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# Analysis of Blast Effect on Nonlinear Behavior of Steel Flexural Frames Using Abaqus Software

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## ABSTRACT

In a situation where terrorist attacks on civilian places and facilities are on the rise, the safe design of buildings against the impact loads caused by explosions is very important. Steel structures are very sensitive to heat, and the pair of explosions and fire can cause progressive failure in such structures. Since explosion is usually associated with fire structures, in this study, the effect of the explosion on steel flexural frames under fire conditions was investigated. This study investigates two five-span frames of the same steel bending frame with differences in their height, one three and the other five-story, which explode under the TNT material at a distance of 10 meters from the frame. The results of numerical calculations for the maximum impact pressure caused by the explosion, the duration of the positive phase of the explosion, and the duration of the negative phase of the explosion equal to 0.1 kgf/ 〖cm〗^2 , 3.89 s, and 0.0139 s, respectively, were entered into the odeling of Abaqus software. Three- and five-story frames were modeled on Abaqus software and subjected to the force of the explosive explosion outside the frame. To compare the explosion behavior of the two frames, stress analysis, displacement, roof floor acceleration, rotation, and work performed on the frame were performed. The minimum stress in a three-story frame (9.07 kgf/cm2) is approximately 2 times less than in a five-story frame (17.25 kgf/cm2), and equivalent compressive loading has created less force in the three-story frame. The results of the analysis show that the more malleable the structure, the better the explosion behavior.

**Keywords:** **Explosion loading, Nonlinear behavior, Steel bending frame, Abaqus**

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## 1. INTRODUCTION

Terrorist attacks such as the bombing of the US Embassy in Nairobi-Kenya, Dar es Salaam-Tanzania (1998), the Ronan Point building in the United Kingdom (1968), the towers of the Al-Khobar military sanatorium in Dhahran-Saudi Arabia (1996), the Mora Federal Building in Oklahoma (1995) and the center World Trade In New York (1993), the need to study the behavior of structures requires explosive loads. Since a blast accompanies a sudden release of a great amount of energy in the form of a shock wave with the sound of an explosion, most infrastructure subjected to a blast or explosion will undergo serious damage to its structural members. In particular, considering the latest terror attacks that have been concentrated on infrastructures, additional concern must be given to major public facilities as military installations to preserve the strength of structures and to ensure public safety. In this context, the structural behavior of reinforced concrete (RC) structures broadly adopted in public facilities in the form of frame structures should be analyzed accurately. Many remarkable studies have been performed to verify the material properties of concrete and steel under high strain rate deformation [1–3] and, in advance, to analyze the structural behavior of RC members under blast loadings [4–6], and the obtained results are used in developing design codes such as the *fib* model code 2010 [7]. Researchers have done many studies on the effect of explosions on various structures and the behavior of buildings against this load. Song et al. proposed a nonlinear analysis method for steel frames against explosions in which the elastoplastic behavior of the steel is modeled, taking into account the effects of high temperature, creep, and high strain [8]. Miyamoto et al. investigated the effects of FVD viscous liquid dampers in a special steel bending frame against explosive loading. Their study showed that the use of FVD is an effective method in reducing lateral displacement and rotation of plastic joints in a special steel bending frame against explosion loading [9]. Mayas and Smith Modeled the failure of concrete structures against explosion load using solid three-dimensional elements [10]. In another study, Kicinger et al., Studied the behavior of steel joints and their role in the response of steel structures to progressive failure due to explosive loads [11]. Also, the behavior of steel frames under the effect of explosive loading has been studied by Summers et al. [12]. Luccioni et al. provided a simple method for the nonlinear dynamic analysis of concrete frames under blast loading. Using the law of conservation of energy and modeling various frames under different loading conditions, they presented relationships to simplify nonlinear dynamic analysis. The numerical results of their research indicated that their proposed method was conservative and had a relatively high error [13]. Richard Liew presented a study on the strength of steel frames under the simultaneous effects of explosion and fire. The results of the study show that the initial deformation due to explosion in the columns, which is observed as local buckling and flow, causes the bearing capacity of the columns under thermal loads due to fire to be significantly reduced [14]. Kim and Kim Evaluated the performance of 3, 6, and 15-story steel structures with a bending frame system under the secondary effects of the explosion in the structure. According to the results, in case of damage to the corner columns, the probability of progressive failure phenomenon increases compared to the middle columns [15]. Lee et al. Investigated the effect of blast load on steel columns with different sections [16]. Urgessa and Arciszewski compared the response of conventionally welded steel frames and side-reinforced joints under blast-induced loads. The results showed that steel frames with joints reinforced with side panels have a better performance against explosion loads compared to conventional types [17]. Parisi and Augenti, by examining the effect of seismic design criteria, on the explosive strength of concrete flexural frame structures, concluded that the seismic design criteria did not provide sufficient structural resistance to different explosion conditions, but are less explosive than the non-seismic site [18]. Hadianfard et al. evaluated the effect of blast load on steel columns with different cross-sections and studied their nonlinear behavior [19]. Mirzaei and Kazemi evaluated the behavior of steel shear wall systems designed for earthquakes under explosive loading (by changing the thickness of the sheet). The results of their study show that this structure does not lose its resistance under explosive load and can continue its operation. On the other hand, by increasing the thickness of the filler sheet, the behavior of the steel shear wall system can be improved [20]. Nassr et al. Also investigated the dynamic response of steel columns to explosive loads. He prepared experimental models of thirteen steel columns with different abutment conditions and with different explosive loads in terms of the amount of mass of the explosive and the distance of the source of the explosion from the columns. The purpose of their experiments was to influence the axial load entering Breston up to 25% of the axial load of the column at the same time as the explosive load, and they concluded that the axial load could both reduce and increase the median displacement of the column length. The increase in this displacement is due to the effect $p-\delta$, and the decrease is due to the effect of column drag [21]. Also, Hassanvand et al. In study, evaluated the behavior of the combined system of the flexural frame and semi-buried concrete shear wall under the effect of explosive loading [22]. In a study, Zhang et al. (2022) investigated the limited explosive loading of steel plates with and without prefabricated holes [23]. In this study, the effect of the explosion on steel bending frames under fire conditions has been investigated. Therefore, two three- and five-story frames were modeled in Abaqus software, then affected by the force of the explosive explosion outside the frame. The results of this study will show the behavior of the structure against explosion.

## 2. MATERIALS AND METHODS

### *2.1. EQUILIBRIUM OF TRINITROTOLUENE (TNT) EXPLOSIVE*

Due to the fact that the data related to the parameters of the explosion wave are expressed in the regulations based on TNT explosives, therefore the weight of other explosives is equalized according to relation (1) with TNT explosives [24].

$$W_E = \frac{H^d_{exp}}{H^d_{TNT}} W_{exp} \qquad (1)$$

Where $H^d_{TNT}$ is the heat of explosion of the TNT explosive, $H^d_{exp}$ is the heat of explosion of the main explosive, and $W_{exp}$ is the weight of the main explosive.

## 2.2. EFFECTIVE PARAMETERS TO THE LOAD CAUSED BY THE EXPLOSION

The two-dimensional frames modeled in Abaqus software are modeled in two models of three and five layers. The details of the modeling are detailed in the previous sections. There are several methods for modeling fast blast load that in this research, TNT equation has been used. For this purpose, we equate the explosion load with the TNT load, and then, considering the distance of the explosives from the structure, we obtain the pressure applied to the side of the structure that is on the explosives side and applies it to the frames under study. The power of an explosive charge is always calculated by the two factors of the weight of the explosive and the distance from the source of the explosion, which is applied as a parameter of the scaled distance Z, Equation (2) [25].

$$z = \frac{R}{W^{1/3}} \qquad (2)$$

Where W is the weight of the explosion explosively in terms of TNT and R is the distance of the structure from the source of the explosion. Assuming the weight of the TNT equivalent in terms of TNT is equal to one TNT, and the distance of the structure from the source of the explosion is 10 meters, the measured distance will be according to Equation (2). In the present study, the effects of applying an explosive load equivalent to the action of one pound of TNT on a three- and five-story five-span steel frame were investigated in Abaqus software. The explosion considered in this research is a type of surface explosion that occurs at a surface or a very close distance to the ground. In this type, at the place of the explosion, the created wave hits the ground and is reflected and amplified, and the amplified wave hits the structure. The waves from the explosion are hemispherical (Mach front). Therefore, by increasing the height of the structure, the pressure of the blast wave on it decreases, and the foot of the structure suffers the most pressure caused by the explosion. The farther the blast site is from the structure, the more uniform the pressure on the structure.

$$z = \frac{10}{\sqrt[3]{1}} = 10 \frac{m}{\sqrt[3]{kg}}$$

All the main parameters that depend on the amount of energy are closely related to the blast wave and its distance. The effects of the wave on the distance can be equated to the relation $\left({}^{E}/{}_{P_0}\right)^{1/3}$ with the pressure. In this formula, E is the amount of energy released per unit kJ and $Po$ ambient pressure, which is usually assumed to be 100 $kN/m^2$. The National Building Regulations Section 21 proposes Brode relations (3) to determine the maximum impact pressure due to an explosion in the open air for medium and long distances, and Henrych relations for distances close to the field that are in good agreement with the laboratory results [26].

$$\begin{aligned} P_{so} &= \frac{6.7}{Z^3} + 1 && P_{so} > 10\, {}^{kg}/{}_{cm^2} \\ P_{so} &= \frac{0.975}{z} + \frac{1.455}{z^2} + \frac{5.85}{z^3} - 0.019 && 0.1 < P_{so} < 10\, {}^{kg}/{}_{cm^2} \end{aligned} \qquad (3)$$

Henrych relations (4) (Z is the distance measured in terms of $m/kg^{1/3}$ ).

$$\begin{aligned} &\frac{5.54}{z^2} + \frac{0.357}{z^3} - \frac{0.00625}{z^4}\, P_{so} = \frac{14.072}{z} && 0.05 \le z < 0.3 \\ &+\frac{0.326}{z^3} + \frac{2.132}{z^2}\, P_{so} = \frac{6.194}{z} && 0.3 \le z < 0.1 \\ &+\frac{4.05}{z^3} + \frac{3.288}{z^2}\, P_{so} = \frac{0.662}{z} && 1 \le z < 10 \end{aligned} \qquad (4)$$

Using Equation (4), the equivalent compressive force obtained from the collision is obtained:

$$P_{so} = 7.816 \ \frac{kgf}{m^2}$$

The maximum impact pressure from the explosion is alculated according to the equation proposed by Kinney, which corresponds very well to the values obtained from the UFC code diagrams 3-340-02 according to Equation (5) [27].

$$\frac{P_{max}}{P_o} = \frac{808[1+\left(\frac{z}{4.5}\right)^2]}{\sqrt{1+\left(\frac{z}{0.048}\right)^2}\sqrt{1+\left(\frac{z}{0.32}\right)^2}\sqrt{1+\left(\frac{z}{1.35}\right)^2}} \qquad (5)$$

Where $P_0$ is the ambient pressure in ${}^{kgf}/_{cm^2}$and $P_{max}$ is the maximum impact pressure due to the explosion in ${}^{kgf}/_{cm^2}$ and z is the scaled distance in $m/kg^{1/3}$ Is. Using the Kinney relation, the value of $P_{max}$ described in Equation (5) is calculated:

$$\frac{P_{max}}{P_o} = \frac{808[1+\left(\frac{10}{4.5}\right)^2]}{\sqrt{1+\left(\frac{10}{0.048}\right)^2}\sqrt{1+\left(\frac{10}{0.32}\right)^2}\sqrt{1+\left(\frac{10}{1.35}\right)^2}} = 0.0986\ \frac{kgf}{cm^2} \qquad (6)$$

$$P_{max}\ \cong 0.1\ \frac{kgf}{cm^2}$$

The duration of the positive phase of the explosion based on the distance measured in seconds by Lam et al. Has been proposed as a logarithmic relation according to Equation (6) [28].

$$log_{10}^{\left(\frac{t_d}{w^{1/3}}\right)} = 2.15log_{10}^{z} + 0.28 \qquad z \leq 1$$

$$log_{10}^{\left(\frac{t_d}{w^{1/3}}\right)} = 0.31log_{10}^{z} + 0.28 \qquad z \geq 1$$

The present study is obtained in Equation 6.

$$log_{10}^{\left(\frac{t_d}{1}\right)} = 0.31log_{10}^{10} + 0.28 = 0.059$$

$$t_d = 3.89\ s$$

The negative phase of the explosion occurs when the pressure caused by the explosion reaches a value less than atmospheric pressure. Using the laboratory results, Martin Larcher expressed the value of $p_{min}$by Equation (7) in terms of scaled distance [29].

$$p_{min} = \frac{0.35}{z}.10^5Pa \qquad z > 3.5$$

$$p_{min} = 10^4Pa \qquad z < 3.5 \qquad (7)$$

The negative phase of the explosion also has a minimum pressure according to Equation (7).

$$p_{min} = \frac{0.35}{10}.10^5 = 3500\ \frac{N}{m^2}$$

The duration of the negative phase of the explosion is suggested by Martin Larcher in terms of seconds, according to Equation (8).

$$t_n = 0.0104.w^{\frac{1}{3}} \qquad z < 0.3$$

$$t_n = (0.003125\log(z) + 0.01201).w^{\frac{1}{3}} \quad 0.3 \leq z \leq 1.9 \qquad (8)$$

$$t_n = 0.0139.w^{\frac{1}{3}} \qquad z > 1.9$$

Where z is the scaled distance in $m/kg^{1/3}$ and w is the weight of the explosive in kg. The duration of the negative phase of the explosion by Martin Larcher is obtained in terms of seconds, according to Equation (8):

$$t_n = 0.0139.10^{\frac{1}{3}} = 0.0139\ \mathrm{s}$$

The loading in the Abaqus environment is based on these calculations. Since the explosive load is of variable load and has a high intensity in a very short period, explicit dynamic analysis was used.

## *2.3. MODELING OF STEEL FRAMES BY ABAQUS SOFTWARE*

In order to achieve the objectives of the present study, two two-dimensional steel frames with five openings, one three and the other five floors, are modeled according to Figure 1. ST37 steel with the specifications in Table 1 is used to model the beams and columns.

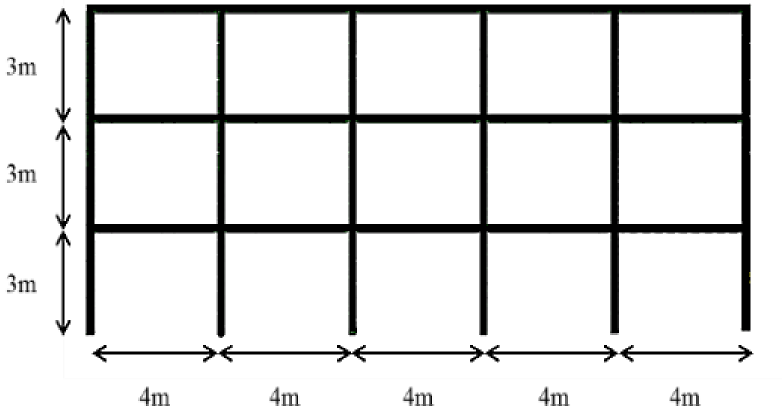


**Figure 1.** Overview of the three-story model

**Table 1.** Specifications of ST37 steel used in the research

| **Specific weight** | **7850 (kg / m3)** |
|---|---|
| Modulus of elasticity | 105 × 2(MPa) |
| Poisson's ratio | 0.3 |
| Elastic compressive strength | 240 (MPa) |
| Plastic compressive strength | 360 (MPa) |

To achieve the desired goals, software should be used that can perform nonlinear static and dynamic analysis and the ability to model elastic and plastic nonlinear elements. So Abaqus software seems appropriate. The solution method in finite element software is based on networking and dividing the model into smaller components (elements), and with a limited number. In plate stress-strain and heat transfer problems, degrees of freedom vary, and separate elements are included in the software for analysis in these areas. Due to the above definitions and the two-dimensionality of modeling, in this research, the beam element has been used to model the beams and columns. The image of the model made in the Abaqus environment is shown in Figure 2. For this purpose, in the part module, two two-dimensional parts are made for beams and columns.

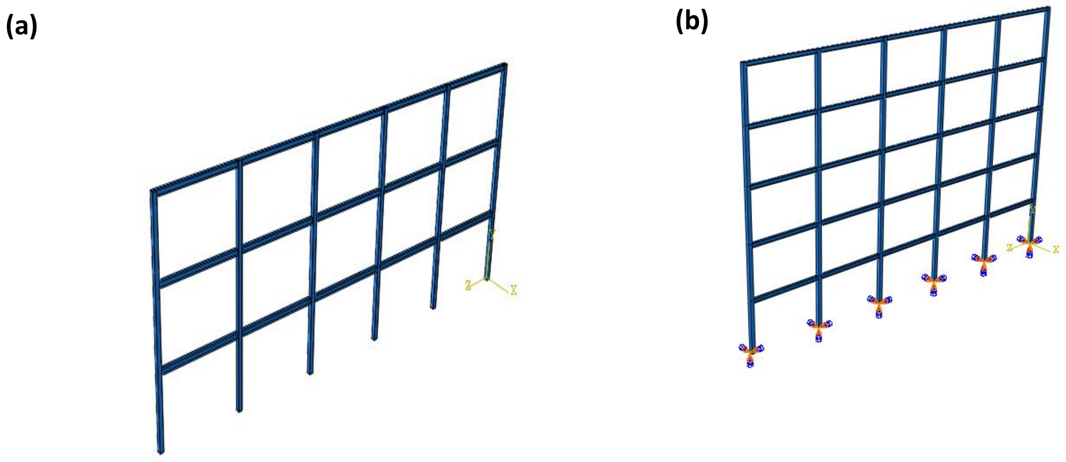


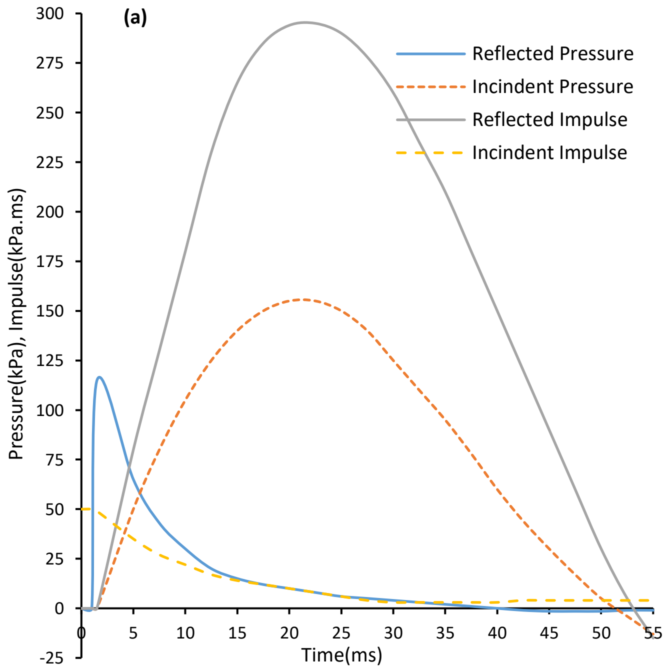
**Figure 2.** Model made in Abaqus software a) three floors, b) five floors

Continuation of the analysis process after defining the appropriate material and cross-section will be possible only by bypassing the assembly module. To analyze a set with a large number of components, you must assemble the set of parts in the assembly environment and their exact location. Operations such as displacement, rotation around an axis, and displacement can be used to position parts of a set correctly, but no doubt, in this process, you will need to apply the work process with higher accuracy and speed by applying some geometric constraints. In the assembly module, the assembly of parts and their precise displacement are performed. In this module, the built-in parts are assembled. The beams and columns are placed exactly in their places, and the openings and floors of the frame are formed. Analysis steps are then defined in the step module. In this study, which aims to compare the behavior of two frames made by the explosion, the explicit dynamic analysis method has been used. The explicit dynamic method calculates the displacement of each node according to the acceleration of that node at each loading step. In this method, the effect of external forces on the body will be in the form of propagation of stress waves, and the problem is solved dynamically, so if the wave velocity in the structure (same as the speed of sound) exceeds the software solution speed, solution errors occur and instability in the problem occurs. Hence the role of inertial forces in the obtained answers is very effective. The calculation method is such that it is not necessary to form a stiffness matrix for the whole structure. One of the advantages of the explicit method over the implicit method is the higher speed of solving complex contact problems. Another advantage of using this method is the need for less storage space in the same issue than the implicit method in the computer. In simulating high-velocity, dynamic phenomena such as explosions and impacts, the convergence of the answer in the implicit method is almost impossible. Convergence also occurs with difficulty in complex problems (despite the possibility of using both methods), and explicit analysis will be more efficient. Problems in which the deformation of the structure leads to fundamental changes in the strength of the material are also good candidates to be solved by the explicit method. This method is good for solving nonlinear problems for nonlinear materials, but one important point should not be overlooked. Stability in the explicit method is conditional on the choice of small-time steps, so to stabilize the solution in this method, the development of a small solution is chosen. Therefore, explicit dynamic analysis has been used in this research. Boundary conditions are defined in the load module. Explosion analysis requires that the underside of the columns is fully enclosed and that the blast load hits the side of the frame opposite the blast. Using the tools in the mesh module, each defined part can be meshed according to the solver selected to solve the problem. The finer the elements, the more accurate the calculations and the greater the analysis time. This highlights the importance of optimally sizing mesh elements.

## 3. RESULTS AND DISCUSSION

### *3.1. MODELING OF THE WAVE PROCESS*

Modeling of the wave process resulting from the explosion of 10 kg of TNT at a distance of 10 meters in MATLAB Software for surface and air was investigated separately. Figure 3.



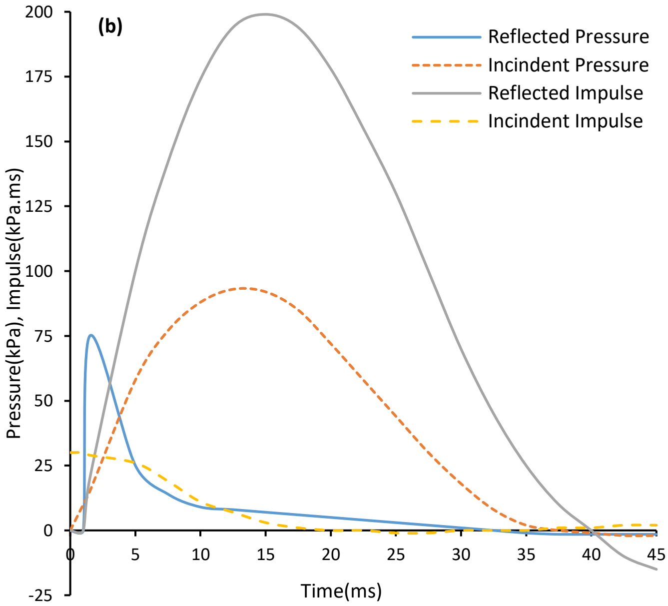


**Figure 3.** Impact of TNT at a distance of 10 meters a) surface b) air

As shown in Figure 3, when an explosion occurs on the surface, the time it takes for the blast wave to reach the target is shorter than the blast in the air. The physical justification for this is that if we consider the blast waves as sound waves, the farther we go from the ground and the higher we go, the lower the temperature.

## *3.2. EXPLOSION LOAD ANALYSIS*

In order to compare the explosion behavior of the two frames under study, we need to analyze the internal force and stresses created in it, displacement, frame rotation, work done on the frame, and the acceleration of the roof floor. Also, to investigate the behavior of steel flexural frames against explosion load, explicit dynamic analysis has been performed for 3.9399 in Abaqus software, and outputs such as internal background-mys stress of model members, displacement, rotation, external work performed on the frame as well as acceleration Created on the roof floor was obtained.

### *3.2.1. VON MISES STRESS ANALYSIS*

In the case of elements subjected to normal and shear stresses, it is possible to check whether the body has reached the yield point using the von Mises stress criterion. In the element in question, the principal stresses are calculated based on the Mohr circle. If we place these principal stresses in the von Mises control relationship, if the amount of von Mises stress obtained is less than the yield stress of the material, that is, failure does not occur, but if this stress is greater than the yield stress of the material, it means the element reaches the point It is surrender. Therefore, this criterion has been used to investigate the behavior of structures under explosion. As shown in Figure 4, the maximum stress created (2400 $kgf/cm^2$) in both models is almost the same as what occurred at the foot of the first floor columns and the reason is the transfer of all forces from the upper floors to the lower floor columns, and therefore the concentration of force at the foot of the first floor columns. But in a three-story frame, almost the entire height of the first column is critical, but in a five-story frame, half of the height of the first-floor column is critical, because of the geometric shape of the two frames. A five-story frame with five openings is a square and symmetrical frame in which the distribution of forces and consequently stresses in it is completely different from a three-story frame with five openings, which is a rectangular frame. In both models, minimum stresses are observed in the beams and columns of the upper floors. The minimum stress in a three-story frame (9.07 $kgf/cm^2$) is approximately 2 times less than in a five-story frame (17.25 $kgf/cm^2$), and equivalent compressive loading has created less force in the three-story frame.

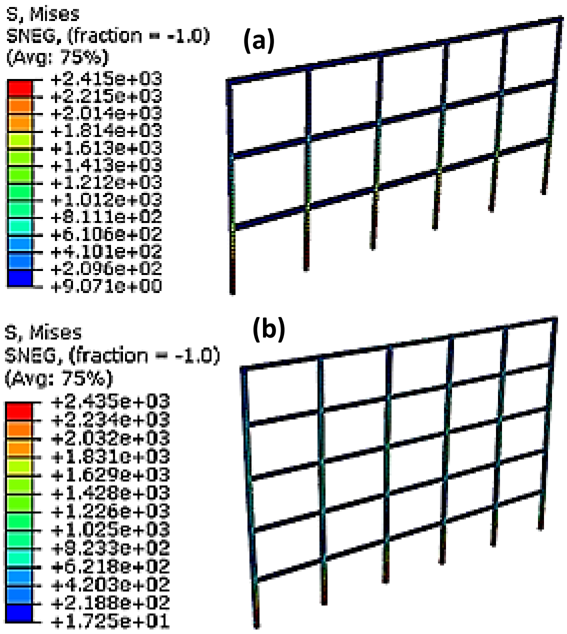


**Figure 4.** Stress created in the frame a) three layers and b) five layers in terms of (kgf/cm$^2$)

### *3.2.2. DISPLACEMENT ANALYSIS*

Since the blast load is applied perpendicular to the frame, the resulting displacement perpendicular to the frame is checked. Figure 5 shows a displacement created in the frames, in which all points are displaced in one direction, and the displacement of the frame is greater on the upper floors. The displacement created at the midpoint of the frame roof during the analysis is shown in Figure 6. As can be seen, the final displacement of both frames is almost identical. The behavior of both frames from the first moment of the explosion to 1.1 seconds after that is completely consistent; the reason for this is the low intensity of compressive forces applied to the structures at the beginning of the explosion, because the raw materials are located at a distance of ten meters from the structure, and the forces are less, and these low forces have created very little displacement in the frames, so the difference in displacement is not noticeable, but over time, the upward trend in roof displacement accelerates faster than time in the three-story frame and increases much faster. , Because the floor frame has fewer members against this external force, and the force from the explosion, which is now comparable, causes more displacement in the three-story frame than in the five-story frame. While the changes in the five-story frame increase. Eventually, at the end of the explosion, both structures move approximately 37 centimeters. In fact, it can be said that the performance of a five-story frame due to the force of the explosion is better than that of a three-story frame, because a displacement equal to a smaller structure has resulted. Better expression is the higher ductility of the five-story frame. This shows the importance of the geometric shape of the structure when the force of the explosion. Of course, as it is obvious, the relocation of the 5-story frame is much less and theoretically more than the three-story frame.

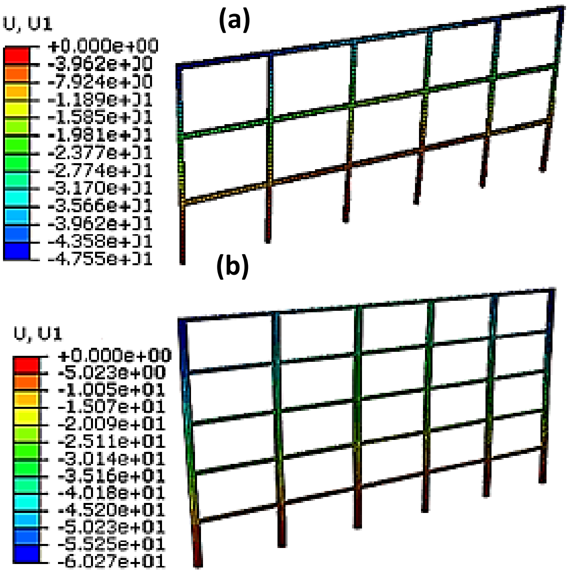


**Figure 5.** Displacement created in frame (a) three floors and (b) five floors in terms of (cm)

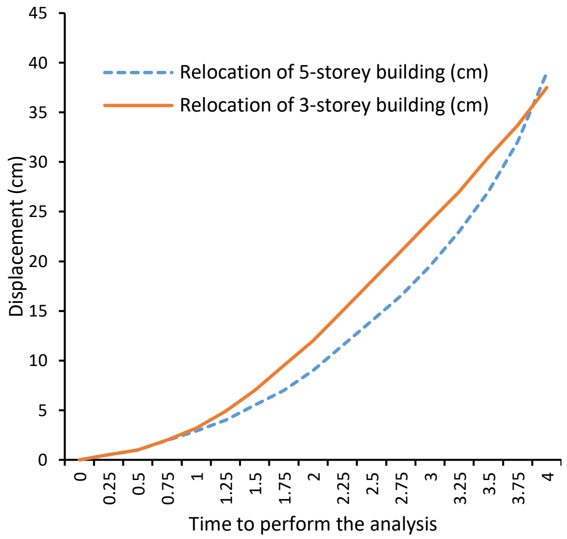


**Figure 6.** Changes in the displacement of three- and five-story frame roofs in Abaqus analysis

### *3.2.3. ROOF FLOOR ACCELERATION ANALYSIS*

Among the factors studied in the behavior of structures is the acceleration created by the load on the roof floor; For this purpose, the middle point of the roof is selected as an example, and the acceleration at that point in the direction of movement of the structure is investigated. The time history diagram of the roof floor acceleration perpendicular to the frame plane is shown in Figure 7. By looking at and comparing the diagrams, it can be said that the acceleration created in both models is almost the same, and in some places, it is slightly higher in the five-story frame than in the three-story frame. To better evaluate the results, the acceleration distribution curve in the studied frames is shown in Figure 8. This curve also confirms the described findings. Since the acceleration created in the structure is directly related to the explosive force. In this study the explosive force of both structures is the same, we expect the accelerations to be different as the structures are different, but in a five-story five-span building, the number of members increases. The structure has more ductility than the three-story three-span frame, and so this high ductility reduces the acceleration created in it, which causes the acceleration created in both the three-span and five-span frames to be almost identical. Given the direct relationship between the acceleration created in the structure and its displacement, it is possible to prove the accuracy of the displacement results because as the accelerations of both structures are almost the same, the displacements of the two are almost the same.

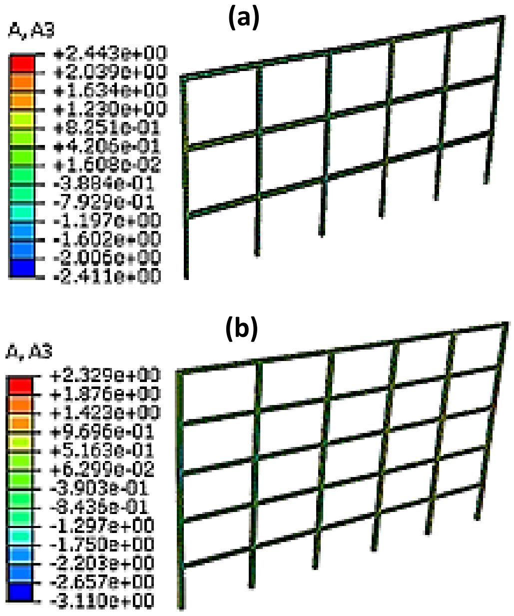


**Figure 7.** Acceleration created in frame a) three floors and b) five floors in terms of (cm / s2)

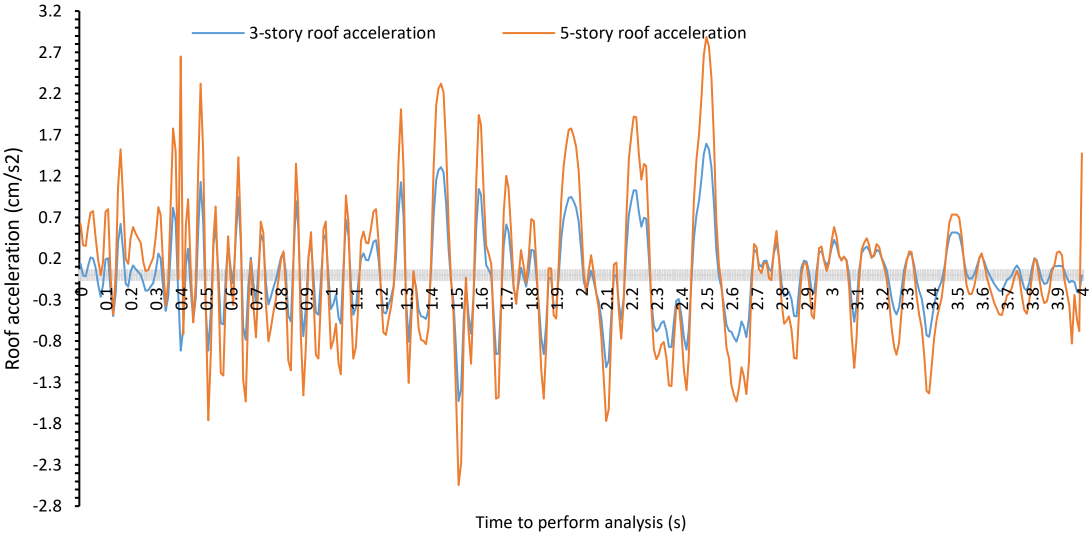


**Figure 8.** Time history diagram of the roof floor acceleration perpendicular to the frame plane

### 3.2.4. FRAME ERA ANALYSIS

Since the modeling is done in two dimensions and the explosion takes place only on one side of the frame, there is a possibility of rotation of the frame members. Therefore, another output that is considered is the rotation of the members around the frame plate, which is shown in Figure 9. As expected, a three-story frame that is rectangular and short has a much longer period than a five-story frame that is square and regular. As can be seen, it is very effective during the formation of the structure. Other notable points of these diagrams include the maximum period on the upper floors in the three-story frame and the maximum period on the middle floors in the five-story frame; the reason for this is quite obvious because on the top of the structure there is lateral support. There is no to prevent off-plane movement while the foot of the structure, is restricted, so the more we move from the restricted part to the free part of the structure, the longer the period created in the structure increases.

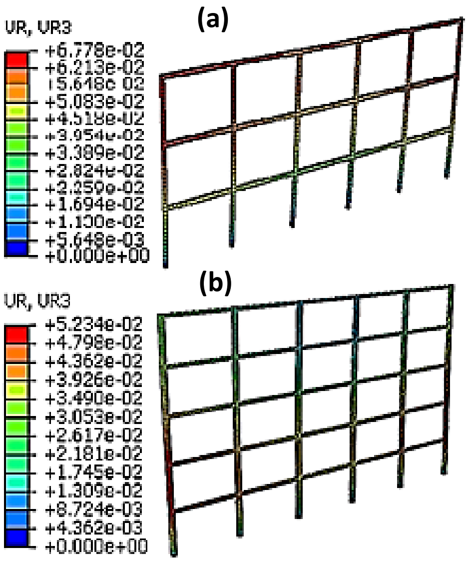


**Figure 9.** The period created in the frame a) three floors and b) five floors

### 3.2.5. ANALYSIS OF THE WORK DONE ON THE FRAME

In the explosion analysis of structures, the most widely used graph is the total curve of work done by the explosive load on the frame, as shown in Figure 10. This curve ascends and increases over time. As can be seen, the work done on a three-story frame is about 4 times the work done on a five-story frame. In other words, the explosion outside the structure does more work in the rectangular frame than the square frame, and of course, the reason is that the frames in question are square and rectangular. The external definition is equal to the force multiplied by the displacement created in the structure, which, of course, is cumulatively added to the previous stage in each stage. The three-story frame was larger than the five-story frame, so the result obtained in the external comparison of the frames is correct and justifiable.

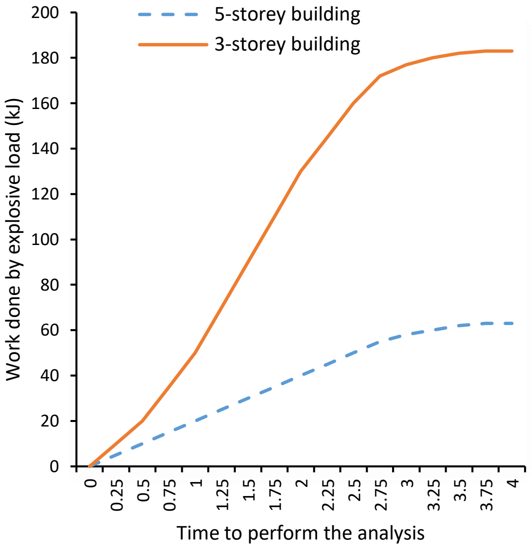


**Figure 10.** External work curve performed during the analysis period for two frames of three and five floors

## 4. CONCLUSION

Civil engineers are looking to design structures that are safe from a variety of natural and man-made disasters. Hence, there is extensive research on various types of disasters such as earthquakes, hurricanes, fires, etc. In the present study, an attempt has been made to investigate the behavior of several different frames against the explosion phenomenon. For this purpose, two frames of three and five floors are designed in finite element software; then they are affected by the force of the explosion of the explosive outside the frame. In this research, conventional frames with a high probability of explosive load have been used. This study investigates two five-hole frames of the same steel bending frame with differences in their height, one three and the other five-story, which are exploded with TNT material at a distance of 10 meters from the frame. The modeling was performed on Abaqus finite element software. The results show that the overall behavior of both frames against the explosion was similar. Also, a five-story frame with five openings has more structural members than a three-story frame with five openings, and they also have a symmetrical geometry, so the ductility of a five-story frame is more than a three-story frame. The displacement observed in both frames is the same, which due to the different classes of structures indicates a better behavior of the five-story frame with regular square geometry than the three-story rectangular frame, in the face of an explosion outside the structure. Since the blasting force is applied to the structure from only one direction, many cycles are observed in the members. These periods are again observed in the three-story frame more than in the five-story frame. Explosions on a shorter structure (three floors) with a rectangular geometry have been observed to be more effective with force, displacement, and acceleration than on a taller structure (five floors) with a square geometry. As a general conclusion, it can be said that ductility is a very influential factor in a load of an explosion, and the more ductile the structure, the better the behavior against explosion.

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CONFLICT OF INTEREST

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