DESIGNING OF THE DESTROYING OF MULTISTORY STEEL BUILDINGS BY EXPLOSION OF ONE OR SEVERAL COLUMNS OF VARIOUS STORIES

1. Asia Adnan Yaseen
Phd Student, dept. of Structural Engineering,
Faculty of Civil Engineering, University of Tabriz
asia_86@yahoo.com

2. Hedayat Veladi
Associate Professor of Structural Engineering,
Faculty of Civil Engineering, University of Tabriz
*hveladi@tabrizu.ac.ir

3. Bahman Farahmand Azar
Professor of Structural Engineering,
Faculty of Civil Engineering, University of Tabriz
b-farahmand@tabrizu.ac.ir

4. Erfan Yahyazad
Phd Student, dept. of Structural Engineering,
Faculty of Civil Engineering, University of Tabriz
Erfan_yahyazadeh@tabrizu.ac.ir

Abstract

Construction sites are one of the most dangerous workplaces because of the variety of hazards and according to the procedure in which they are classified as hazardous work sites and mortality in construction sites with a large distance is among the most important causes on the list of occupational deaths. Safety is changing as a concept and method of coping with the risks to protect the lives of people and prevent damage as it the beginning of process. In this study, 15 story structure has been modeled and in 8 blast models by applying high heat to the columns, this modeling has been completed. The demolition of the upper floors does not lead to the destruction of the lower floors. Destruction of corner columns will destroy the whole structure and also it will cause the deflection of it, and the blast is better if it is symmetrical. An asymmetry in the loading does not affect the structure to exit the centrality. The destruction of the middle and bottom columns is suggested for the progressive failure of the best state

Keywords: Progressive failure, Explosion, Blast, Column, Deflection.

Introduction

Buildings are not designed for pulses such as explosions, fires, and so on. Since the buildings are exposed to such unusual loads, the fire caused by technical connection is one of the most widespread injuries after the earthquake, and this phenomenon has gained considerable importance due to the ability of highly destructive destruction and rapid diffusion. Structural safety has always been a key willingness to engineer engineering projects. One of the structural failure mechanisms that have attracted much attention in recent decades is a progressive breakdown. One or more of the structural members are suddenly destroyed because of an accident or explosion, and any redistribution destroys other structural elements and the structure is progressively destroyed [6]. The incremental failure phenomenon can be investigated by a variety of analytical methods ranging from very simple analyses to highly complex analyses. In general, these analyses can be done by applying finite element software that has the perfect ability to take into account the dynamic and nonlinear properties [2]. It is clear that the phenomenon of progressive failure is due to its occurrence over a very short period and the introduction of nonlinear forms to pre-rupture elements is a dynamic and nonlinear phenomenon. The progressive breakdown is a phenomenon where a partial loss or local loss causes a whole structure or a large part of it, as the final breakdown is not proportional to the original failure. To investigate the progressive failure of structures, the nonlinear dynamic method has more accurate responses to static methods. Due to the lack of nonlinear dynamic analysis, the use of simpler models and approximate methods has been very important. Hence, this study aims to investigate progressive breakdown in steel structures with the Abaqus finite element method.

Predicting damage to a building

Air blast pressures are usually several orders of magnitude greater than the loads for which the building is designed. Fortunately, these only act for a fraction of a second on the building. It is because of the short duration of the loading that is possible to design structures to withstand blast loads. The extent and severity of damage and injuries in an explosive event can not be predicted with a high degree of certainty. Past events show that the overall level of damage can be influenced by the specific type of construction [3,4], the arrangement of buildings and their heights, the size of the structure, the presence of fragment loading, and other factors. Despite these uncertainties, it is possible to predict the expected extent of the damage for a specific explosive event based on the size of the explosive device, distance from the explosion, and information about the construction type of the building. In addition, the extent of injuries can be correlated with structural damage patterns. Certain types of construction are highly blast-resistant while some others are not. Damage is prevalent for wood construction even at large standoff distances, which is due to the inherent fragility of wood components to explosions. Conversely, reinforced concrete frames offer a high level of blast resistance, even though some infill panels between structural columns may be destroyed. The size of the structure relative to the bomb size is a significant factor in the amount of damage inflicted. A small, strong masonry building may withstand damage better than a large, two-story, lightly reinforced concrete building. Damage to various building types can be calculated based on computer simulations and existing blast damage assessment tools such as P-I diagrams for various structural elements. One example of blast damage prediction for a typical steel pre-engineered building is given in Table 1.

Table 1. Pre-engineered Steel Building (one-storey, pre-engineered steel, 6 metres by 24 metres, steel frames at 6 metres, corrugated steel roof on purlins)

Charge Weight (kg)	Distance for Specified Damage and Injury (m)				
	Minimal	Minor	Moderate	Heavy	Severe
25	26	21	16	11	6
100	50	40	31	25	16
225	76	61	50	40	27
450	116	90	70	59	44
1,800	238	189	143	122	91
18,000	747	625	433	372	229

Introduction Modeling examples

In order to avoid the design of beam and column, in this study, the plan, number of floors and sections of the beam and columns were similar to [5] model. In this section, the selected plan presented in figure 1 and also the beam and column sections in table 1 are modeled in the Abaqus finite element software. However, the roof system has been selected as compound, that is, at the bottom of the steel roof, above the concrete slab. It is also quite rigid connections.

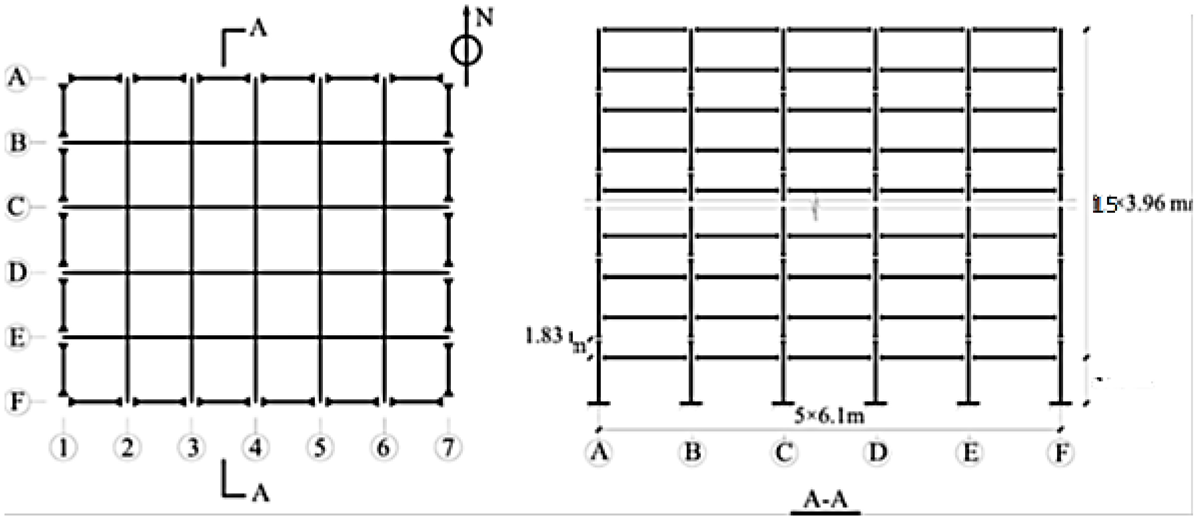

Figure 1: Plan of structure

Loading

In this environment as its name implies, loading and determining boundary conditions are done.

The acceleration rate for gravity loading is 981(cm/s^2). In order to load the blast load in columns and at the time of several columns in the structure of 15 story steel structure [1]. Heat generation has been used in the whole column, as heat 1200 (°C) is produced in the column and in a second to the melting temperature, as shown in Figure 2.

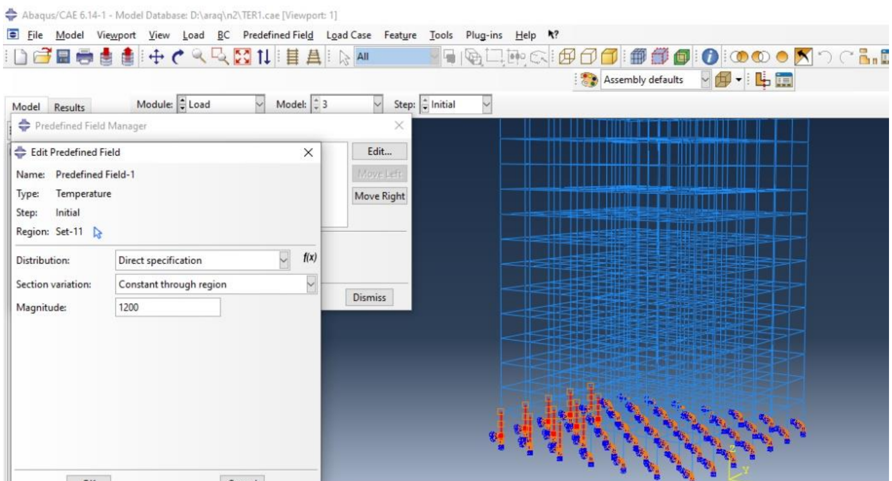

Figure 2: Apply Explosion load

Result

Sample Tr1 results

This specimen explodes at 11 columns in the corner of the building on the ground floor of the structure, and the plan of the blown columns is shown in Figure 3.

The study of this specimen is for loading and asymmetric explosion of the corners of the structure on the ground floor.

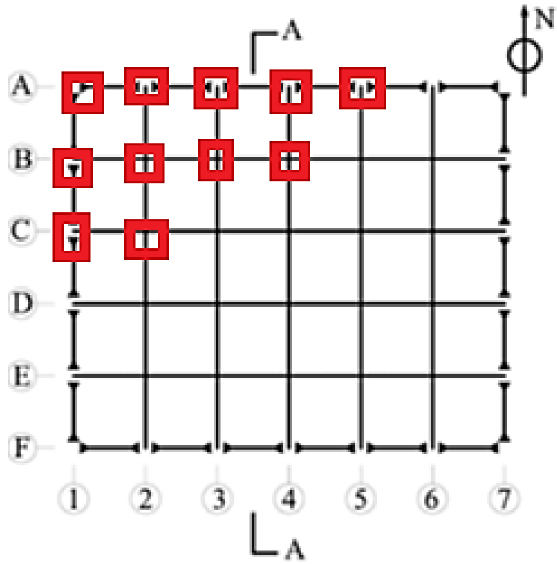

Figure 3: Plane of Tr1 in load

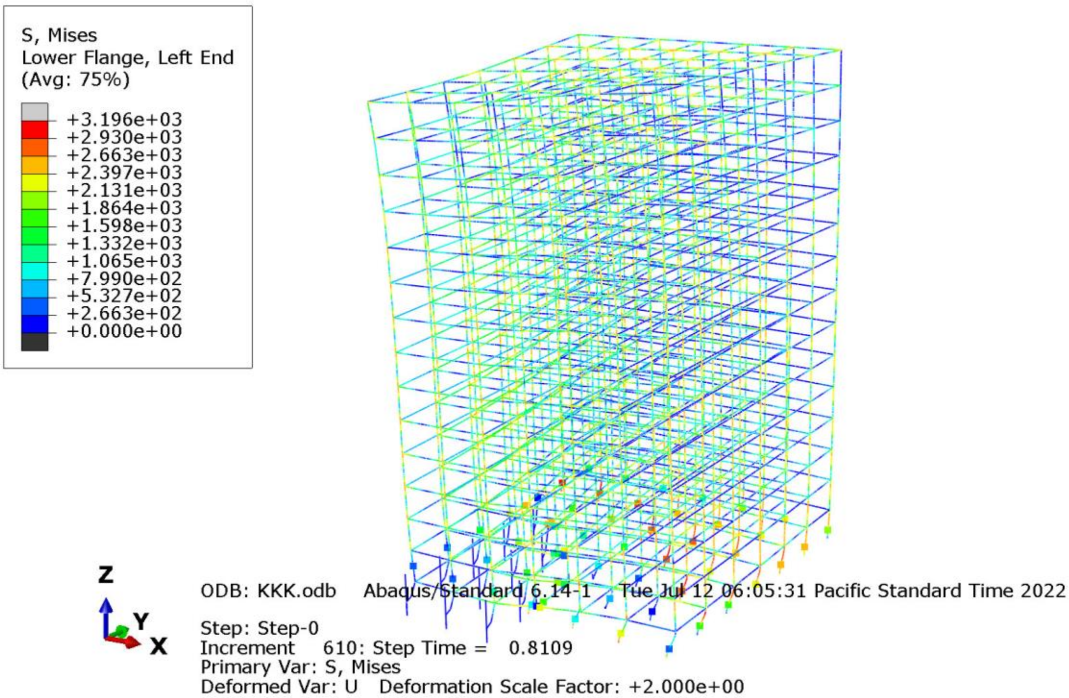

Figure 4: Failure of the Tr1 specimen after the blast

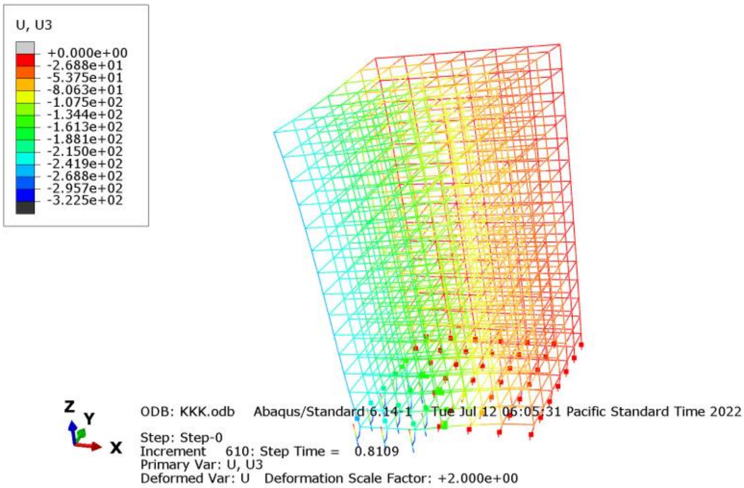

Figure 5: Settlement of the Tr1 specimen after the blast

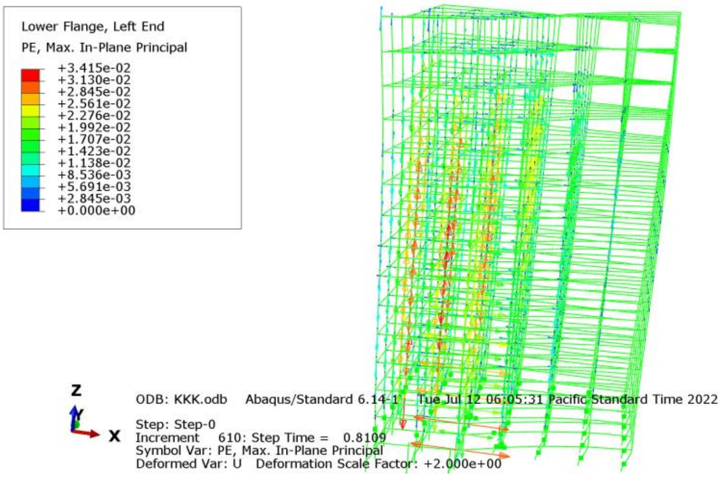

Figure 6: Plastic strain of the Tr1 specimen after the blast

According to Figs. 4 and 5 and 6, columns destroyed which happens in 3 seconds .and at the first second a 3 m session difference is created and in seconds 1 creates a 3 m session difference and the original strain on the side columns is not damaged and causes progressive failure.

Sample Tr2 results

This specimen explodes at 35 columns in the middle of the building on the ground floor of the structure, and the plan of the blown columns is shown in Figure 7.

The study of this specimen is for loading and asymmetric explosion of the center of the structure on the ground floor.

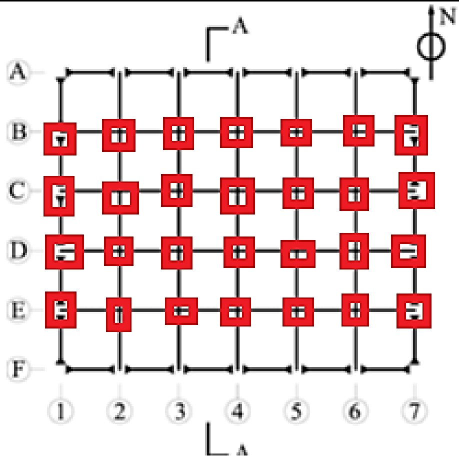

Figure 7: Plane of Tr 2 in load

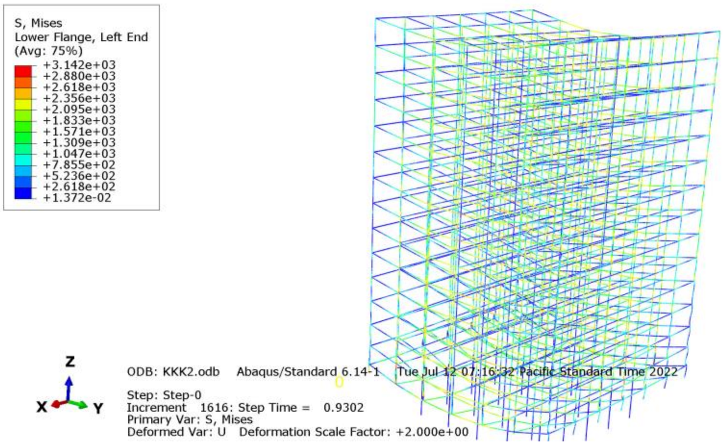

Figure 8: Failure of the Tr2 specimen after the blast

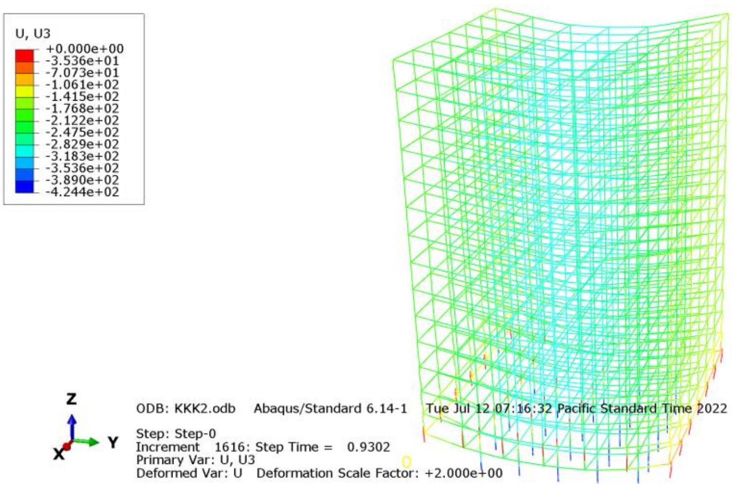

Figure 9: Settlement of the Tr2 specimen after the blast

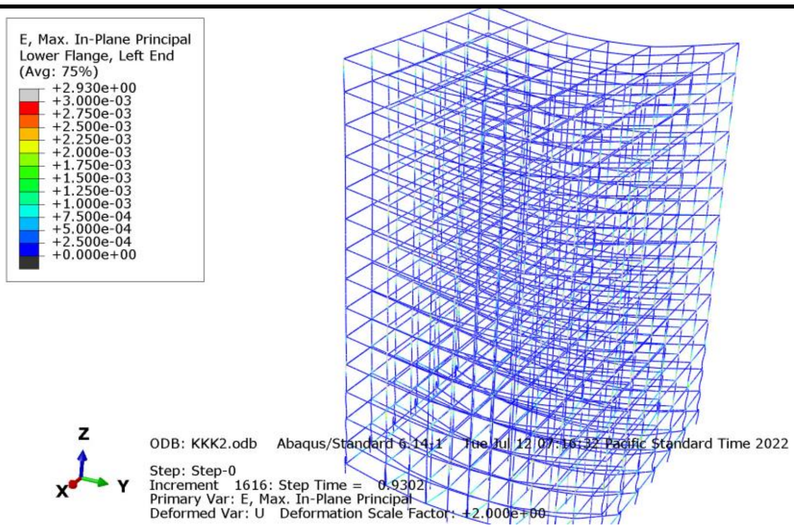

Figure 10: Plastic strain of the Tr2 specimen after the blast

Sample Tr3 results

This specimen explodes at 42 columns in the 10th floor of the building, and the plan of the blown columns is shown in Figure 11. The study of this specimen is for loading and asymmetric explosion of the 10th floor.

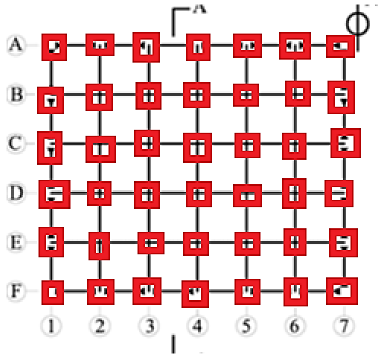

Figure 11: Plane of Tr3 in load

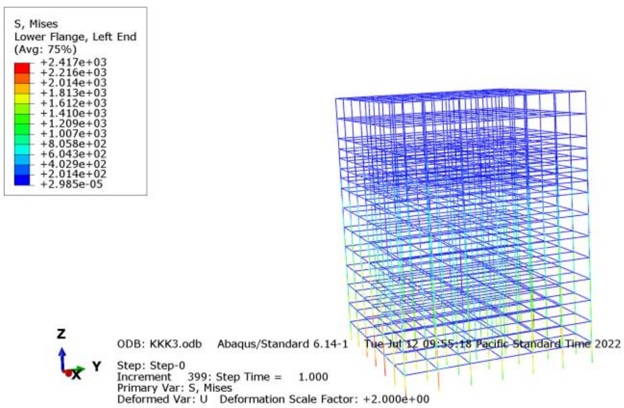

Figure 12: Failure of the Tr3 specimen after the blast

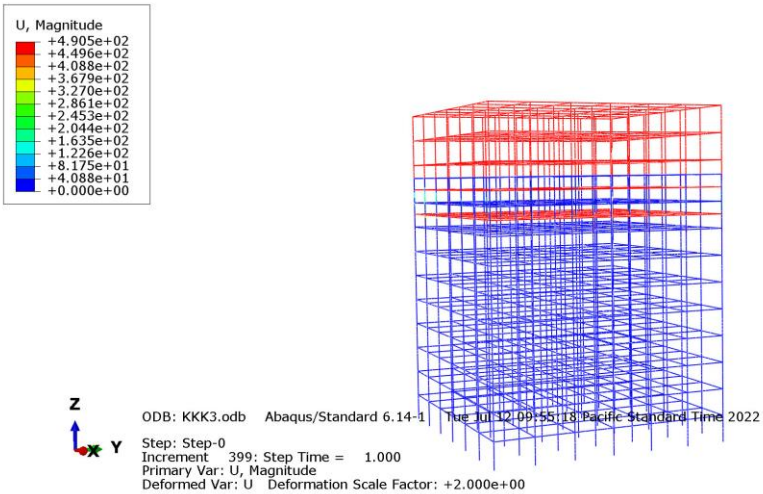

Figure 13: Settlement of the Tr3 specimen after the blast

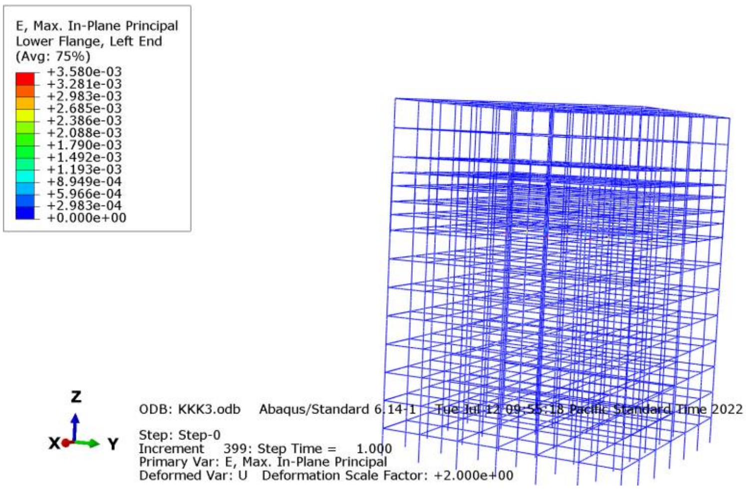

Figure 14: Plastic strain of the Tr3 specimen after the blast

According to Figs 12 and 13 and 14 in this instance, when the explosion occurred in all the columns of the Top 10, the upper floors collapsed, but nothing happened to the lower floors, which could not lead to a progressive breakdown of the structure. And the columns of the structure are also studied at the top 10 of the case of failure and strain is high in this story.

Sample Tr4 results

This specimen explodes at 20 columns in the 10^{th} floor of the building, and the plan of the blown columns is shown in Figure 15. The study of this specimen is for loading and asymmetric explosion of the center of the structure in the 10^{th} floor.

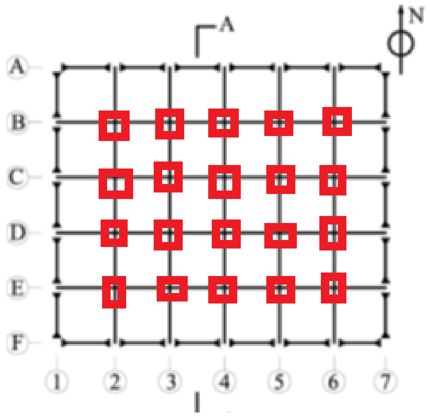

Figure 15: Plane of Tr4 in load

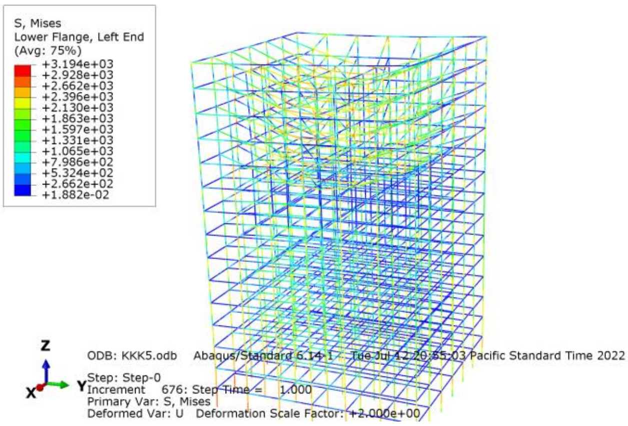

Figure 16: Failure of the Tr4 specimen after the blast

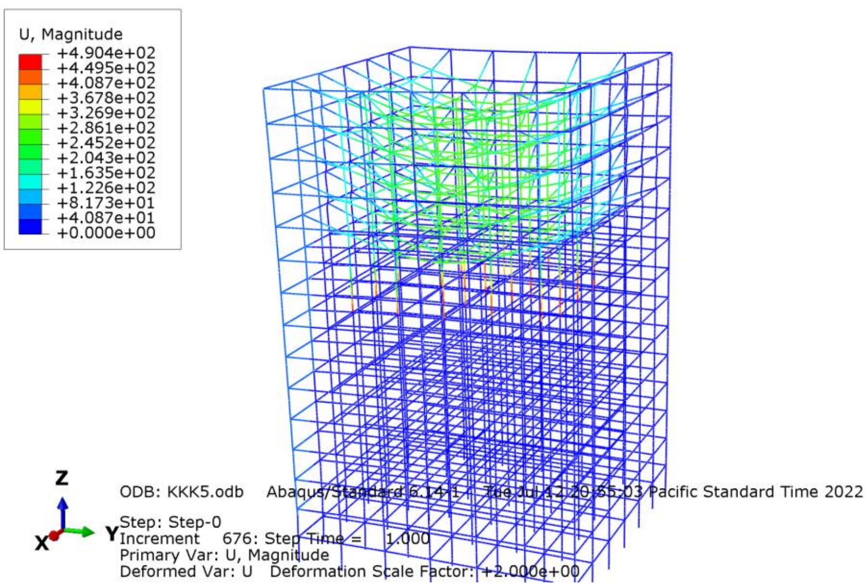

Figure 17: Settlement of the Tr4 specimen after the blast

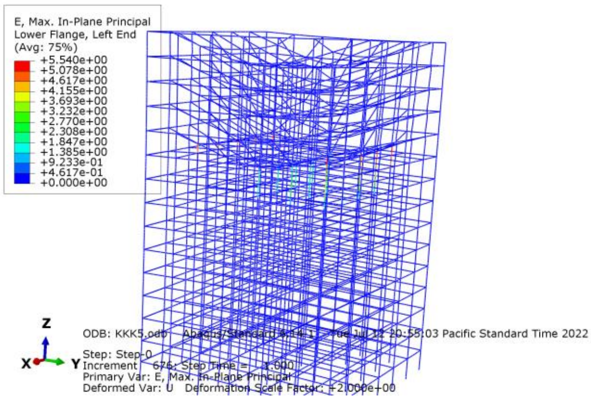

Figure 18: Plastic strain of the Tr4 specimen after the blast

According to Figs16 and 17 and 18 in this instance, the lower columns will endure the higher load and create a progressive breakdown for upper floors but cannot sustain such destruction for the whole structure.

Sample Tr5 results

This specimen explodes at 20 columns in the 2th to 13th floor of the building, and the plan of the blown columns is shown in Figure 19.

The study of this specimen is for loading and asymmetric explosion of the center of the structure in the 2th to the 13th floor.

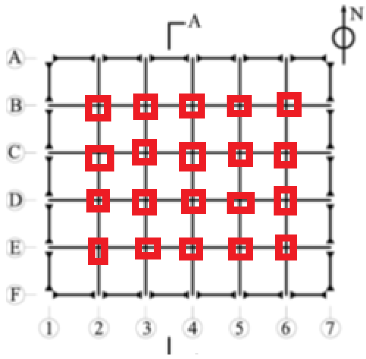

Figure 19: Plane of Tr5 in load

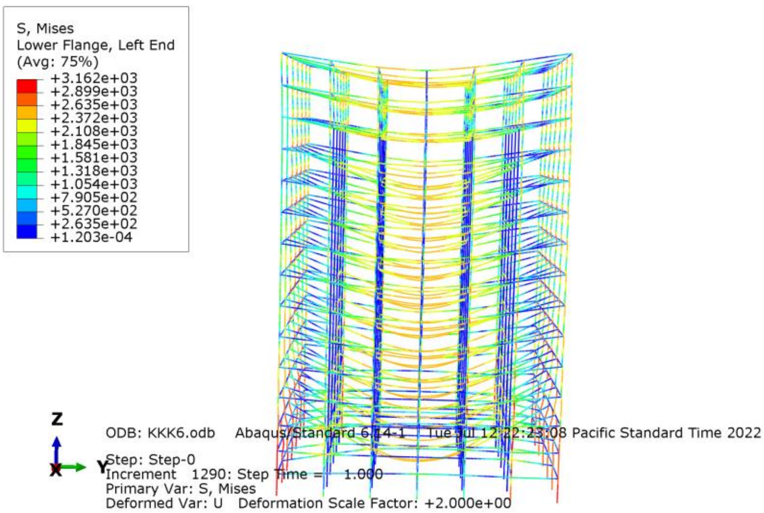

Figure 20: Failure of the Tr5 specimen after the blast

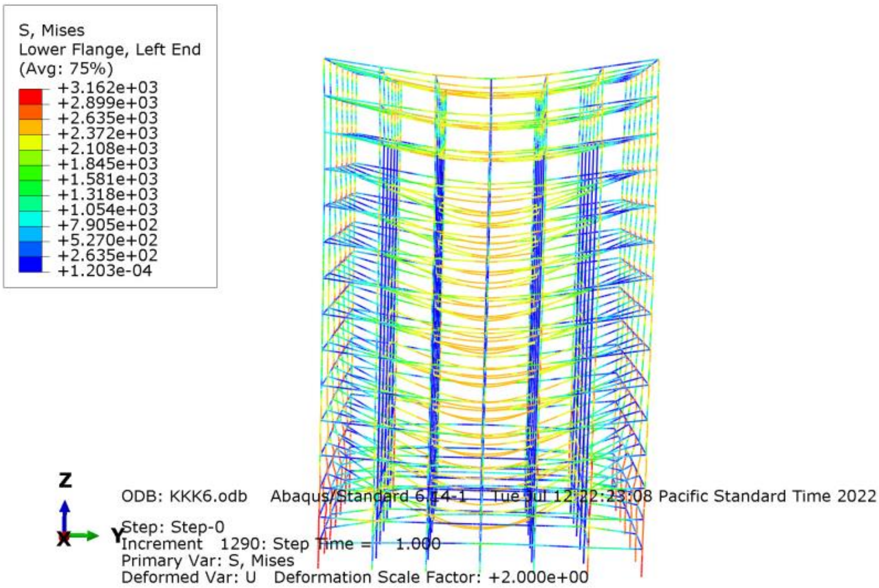

Figure 21: Settlement of the Tr5 specimen after the blast

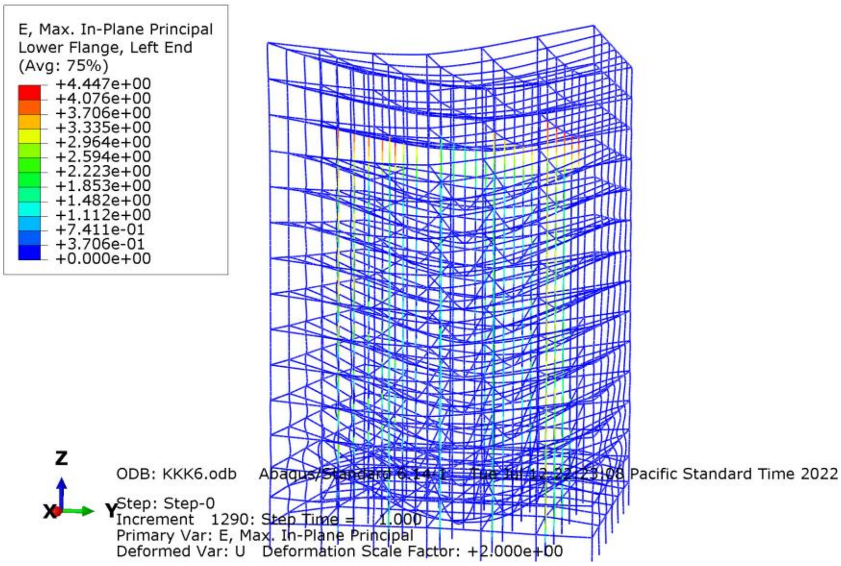

Figure 22: Plastic strain of the Tr5 specimen after the blast

According to Figs 20 and 21 and 22 this specimen had destroyed all the pillars of the structure and destroyed the upper structures, increasing the strain on all the columns involved and causing progressive damage to the structure, but it should be noted that the cost of destruction would be costly.

Sample Tr6 results

This specimen explodes at 42 columns in the 1th floor of the building, and the plan of the blown columns is shown in Figure 23.

The study of this specimen is for loading and asymmetric explosion of the center of the structure in the 2th to the 13th floor.

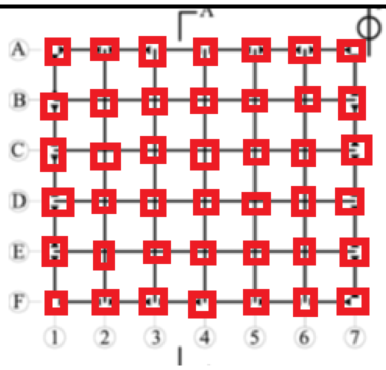

Figure 23: Plane of Tr6 in load

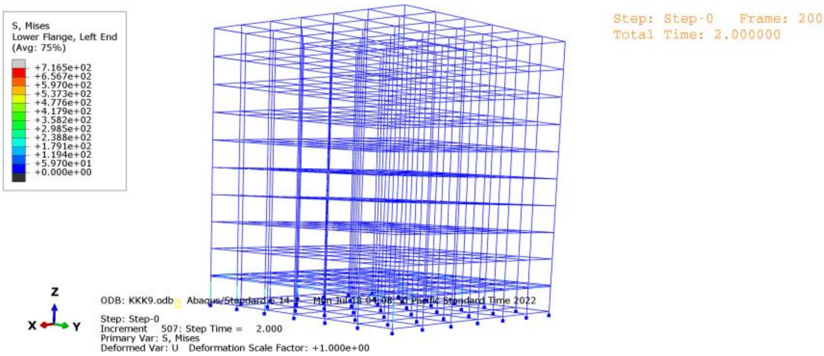

Figure 24: Failure of the Tr6 specimen after the blast

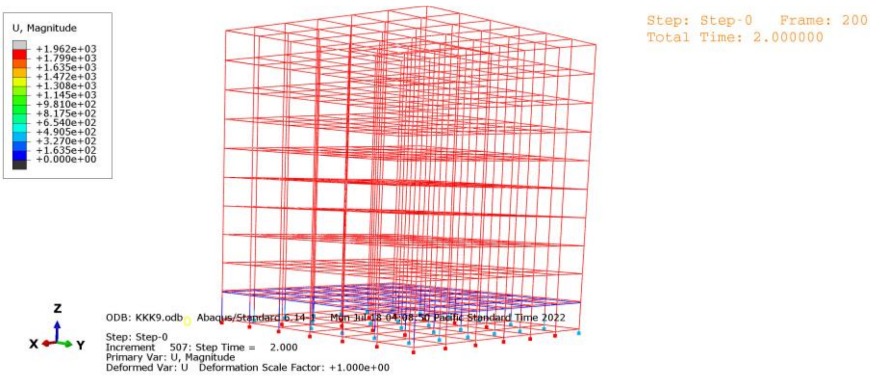

Figure 25: Settlement of the Tr6 specimen after the blast

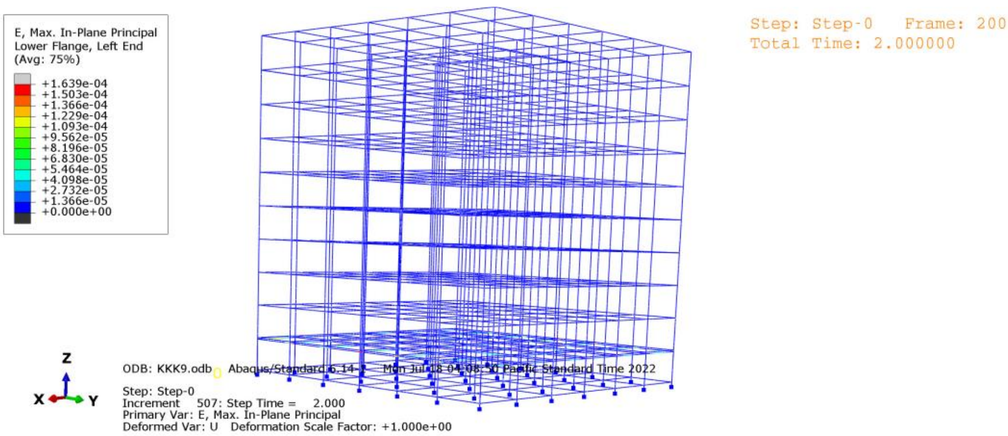

Figure 26: Plastic strain of the Tr6 specimen after the blast

According to Figs 4 - 25 and 4 - 26 and 4 – 27 this is the most reliable mode for progressive failure. It can be reached within 2 seconds and can be destroyed with less than 6 seconds of the whole structure and the structure is drawn up without twisting it.

Sample Tr7 results

This specimen explodes at 42 columns in the 1th floor of the building like tr6,

Only with the difference that the amount of mass concentrated in the nodes is symmetric, you can see the distribution in Fig. 27. The purpose of this specimen is to examine the rotation or side effects of the specimen by this load distribution. Study of this specimen is for loading and asymmetric explosion of the center of the structure in the 2th to the 13th floor.

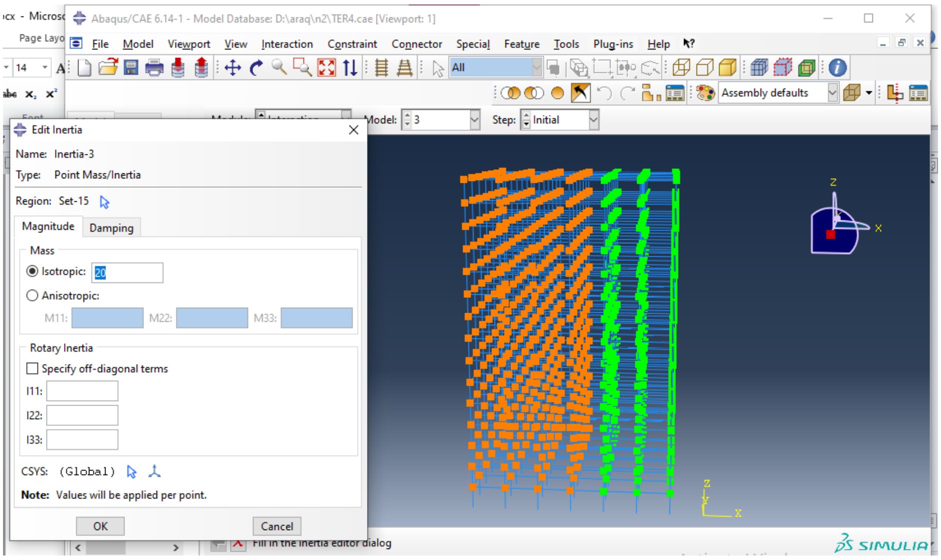

Figure 27: Plane of Tr6 point load

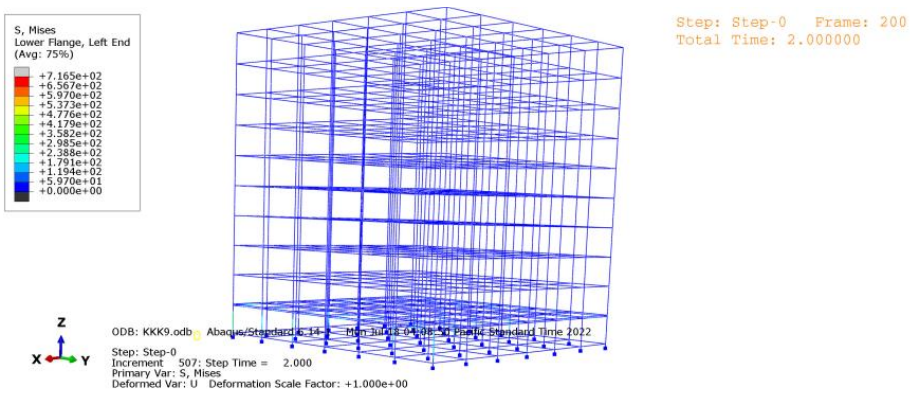

Figure 28: Failure of the Tr6 specimen after the blast

According to Fig 28 this example, if all the columns are destroyed at a moment, there is no symmetry in loading any torsional loading.

Sample Tr8 results

This specimen explodes at 9 columns in the grand floor of the building, and the plan of the blown columns is shown in Figure 29.

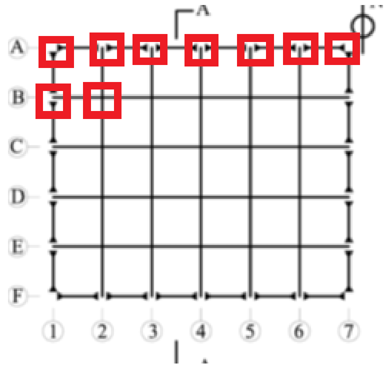

Figure 29: Plane of Tr8 in load

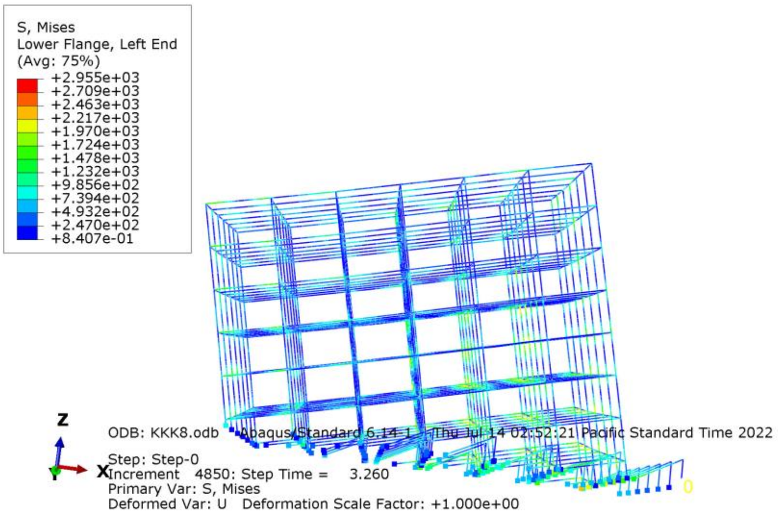

Figure 30: Failure of the Tr8 specimen after the blast

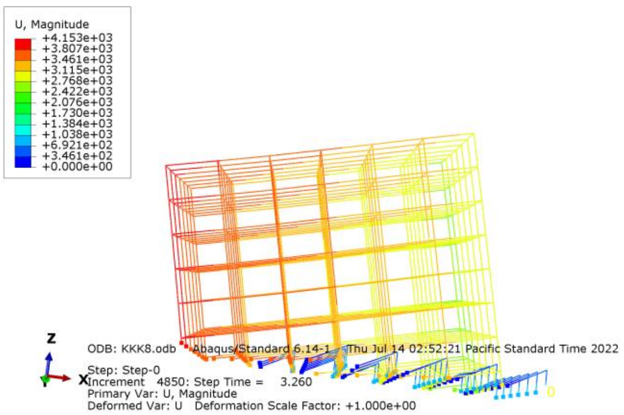

Figure 31: Settlement of the Tr8 specimen after the blast

According to Figs 30 and 31 in this instance, the blast occurred in the corner of the structure, and the entire structure was damaged in 4 seconds, but due to the failure at the corner of the building, the sample was totally distorted due to progressive breakdown.

Conclusion

Based on research, the following results can be extracted:

- The destruction of the structure is better than the lower floor. For example the ground floor or the first floor.
- The demolition of the upper floors does not lead to the destruction of the lower floors.
- Destruction of corner columns will destroy the whole structure and also it will cause the deflection of it, and the blast is better if it is symmetrical.
- An asymmetry in the loading does not affect the structure to Exit the centrality.
- The destruction of the middle and bottom columns is suggested for the progressive failure of the best state.

References

[1]ASCE7–22 Minimum Design Loads for Buildings and Other Structures. Reston,Virginia: American Society of Civil Engineers; 2022.

[2]GSA (2013). Progressive collapse analysis and design guidelines for new federal office buildings and major modernization projects. The U.S. General Services Administration.

[3]Kaewkulchai Griengsak, Williamson Eric B.(2004). Beam element formulation and solution procedure for dynamic progressive collapse analysis. Computer and Structures March;82(7–8):639–51.

[4]Khandelwal, K., El-Tawil, S. and Sadek, F. (2009). Progressive collapse analysis of seismically designed steel braced frames", Journal of Constructional Steel Research, (3)65 pp. 699-708.

[5]Shan Gao & Lanhui Guo. (2015). Progressive Collapse Analysis of 20-storey Building Considering Composite Action of Floor Slab, International Journal of Steel Structures 15(2): 447-458.

[6] Starossek, u. (2009). Progressine collapse of structures. London: Telford Publishing.