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Döngüsel Yükleme Altında Hibrit Sürtünme Verimli Sönümleyicinin Davranışının İncelemesi

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Özet

Geçtiğimiz on yıllarda, sınırlandırılmış destek çerçevelerinin plastisite gelişimi (sertliği) üzerine kapsamlı çalışmalar yapılmıştır. Yeni yöntemlerden biri, metal halkaların, parantezlerin kesişme noktaları arasında bir enerji kaybı (dağıtımı) olarak kullanılmasıdır. Önceki çalışmalar, halkalı braketlerin döngüsel yüklerde sabit bir histerezis eğrisi sergilediğini ve bunun yanı sıra bileşenlerine olan kuvvet talebini azaltmaya neden olan enerji kaybettiğini göstermiştir. Bu damperlerin performansı planlanan depremler için tahmin edilmekle birlikte (yapıların sismik tasarımı), ancak elastik çelik halkalar bu kapsamdan daha az depremlerde kalacaktır. Bu çalışmada, iki farklı deprem seviyesinde enerji dağıtabilecekleri yayların paralel birleşimi olarak üç çelik halkadan oluşan bir damper bulunmaktadır. Medial depremlerde (planlanan depremden daha az), daha büyük çaplı (daha az sertlik) bir döngü modifiye edilmiştir, ancak içten akma döngüleriyle planlanan depremlerde, yapının dinamik özellikleri iyi bir şekilde değiştirilecektir. Bu tip sönümleyicilerin davranışını incelemek için modellerin davranış eğrileri ANSYS sonlu eleman yazılımı kullanılarak yuvarlak yüklerin etkisinden türetilmiştir. Davranış eğrileri, iki seviyeli sismik tasarım için iki seviyeli özgül enerji kaybı elde edildiğini gösterdi ve sonuçlar, ikinci bir fazın eklenmesiyle enerji kaybının arttığını, birinci faza önemli ölçüde damper verdiğini gösterdi. Ayrıca, akma damperinin (çelik halka) belirtilen deplasmana eklenmesinden dolayı, akma damper daha kararlı bir davranış sergilemektedir.
Anahtar Kelimeler: Sonlu elemanlar, kombine damper, orta deprem, verimli damper, sürtünme

Studying of the Behavior of Hybrid Friction-Yielding Damper under the Cyclic Loading

Abstract

Over the past decades, it has been done extensive studies on the plasticity development (stiffness) of the restrained bracing frames. One of the new methods is the use of metal rings as an energy loss (dissipations) among the intersection of braces. Previous studies have shown that the braces with a ring exhibit a stable hysteresis curve in cyclic loadings as well as losing energy that makes to decrease the force demand on its components. Although the performance of these dampers is predicted for the planned earthquakes (Seismic design of structures), but the elastic steel rings would be remained in the earthquakes less than this extent. In this study, there is a damper consisting of three steel rings as a parallel combination of springs which they are able to dissipate energy at two different levels of earthquake. In medial earthquakes (less than planned earthquake), it was modified a loop with a larger diameter (less stiffness), but in the case of planned earthquakes with internal yielded loops, dynamic characteristics of the structure would be modifies well. In order to study the behavior of this type of the dampers, the behavioral curves of the models are derived from the effect of round loads using the ANSYS finite element software. The behavioral curves showed that two levels of specific energy loss were obtained for two levels of seismic designs, and the results showed that the energy loss increases by adding of a second phase yielded damper to the first one considerably. Also, due to the addition of the yielded damper (steel ring) in specified displacement, the yielded damper shows a more stable behavior.
Keywords: Finite element, combined damper, medium earthquake, yielded damper, friction

INTRODUCTION

Design of structures against seismic forces is one of the main developing areas in civil engineering. Considering the progress on this area made in the effects of the past earthquakes experience, so that high volume failures and collapse of the structures from destructive earthquakes lead to an attempt to improve the response capacity of the structures by advanced equipment applying. Decreasing the seismic forces, structural response to demand forces and improving of structure damping are some approaches that are in consideration for improving the response of the structures. Among them, increasing the damping of the structures is achieved by using devices for energy dissipation in the structural system to absorb energy and modify the period of the structure in order to reduce the overall response of the structure. Circular elements are designed as yielding dampers for earthquake forces created in the planned earthquake. The other sections of the structural members are obtained based on the design method and the related capacity in terms of fuse capacity (Keh-Chyuan Tsai and Huan-Wei Chen, 1993). Three different types of equipment are seismic separators, passive and active and semi-active dampers. Although, use of different inactive dampers including yielding type, buckling restrained brace frames (BRBFs), tuned mass dampers (TMDs), MR dampers, viscosity or frictional dampers have been considered in a large number of structures and regulations, but they still need to be modified and spread. Moreover, need to increase the capacity and to improve the behavior of the structure in severe seismic stimulation and also protecting the structures against less actuations or triggers (with more likely occurrence) such as moderate earthquakes or induced actions by wind force which are not covered under the functional area of high-capacity dampers have been in consideration well (Dumne et al., 2017). Several studies over the past years, with the feasibility of combining a variety of energy dissipation devices as compound dampers have been provided a new stage for the effective use of these dampers with a fitted decreasing of seismic responses. By studying on the behavior of the structures equipped to inactive dampers including yielding damper or frictional dampers, it has been determined that the design force for yielding or the optimum slipping force of the dampers should be in a range that causing in energy dissipation on the structure related to the planned earthquakes. Obviously, due to large reduction of this force (the stiffness of the dampers depended on displacement), the appeared deformations in the structure would be exceeded than the allowed and defined value. On the other hand, high stiffness or high slipping force in friction dampers will result in energy dissipation or the restraining it in high intensity earthquakes and more importantly it will be along with a high demand of sheared base and structural components' force. Therefore, a need to provide a compound (combined or mixing) inactive damper (hybrid damper) is necessary that will be able to dissipate energy at various levels of earthquake stimulation (Lee et al., 2017). Hybrid dampers are a special type of multiphase systems that many of them have been studied in numerous studies by researchers, and the effectiveness of these systems has been shown in controlling the structural responses (Uriz et al., 2008). The mixing damper is a combination of a block with visco-elastic materials compacted between two steel plates and it could be bent in a certain direction. The idea of combining the yielding dampers of buckling restrained brace frames (BRBFs), and visco-elastic dampers was also tested for other high structures by other researchers to control two different levels of earthquake. Buckling restrained brace frames (BRBFs) were also tested as a yielding damper with a suitable energy dissipation in a series combination with a high damping materials. M.A Kafi proposed two spring using in series to control medium and high seismic forces. In this damper, the energy input in moderate earthquakes was dissipated by friction damper but in severe earthquakes, it was wasted by a comb teeth yielding damper. Two-level performance of these dampers in the behavioral curve showed that combined or mixed dampers can modify the dynamic specifications of the structure in defined displacements well. Circular elements that can be used along the restrained braces are plasticity ones that are capable to absorb input and arrived energy to the structure and, in the form of a fuse member can prevent the buckling of the bracing as well as increasing the structural damping by energy dissipation through steel plasticization process (Keh-Chyuan Tsai and Huan-Wei Chen, 1993). Some of the conducted studies on these types of the elements have been shown that if a fitted diameter and thickness are selected for these dampers, the loops can exhibit a suitable plasticity and energy dissipation capability without of any resistance fall [10]. The performance of yielding dampers including steel rings has been always questioned in earthquakes less than planned one Irritable (Badband, 2005). According to previous studies, the yielding displacement of the rings is very small compared with applied displacements into the structures on moderate earthquakes (smaller earthquakes than the planned one). It is evident that the behavior of the rings will not remain elastic in the middle earthquakes and this will result in decreasing the deformation capacity of the yielding damper due to persistent strains or residual stresses in the main earthquakes. In this study, a secondary fuse was used to improve the behavior of the circular yielding damper and this makes in performance improving of the circular damper in the major earthquakes by combining as like as parallel spring form with main fuse (Ming-Hsiang and Sung, 2004). In this way, the capacity of the circular damper makes to transfer energy dissipation act in the moderate earthquakes into a larger loop with a lower stiffness in the main fuse by adding an outer ring as a secondary fuse and providing a specific displacement between the main and secondary fuses. While internal circular fuse remains ineffective in moderate earthquakes and in severe earthquakes only energy dissipation occurs. In this regard, it has been used from ANSYS finite element software to determine the function of the mixing damper. Models with different specifications are under reciprocating (round) loads and the behavioral curve of the mixing damper has been obtained in the related models (Iwata and Wada, 2000). The equivalent damping coefficient, the equivalent stiffness and also the amount of energy dissipation in different cycles are compared in finite element models 2. The concept of a mixing damper In this study, a proposed mixing damper is considered under a series combination of two yielding dampers. This damper is made up of two-springs in series with a specific displacement, and consists of two main and secondary fuses. The main fuse in this study is a fuse that should absorb the main earthquake energy, and the secondary one is part of the fuse that can dissipate input energy without interfering of main fuse for moderate earthquakes. Secondary fuse (larger loop) in medium amplitude earthquakes that is created in the floor with corresponding and relative displacement has a potential for energy dissipation. Energy dissipation is performed in this fuse without involving the main fuse (internal loops). This possibility is provided by applying a lagging phase shift (using a preservative device). After increasing the seismic intensity, the second fuse will be added to the energy absorption system after a lagging phase shift spent. These dampers are designed for two moderate and severe earthquakes, and required stiffness for these dampers is obtained for each seismic level separately (Kumar et al., 2007).

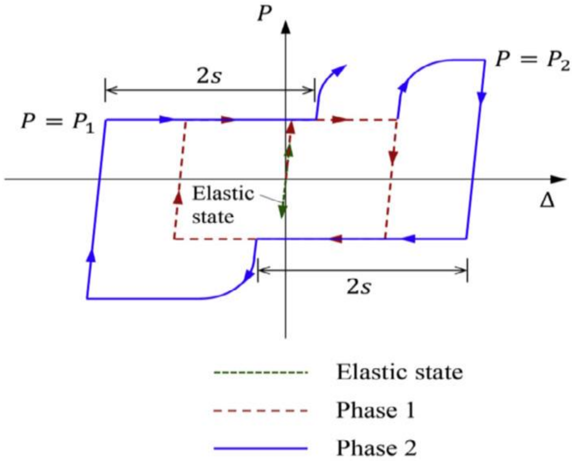

Figure 1. The ideal behavioral curve for a two-level

Figure 1 shows the ideal hysteresis curve of a compound or mixing damper under cyclic loading. In this diagram, it has been used from a system dependent to displacement in both energy dissipation phases, for instance the first phase is related to outer ring and the second phase of the damper have been selected from inner rings. When the force P increases and reaches to the amount of yielding force at the first damper, plastic deformation begins in phase one (secondary fuse). If the maximum displacement rate, D is exceeded in the same direction, the motion will continue without any changing in the load value. On the other hand, if the direction is reversed, plastic deformation occurs as same as the load rate in the opposite direction. This behavior is repeated again in the same range, and its hysteresis loops appear as a result from the performance of the first phase yielding damper. To control the structure from a low to moderate earthquake, the first phase is planned to be dissipated only by plastic deformation. Accordingly, due to low structure requirement, the yielding force hardly remains at the required level in phase 1 of the mid-earthquake. Under a strong earthquake, the damper system may experience over-predicted displacement. In this situation, the combined behavior occurs through the activation of the first and second phase dampers during a few steps. When D as a maximum displacement point is exceeded from specified range of amplitude for the first phase, then two sides of the retaining plates prevent from the mentioned sliding motion that is continued. In this case, the damper moves into phase 2 and the metal ring begins to operate in the yielding section. Since energy is eliminated through the yielding behavior of the second and first dampers at this stage, the use of energy dissipation significantly increases compared to the first phase. Rising load resistance capacity P to phase 2 can prevent excessive deformation in a particular direction, especially when the damper is exposed to various levels of cyclic loads during an earthquake (Altan and Yunus, 2018).

MATERIALS and METHOD

Numerical studies of cyclic damper

Resistance of materials and geometrical; The case of the plastic joints is shown in figure.11 prior to the formation of plastic joints, the force-displacement relationships (ring diametr changes) and their internal forces are in the elastic range under the load P and radius R.

$$(1)\ M^{+} = 0.3183PR \qquad \theta = \frac{\pi}{2}$$

$$(2)\ M^{-} = 0.117PR \qquad \theta = 0$$

If the moment of inertia for the barrier steel ring $ti^3/12$ Consider that the shift positions of the yield stress and compression direction can be calculated as follows. The rubber is formed by increasing the load of four plastic joints in the ring. Delayed relations are as follows.

$$(3) \qquad \delta_y^- = -0.149\frac{PR^3}{EI}$$

$$(4) \qquad \delta_X^+ = 0.137\frac{PR^3}{EI}$$

$$(5) \qquad 2M_P = \frac{PR}{2} \rightarrow P = \frac{4M'}{R}$$

$$(6) \qquad M_P = \frac{t^2 l\delta_y}{4}$$

$$(7) \qquad M_P = \frac{t^2 l\delta_y}{R}$$

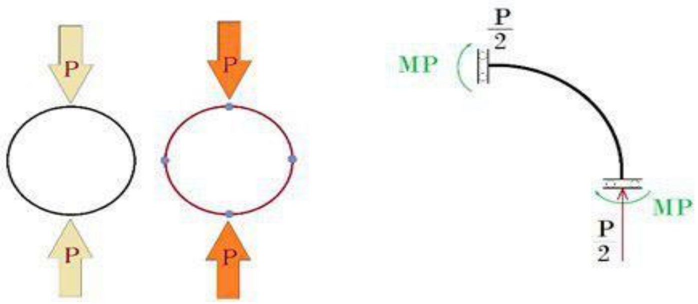

Figure 2. Formation of plastic joints in steel ring

Modernization of limited components

In this paper, ANSYS elements software is used to model the nonlinear behavior of the proposed damper. The 185 solid element was used to model the steel rings in the surrender section. This element is suitable for 3D modeling of desert elements. This element is rounded and has three degrees of freedom per node. Each node has a transient degree in direction and a LOVE 2. This element has the properties of elasticity, plasticity, hierachical elasticity, tensile strength, creep, large deformation, large strain and can show all anchors, internal forces, internal loading and external loading in nonlinear analysis. An image of this element is shown in the (Figure. 3)

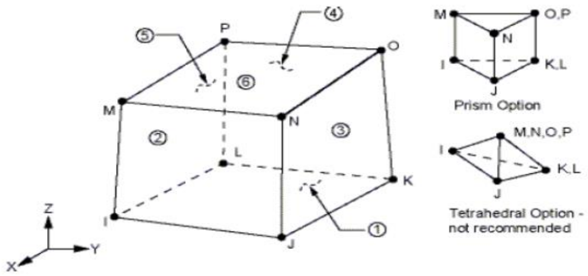

Figure 3. Three-dimensional element, node 185 solid

The 170 CONTA and 170 TARGE contact elements are used to model the collision and the inner surface of the horizontal holes. The contact elements used are capable of modeling all the nonlinearities between the surface and volumetric elements are shown in Figure 4 of the contact element 174 CONTA. Fine steel with a stress tolerance of 240 MPA and a use coefficient of 0.3 was used to aggregate the damper components other than the screws.

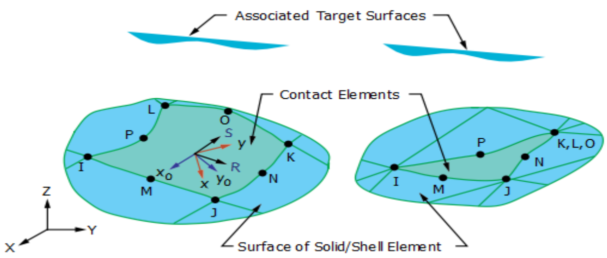

Figure 4. Contact elements 174 CONTA

A two-level aggregate model with a modulus of elasticity of 2.1×10^5 MPA and a slope of 0.02 is considered for the nonlinear behavior of the aggregates. The gap spacing is determimed based on the spatial variation limit set in table C1.3 in FEMA356 for the lateral safety performance level of one percent drift.

RESULTS and DISCUSSION

Figure.5 shows the model built into the ANSYS software. It is built for simplicity of analysis using finite element symmerty and boundary conditions are defined symmetrically. The geometric properties of the ten loaded finite element models are presented in Table 1.

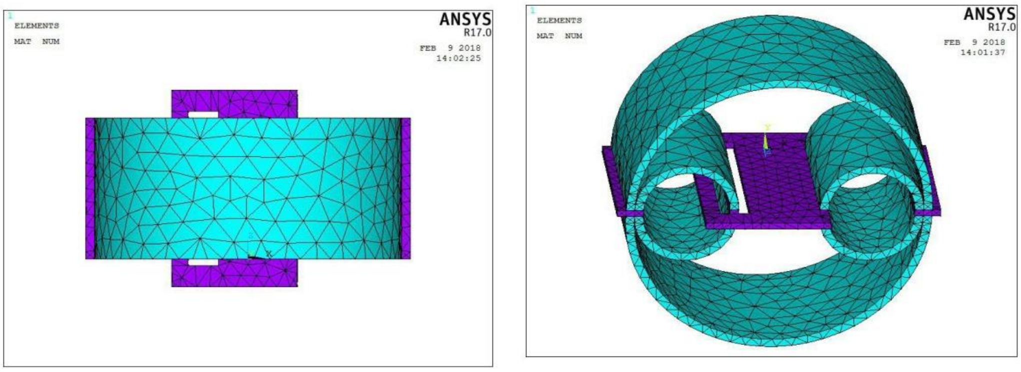

Figure 5. Model built in ANSYS software

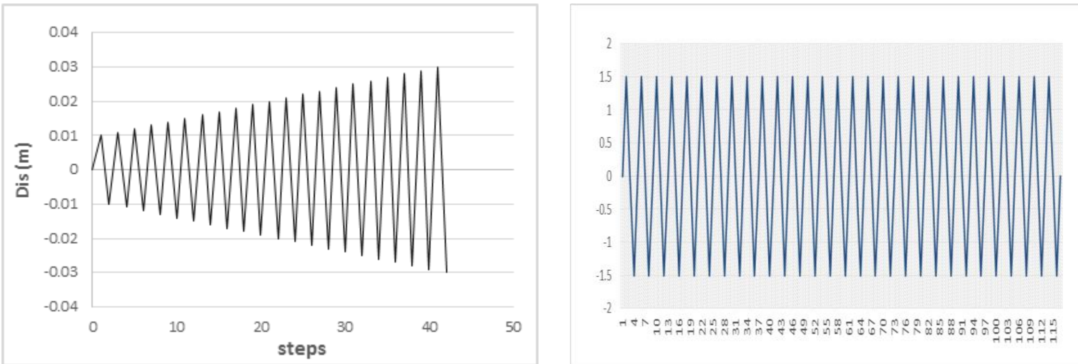

Figure 6. Upload history

Table 1. Specifications of damper samples

MODEL	INTERNAL FUSE DIAMETR (CM)	EXTERNAL FUSE DIAMETR (CM)	INTERNAL FUSE THICKNESS	EXTERNAL FUSE THICKNESS
1	8	40	1	1.2
2	10	40	1	1.2
3	12	40	1	1.2
4	15	40	1	1.2
5	10	40	0.5	1.2
6	10	40	0.8	1.2
7	10	40	1	1.2
8	10	40	1.2	1.2
9	10	40	1	0.5
10	10	40	1	0.8

The introducted models were subjected to a reciprocal loading 360 cycle of the analysis result tolerance of reciprocal loading. The figure 7 shows the distribution of stresses on the desk in the first example. The stress distribution shown is illustrated. The pressure applied to the element is shown in the figure. The pressure distribution indicates that these elements are sliding on the friction plate.

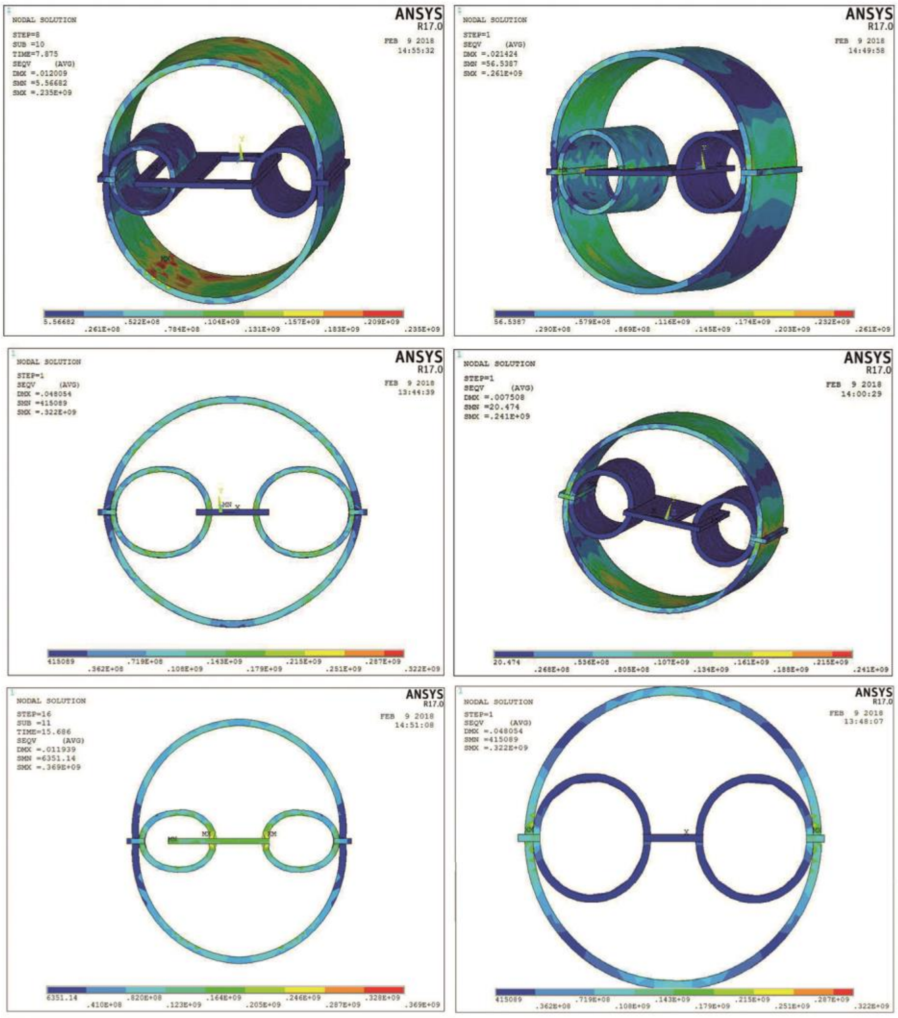

Figure 7. Contact element tension

The results of the stepwise tibet force and displacement under increasing and constant amplitude cycles loading are shown in figure 8 through figure 17. These graphs show that friction damping alone contributes to energy loss until the displacement is less than 15 mm. After the reshaping mechanism of this steel ring transitions, it can contribute to energy absorption in higher spatial demand.

Thickness changes

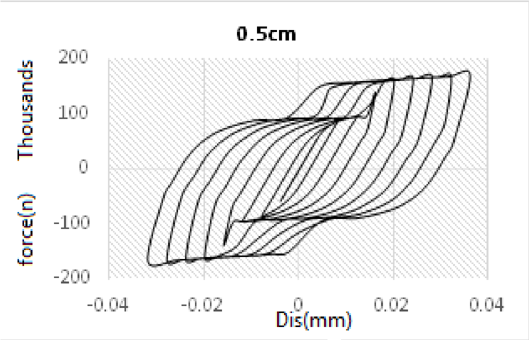

Figure 8. Curve of force and displacement for 0.5 cm

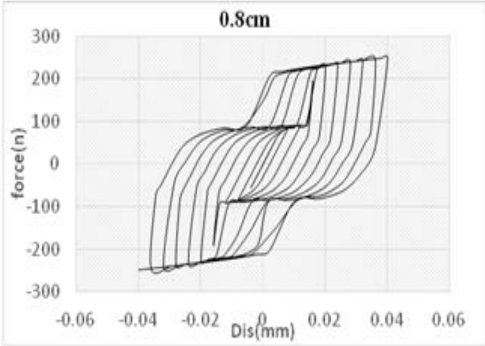

Figure 9. Curve of force and displacement for 0.8 cm

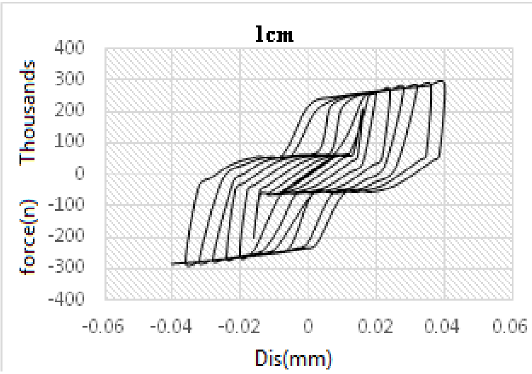

Figure 10. Curve of force and displacement for 1 cm

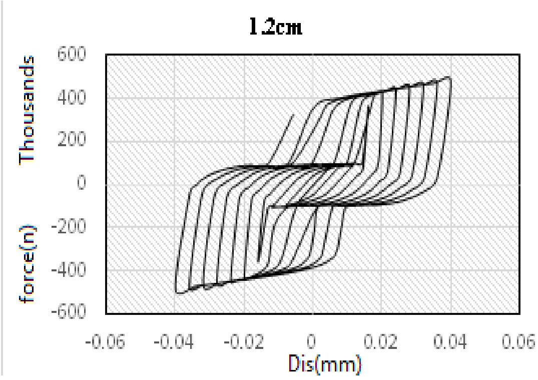

Figure 11. Curve of force and displacement for 1.2 cm

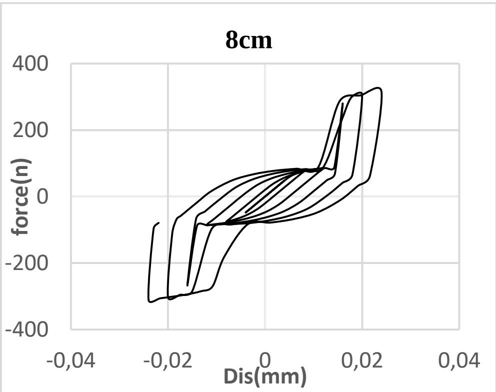

Figure 12. Curve of force and displacement for 8 cm

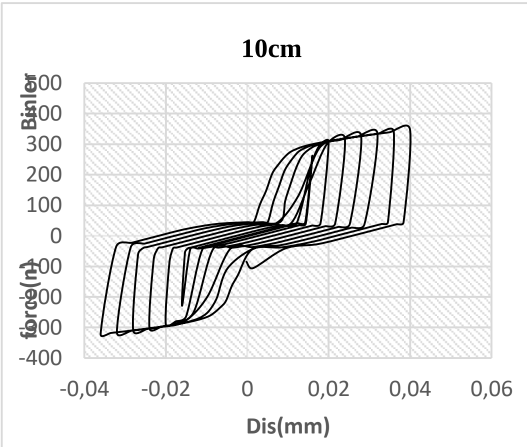

Figure 13. Curve of force and displacement for 10 cm

DİAMETER CHANGS

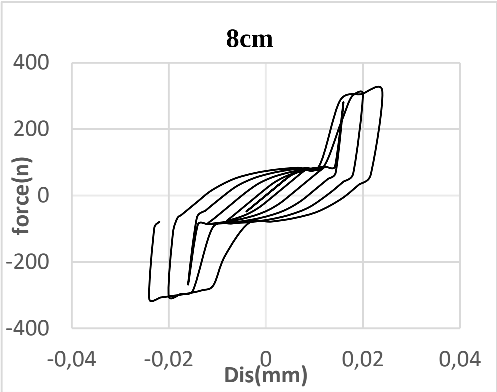

Figure 14. Curve of force and displacement for 12 cm

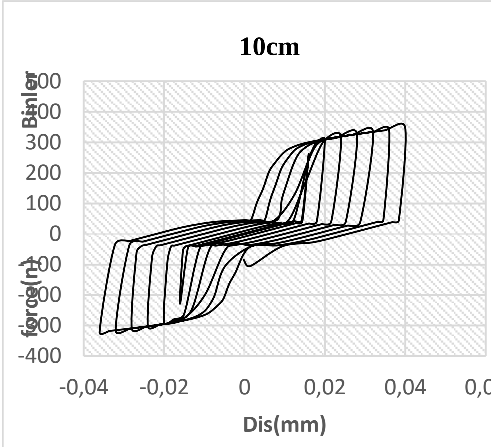

Figure 15. Curve of force and displacement for 15cm

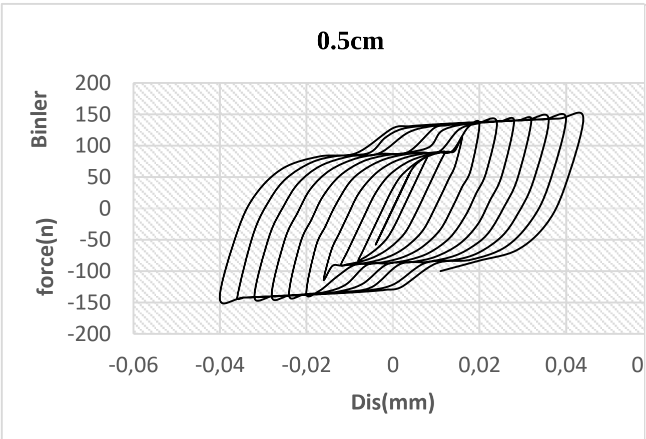

Figure 16. Curve of force and displacement for 0.5 cm

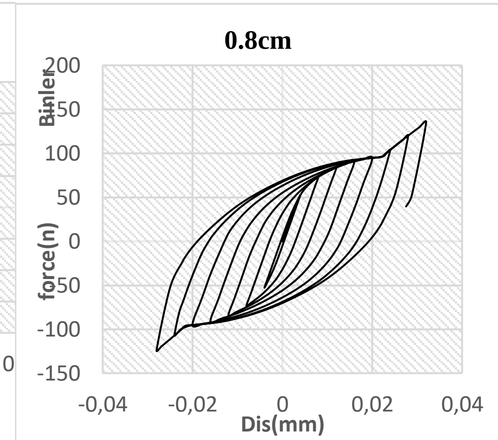

Figure 17. Curve of force and displacement for 0.8 cm

In previous research, another type of energy dissipator has been introduced (Figure 18). This absorber is made in the form of concentric steel rings and can be installed in bracing structures to increase ductility and energy absorption. During an earthquake, the consuming member consumes a significant portion of the energy entering the structure by entering the nonlinear phase and forming flexural paste joints, thus preventing or delaying the buckling of the bracing members. The diametr and thickness of the rings are a function of the expected axial force of the brace, while the steel ring design will be such that before buckling occurs in the compression member of the brace, the proposed element will yield and prevent the buckle from buckling while absorbing adequate energy (Keh-Chyuan Tsai and Huan-Wei Chen, 1993). But in our studies, the destructive earthquakes that have occurred in recent years show that special levels of the main characteristics of the building are needed to deal with earthquakes (Figure 19). One of the effective methods for energy consumption is to reduce the needs. Seismic, the use of inelastic deformations of steel sheets in yield dampers increases damping and hardness. This damper is used in the construction of earthquake-resistant buildings, and is an economical method. Using this method causes the act of destruction to occur on a predetermined part, which can be replaced after loading.

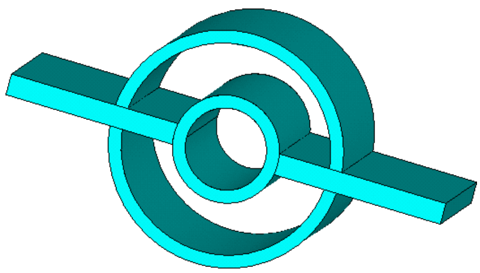

Figure 18. Energy absorbing member and fuse to control the buckling buckle

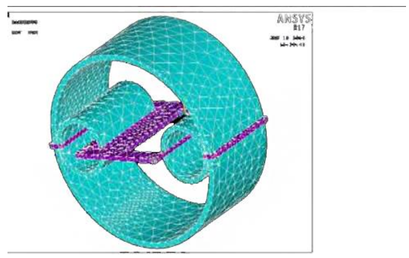

Figure 19. Proposed model

CONCLUSION

In this study, an attempt was made to increase the ductility of coaxial braces using an organ, which, while having the appropriate efficiency and capability and the possibility of preparing and installing it at the end of all types of coaxial braces, is possible. Analysis studies have shown that increasing the capacity of formable annular elements is possible by using uniform concentric annular members and due to the formability of this element and its high energy absorption, a major part of the structural energy absorption of plastic can be obtained from these members. Due to the fact that the capacity of the element depends on the thichnes and ring materials and connecting plates, the design is possible for various loads, considering that the maximum force applied to the brace is equal to the maximum force tolerated by the element. It was designed the brace and the element to make sure the brace did not fail. The proposed element has a very simple implementation and does not require expert force for use in the structure. Also inactive control methods reduce the vulnerability of structures to earthquakes by reducing the need for seismicity and increasing ductility.

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