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# The Effects of Damper Location on the Retrofit of Steel Buildings under Blast Loading

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**ABSTRACT:** Thin-walled tubes might be considered as the simplest and, probably the oldest, type of dampers used in energy-absorbing systems. This paper investigates the effect of thin-walled accordion metal dampers and their arrangement in the frame on the behavior of steel frames against blast loading. For this purpose, one-bay frames with either one or four stories, and in both cases of with and without dampers, have been analyzed in ABAQUS software under two different blast intensity conditions. Results demonstrate that using such dampers would improve frame displacement to a large extend (up to 98% for one-story frame and 64% for four story frame), especially during an intensive blast. Furthermore, local Plastic deformations of the frame would be reduced by locating the dampers in points with large deformations.

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## 1- Introduction

The occurrence rate of terrorist attacks has been increased in recent years, which necessitates analyzing and designing buildings against blast conditions. In the past, only military and nuclear power plant buildings were designed against blast loading. Today, however, official and residential buildings should also be retrofitted against explosive conditions. In recent years, using seismic isolation systems, passive energy dissipation tools and active and semi-active control systems has been developed rapidly. Among them are inactive dampers, which consist of both velocity-related tools, such as viscous or viscoelastic dampers, and displacement-related tools such as frictional or metal dampers. Metal dampers are of hysteretic type and dissipate energy through yielding at inelastic cyclic deformation, which leads to damage concentration in dampers and consequent reduction in the dynamic response of the structure.

There are many works that focus on the effect of blast loads on the behavior of various structures. Taylor [1] was among researchers, whose studies on the effects of explosion waves played a fundamental role for Britain ministry of defense. Motley et al. [2] used ABAQUS software for improving the response of portal frames against explosive loadings. Chen et al. [3] utilized hybrid elements for analysis against blast and fire conditions. Krauthammer [4] carried out a series of studies on the overall behavior of connections in steel and reinforced concrete structures under blast loading. In the field of inactive damper, Motamedi et al. [5] used accordion thin-walled tubes for exciting buckling pattern and increasing energy absorption. They recommended that this damper is capable of bearing large deformations through accordion buckling mode.

In the present study, a one-bay steel frame with one and four story is modeled in finite element software "ABAQUS", in two cases of with damper and without that, and analyzed with non-linear dynamic methods under the effect of two different blast loadings. Finally, the results are compared with each other.

## 2- Verification of the Finite Element model

In this paper, an experimental specimen introduced in Reference [6] has been used for verification. Finite element model of the specimen is shown in Figure 1, in which all of the frame members are modeled using shell elements with S4R meshes to account more accurately the non-linear effects caused by shear and explicit procedure is used for dynamic analysis. Also, Beam to column connections, as well as column end connection are assumed rigid. Similar to the experimental specimen, A304 type steel with yield and ultimate stresses of respectively 2100 and 5000 kg/cm$^2$ and ultimate strain of 0.6 is used in the numerical analysis.

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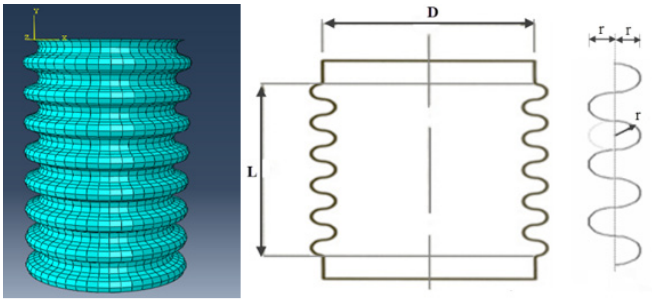


**Figure 1. Finite Element model of the specimen**

Loading is also applied in a sinusoidal form with variable amplitude from a minimum of ±10 mm up to a maximum of ±35 mm. The Force-Displacement curve of the numerical model is shown in Figure 2. By comparing with that obtained from experiment, a good agreement can be observed, although we can improve analytical results by applying some modifications in the finite element model.

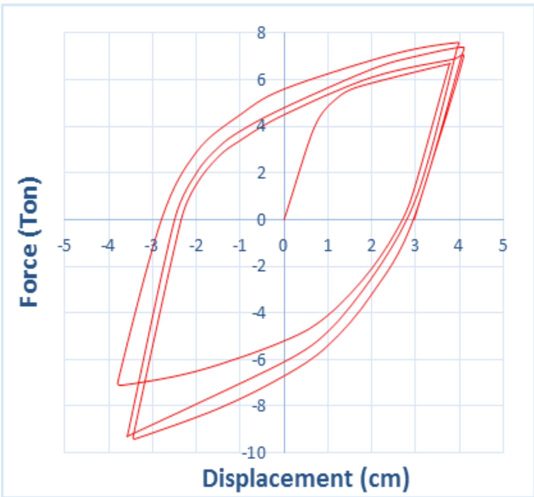


**Figure 2. Hysteresis curve of numerical model**

## 3- Analysis and discussion on results

At the first stage and for investigating the effect of accordion thin-walled damper on blast response of frames, one-story cases with 3 m height and 4 m width and beam and column sections of, respectively, Box 10×10×0.5 cm and IPE140 are modeled in the software. For dynamic analysis, density of $7850 \times 10^{-6}$ kg/cm$^3$, poisons ratio of 0.3, young modulus of $2.1 \times 10^6$ kg/cm$^2$ and yield stress of 3000 kg/cm$^2$ are used for steel.

In the second stage, four story frames with heights and widths similar to one story frame and with column of Box 30×30×1.6 cm section for the first two stories and Box 24×24×1.42 cm for top two stories are used in the numerical model. Figure 3 shows a view of the four story model in both cases of using two types of damper and without that. By completing the numerical models, we can now analyze them to find out the effects of damper location on the behavior of the frame. Figure 4 shows von-mises stress contour of one-story frame (damper case A) in the deformed shape against a blast with intensity of 36 kg/cm$^2$. The figure indicates that column base at the blast side has the highest value of stress and middle of that column has largest plastic deformations.

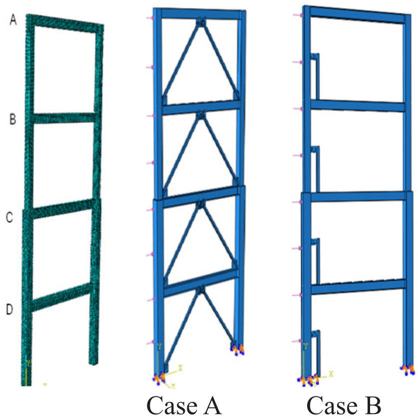


**Figure 3. View of four- story frames with and without dampers and braces**

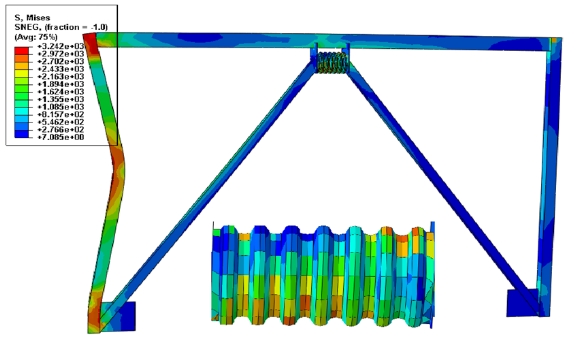

**Figure 4. Von-mises stress contour for one story frame with damper case A under a blast with intensity of 36 kg/cm2**

damper case A under a blast with intensity of 36 kg/cm$^2$

Figure 5 shows von-mises stress contour of one-story frame (damper case B) in the deformed shape against a blast with intensity of 36 kg/cm$^2$. The figure indicates that again column at the blast side has the highest value of stress and middle of that column has largest plastic deformations.

For four-story frames, von-mises stress contours of one story frames with damper cases of A and B are shown in Figure 6, which again high values of stress at beam to column connections at the blast side is observable. Furthermore, time histories for the displacement of these two numerical frames are shown in Figures 9 and 10 for joints A (top level) and B (third story levels), respectively. From these figures, it is obvious that the top displacement of the frame at the blast side is reduced, although this reduction is weaker compared to one-story models.

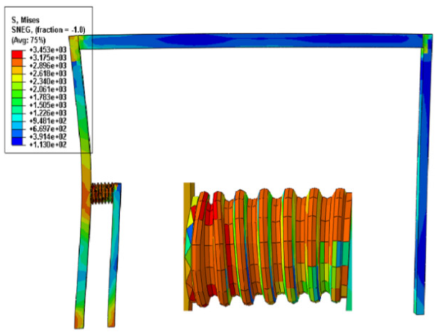

**Figure 5. Von-mises stress contour for one story frame with damper case B under a blast with intensity of 36 kg/cm$^2$**

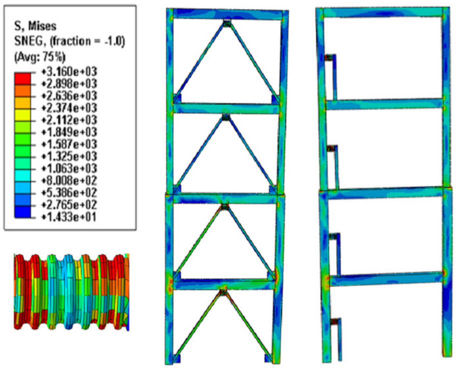


**Figure 6. Von-mises stress contour for one story frame with two cases of dampers under a blast with intensity 36 kg/cm²**

Figure 7 shows the time history of column top displacement at different floors (joints) located on the blast side, from which a maximum displacement of 44.16 cm is obtained. In Figures 8 and 9, the time histories of the joint A displacement for three conditions of damper case A, damper case B and without any damper were shown. This figure obviously highlights the reduction in the response of the frame when damper is used together with bracing (damper case A), although this reduction is not obvious for case B, where bracing is without any diagonal action.

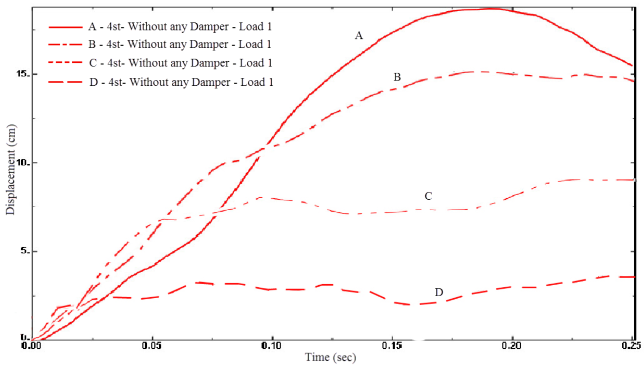


**Figure 7. Time history of joint A for a four-story frame with damper cases A and B and without them (under blast of 36 kg/cm² intensity)**

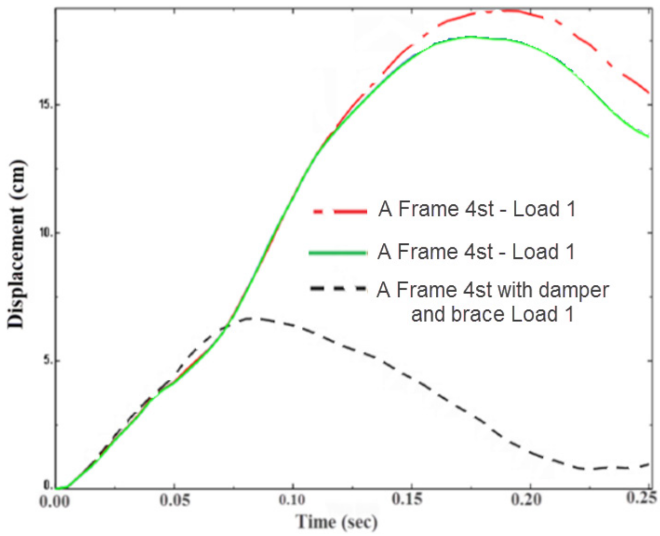


**Figure 8. Time history of joint A for a four-story with damper cases A and B and without them (under blast of 36 kg/cm² intensity)**

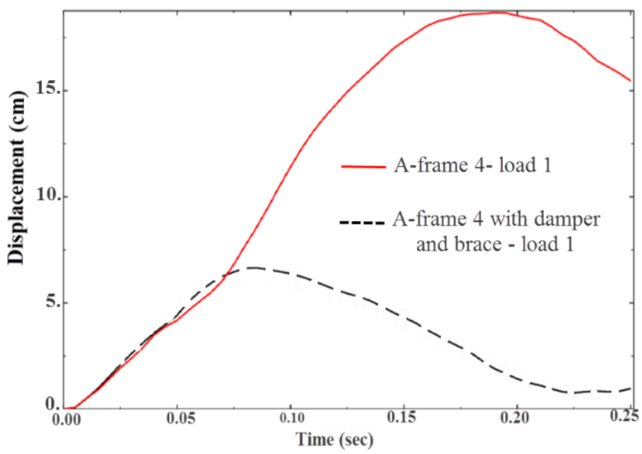


**Figure 9. Time history of joint A for a four-story frame with damper cases A and B and without them (blast 36 kg/cm²)**

## 4- Conclusions

In this paper, the effect of location of accordion thin-walled dampers on the response of frames to blast loading has been studied. For this purpose, frames with one and four stories and with two cases of damper arrangement were modeled and analyzed using finite element software and the followings can be outlined:

1. Larger deformation is produced on the middle of the column, compared to the top, on the blast side, which can be attributed to significant local plastic deformation that occurs in highly intensive blasts.
2. Using damper in both one and four story frames would totally reduce the frame response However, this reduction is more severe in one-story frame than four-story one.
3. Using damper and brace together (case A) would be much more effective in reducing frame response under blast loading, compared to case B without bracing.

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