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Structural Performance of Grooved Gusset Plate Damper in Concentrically Braced Frame

Darshana Divakaran K V
Department of Civil Engineering
Sree Narayana Guru College of Engineering
Kannur, India

Mrs. B Mary Sonia George
Department of Civil Engineering
Sree Narayana Guru College of Engineering
Kannur, India

***Abstract*- The purpose of this study is to modify the braces by installing some energy dissipating device, which is added to the braces to absorb the energy and protects the structures from severe earth quake. Here we use Concentrically Braced Frame (CBF) with a metallic plate. It prevents all other member including beam, column, connection, and also braces from seismic damages and improves seismic performance of structure. The proposed device includes a gusset plate which is grooved so that it yields in several places and also prevents the plastic action or buckling in the braces. These types of device are known as Grooved Gusset Plate Damper (GGPD). The damper is a small plated metallic element. It can be installed in a braced frame then it act as an energy dissipater. It dissipates the energy from seismic through inelastic deformation at its steel strips and absorbs the complete shear. The finite element models of the braces are analysed using ANSYS and its structural performance is checked when the dampers are installed in different manner in a 3-bay 6-storied frame and three parameters are observed. Base shear, total acceleration and storey displacement.It is concluded that base shear of the structure is considerably reducing when the damper is installed in the frame. From the studies, it is concluded that lesser time period is produced for the model which occupied with complete braces and damper.**

Keywords: Grooved Gusset Plate Damper, Concentric Braced Frame, Seismic performance.

1. INTRODUCTION

Concentrically Braced Frame (CBF) is a type of bracings. They are mostly used in high rise building structures as lateral load resisting systems. A vertical concentric truss system with member axes aligned concentrically at the joints forms the CBF class of structures, which withstand lateral loads. Due to its great strength and stiffness, CBFs are typically effective in resisting lateral stresses. Recently, various studies have been planned to be conducted to enhance the braced frame's performance

Initially, simple braced frames were used. But by adding a few energy dissipation devices, additional adjustments are gradually made. Cost-effective steel energy dissipation devices were found to be applicable for minimal-damage seismic design of steel frames. To anticipate the fracture deformation capability of this device, more research is necessary. It can reduce damage repair costs and downtime, and, can be further enhanced by using rate-dependent dampers in parallel to steel devices to achieve drift reduction and protection of drift-sensitive non-structural elements [1].

Firstly damper plate connections were used by J.J Rogger Cheng et al. and where the ultimate load of the structure increased linearly proportional to the gusset plate thickness and decreases with increasing plate size [2]. The slit damper is introduced by Sang Hoon Oh et al. The proposed connection showed an excellent hysteretic behaviour[3]. A Low Yield Point steel gusset plate was proposed by Sheng Jin Chen and placed in to the frame. Then the energy dissipation capacity of the gusset plate is also increased substantially [4]. Based on the buckling analysis, utilizing Block Slit Damper (BSD) was proposed by Hossein Ahmadie Amiri et al. The BSD devices, one can decreases the costs and make sure that the utilized device is resistant to buckling while the energy dissipation efficiency is not decreased [5].After that Block Slit Dampers (BSD) were introduced by Mohemmad Reza Shirinkam et al. BSD is a box made of several steel plates which is mounted along diagonal members of a braced frame [6]. Unlike many existing seismic dampers, the stiffness and strength of the Box Shaped Damping device are not interdependent parameters and the designer can choose the required stiffness while keeping the strength constant. Also Application of Slit Beam in Eccentrically Braced Frame and An Innovative C-Shaped Yielding Metallic Dampers for Steel Structures are studied [7,8].At the same time a Modified Bar-Fuse Damper in Gusset Plate is introduced by Ramin Tabatabaei and found that it will be improve the seismic behaviour of the system[9].The structural performance of a concentrically braced frame is improved by installing an innovative shear damper and which effectively protects the structures[10]. A new brace type damper consists of two slit damper and it comprises a few perforated webs and two flanges (Perforated Web H-type Braced Damper PWHBD) was proposed by Baocheng Zhao et al. which are designed for protecting structure from earth quakes[11]. Improving the CBF Brace's behaviour using I-Shaped Dampers [12] and Torsional Hysteretic Damper for Frames (THDF), is introduced [13]. Gradually it changes to some gusset plates. But gusset plates will cause fracture because of post buckling deformation of the braces. So that strong brace member and weak gusset plates are used by M. Almohamad Albakkar et al.. Hence slits are provided in the gusset plate [14].

The slit dampers are a type of metallic damper. In this study a grooved gusset plate damper is installed in CBF and the complete performance of the structure will be checked. The complete study will be carried out by ANSYS software.

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1.2. Grooved Gusset Plate Damper (GGPD)

A new variety of metallic damper is called a Grooved Gusset Plate Damper (GGPD). Concentrically braced frames exhibit poor energy dissipation behaviour due to severe post-buckling deformations of the braces. A solution to this problem, as recommended, that is "strong brace member-weak gusset plate" issue. Grooved Gusset Plate Damper is the term for this particular type of damper [14]. The GGPD serve as an energy dissipater and protect the frame from powerful earthquakes. The GGPD will be completely absorbed, and it will fail. Therefore the frame does not have any damage.

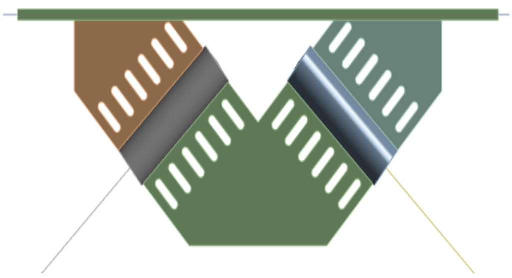

Fig. 1 Grooved Gusset Plate Damper

2. VALIDATION

2.1 Description

The validation was conducted on the Grooved Gusset Plate Damper (GGPD) in X braced frame. The model dimensions and all other detailed parameters were selected from [14]. The models were created using finite element software, ANSYS 19.0. The thickness of the gusset plate was taken as 10mm, the length of the damper was 230mm, length of strip was 60mm and mesh size is 5mm. The nonlinear analysis of the model was carried out. The analysis results were compared with the journal [14] results.

2.2 Finite element model

The validation of the GGPD was done using ANSYS workbench 19.0. The validation was done on a GGPD which was installed in an X braced frame.

Solid 186 element type was used for the specimen with 5mm mesh size and hexahedron shape. Displacement control methods are used. Therefore, displacement was applied to the specimen and force was the output. Fixed support was provided.

Table 1. Comparison of results.

	P_y (kN)	P_u (kN)	K_e (kN/mm)
Software	58.96	130.4	393.06
Old work	63.89	132.5	377.11
% in error	7.72	1.60	4.23

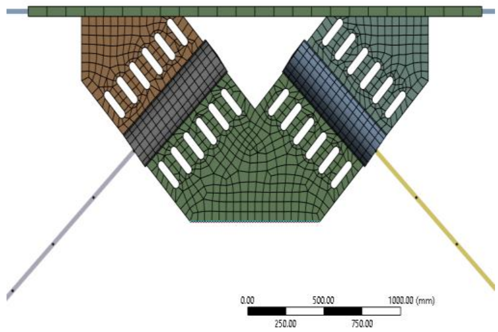

Fig. 2 Finite element model of GGPD

3. MODELLING OF GGPD IN CONCENTRICALLY BRACED FRAME

The structural performance of Grooved Gusset Plate Damper in concentrically braced frame was investigated by using ANSYS 19.0 WORKBENCH. Engineering data sections in ANSYS software was used to assign the material properties of the model, these engineering data sets already has pre-assigned values for each material. Table 1 shows the material property.

The columns are fixed supported to the base and to the base of columns braces are connected. Parametric study was conducted with 3 parameters. That is thickness of damper, length of slit and width of damper. The minimum sizes of the parameters are selected according to the suggestion made by journal [14]. By comparing the performance of the damper best one is selected. The geometry of the model used in this study is shown in figure 3.

Figure 5 shows the support and loading condition for CBF. Lateral load is applied to the top corner of the frame, fixed supports are provided at the bottom of the frame, as the length of the beam is selected 9m.

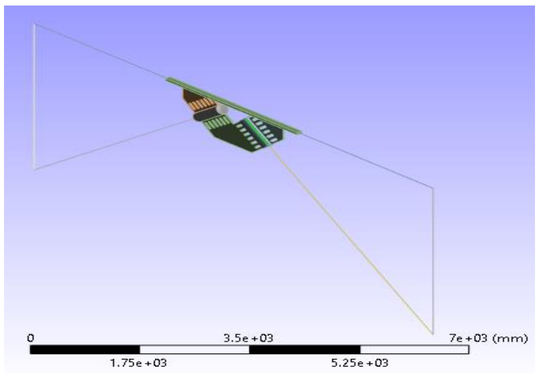

Fig. 3 Isometric geometry of model

Table 2. Material properties

Material	Steel
Yield strength	344 MPa
Modulus of elasticity	$2x10^{11}$ N/m^2
Poisson's ratio	0.3
Density	7850 kg/m^3
Brace size	HSS 12.75 x 0.5 inches

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3.1 Analysis of Model

Analysis was carried out in different dimension of GGPD. The parameters varied are thickness of the damper (10, 15, 20 and 25mm), width of the damper (650, 675, 700 and 725mm) and length of slit (170, 180 and 190 mm). In this study, the parameters were changed to determine more effective model. The minimum thickness, width of GGPD and the length of slit of model are selected according to the suggestions made by the base journal. Solid 186 element type was used and the mesh size was 50mm. The element shape of meshing was hexahedron.

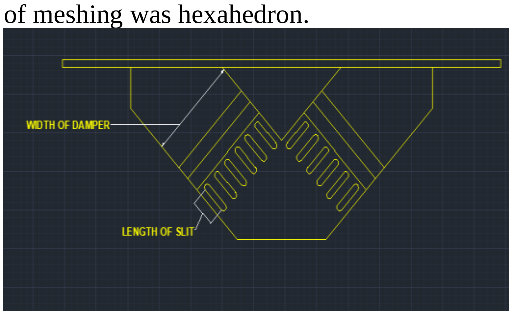

Fig. 4 modelling of GGPD

In the first step , by fixing the dimension of width of GGPD and length of slit. Then the thickness values are changed. In the second step, the thickness and length of slit are fixed and width of GGPD is changed. In the third step, the thickness and width of GGPD are fixed and length of slit is changed. After obtaining the suitable size of dimension, the damper was placed in a 3bay- 6storied frame. The dampers were arranged in a different configuration and the time history analysis was carried out. After that the performance will be checked.

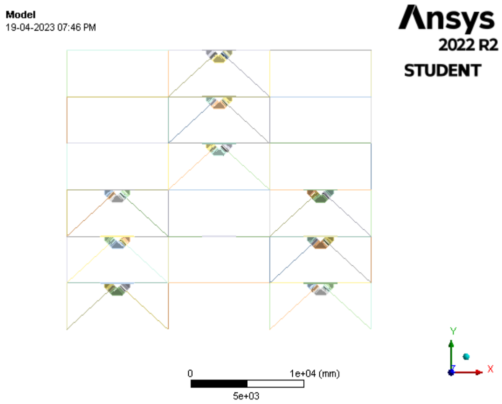

Fig. 6 Model 1

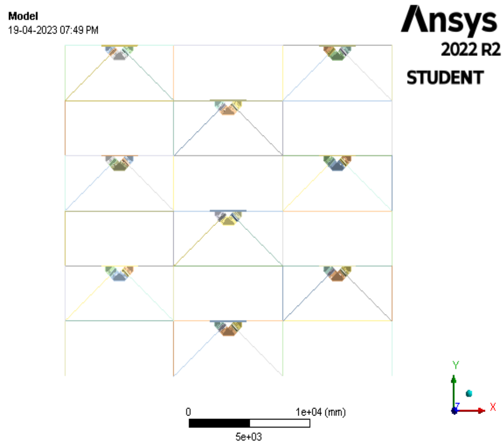

Fig. 8 Model 2

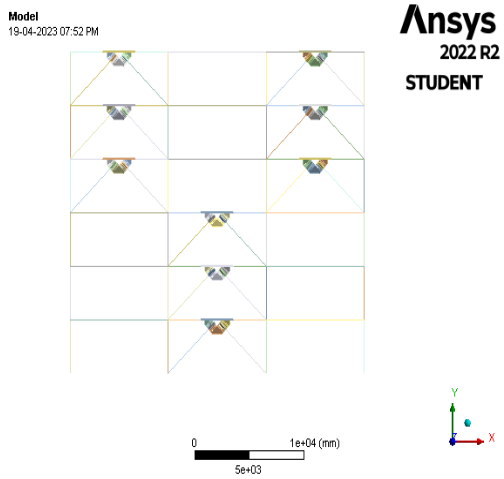

Fig. 10 Model 3

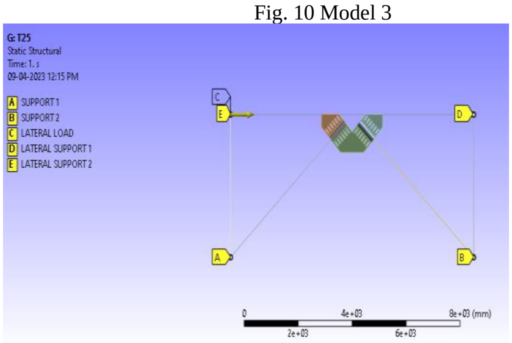

Fig. 5 Support and loading condition

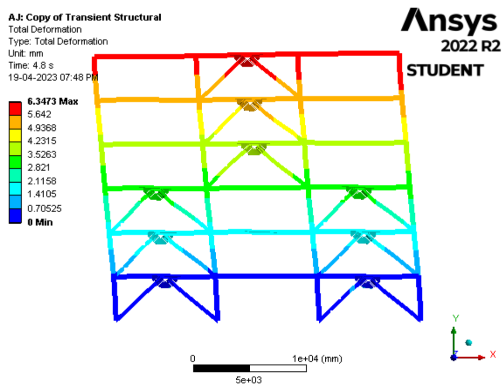

Fig. 7 Deformation of model 1

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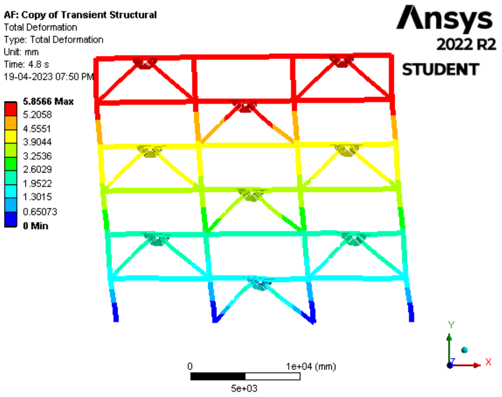

Fig. 9 Deformation of model 2

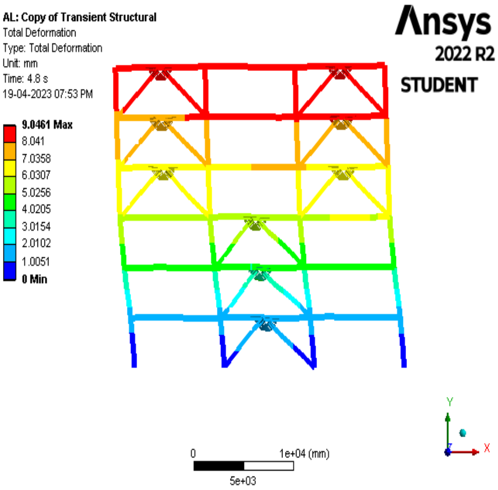

Fig. 11 Deformation of model 3

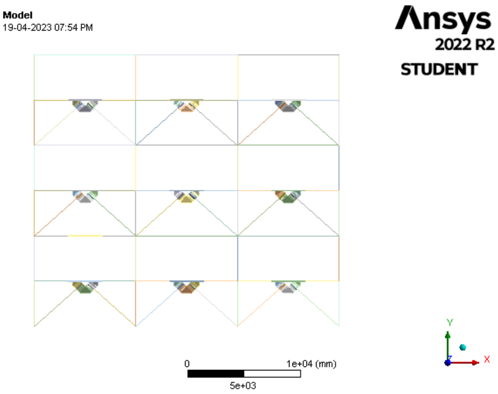

Fig. 12 Model 4

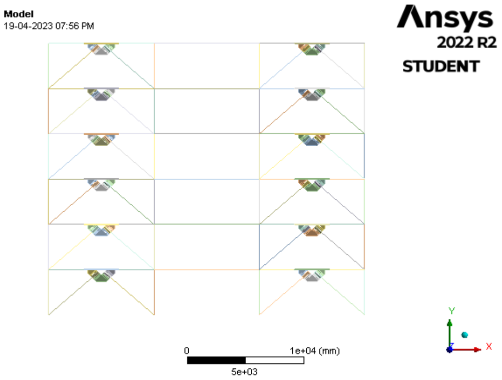

Fig. 14 model 5

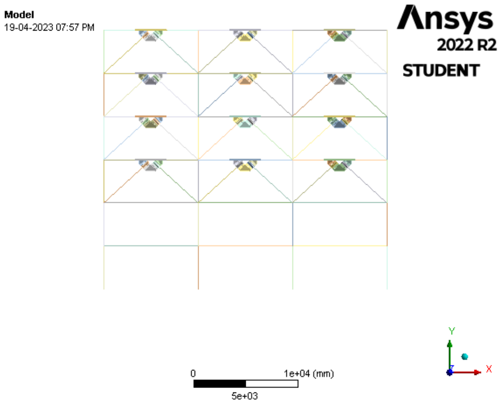

Fig. 16 model 6

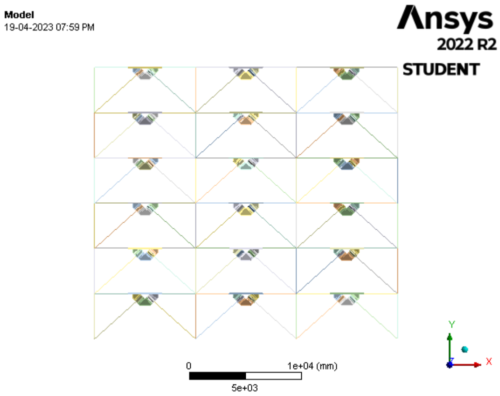

Fig. 18 model 7

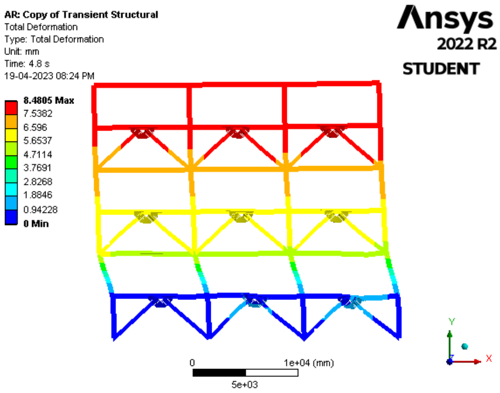

Fig. 13 Deformation of model 4

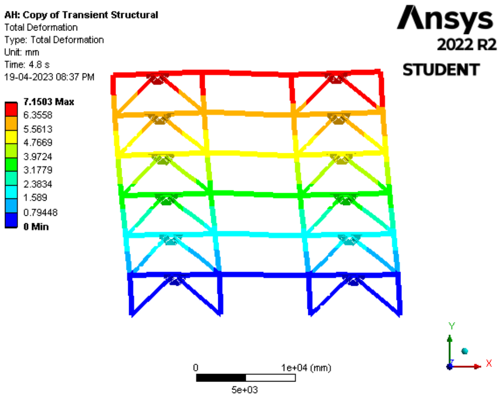

Fig. 15 Deformation of model 5

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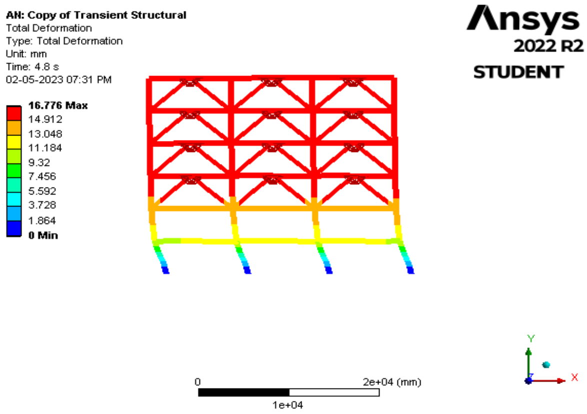

Fig. 17 Deformation of model 6

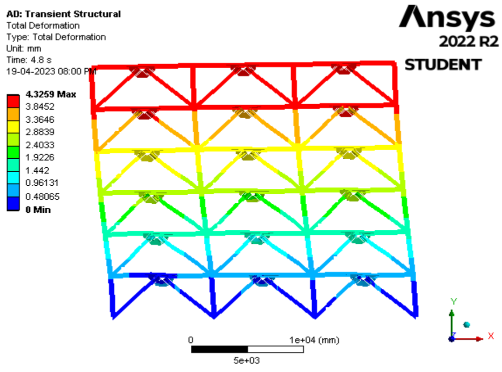

Fig. 19 Deformation of model 7

4. RESULTS AND DISCUSSION

From the parametric study of models the ultimate load value is increased as the thickness of the damper, width of the damper and length of the slit was increased at a particular range. As other parameters like ultimate deflection, yield load, yield deflection and ductility are equally important. In the study their performance should also be evaluated. These results are given in table 3. The results indicate that the ultimate load of the damper will be higher at thickness of the damper = 700mm and length of slit = 180mm. Then the effective GGPD is installed in 3 Bay 6-storied building with various

Table. 3. Results of GGPD in single frame

Model	**Ultimate load (kN)**	**Ultimate deflection (mm)**	**Yield deflection (mm)**	**Yield load (kN)**	**Ductility**
Bare frame	4468.3	17.281	4.32	548.41	4.320
Thickness 10 mm	2744.6	230.71	0.970	332.44	237.813
Thickness 15 mm	3452.4	329.58	1.161	518.41	283.803
Thickness 20 mm	4034.5	344.57	1.485	791.13	232.033
Thickness 25 mm	4650.5	355.66	1.181	984.87	320.96
Width 650 mm	4285.5	388.93	1.867	981.34	208.318
Width 675 mm	4312.6	353.57	1.216	666	290.76
Width 700 mm	4650.5	355.66	1.181	984.87	320.96
Width 725 mm	4907.5	357.75	1.418	858.87	252.291
Length of slit 170 mm	4383.2	343.49	1.1925	702.27	288.042
Length of slit 180mm	4650.5	355.66	1.108	984.87	320.96
Length of slit 190 mm	4681.2	372.66	1.21	663.43	306.414

Table 4. Result of GGPD in building

Model	Number of dampers	Total acceleration(mm/s^2)	Storey displacement (mm)	Base shear (kN)	Natural frequency (Hz)	Time period (s)
Frame without damper	0	90.339	1.5815	1749.4	8.454	0.1183
1	9	90.956	7.383	1336.7	8.741	0.114
2	9	89.638	7.332	1509.4	8.498	0.177
3	9	117.42	11.183	1515.8	7.178	0.139
4	9	122.14	10.153	1437.6	6.805	0.147
5	12	102.11	8.443	1399.3	8.655	0.124
6	12	238.76	20.935	1774.1	4.536	0.220
7	12	67.738	5.149	1558.2	9.90	0.101

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configurations. Then the performance of the structure will be checked.

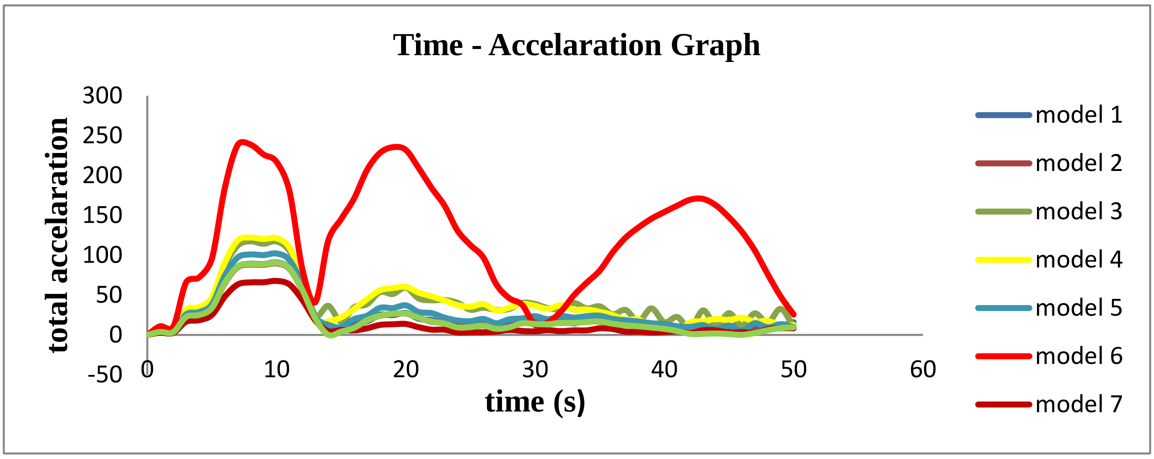

Fig 20. Time- acceleration graph

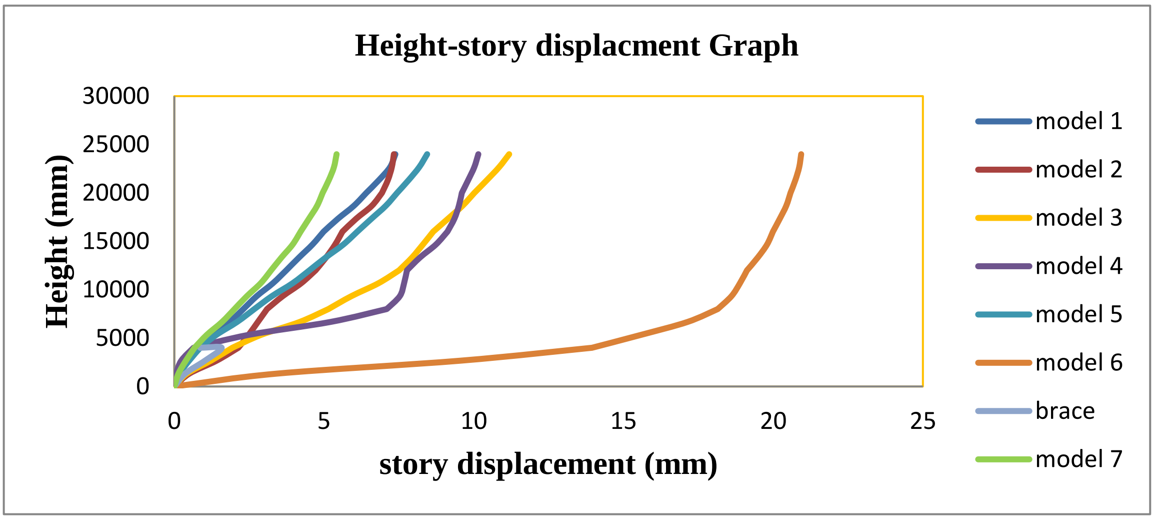

Fig.21 Height- Storey displacement graph

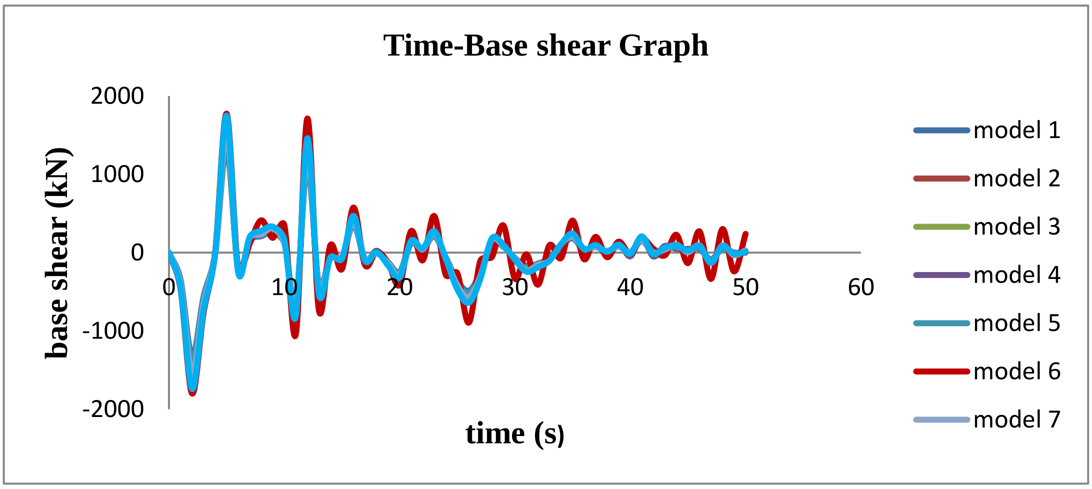

Fig 22. Time- base shear graph

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5. CONCLUSION

The influence of GGPD is determined when the thickness of damper, width of damper and length of damper was changed. The GGPD was placed in an inverted V shaped/ chevron braced single storey frame. The increase in the dimensional parameters of dampers shows an increase in the load carrying capacity of the single storey frame. When dampers were introduced in a braced frame the overall performance of selected frame improved when comparing the output parameters like ultimate deflection, yield load, yield deflection and ductility with the braced frame model developed. After that, the optimum size of damper is installed in a 3 bay 6storied frame. Number of the damper was reduced and the performance of CBF is checked. And also checked that, which configuration is better than the frame without damper. The modal analysis and time history analysis have been done. In time history analysis El Centro earth quake data are used. From the above studies various configuration of model has to be observed, lesser time period is produced for model 7. Because it is occupied with complete braces and damper. Hence its stiffness is high so time period is getting very lesser. When damper is placed then the performance will be increases. And also the model 1 and model 2 have lesser time period than frame without damper. From the time history analysis, the three observed parameters are base shear, total acceleration and storey displacement. Base shear of the structure is considerably reducing when the damper is installed in then frame. 6^{th} model is not a better model. That is, the model 6 shows considerably not much improvement in the performance. Because the bottom stories are left free, that is without bracing and damper. It is a soft storey. The behaviour of soft storey makes the structure accelerate more, so that it displace more and not able to take reduction in the base shear. Model 1 and 5 are considerably reducing the base shear very much compared to bracing without damper. Model 7 has the lesser storey displacement and total acceleration. Out of all parameters of investigation, it is observed that model 7 give the effective performance than the other stories. The damper is very effective and also a small size of metal so that it is very cost effective.

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