assumptions such as rigid diaphragm and rigid connections were included in the model. To investigate the critical column position under seismic progressive collapse, the structure was analyzed three times: At the first analysis, the structure had no weakened column; in the second one, it had one weakened corner column, and in the third analysis, one of the external columns beside the corner column was weakened. The position of the corner and external columns is shown in Figure 1.

Since whole plastic hinge rotations show the amount of energy absorbed by the structure due to strains and deformations [18], sum of plastic hinge rotations of the frames during the mentioned three analyses was obtained. To have better judgment about the mentioned analyses results, energy absorption diagrams of the corresponding frames in all the three analyses are shown in one figure (Figure 2).

In the first analysis, energy absorption had the same value in the corresponding frames. Non-linear behavior was triggered from the interval frames, which had more participation in supporting the gravity loads, and was distributed uniformly to the other parts of the structure. However, in the second and third analyses, energy absorption of the damaged frame had more value in comparison with that in the first analysis. By getting far away from the damaged frame, sum of plastic hinges rotations of the frames decreases. Graphs acquired from the third analysis showed that the damaged frame and the one beside it had the most participation in supporting the lateral deformations. That is because that, by weakening of the external column, two beams located above the weakened column lose their performance in supporting the lateral loads; whereas in the second analysis, by weakening of the corner column, only one beam, located just above the weakened corner column, does not participate in supporting the lateral loads. Hence , the results of the third analysis are the sign of more critical behavior when the structure is subjected to lateral loading. Lateral displacement of different frames obtained from the third analysis is also plotted at various loading steps in Figure 3. As indicated, the damaged frame has the most lateral displacement, and by distancing away from it, displacements of frames decease. This can be due to displacement of the stiffness center that leads the structure rotate around an axis far from the damaged column and causes the most lateral displacement at the damaged frame.

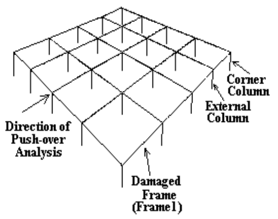
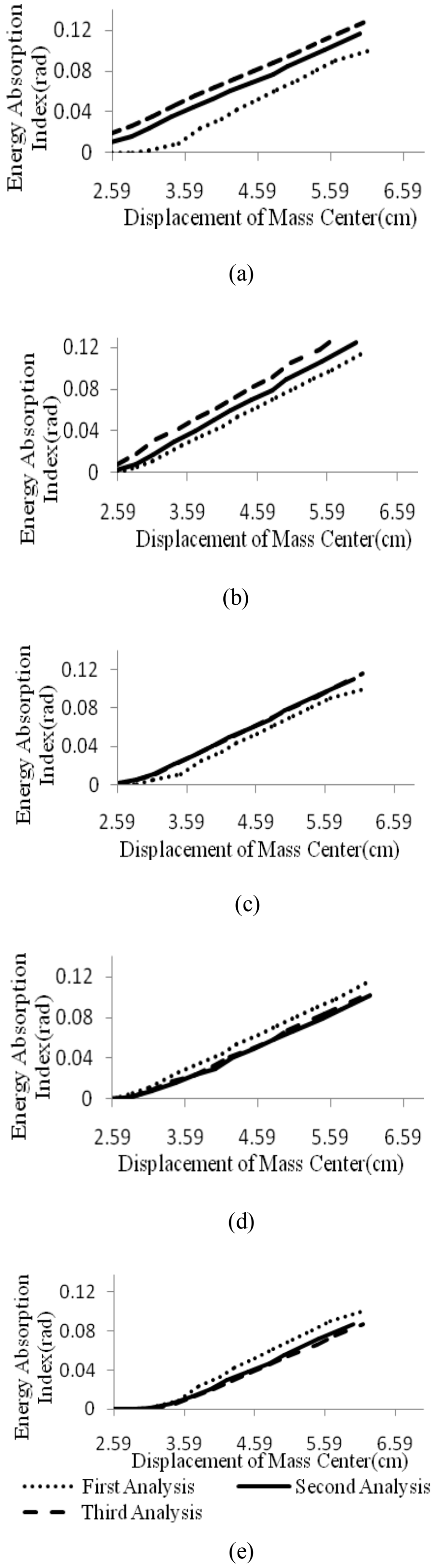


Figure 1. 3-D model of the first structure and weakened column positions of the second and third analyses.



(a)

(b)

(c)

(d)

(e)

Figure 2. Energy absorption indices of three models, (a) Frame 1, (b) Frame 2, (c) Frame 3, (d) Frame 4 and (e) Frame 5.

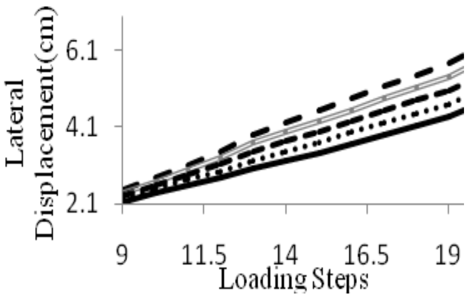


Figure 3. Lateral displacements of the frames (Third analysis)

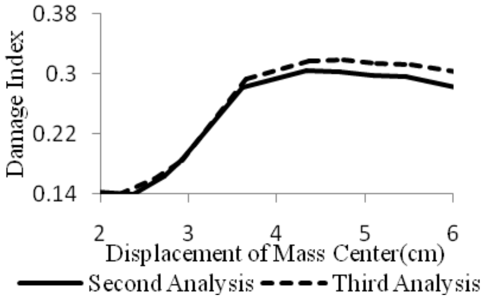


Figure 4. Damage indices of the second and third analyses.

Based on the results of three analyses, it can be concluded that torsion is an important parameter in determining the structure behavior. So to evaluate the behavior of structures, a damage index (DI) was introduced that includes torsion effects.

$$DI = (\Delta_f - \Delta_e)/\Delta_{mc} \qquad (2)$$

where, Δ_f, Δ_e and Δ_{mc} are lateral displacement of the damaged frame, lateral displacement of the frame located at the farthest position to the damaged frame and lateral displacement of mass center, respectively. By calculating the damage index at various steps of analysis and plotting this parameter versus the displacement of mass center, the diagram presented in Figure 4 is obtained. As Figure 4 shows, the damage index obtained from the third analysis has more value than that of the second analysis because the structure behaves more critically.

Then the effect of variation in length and number of spans in two directions of structure was studied. To this end, several models with different spans length and number were considered. Table 2 represents the specification of models. In all models, one of the external columns, which is located in the frame 1 (see Figure 1), has been weakened.

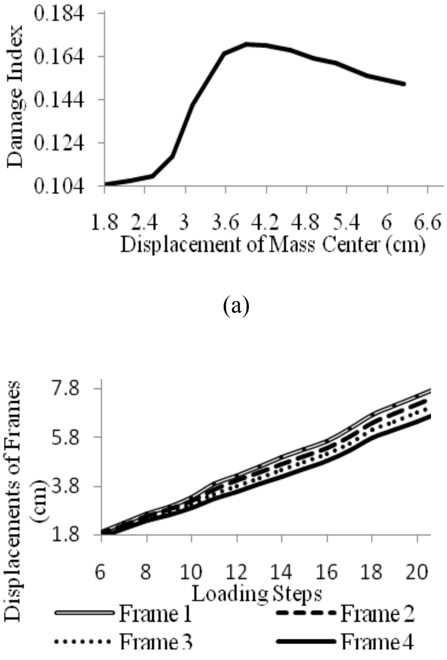
TABLE 2. Specifications of Models with Different Ny/Nx and Ly/Lx values.

Model Number	Number of Spans in Y Direction (N_y)	Number of Spans in X Direction (N_x)	Spans Length in Y Direction (L_y)	Spans Length in X Direction (L_x)	N_y/N_x	L_y/L_x
1	3	5	5.164	5.164	0.6	1
2	4	5	4.472	4.472	0.8	1
3	4	3	5.773	5.773	0.75	1
4	2	5	6.32	6.32	0.4	1
5	3	6	4.71	4.71	0.5	1
6	2	6	5.77	5.77	0.33	1
7	5	3	5.164	5.164	1.67	1
8	5	4	4.472	4.472	1.25	1
9	3	4	5.773	5.773	1.33	1
10	5	2	6.324	6.324	2.5	1
11	6	3	4.71	4.71	2	1
12	6	2	5.773	5.773	3	1
13	4	4	5	5	1	1
14	4	4	6.25	4	1	1.56
15	4	4	4	6.25	1	0.64
16	4	4	5.95	4.2	1	1.42
17	4	4	4.2	5.95	1	0.7
18	4	4	4.5	5.55	1	0.81
19	4	4	5.55	4.5	1	1.23
20	4	4	5.21	4.8	1	1.08
21	4	4	4.8	5.21	1	0.92

After push-over analysis, the results obtained from the models were compared with each other. Models No. 1 - 13 were analyzed to investigate the effect of variation in the spans number. For example, the damage index of Model No.1 at different loading steps and the lateral displacement of different frames are shown in Figure 5.

Figure 6 compares the damage index of Models No 1 and 13. It can be seen that the damage index of Model No. 1 has more values than that of Model No. 13. So it seems that by raising Ny/Nx value, the structure's behavior becomes more critical.

The graphs obtained from the analysis of all 13 models are shown in Figure 7. Based on the equation of regression, by increasing of Ny/Nx value, the damage index in all models increases.



(a)

(b)

Figure 5. (a) Damage index and (b) Lateral displacements of the frames of Model No.1.

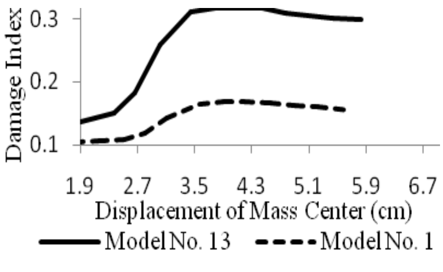


Figure 6. Damage indices of Models No. 1 and 13

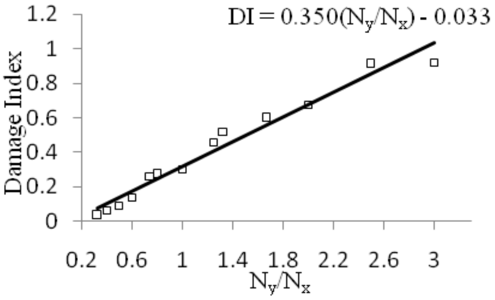


Figure 7. Damage index versus N_y/N_x value of different models

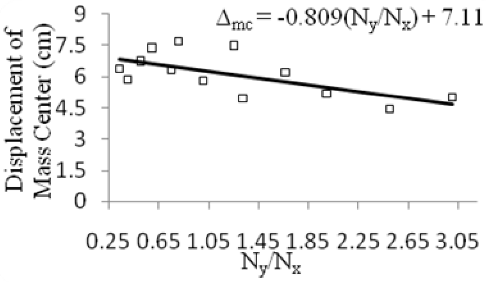


Figure 8. Lateral displacement of mass center versus N_y/N_x value in different models.

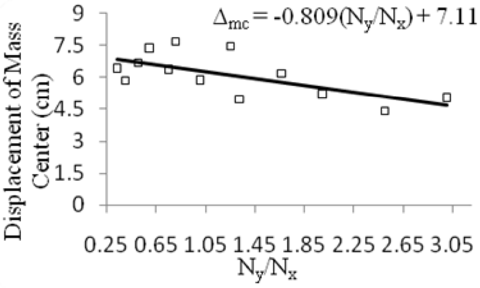


Figure 9. Damage index versus the lateral displacement of mass center at the final step of analyses.

Displacement of mass center at the final step of analysis (the step in which the first plastic hinge reaches the strength reduction) is also plotted versus Ny/Nx (see Figure 8). As shown, by increasing of Ny/Nx value, mass center of all models gains less lateral displacement at the final step of analysis, so the structure can support less lateral displacement before strength reduction.

Figure 9 indicates the graph in which the damage index versus the displacement of mass center at the final step of analysis is plotted.

The acquired equation indicates that by decreasing of the displacement of mass center at the final step of analysis, the damage index of all models increases, so the models behave more critically. In other words, if the structure undergoes more lateral displacement before strength reduction, the value of damage index will decrease and the structure will have better behavior against seismic progressive collapse.

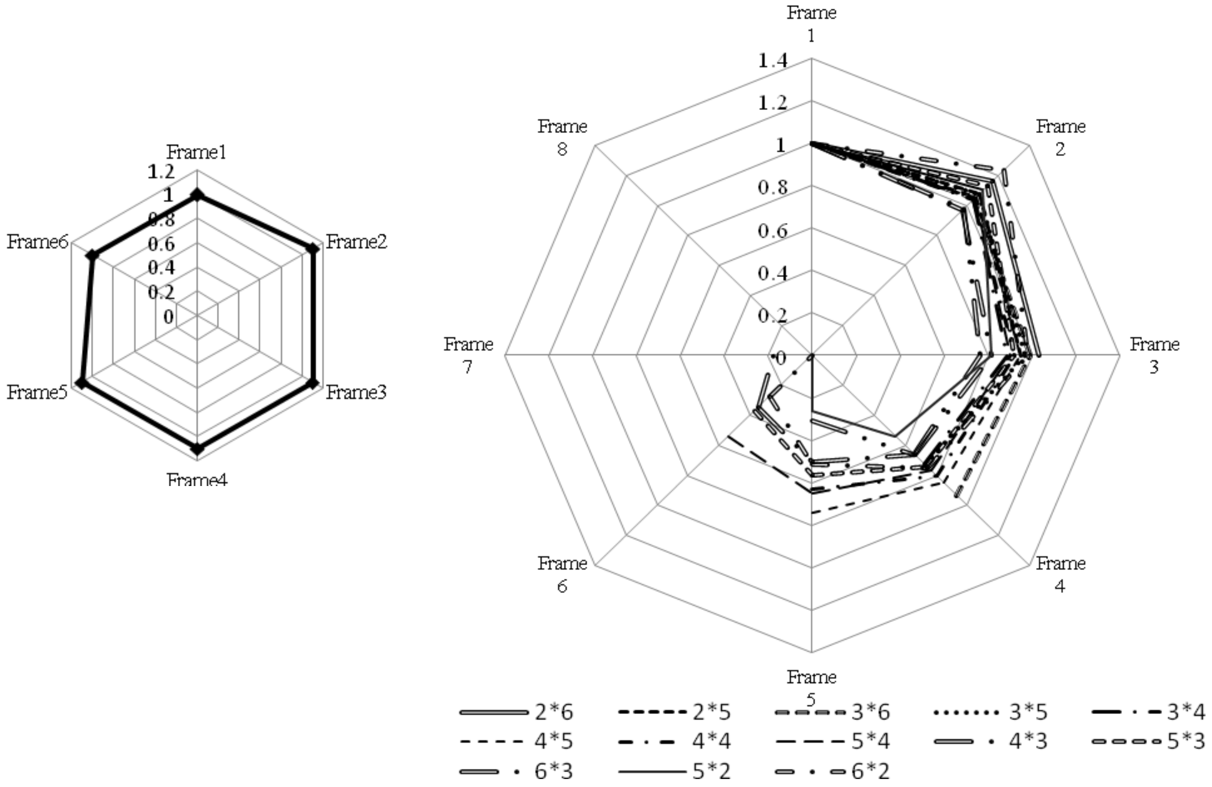
To obtain the failure pattern of the models, energy absorption levels at different frames were considered. At an undamaged model (including no weakened column), hinges rotation of the corresponding frames has approximately the same value as shown for Model No. 8 in Figure 10 (a).

Figure 10 (b) indicates the energy absorption parameter in different frames of Models No. 1 - 13. In all models, energy absorption value of different frames has been normalized to the value of the damaged frame (frame 1). In Models No. 1 - 13, the energy absorption of the damaged frame has more value and by getting away from the damaged frame, the amount of energy absorption decreases. Therefore, the damaged frame and the neighboring frames have more participation in the undergoing lateral deformations, whereas farther frames have less participation. In the models with much N_y/N_x value, participation of the frames far from the damaged frame in supporting lateral displacement equals almost zero. So collapse pattern is in a way that the deformation of the damaged frame as well as the nearby ones increases by enhancing of the N_y/N_x value, and by distancing away from the damaged frame, deformation of the frames is decreased.

To evaluate the effect of L_y/L_x variation, Models No. 13 - 21 were analyzed. Damage index and displacement of frames were obtained for all models. By plotting the damage index versus L_y/L_x for different models, the below graph was obtained (see Figure 11).

According to the graph, increasing of the L_y/L_x value leads to the raise of the value of damage index in all models, so the models have more critical behavior. Also the obtained equations in Figures 7 and 11, show that variation in L_y/L_x value is more effective on the structure behavior than the variation in N_y/N_x value.

Figure 12 also indicates the displacement of mass center at the final step of analysis for different values of L_y/L_x. The graph shows reduction in displacement of mass center by increasing of the L_y/L_x value. In other words, increasing of the L_y/L_x value leads to the onset of lateral strength reduction at less displacement of mass center. So the structure can undergo less lateral displacement before strength reduction and thus show more critical behavior.



(a) (b)

Figure 10. (a) Energy absorption index of different frames of model no. 8 with no weakened column and (b) Failure pattern of the structures with different N_y/N_x values

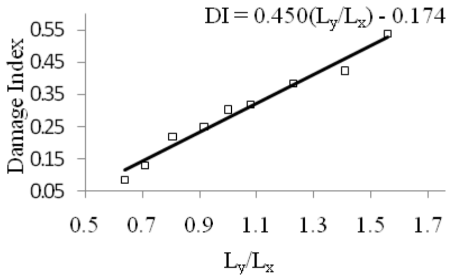


Figure 11. Damage index versus L_y/L_x in different models.

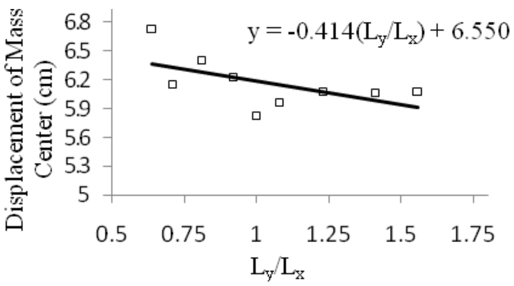


Figure 12. Lateral displacement of mass center versus L_y/L_x in different models.

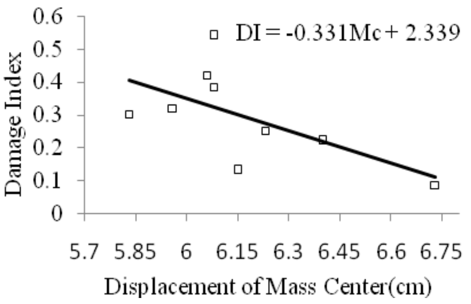


Figure 13. Damage index versus lateral displacement of mass center at the final step of analyses.

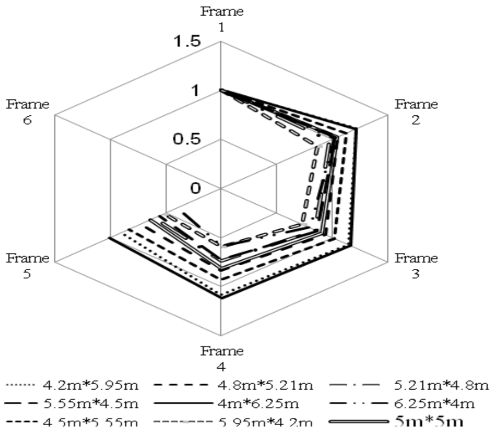


Figure 14. Failure pattern of structures with different L_y/L_x values.

Damage index versus L_y/L_x is also plotted in Figure 13. Based on the equation of regression, if the first plastic hinge reaches strength reduction at more lateral displacement of mass center, the damage index will have less value. It means that if the structure supports more lateral displacement before the first plastic hinge reaches the strength reduction, damage index will decrease, so the structure will have better behavior against seismic progressive collapse.

Figure 14 indicates the energy absorption index in different frames of Models No. 13 - 21. In all models, energy absorption values of different frames were normalized to the value related to the damaged one (frame 1).

As the graphs indicate, frame 1 and the frames beside it have maximum energy absorption and have the most participation in supporting the lateral deformation. However, by getting away, energy absorption of the distant frames decreases and in the models with large value of L_y/L_x, it equals almost zero.

2. 2. Behavior under Column Removal without Lateral Loading

At the second part of the research, structure behavior subjected to sudden column removal without lateral loading was investigated. In this part, the models have no weakened column. Instead, a column was removed. The assumptions such as rigid diaphragm and rigid connections were included in the model.

Similar to the previous part, the static load combination, recommended by GSA, was applied to Model No. 13. A corner or external column was removed in two separate scenarios (see Figure 1). To simulate sudden column removal, after applying the GSA load combination, the forces equal to the member forces of the failed column were applied to the node connecting to the failed column so that static deformations were obtained. At a time step of 0.01sec, the applied forces (P, V and M) were removed to simulate column removal. The amplitudes of applied loads are presented in Figure 15. For non-linear dynamic analysis, bilinear material model was used and the post-yield stiffness of the material was assumed to be 3% of the initial stiffness. As the sudden column removal analysis does not contain load reversal, to use hysteretic model was not necessary [3].

Based on the results of analyses, vertical displacements of the joints connected to the removed column were obtained at both column removal scenarios (see Figure 16).

According to the acquired graphs, the joint above the removed column, has more displacement in the corner column removal scenario, because catenary action capacity of the beams above the removed external column causes less vertical displacement of beams, whereas the beams above the removed corner column support the loads of removed column just by their flexural action. So the corner column removal causes the structure behaves more critically and this is compatible with the findings of Pretlove et al. [19].

To investigate the effect of variation in N_y/N_x on the vertical displacement of the joint connected to the removed column, nonlinear dynamic analysis was carried out on Models No. 1 - 13 (The models have no weakened column). In all models, an external column was removed, and the position of the removed external column is shown in Figure 1. The vertical displacement time history of the joint above the removed column was obtained, and the results indicated that there is no regular relation between maximum vertical displacement and N_y/N_x value. The results are affected only by increasing the load bearing area of the removed column that leads to increment of maximum vertical displacement.

At the last step of the research, an external column of Models No.13 - 21, which have no weakened column, was removed and vertical displacement of the joint above the removed column was studied. The relevant graphs are plotted in Figure 17. For avoiding confusion, Figure 17 has been divided into Figures 17 (a) and 17 (b) and the results are shown after the 4th second. The maximum vertical displacements versus Ly/Lx value are also plotted in Figure 18. According to the regression presented in Figure 18, by decreasing of L_y/L_x value, vertical displacement is increased, which can be due to increase in the length of the beam located above the removed column. This result is different with that is obtained from investigating the effect of variation in L_y/L_x on the structure behavior under seismic progressive collapse.

3. RESULTS AND DISCUSSION

Progressive collapse studies are mostly threat-independent researches that do not consider the type of triggering event. Structure behavior is evaluated by removing load-carrying members and investigating alternative load paths to carry the loads of the removed element. In this research, lateral loading was applied to the structure which had a weakened column to simulate seismic progressive collapse. With regard to the different results obtained from seismic progressive collapse and sudden column removal analyses, the importance of considering lateral loading as the triggering event becomes more obvious.

Here, seismic progressive collapse of one-story steel buildings was investigated and failure pattern of the structure was obtained. A column in the different position was weakened and the critical column position was evaluated. As indicated before, the number of the beams, which lose the flexural performance during the lateral loading on the structure, has important role in determining the position of critical column.

The effect of variation in spans number and length on seismic progressive behavior was also studied. Based on the results obtained, increasing in N_y/N_x and L_y/L_x values caused more rotation in the structure around an axis far from the damaged column.

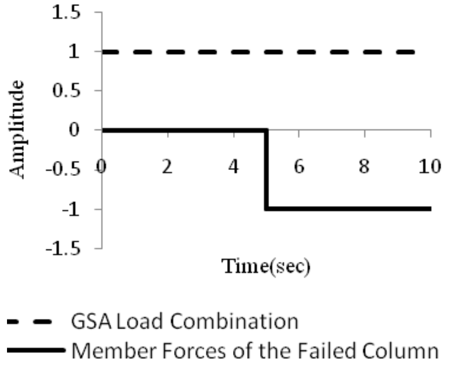


Figure 15. Amplitude of the applied loads during the non-linear dynamic analyses.

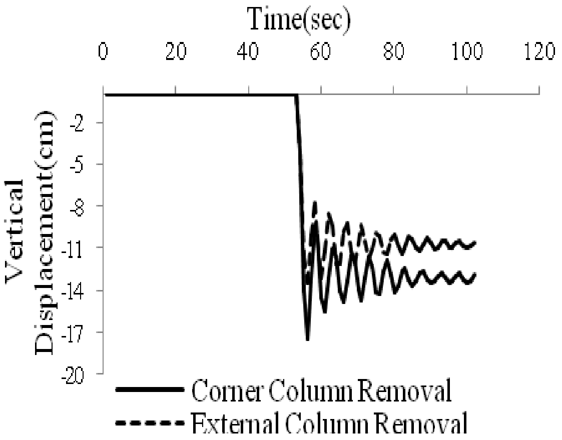
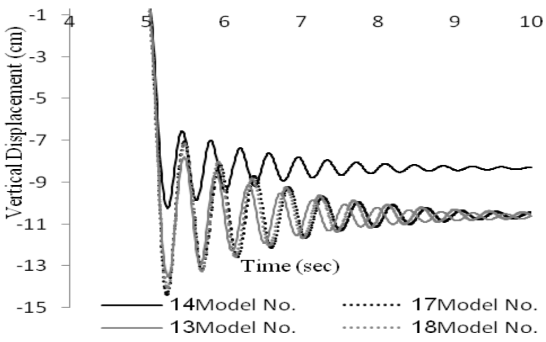
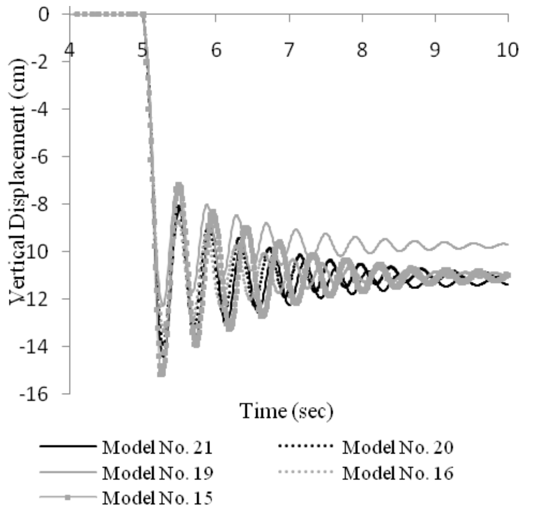


Figure 16. Vertical displacements of the joints just above the removed columns at two different scenarios.



(a)



(b)

Figure 17. Vertical displacements of the joints above the removed columns of (a) Models No. 13, 14, 17 and 18, and (b) Models No. 15, 16, 19, 20 and 21.

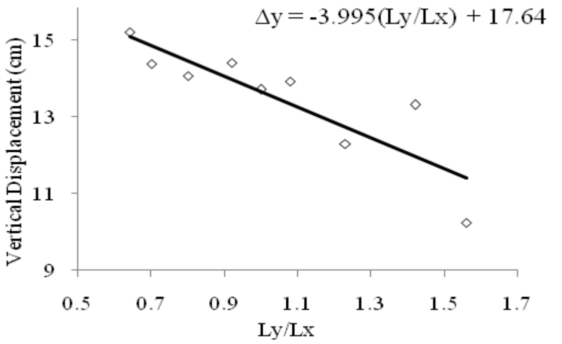


Figure 18. The effect of variation in Ly/Lx value on maximum vertical displacement.

4. CONCLUSIONS

Most important findings of the present research are as follows:

1. Weakening of an external column in the presented position causes more critical behavior of the structure under seismic progressive collapse rather than the weakness of the corner column.
2. Increasing the values of N_y/N_x and L_y/L_x causes more rotation and more critical behavior in the structure, so the damaged frame and nearby ones will have most participation in supporting the lateral loads.
3. If the structure can support more lateral displacement before the strength reduction, it will have better performance against seismic progressive collapse.
4. In the case of seismic progressive collapse, failure starts from the damaged frame and nearby ones, and is distributed to other parts of the structure. Therefore, failure is concentrated to the damaged frame and neighboring frames and has no uniform distribution in the structure.
5. The investigation of the position of critical column and the effect of variation in N_y/N_x and L_y/L_x gave different results against the sudden column removal analysis and seismic progressive collapse evaluation. So the lateral loads should be considered when studying the seismic progressive collapse of structure and the studies could not be carried out as a treat-independent progressive collapse analysis.

5. REFERENCES

1. Sasani, M., and Sagiroglu, S., "Progressive collapse resistance of hotel San Diego", ***Journal of Structural Engineering***, ***ASCE***, Vol. 134, No. 3, (2008), 478-488.
2. Marjanishvili, S. and Agnew, E., "Comparison of various procedures for progressive collapse analysis", ***Journal of Performance of Constructed Facilities***, ***ASCE***, Vol. 20, No. 4, (2006), 365-374.
3. Kim, J. and Kim, T., "Assessment of progressive collapse-resisting capacity of steel moment frames", ***Journal of Constructional Steel Research***, Vol. 65, (2009), 169–179
4. Kim, J. and Park, J., "Design of steel moment frames considering progressive collapse", ***Steel and Composite Structures***, Vol. 8, No. 1, (2008), 85-98.
5. GSA, Progressive collapse analysis and design guidelines for new federal office buildings and major modernization project, The U.S. General Services Administration, (2003).
6. Kim, J., Park J. and Lee T., "Sensitivity analysis of steel building subjected to column loss", ***Journal of Engineering Structures***, Vol. 33, (2011), 421-432.
7. Fu, F., "3-D nonlinear dynamic progressive collapse analysis of multi-storey steel composite frame building-parametric study", ***Journal of Engineering Structures***, Vol. 32, (2010), 3974-3980.
8. Kwasniewski, L., "Nonlinear dynamic simulation of progressive collapse for a multistory building", ***Journal of Engineering Structures***, Vol. 32, (2010), 1223-1235.
9. Kandelwal, K., El-Tawil, S. and Sadek, F., "Progressive collapse analysis of seismically designed steel braced frames", ***Journal of Constructional Steel Research***, Vol. 65, (2009), 699-708.
10. Astaneh-Asl, A., Jones, B., Zhao, Y. and Hwa, R. "Progressive collapse resistance of steel building floors", Report No.: UCB/CEE-STEEL-2001/03.
11. Astaneh-Asl, A., Madsen, E. A., Noble, C., Jung, R., McCallen, D. B., Hoehler, M. S., Li, W. and Hwa, R., "Use of catenary cables to prevent progressive collapse of buildings", Report No.: UCB/CEE-STEEL-2001/02.
12. Wibowo, H. and Lau, D. T., "Seismic progressive collapse: qualitative point of view", ***Civil Engineering Dimension***, Vol. 11, No. 1, (2009), 8-14.
13. Pekau, O. A., and Cui, Y., "Progressive collapse simulation of precast panel shear walls during earthquakes", ***Journal of Computers and Structures.*** Vol. 84, (2006), 400-412.

14. Ghodrati Amiri, G. and Hamidi Jamnani, H., "The effect of analysis methods on the response of steel dual-system frame buildings for seismic retrofitting", ***International Journal of Engineering***, Vol. 22, No. 4, (2009), 317-331.

15. Rezaiee-Pajand, M., Bambaeechee, M. and Sarafrazi, S. R., "Static and dynamic nonlinear analysis of semi-rigid steel frames with new beam-column element", ***International Journal of Engineering***, Vol. 24, No. 3, (2011), 203-221.

16. Parsaeifard, N. and Nateghi Allahi, F., "Analytical study of seismic progressive collapse in a steel moment frame building", ***Advanced Materials Research***, Vol. 446-449, (2012), 102-108.

17. FEMA 356, “Pre-standard and commentary for the seismic rehabilitation of buildings”, Federal Emergency Management Agency, Washington, D. C. D. T., (2006).

18. Ruth, P., Marchand, K. A. Eric, B., and Williamson, E. B., "Static equivalency in progressive collapse alternate path analysis: reducing conservatism while retaining structural integrity", ***Journal of Performance of Constructed Facilities, ASCE***, (2006), 349-364.

19. Pretlove, A. J., Ramsden, M. and Atkins, A. G., "Dynamic effects in progressive failure of structures", ***International Journal of Impact Engineering***, Vol. 11, No. 4, (1991), 539-546.

The Effect of Local Damage on Energy Absorption of Steel Frame Buildings During Earthquake

N. Parsaeifard, F. Nateghi-A

International Institute of Earthquake Engineering and Seismology, Tehran, Iran

PAPER INFO

Paper history:
Received 24 July 2012
Accepted in revised form 18 October 2012

Keywords:
Seismic Progressive Collapse
Failure Pattern
Nonlinear Dynamic Analysis
Steel Structure

چکیده

تخریب پیش رونده نوعی از خرابی است که در آن بخشی از سازه دچار فروریزش شده و این فروریزش در کل سازه و یا بخش بزرگی از آن توزیع می‌شود. از آن‌جاکه خرابی پیش‌رونده‌ی لرزه‌ای می تواند در هرسازه‌ای مستقل از تعداد طبقات رخ دهد، در تحقیق حاضر به مطالعه‌ی رفتار ساختمان فولادی یک طبقه در برابر خرابی پیش‌رونده‌ی ناشی از بارهای لرزه‌ای پرداخته شده است. همچنین، تاثیر نسبت تعداد و طول دهانه‌ها در دو راستای سازه بر روی رفتار آن ارزیابی شده و الگوی خرابی سازه تحت اثر خرابی پیش‌رونده ناشی از اثر توام بارهای ثقلی و لرزه‌ای استخراج شده است. بر اساس نتایج به دست آمده، با کاهش نسبت طول و تعداد دهانه‌ها در راستای اعمال بار جانبی بر مقدار متناظر در راستای دیگر، سهم قاب آسیب دیده و قاب‌های مجاور آن در تحمل تغییرشکل‌های جانبی افزایش پیدا می‌کند. در انتها جهت مقایسه رفتار سازه در برابر خرابی پیش رونده ناشی از بارهای ثقلی و ترکیب اثر بارهای ثقلی و لرزه‌ای، تحلیل دینامیکی غیرخطی حذف ستون نیز انجام شد. نتایج به دست آمده حاکی از تفاوت رفتار سازه تحت اثر دو نوع خرابی پیش رونده است.

doi: *10.5829/idosi.ije.2013.26.02b.05*