Evaluation of the Performance of Ring-Shaped, Elliptical, and T-Adas Yielding Dampers in Chevron Bracing

Erfan Najaf, Hassan Abbasi*, Maedeh Orouji
Department of Civil Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran
*Corresponding Author E-mail: h_abbasi@azad.ac.ir

1. Introduction

The choice of the best mechanism to deal with earthquakes in steel structures has always been considered by many designers. Designers’ desire for ductility of frames due to increased energy loss has caused special attention to flexural frames. On the other hand, the satisfaction of difficult conditions and stability has caused the braced frames to always maintain their position as a bracing system. Balancing the above conditions has led the minds of designers to a combination of these features in the structure. It has always been tried that the mechanism in question, in addition to proper formability, has the necessary difficulty to control the criteria related to displacement. In this case, the structure will suffer the least damage even in severe earthquakes (1) (Whittaker et al., 1989).

To achieve this goal, many ideas and efforts have been made, each of which has its advantages and disadvantages. For example, the use of horizontal beams in the structure, in addition to the appropriate stiffness, will also provide the necessary ductility. But on the downside, replacing the girder after an earthquake can be a difficult and costly task. Much of the researchers’ efforts have focused on solving problems or improving the performance of the lateral load-resistant system. The use of a vertical beam as a suitable alternative to a horizontal beam is a testament to this claim. Zahraei and Moslehi Tabar (5) performed parametric studies on several braced frames with vertical connection beams to investigate the periodic behavior of this system. Zahraei and Moslehi Tabar (2013)

Surrendering dampers are a group of dampers that waste energy entering the structure when they reach the plastic area. The geometry of the submersible dampers should be such that the maximum points are reached and the energy loss due to plasticization is maximized. The use of surrender dampers as a D.C. member will focus the damage on the damper and minimize damage to the main members of the structure such as columns, beams, and braces. (7) The use of surge arresters in Chevron braces can always be a good solution for energy loss in metal frames. One of the biggest problems with braces is their poor pressure behavior due to different types of buckling. The surrendering dampers act as a fuse in the path of the braces and are designed in such a way that by surrendering, in addition to wasting energy, the force that causes the buckles to buckle is prevented from entering. (6)

The geometry of the centrally yielding dampers must be such that, firstly, it experiences and tolerates significant trans-elastic deformations with minimal buckling, and secondly, uniform yield occurs in the damper (8). In this case, a stable and wide hysteresis curve will be created, which will result in more energy loss by the damper and less damage to the main members of the structure. In fact, with proper design, more plastic deformation can be concentrated in the yield damper and the main members of the structure remain in the linear range. It is also necessary to pay attention to the fact that the excessive stiffness of the damper causes more force in the braces which can cause it to give in or buckle. For this reason, the damper must be designed with optimal difficulty. (2) (NajariVarzaneh et al., 2012)

2. Circular Damper System

As shown in the figure, this damper is made of a circular cross-section. This damper will be connected to the horn and beam braces with proper connections. The geometric characteristics of the damper are shown in Table 1.
3. Elliptical Damper System

As shown in the figure, this damper is made of an oval cross-section that has a constant thickness. The choice of the elliptical cross-section for yield dampers is because under the same shear force it will perform better than the tubular cross-section. This damper will be connected to the horn and beam braces with proper connections. The geometric characteristics of the damper are shown in Table 2.

![Figure 1. Circular damper](image1)

![Figure 2. Elliptical damper](image2)

Table 1. Geometric properties of the frame

<table>
<thead>
<tr>
<th>Frame specifications</th>
<th>Frame width</th>
<th>Frame height</th>
<th>Type of frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>330</td>
<td>moment frame with X-brace</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Geometric characteristics of elliptical dampers

<table>
<thead>
<tr>
<th>a(cm)</th>
<th>b(cm)</th>
<th>t(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large radius</td>
<td>Small radius</td>
<td>Thickness</td>
</tr>
<tr>
<td>20</td>
<td>15</td>
<td>1</td>
</tr>
</tbody>
</table>

4. TADAS Damping System

In this part, according to the design, 3 models have been made. The first model according to the design and the second model has stronger dimensions than the design and the third model has weaker dimensions than the design.

Case 1: 16 TADAS sheets with a thickness of 2 cm

The first model according to the design consists of 16 TADAS sheets with a thickness of 2 cm.

Second case: 16 sheets of TADAS with a thickness of 4 cm

Third case: 16 sheets of TADAS with a thickness of 1 cm

![Figure 3. T-Adas damper](image3)

5. Geometric Properties Of The Frame

The geometric characteristics of beams, columns, and braces are given in Table 3. Also shown in Figures 4, 5, and 6 are the frame system with the elliptical damper, the circular damper, and the TADAS damper, respectively.

![Figure 4. Frame with oval damper](image4)

The height of the frame is 3.5 meters and the length of the opening is 4.5 meters. The selected IPB400 beam and columns and braces are also of BOX type.

Table 3. Geometric properties of the frame

<table>
<thead>
<tr>
<th>Section</th>
<th>Flange sheet specifications</th>
<th>Web sheet specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Width(cm)</td>
<td>Thickness(cm)</td>
</tr>
<tr>
<td>Beam</td>
<td>18</td>
<td>1.25</td>
</tr>
<tr>
<td>Column</td>
<td>30</td>
<td>0.2</td>
</tr>
<tr>
<td>Brace</td>
<td>15</td>
<td>0.1</td>
</tr>
</tbody>
</table>
6. Specifications of The Steel Used

The steel used is ST-37, which specifications is shown in Table 4.

<table>
<thead>
<tr>
<th></th>
<th>Elastic</th>
<th>Plastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poisson’s ratio</td>
<td>0.3</td>
<td>0.0013</td>
</tr>
<tr>
<td>Modulus of elasticity (GPa)</td>
<td>210</td>
<td>240</td>
</tr>
<tr>
<td>Strain</td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>Stress (MPa)</td>
<td></td>
<td>450</td>
</tr>
</tbody>
</table>

Loading:

The loading method is single and cyclic. (4)

In loading the single track concerning the height of 350 cm of the frame, a relative displacement equal to 10.5 cm is applied on the upper wing of the beam. The ATC 24 method is used to determine the displacement equivalent to frame surrender. In this case, the push-over curve approximates the yield shift and defines how to apply the cycle load based on it. According to this method, the force-displacement diagram of the frame is determined by two approximate lines in such a way that the area below the force-displacement diagram is approximately equal to the area below the two-line graph. The intersection of the two graphs is considered as the yield force. Displacement equivalent to 0.75 surrender force is estimated as surrender displacement. Figure 7 shows how to determine the surrender location, according to which the surrender relocation is equal to 0.6 cm.

How to apply cyclic loading is also based on the proposed ATC 24 method in the form of cyclic loading with increasing displacement amplitude. Figure 8 also shows how to cycle. Applied Technology Council,(1992)

7. Abaqus Software

It is out of the question to state all the details included in the software, so only some of the main issues are mentioned. In this software, Solid elements in 3D space are used. The type of steel is defined in such a way that it enters the plastic area from the elastic region, but it will never rupture. Because the load is applied slowly, the load is quasi-static and the effects of velocity and acceleration are negligible. Therefore, Static and general analysis has been used in the software, which in this type of load analysis will be applied to the model in 14.4 seconds. To draw the cyclic curve, a set called Displacement is defined at points on the upper wing of the beam, and another set called Reaction is defined at the locations of the supports. The base of the columns is considered to be completely clamped, and on the other hand, because in the real model of the frame, it was restrained in the out-of-plane direction, supports were provided for tying at the top of the columns. Loads are applied to the model as Displacement in both single and cycle modes. ABAQUS Inc (2004) (3)

8. Results of Modeling

First, the 3 states of TADAS refrigerants are compared and their hysteresis diagram and diagram of energy absorption due to their plasticization are compared with each other.
Then we show the diagram of energy absorption of dampers due to plasticization for all three modes and compare them with each other.

As shown in Fig 10 the above comparisons, the first type of damper has shown good behavior, but after the damper sections become stronger, the energy absorption of the damper decreases sharply and becomes close to zero, and in the third case, after weakening the damper. Its behavior improves slightly. The following figures show the surrendered points for all 3 states.
Now let's compare the behavior of circular and elliptical dampers and TADAS dampers (the best case of the above 3 models).

As can be seen in Fig 14, the surface below the hysteresis diagram, which indicates the absorbed energy, is better for the TADAS damper than the circular damper and the oval damper.

9. Conclusion

The use of circular dampers absorbs more energy than oval sheet dampers, and TADAS dampers perform better than both. So that TADAS damper absorbs 91% of the total energy of the frame, circular damper absorbs 84% of the total frame and elliptical damper absorbs 78% of the energy relative to the frame. The surge arrester must not only waste most of the energy entering the frame, but must, like a fuse, prevent excessive force from entering, which will cause the braces to buckle. For this reason, the thickness of the damper, as well as the thickness and number of hardening sheets, must be designed in the optimal state. Excessive stiffness of the damper causes the braces to buckle or give way, which will be considered undesirable because the purpose of designing this style of a damper is to focus the damage on the damper so that the main members of the structure...
such as columns, beams, and braces are low. The thickness of the damper, the thickness, and the number of hardening sheets are the most important factors in achieving the most desirable result so that it can be selected with a more appropriate choice than the stated models. Better results were obtained. Finally, the use of circular dampers is recommended due to the simplicity of the execution steps.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References


