Seismic Resilience Evaluation of Steel Frames With Y-Shaped Braces Equipped with Cost Effective Damper

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***Abstract*— The steel frames are mainly installed in construction in order to resist the lateral force developed during the earthquake. They are having high stiffness and strength to resist the lateral systems, most of them do not have enough ductility and architectural performance. Y shaped bracing can deal with the architectural performance whereas the ductility of the braces is not sufficient. Due to the long length and sufficient compressive force in the members buckling occurs. The use of Steel Dual-Ring Damper (SDRD) in the frame of structure properly can solve the buckling risk. In this research, an innovative cost-effective Steel Dual-Ring Damper (SDRD) was used on the long member of the Y bracing to increase ductility capacity and reduce the buckling risk. A single-story single-span frame with Y shaped bracing was considered and subjected to lateral seismic load analytically. Using the nonlinear finite element method, the complete analytical model and parametric studies have been carried out using ANSYS work bench software.**

Keywords*— *Steel Dual-Ring Damper, Ductility, Compressive force, long length

I INTRODUCTION

The simple diagonal bracing to a bracing system consisting of several members are the different bracings used in the construction. Based on the structural and architectural demands the bracings are selected. Generally, the braced frames can be classified into two groups, concentrically braced frames (CBFs) and eccentrically braced frames (EBFs). In the case of concentrically braced frames, beams, braces, and columns intersect at a common point. This type of system has inappropriate behaviour and poor performance in terms of energy absorption during intense seismic loads due to the buckling of the braces and inadequate ductility. Y-shaped concentric bracing, which is commonly used to solve architectural problems, while this bracing does not have ad- equate ductility. Seismic energy-absorbing systems are used in structures in the form of steel dual ring damper, metallic yielding dampers, friction dampers, viscoelastic dampers, and viscous fluid dampers. The use of steel rings as dampers in controlling displacement and ductility as well as significant energy dissipation in concentrically braced frames systems (CBFs). The study on steel ring dampers as ductile and energy-absorbing elements in concentrically braced frames have shown good ductility, hysteresis-stable loops and energy dissipation. The main aim in the present study is to develop a full-scale model for a steel structure with braced configuration and perform the lateral loading testing on a braced steel frame with and without damper. Finding the optimum size of the damper in a full-scale model. The parametric study is carried by changing the parameters of the SDRD dimensions to find the optimum size that is bests suited for the seismic performance of the structure. To evaluate hysteresis performance and the energy dissipation capacity by placing SDRD damper in a Y shaped bracing system.

II OBJECTIVES

- To develop a full-scale model for a steel structure with braced configuration
- To perform the lateral loading testing on a braced steel frame with and without damper.
- To finding the optimum size of the damper in a full-scale model.
- The parametric study is carried by changing the parameters of the SDRD dimensions to
- find the optimum size that is bests suited for the seismic performance of the structure.
- To evaluate hysteresis performance and the energy dissipation capacity by placing SDRD damper in a Y shaped bracing system.
- Stiffness, Total dissipated energy, Hysteresis behavior

III SCOPE OF THE WORK

- An Innovative Cost-Effective Steel Dual-ring Damper (SDRD) was utilized on the member.
- Ductility capacity is enhanced and decrease the risk of buckling.
- Performing the effective model under cyclic testing to evaluate hysterias performance and the energy dissipations capacity of structure.

IV SUMMARY OF LITERATURE

The strengthening and retrofitting of the existing structure the steel bracing is one of the advantageous concepts. The concentric inverted V braced model gave better values for storey drifts when compared to other models and gives a better result. Steel frame with X knee bracing having less displacement and having high load carrying capacity compared to other bracing system. Y-HSS-EBFs (Y Shaped High Strength Steel Eccentrically Braced Frame) possess high elastic stiffness, good deformability, and excellent energy dissipation capacity. In the case of Y-shaped braces, the greater the distance between the junctions of the three brace members from the column, which has a better seismic performance of the structure. A good result is obtained from the measurement of yielding capacity of steel dual ring damper using analytical equations and parametric studies. Also, yield force is directly related to the length and diameter of the steel ring. When comparing the results of parametric models and analytical relations it showed that by increasing steel ring diameter, ductility decreases and energy dissipation increases.

V VALIDATION

The most important parts of the numerical method is the validation of the FE model and is done using Ansys Workbench software. To evaluate the validity of the finite element modelling methodology, a comparison has been made between the results obtained from the finite element models and test on steel dual ring damper. The FE modelling methodology, method of analysis, properties of materials, cyclic loading, support conditions, and contact interactions are considered. The table 1 presents the dimensions details the steel ring dampers with the maximum tensile and compressive forces of the finite element models and the experimental results.

TABLE I. DIMENSION DETAILS

Length	100 mm
Inner Diameter (Di)	50 mm
Outer Diameter (Do)	100 mm
Outer Diameter Thickness (to)	5.00 mm
Inner Diameter Thickness (to)	2.50 mm
D/t	20mm

A. MATERIAL PROPERTIES

The material property used in the validation as well as in the model is with the modulus of elasticity 300Gpa and Poisson's ratio 0.3. The non-linear steel behaviour is considered in the modelling.

B. MESHING

Three-dimensional Solid element which is an 8-node isotropic 3D element was used for meshing. The geometry and meshing of the finite element models of the experimental specimens. The effects of strain hardening and large deformation of the elements have been taken into account in the modelling of geometry and the non-linear behaviour. For the analysing of finite element models the following data are considered.

Element Type – Solid 186
Element Shape - Hexahedron.
Element Size – Adaptive Mesh Sizing (Refinement Level 2)
Minimum Element Size -2.5 Mm

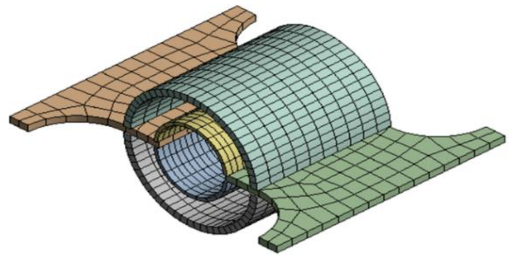

Fig.1.Meshed Steel Dual Ring Damper

C. BOUNDARY CONDITIONS

The boundary conditions considered are based on the test setup. According that end of the connection plates is fully restrained and other end is subjected to cyclic loading. Cyclic loading of displacement type is used and are applied to parametric models based on the FEMA 461 loading protocol The maximum value of displacement applied to the cyclic loading is based on the ring diameter. the maximum displacement of the cyclic loading protocol is assumed to be 0.13d. The loading case is shown in the below table

TABLE II. LOADING

PROTOCOL	DISPLACEMENT VALUE(mm)
0.048Δm	0.624
0.068Δm	0.884
0.095Δm	1.235
0.133Δm,	1.729
0.186Δm	2.418
0.260Δm	3.38
0.364Δm	4.732
0.510Δm	6.63
0.714Δm	9.282
1.000Δm	13

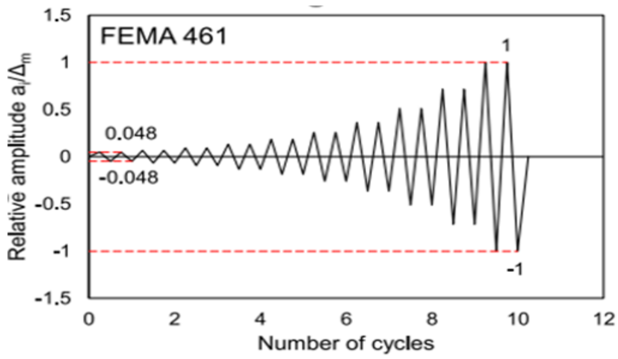

Fig.2.Loading procedure applied in FE model

D VALIDATION RESULTS

The results of the analytical method and finite element models in ANSYS software are discussed. A comparison was made between the analytical and the nonlinear finite element method for the steel dual ring damper.

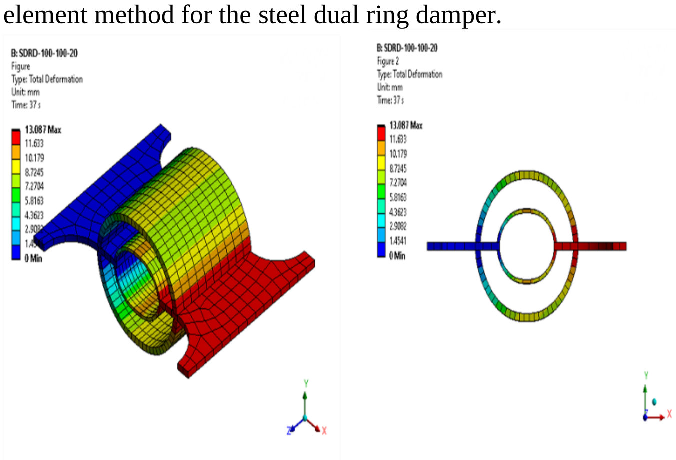

Fig.3. Total Deformation- Tension

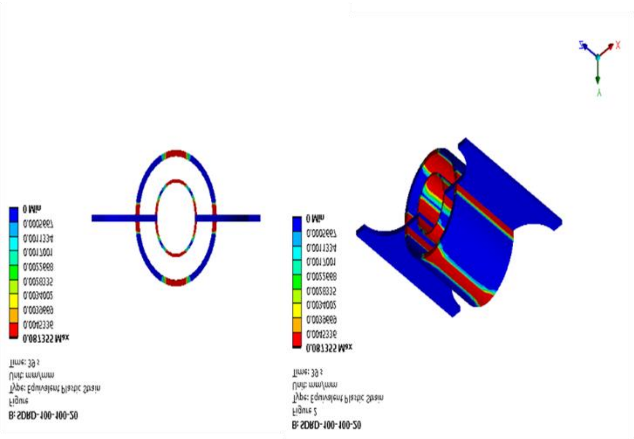

Fig.4. Plastic Strain Distribution- Compression

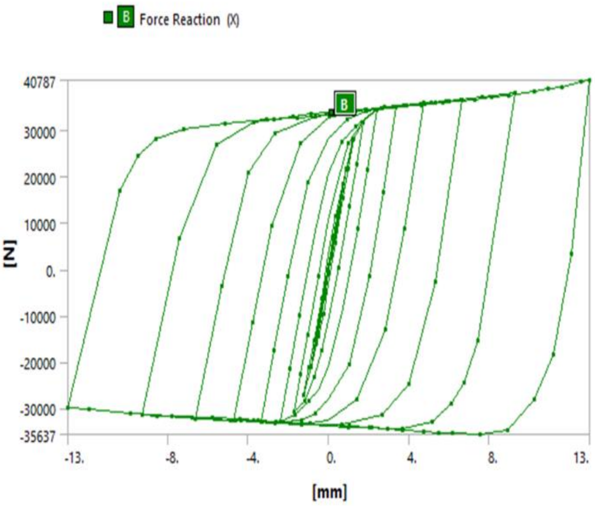

Fig. 5. Hysteresis graph

TABLE III. COMPARISON OF THE RESULT OBTAINED FROM VALIDATION

	mm	mm	KN	Stiffness	Ductility	Plastic displacement
ANSYS	0.88	13.00	21.78	24.63	14.71	12.12
Analytical	0.96	13.00	22.50	23.52	13.54	12.04
% Difference	7.92	0.00	3.22	4.73	8.60	0.63

VI MODELLING

In this section, numerical methods of modelling have been developed by ANSYS Workbench, in order to predict the cyclic behaviour of steel ring dampers and the seismic performance of the steel frames with y shaped braces equipped with steel dual ring damper

A. SECTIONAL PROPERTIES

European Standard I Sections, IPE Column, IPB (European Wide Flange Beam) and UPN European Standard U Channels are used for the design.

TABLE IV. SECTIONAL PROPERTIES

Members	Section	Area (mm2)
Column	2IPE180	2390
Beam	2IPB200	7810
Braces	2PL50*8+2UNP100	1750

B. GEOMETRIC PARAMETERS

The geometric parameters of the Y shaped sample is considered and tabulated as following.

TABLE V. GEOMETRIC PARAMETERS

I z (mm)	I x (mm)	∝1 (Deg)	∝2 (Deg)	∝3 (Deg)
1140	810	14.8	35.5	27.5

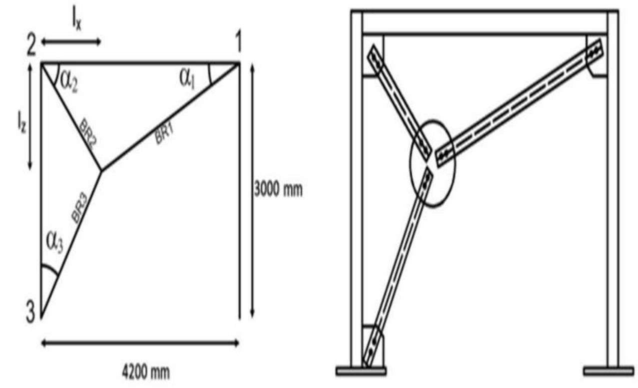

Fig.6. Specification of the braces

C. *MODELS*

To analyse the seismic performance of the steel frames with y shaped bracing with steel dual ring damper many models are modelled. Steel Dual-Ring Damper (SDRD) was utilized on the long member of the Y bracing to increase ductility capacity and reduce the risk of buckling. The parametric study includes changing the length and diameter. This specimen was modelled in ANSYS Workbench software. The Models considered in this project are as followings.

Model 1: Single span Bare frame
Model 2: Single span frame with Y shaped bracings
Model 3: Steel Dual Ring Damper
Model 4: Frame with Y shaped bracing and damper at brace 1 (BR1)
Model 5: Frame with Y shaped bracing and damper at brace 2 (BR2)
Model 6: Frame with Y shaped bracing and damper at brace 3 (BR3)

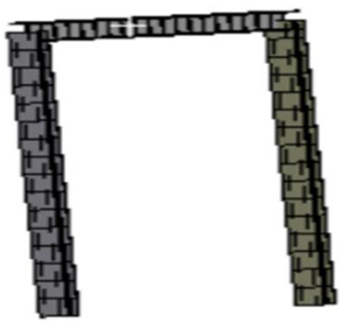

Fig .7. Model 1

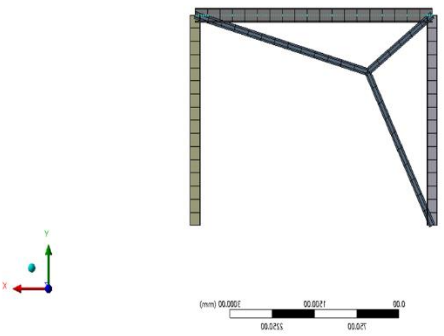

Fig.8. Model 2

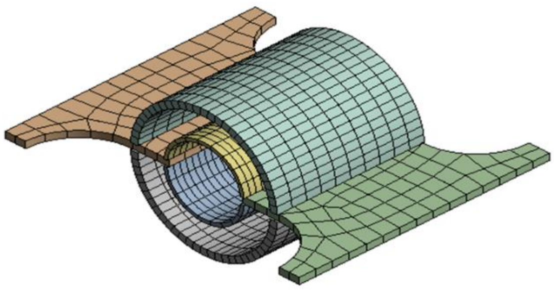

Fig.9. Model 3

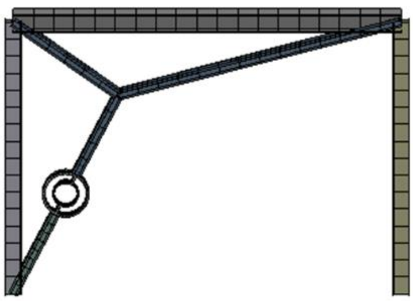

Fig.10. Model 4

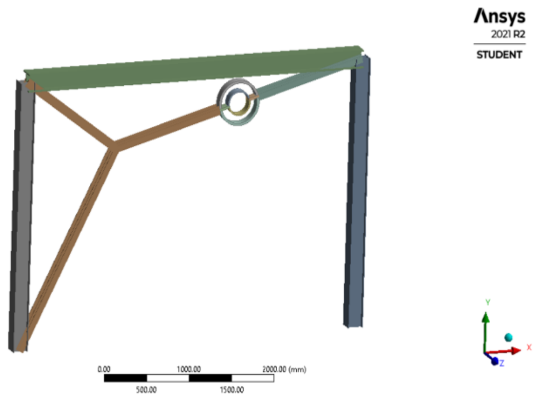

Fig.11. Model 5

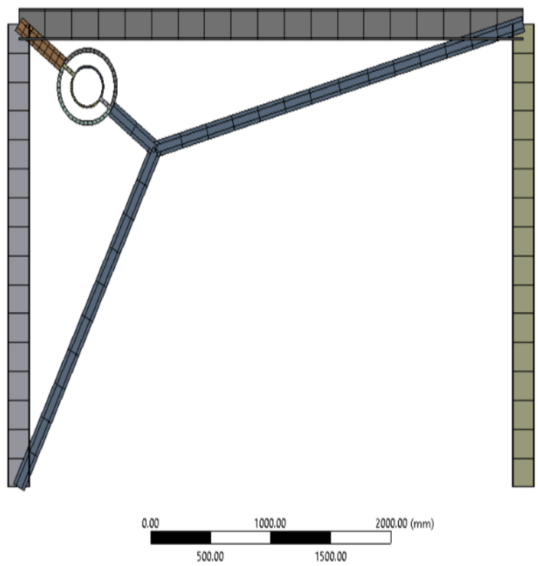

Fig.12. Model 6

D PARAMETRIC STUDY

In the parametric studies of the steel dual-ring dampers have been investigated against changes in the geometrical parameters. According the parameters examined in this study included the length (L), outer diameter (Do) and inner diameter (Di) of ring. The length is assumed as 100mm ,200mm and 300 mm. Similarly, the inner diameter as 12.5mm ,22.5mm,32.5mm and outer diameter as 25mm, 35mm, 45mm.The simultaneous occurrence of plastic hinges in both inner and outer rings results in optimum seismic performance in an SDRD.

VII ANALYSIS

ANSYS Workbench software was used to develop the models. Complete Analysis of damper system by carried out using static non-linear analysis and cyclic analysis with respect to FEMA loading protocol. To evaluate the energy dissipation of SDRDs. The maximum load at which the specimen breaks are found and the Load -Deformation values are found.

TABLE VI. LOAD AND DEFORMATION VALUES FOR BARE FRAME

BARE	
Deformation	Load (KN)
0	0
60.126	46.169
120.3	92.36
165.47	127.04
188.09	139.84
210.67	144.89
233.17	145.28
266.88	143.55
300.73	139.32

TABLE VII. LOAD AND DEFORMATION VALUES FOR FRAME WITH Y BRACE

Y BRACE	
Deformation	Load (KN)
0	0
15.015	185.37
30.035	373.4
52.572	659.99
63.841	783.99
64.193	786.84
64.545	789.72
64.677	790.84
64.752	791.45
66.221	802.5
66.334	803.65
66.503	804.62
66.629	805.78
66.756	806.87
66.958	808.13
67.033	808.93
67.108	809.28
67.221	810.27
67.39	811.64
67.559	812.94
67.685	813.55
67.812	814.69
67.887	815.21
67.962	816.14
68.075	816.96
68.244	818.22
68.319	818.96

TABLE VIII. LOAD AND DEFORMATION VALUES FOR FRAME WITH Y BRACE AND DAMPER AT BRACE 1

BRACE 1 (BR1)	
Deformation	Load (KN)
0	0
70.008	140.64
73.01	143.63
76.012	146.61
80.515	151.08
87.271	157.79
97.404	167.91
102.72	173.26
108.05	178.65
137.98	208.11
144.88	214.85
333.54	447.75
335.59	448.56
337.64	449.22
345.07	451.41
346.22	451.68
346.57	451.77
346.93	451.85
347.28	451.91
347.63	451.81

TABLE IX. LOAD AND DEFORMATION VALUES FOR FRAME WITH Y BRACE AND DAMPER AT BRACE 2

BRACE 2 (BR2)	
Deformation	Load (KN)
0	0
114.48	84.699
236.78	154.94
312.64	160.47
388.45	165.46
445.39	169.23
502.25	173.05
587.78	178.86
640.73	181.81
695.59	181.88

TABLE X. LOAD AND DEFORMATION VALUES FOR FRAME WITH Y BRACE AND DAMPER AT BRACE 3

BRACE 3 (BR3)	
Deformation	Load (KN)
0	0
120.75	89.872
243.02	175.95
276.68	189.43
310.39	203.05
335.71	213.36
347.93	218.33
360.27	223.25
378.98	230.56
393.07	236.06
407.26	241.54
421.64	246.95
436.04	252.38
506.68	275.38
508.64	275.72
510.12	275.92
511.21	276.03
512.31	276.09
513.4	276.08
514.2	276.01
514.87	275.87
515.54	275.63

From the above load deformation result we got the frame with y shaped bracing and the damper position at brace 1 (BR1) is more effective. Then the parametric study is done in that effective model. There after by parametric study we got 6 other models by varying the length, inner diameter and outer diameter of the ring, then analysis is done to those 6 models. Total of 11 models are got from the ANSYS Workbench software and their results are compared.

VIII RESULTS AND DISCUSSIONS

The outcomes obtained from ANSYS software after evaluating the models and results have been specified in figures. Fig 13 shows among the 5 model the frame with y shaped braces with the damper position at brace 1 is more effective and the fig 14 shows the corresponding percentage of decrease.

Fig.13. Load -Deformation graph of models

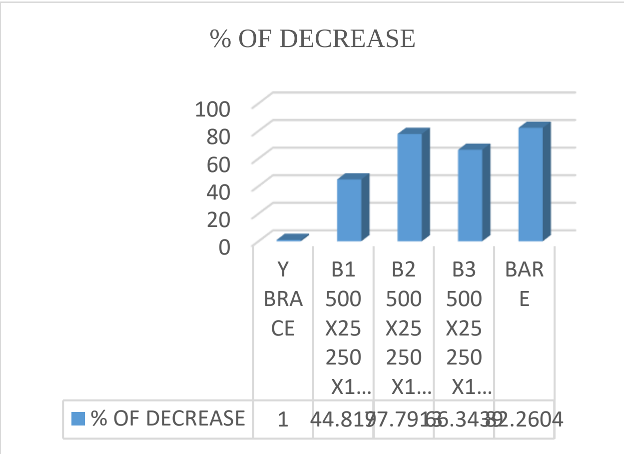

Fig.14. % Of decrease of model

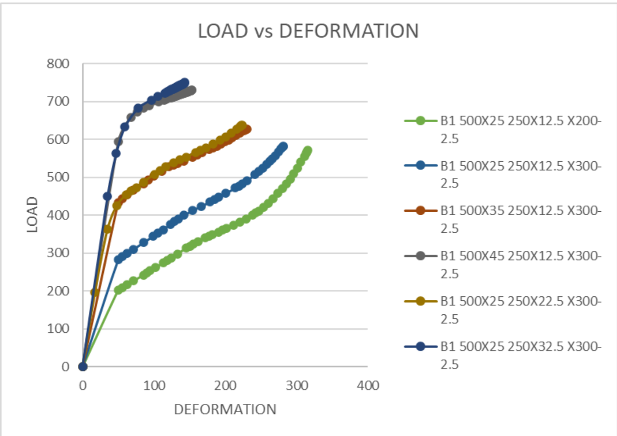

Fig.15. Load- Deformation graph of parametric studied models

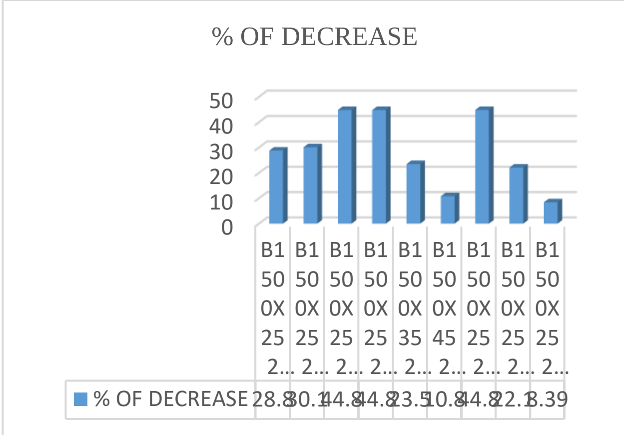

Fig.16. % Of decrease of the parametric studied models

From this parametric study of the model, we got that the length of 300mm, inner diameter of 12.5 mm and outer diameter of 45 mm modelled specimen is more effective for withstand the loading. Hence adopted that model for the seismic performance.

VIII.CONCLUSIONS

The ANSYS Workbench software is used for the modelling of the single span steel frame with Y shaped bracing equipped with steel dual ring damper. The following results are obtained

- 5 models are modelled such as Single Bay frame, Frame with Y shaped Bracings, Dampers and the damper positioning at different braces.
- From the Bare frame and Frame with Y shaped bracing study we found ultimate load is for the frame with Shaped bracing. So, use of Y shaped bracing is effective in steel frames.
- Comparing the position of dampers in 3 different positions at braces such as BR1, BR2, BR3 the ultimate load is for the BR1.
- Hence the damper placing at the brace BR1 in the Y shaped bracing steel frame is more effective.
- From the parametric study the frame with y shaped bracing with the damper at the brace 1of length 300mm, inner diameter 12.5 mm and outer diameter 45 mm modelled specimen is more effective for withstand the loading. Hence adopted that model for the seismic performance.

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