STUDY ON SEISMIC PERFORMANCE OF BUCKLING RESTRAINED BRACE WITH DUAL PIPE DAMPER

Sukrutha Sudhakaran[1], Aswathy P[2]

[1]M-Tech Student, Dept. of Civil Engineering, Thejus Engineering College, Kerala, India
[2]Assistant Professor, Dept. of Civil Engineering, Thejus Engineering College, Kerala, India

---

Abstract - *Frames with braces are being used as a prominent lateral loads(such as high intensity seismic forces, wind loads etc.)Resisting structures. Even though it resist lateral forces, these forces are being transferred to other load carrying members. Buckling resisting braces, whose core and restrainer made of steel was a very effective element against buckling. Because of its easiness in maintenance, economy, lightweight and replaceable character their applications in structure was more. These braces dissipates energy during the action of lateral forces, but under a high intensity earthquake the other load carrying elements suffer from high stress and deformation due to the transferring of force to them, which causes destruction of the structure. This study particularly focus on reducing the force that are being transferred to the other members and to increase the life of structure. For that a new passive earthquake energy absorbing device called Dual Pipe Damper are incorporating with the core of the buckling restrained brace and the performance were studied by varying the width and thickness of the damper. And also comparison of a simple frame with and without the dual pipe damper on buckling restrained brace were also done. From all the studies it was clear that the dual pipe damper absorbs more energy and the variation in the shape of the damper had influence on the energy absorption capacity and stiffness of the structure.*

***Key Words*: Energy dissipation, Buckling restrained braces, Passive controlling devices, Dual pipe damper, Seismic performance**

1. INTRODUCTION

A braced frames are structures which are developed in order to resist high intensity lateral loads acting over the structures. Because of the cyclic and periodic action of these forces result in the reduction of stiffness and strength of the braces when constructed in the seismic prone areas. The beams and column in the frame structure transfer vertical loads while the bracing carries the lateral loads. Severe shaking of the structure due to ground motion causes large amount of energy to be transmitted to the structures. But researches and codal provision shows that the energy dissipation due to this forces were uneconomical and it is better to forecast the yielding in some controlled elements. Bracing was one such element which dissipate energy due to sever shaking caused by earthquake in a better manner. Buckling restrained brace [BRBs] is a type of braces that will not buckle under compression and also increase brace ductility as well as postpone the failure. Even-though braces are one of the prominent energy dissipating element in structures ,they generally transfer the dissipating energy to the other frame members, and the force that are being transferring is quite large in case of high intensity seismic forces. This can lead to severe damages to the load carrying structural members resulting in strength deterioration and low damping after excitation. Pipe dampers are one such efficient yielding metallic damper due to its excellent ductility but it has low stiffness so in order to enhance its performance a new concept called dual pipe damper[DPD] was developed by Maleki and Mahjoudi[10].The DPD has the capacity to absorb the maximum seismic energy which prevent the other frame from destruction. That is the force transferring to the supporting members will be reduced. In this work such a improvement for the braces with good energy absorption and stiffness were investigated by implementing the dual pipe damper concept on the buckling restrained braces. Thus the influence of dimensional parameters of dual pipe damper on the braces for resistance against lateral loads were identified as this concept were not studied in the recent past

2. OBJECTIVES OF THE WORK

This work mainly carried out:

- To study the performance of buckling restrained braces with varying width of dual pipe damper
- To study performance of buckling restrained braces with varying thickness of dual pipe damper
- Comparative study of the performance of buckling restrained brace frames with and without dual pipe damper

3. GEOMETRIC DETAILS

Three buckling restrained braces were modeled with dual pipe damper of varying width and nine buckling restrained braces were modeled with dual pipe damper of varying thickness. For the study models with dual pipe damper of outer diameter, 58 mm opted which were modeled by using ANSYS Workbench 16.1 software. Figure below shows the geometry of dual pipe damper.

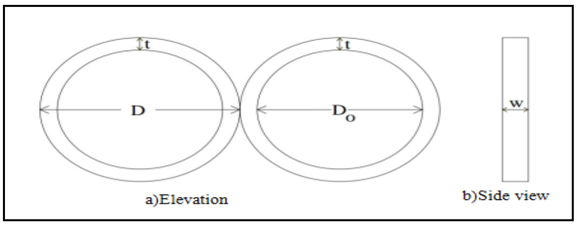

Fig -1: Geometry of dual pipe damper

Where,

D -Outer Diameter of the damper

D_O -Inner Diameter of the damper

t -Thickness of the damper

w -Width of the damper

Buckling restrained brace of length 2000 mm was used for the study with gap size of 5 mm between restrainer and the core. Table -1 shows the dimension details of buckling restrained brace and Table-2 shows the dimensions of dual pipe damper with varying width and Table-3 shows the dimensions of dual pipe damper with varying thickness.

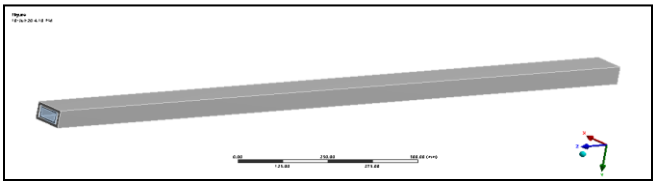

Fig -2 Geometry of buckling restrained brace with dual pipe damper

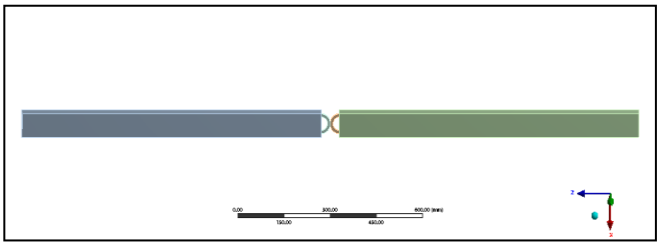

Fig -3 Geometry of buckling restrained brace showing core and dual pipe damper

Table -1: Dimension of buckling restrained brace

Restrainer dimension (mm)	100 X 80 X 10
Core dimension (mm)	70 X 60 X 6
Length of specimen (mm)	2000
Gap size(mm)	5

Table -2: Dimension of dual pipe damper with varying width

D [mm]	D_O[mm]	t [mm]	w [mm]
58	40	18	2
58	40	18	3
58	40	18	4

Table -3: Dimension of dual pipe damper with varying thickness

D [mm]	D_O[mm]	t [mm]	w [mm]
58	40	18	2
58	41	17	2
58	42	16	2
58	43	15	2
58	44	14	2
58	45	13	2
58	46	12	2
58	47	11	2
58	48	10	2

4. MATERIAL PROPERTIES

Frictional contact was provided between the core and the restrainer with a coefficient of friction as 0.1 to enable easy sliding. The damper has to be welded, bonded contact was provided between damper rings and at the point of contact between damper and the core. The isotropic hardening rule was implemented to model. Every model which was meshed with the element-SOLID186 (20 noded) to obtain good non-linear performance, with bi-linear isotropic hardening. Table -4 shows the material properties

Table -4 Material properties

Young's Modulus	200 GPa
Yield Stress	325 MPa
Poisson's Ratio	0.3
Density	7850 kg/m3

5. LOADING AND BOUNDARY CONDITIONS

One end of brace was restrained against all degrees of freedom and other end was applied by a cyclic loading. Same boundary conditions was provided for all models. The displacement were given in the alternative positive and negative cycles as per the AISC protocol

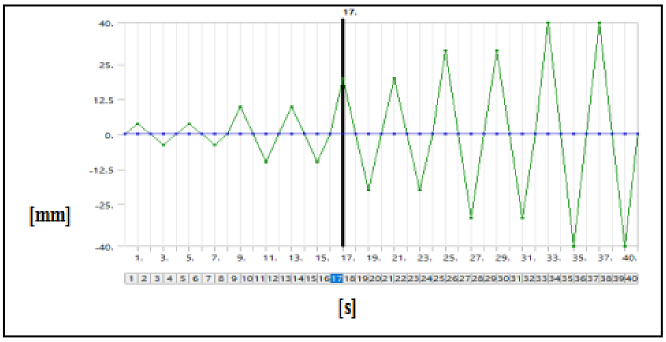

Fig -4: Loading

6. FINITE ELEMENT ANALYSIS RESULT OF THE STUDY

As we know about stress, which is referred to as the internal force that resist deformations. While considering the failure of a structure the factor which likely to be considered is the stress, thus the equivalent stress distribution of the models were considered as the criteria for analyzing the performance of models as it were made of steel. With the increase in width of the dual pipe damper the stress was also increasing. Failure was more likely to be happen soon in DPD with more width as its capacity to resist deformation has reached the limit. The model with damper width 4mm experienced more stress of about 341.65 MPa that was about 17.5% more than 2 mm. From the results it was evident that 2 mm wide damper model show better performance as it can resist more deformation.

Table -5 Stress distribution [Width]

Width (mm)	Stress (MPa)
2	281.7
3	324.84
4	341.65

With increase in thickness of the dual pipe damper the stress also increasing. The deformation of the damper was also reducing because of its capacity to absorb energy increases with increase in thickness. Failure was more likely to be happen soon in DPD with less thickness as its capacity to resist deformation has reached the limit but as if the thickness increase its ability of energy absorption were also increasing. The model with damper thickness 10 mm subjected to more stress of about 368.57 MPa that was about 25.5% more than 18 mm. As the thickness increases the stress induced was decreasing and from this results it was evident that 18mm thick damper model show better performance as it can resist more deformation.

Table -6 Stress distribution [Thickness]

Thickness (mm)	Stress (MPa)
10	378.07
11	368.57
12	359.94
13	355.89
14	336.66
15	324.87
16	308.67
17	290.9
18	281.7

The total deformations of all the models with varying width of damper from 2 mm to 4mm were shows that the with decrease in width of the dual pipe damper the deformation value was reducing. The model with damper width 4 mm shows more deformation that was about 19.74% more than 2mm. Even though the deformation values have not much variation between each other, 2 mm wide damper model show better performance compare to others. Similarly, with increase in thickness of the dual pipe damper the deformation value is reducing, the model with damper thickness 10 mm shows more deformation that was about 30.8% more than 18 mm. This indicates that 18mm thick damper model show better performance as it can resist more load intensity.

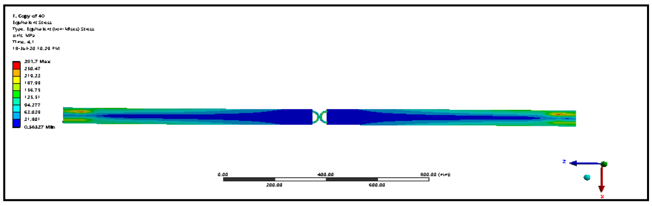

Fig-5: Stress distribution of BRB with Dual Pipe Damper with 2 mm width

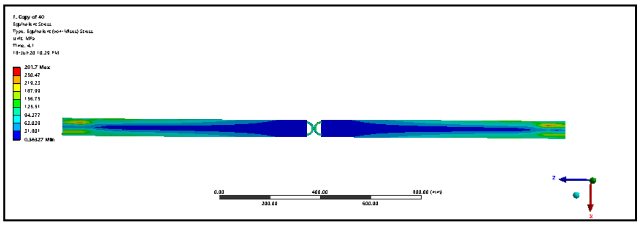

Fig-6: Stress distribution of BRB with Dual Pipe Damper with 18 mm thickness

The hysteretic curves obtained for all the specimens shows the models with width 4mm shows instability due to the maximum deformation and stress induced over the damper caused by the large intensity of forces. And this instability implies that the width of the dampers has significant effect in the energy absorption capacity. There was also severe loss of stiffness for 4 mm wide dual pipe damper placed braces. The model with 2mm and 3mm width shows better performance and stable hysteretic curve the deformation of the damper was also less and the force that were transferring to the other members were also less. Width of 2 mm show more stable hysteretic curve comparing with that of 3mm.So in this case the performance of less wide damper found to be good. The model with thickness ranging from 15 mm to 18 mm shows better performance and stable hysteretic curves the deformation of the damper was also less and the force that are transferring to the other members were also less comparing with other models with thickness from 10 mm to 15 mm. Of these 18 mm has more stable curve with less deformation and stress.

Table -7 Total deformation [Width]

Width (mm)	Deformations(mm)
2	50.625
3	53.727
4	63.077

Table -8 Total deformation [Thickness]

Thickness (mm)	Deformations(mm)
10	73.187
11	73.062
12	71.353
13	69.35
14	63.391
15	59.877
16	52.697
17	51.795
18	50.625

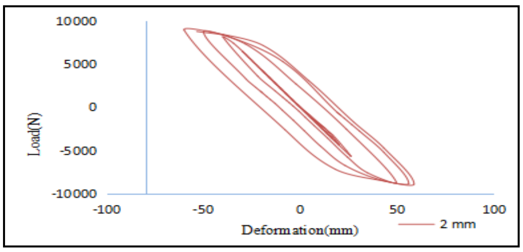

Chart-1: Hysteretic curve of BRB with Dual Pipe Damper with 2 mm width

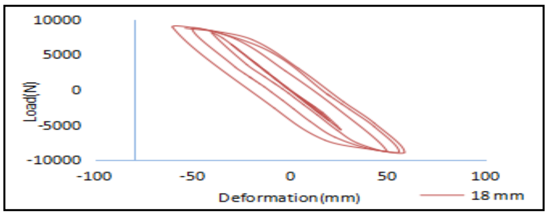

Chart-2: Hysteretic curve of BRB with Dual Pipe Damper with 18 mm thickness

7. COMPARATIVE STUDY OF BUCKLING RESTRAINED BRACE WITH AND WITHOUT DUAL PIPE DAMPER

The study was conducted on a simple frame with buckling restrained brace only. For the analysis HSS of 10 mm thick frames was used with dimension of BRB as given in Table -1.The dual pipe damper of 18 mm thick and 2 mm width was used for the study.

Table -9 Dimensions of frame

Length of Frame	1590 mm
Breadth of Frame	60 mm
Height of Frame	1700 mm

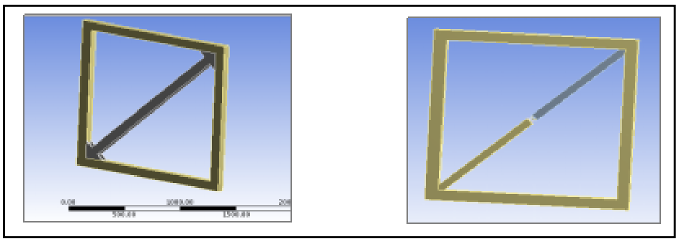

Fig -7: Geometry of buckling restrained brace frame

The model was designed with same datas as in previous studies. The displacement was given in the alternative positive and negative cycles as per the AISC protocol

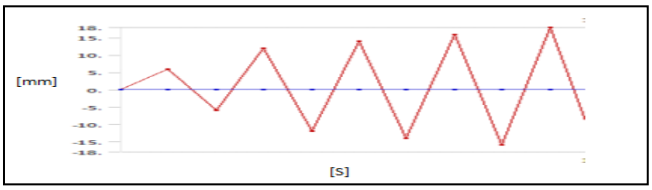

Fig -8: Loading

8. FINITE ELEMENT ANALYSIS RESULT OF THE STUDY

From the study it was clarified that the above studies stating about the performance of dual pipe damper was justified. The comparative results of BRB frame with and without DPD showcases that the performance of BRB with DPD shows better result as the damper absorbs more energy which prevent transferring of the loads to the load carrying members. And it was clear from the hysteretic curve also that the stiffness and energy absorption of BRB with DPD shows good seismic performance.

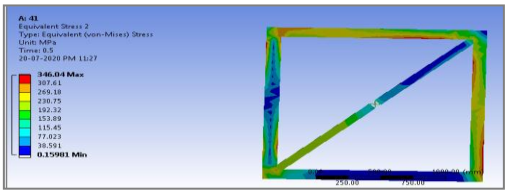

Fig -9: Stress distribution of BRB frame with Dual Pipe Damper

From the non linear analysis the stress acting on the buckling restrained brace without dual pipe damper was larger than that of the brace with dual pipe damper. Which says that the brace with damper shows good performance as the damper was absorbing more seismic forces and preventing its transfer to other sections of the frame.

Table -10 Equivalent stress distribution values

BRB without DPD frame	374.09 MPa
BRB with DPD frame	346.04 MPa

The total deformation of the frame with BRB without the damper is more than that of the BRB with DPD frame

Table -11 Total deformation values

BRB without DPD frame	18.012 mm
BRB with DPD frame	12.427 mm

From the hysteretic curves obtained from the analysis of frames with and without DPD on BRB. It was very vivid that the curve for DPD incorporated BRB frame shows good energy absorption as its enclosing area was more than that of the frame with BRB only. And also stiffness of the BRB with DPD frame was higher. The force transferred by the BRB with DPD were also less compared with the other. Which clarifies the better seismic performance of the brace with DPD.

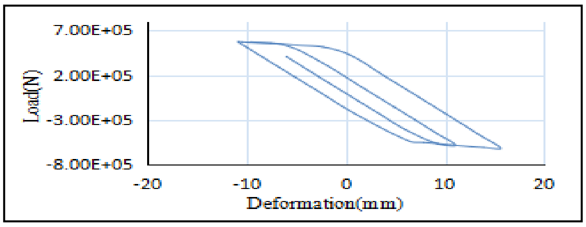

Chart-3: Hysteretic curve of BRB frame with Dual Pipe Damper

9. CONCLUSIONS

Various studies was done on the braces in order to understand the resistance against seismic forces. BRB was one such braces which was developed for controlling buckling. From the study conducted by incorporating the dual pipe damper which was was developed by Maleki and Mahjoudi [10]on BRB following conclusions were obtained:

- The studies indicates that minute variations in the shape of the damper significantly effects the absorption capacity and stiffness of the brace
- The equivalent stress distribution of 2 mm wide damper was less compared to that of 4mm.The equivalent stress distribution of 18 mm thick damper was less compared to that of 10 mm,
- Models with dual pipe damper having 2mm width and 18 mm thick shows better seismic performance and good energy absorption capacity comparing with other thickness and width studied
- Study conducted to compare the performance of BRB with and without DPD shows that BRB with DPD had very effective performance against seismic force
- On BRB without damper stresses were distributed over the core, but by the incorporation of the dual pipe damper shows that stress were mainly carried by the dampers which increases the stiffness of the brace.
- The DPD incorporated BRB can be used in buildings or bridges as it will prevent the instability and collapsing due to low stiffness of structure and by the absorption of high frequency seismic force

REFERENCES

[1] AlHamaydeh, M., Abed, F. and Mustapha, A. (2016). “Key parameters influencing performance and failure modes for BRBs using nonlinear FEA”. Journal of Constructional Steel Research, 116, pp.1-18.

[2] Fahnestock, L., Ricles, J., and Sause, R. (2007). "Experimental Evaluation of a Large-Scale Buckling-Restrained Braced Frame". Journal of Structural Engineering, 133(9), 1205-1214.

[3] Fahnestock, L., Sause, R., and Ricles, J. (2007). "Seismic Response and Performance of Buckling-Restrained Braced Frames". Journal of Structural Engineering, 133(9), 1195-1204.

[4] Fell, B., Kanvinde, A., Deierlein, G., and Myers, A. (2009). "Experimental Investigation of Inelastic Cyclic Buckling and Fracture of Steel Braces". Journal of Structural Engineering, 135(1), 19-32.

[5] Goggins, J., Broderick, B., Elghazouli, A., and Lucas, A. (2006). "Behaviour of tubular steel members under cyclic axial loading". Journal of Constructional Steel Research, 62(1-2), 121-131.

[6] Han, S., Kim, W., and Foutch, D. (2007). "Seismic Behavior of HSS Bracing Members according to Width–Thickness Ratio under Symmetric Cyclic Loading". Journal of Structural Engineering, 133(2), 264-273

[7] Hosseinzadeh, S., and Mohebi, B. (2016). "Seismic evaluation of all-steel buckling restrained braces using finite element analysis". Journal of Constructional Steel Research, 119, 76-84.

[8] Hoveidae, N., and Rafezy, B. (2012). "Overall buckling behavior of all-steel buckling restrained braces". Journal of Constructional Steel Research, 79, 151-158.

[9] Hsu, H., and Li, Z. (2015). "Seismic performance of steel frames with controlled buckling mechanisms in knee braces". Journal of Constructional Steel Research, 107, 50-60.

[10] Maleki, S., and Mahjoubi, S. (2013). "Dual-pipe damper". Journal of Constructional Steel Research, 85, 81-91.

[11] Mirtaheri, M., Gheidi, A., Zandi, A., Alanjari, P., and Samani, H. (2011). "Experimental optimization studies on steel core lengths in buckling restrained braces". Journal of Constructional Steel Research, 67(8), 1244-1253.

[12] Momenzadeh, S., Seker, O., Faytarouni, M., and Shen, J. (2017). "Seismic performance of all-steel buckling-controlled braces with various cross-sections". Journal of Constructional Steel Research, 139, 44-61.

[13] Nip, K., Gardner, L., and Elghazouli, A. (2010). "Cyclic testing and numerical modelling of carbon steel and stainless steel tubular bracing members". Engineering Structures, 32(2), 424-441.

[14] Sabelli, R., Mahin, S., and Chang, C. (2003). "Seismic demands on steel braced frame buildings with buckling-restrained braces". Engineering Structures, 25(5), 655-666.

[15] Seker, O., and Shen, J. (2017). "Developing an all-steel buckling controlled brace". Journal of Constructional Steel Research, 131, 94-109

[16] Shen, J., Seker, O., Akbas, B., Seker, P., Momenzadeh, S., and Faytarouni, M. (2017). "Seismic performance of concentrically braced frames with and without brace buckling". Engineering Structures, 141, 461-481..

[17] Shen, J., Seker, O., Sutchiewcharn, N., and Akbas, B. (2016). "Cyclic behavior of buckling-controlled braces". Journal of Constructional Steel Research, 121, 110-125

[18] Shen, J., Wen, R., and Akbas, B. (2015). "Mechanisms in two-story X-braced frames". Journal of Constructional Steel Research, 106, 258-277.

[19] Shen, J., Wen, R., Akbas, B., Doran, B., and Uckan, E. (2014). "Seismic demand on brace-intersected beams in two-story X-braced frames". Engineering Structures, 76, 295-312.

[20] Xie, Q. (2005). "State of the art of buckling-restrained braces in Asia". Journal of Constructional Steel Research, 61(6), 727-748.