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Response Reduction of Multistoried Building through Metallic Fuses

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Abstract— Metallic fuses are supplemental energy dissipating devices that are fabricated into the structure to ensure safety of primary structural members. During a severe earthquake the fuse elements yield to dissipate seismic energy through structures. Elastic analysis gives a good estimate of elastic capacity of structure and also can indicate the first yielding point but it cannot predict the failure mechanism and account for the redistribution of forces during yielding. In the present work nonlinear analysis is studied with passive energy dissipation devices. The passive energy dissipation devices that are chosen for investigation include metallic bracings which are used as metallic fuses. They are installed in the second and third bay location of the investigated building. Three different configuration of bracing utilized are X, V and inverted V. For carrying out analysis a G+7 building is modeled using SAP-2000 software and designed according to IS1893:2002 code specification. The dynamic time history analysis is carried out by imposing accelerogram of three different earthquakes. Interstorey drift, storey displacement, shear force and moment proved to be the key constraints in accessing the performance of the building structure. These PED's brought about 30% to 50% reduction in values of displacement and storey drift and helped in improving the seismic performance of building and the purpose of using bracings and metallic damper as structural fuses fulfilled.

Key words: X-Bracing, V-Bracing, Inverted V-Bracing, Inelastic Time History Analysis

I. INTRODUCTION

Seismic design is based on the strength and ductility characteristic of any type of building structure. The structure is expected to remain in the elastic region (no plastic hinge formation) for small and frequent disturbing ground motion. But this is not the case with seismic excitation of greater disturbing effect. Here the structure undergoes large displacements which results into the inelastic straining of rebar inside the frame element thereby forming plastic hinges. So there is a need to improve the current seismic design process and also improve the functioning of the building with use of any external agent. This external agent should have energy absorbing capability during seismic excitation thereby protecting the parent structure. Passive energy dissipation device (PED) is the answer for this obstacle.

There are various types of passive energy dissipation devices such as of Metallic Dampers, Friction Dampers, Viscoelastic Solid Dampers, Viscoelastic or Viscous Fluid Damper, Tuned Mass Damper and Tuned Liquid Damper. But out of these metallic dampers is best one. Metallic dampers are very easy to install and also they require very minimum cost for maintenance. So for the present work metallic bracings are used as fuse element in the structure. A fuse element is a self sacrificable material. During the earthquake excitation the seismic energy is transferred from frame to these fuse element. This fuse undergoes in elastic straining during the earthquake preserving the parent building structure from yielding. The concept of this technique is derived from an electric fuse. In an electric circuit, when there is an excess flow of current the electric fuse filament breaks down there by protecting all the appliances working on it. These bracings also impart additional stiffness to the structure thereby decreasing the time period of the structures which do not allow large storey displacement to occur in the structure. This structural fuse system is superior to the shear wall system. Adding shear wall system to a building structure adds additional seismic weight to the structure and in comparison to shear wall bracing elements is very light weight.

Tremblay et.al. worked on the concept of Self Centering Energy Dissipative Steel Braces (SCED). For carrying out the program 2, 4, 8, 12 and 16 storey steel frame building which were assumed to be located in Los Angeles and California. Similar buildings were modeled and building Buckling Restrained Braces (BRB) was installed in first building whereas other was installed with Self Centering Energy Dissipative braces. Evaluation of the structures took place through Incremental Static Analysis (i.e. Pushover Analysis). The study demonstrated that the system with Self Centering Energy Dissipative Steel Braces (SCED) proved to be superior to the Buckling Restrained brace System. The SCED system had a reduced peak storey drift and eliminated residual deformation for greater storey structures and there was an increase in seismic load demand for low rise structures. Results of pushover analysis are approximate therefore to study actual behavior buildings with SCED nonlinear dynamic time history analysis should be performed.

Vargas experimentally validated the concept of structural fuse. Structural fuse is a type of material that will prevent the inelastic yielding of primary members (i.e. columns and beams) by self-sacrificing itself. This element in the frame structure is easy to install and repair. The theory was proposed on MDOF system by experimenting on SDOF system. For carrying out analytical work a three storey one bay frame was modeled with and without buckling restrained braces that are used as metallic fuses. For the purpose of experimental validation they conducted nonlinear static analysis (i.e. pushover analysis) on the structure. They validated results in terms of ductility of frames global ductility and axial deformation of the buckling restrained braces. The results showed that the model with buckling restrained braces had ductility less than one when compared to the bare frame ductility which was found to be greater than one. Global ductility or the ductility of the whole structure also reduced in comparison to the bare frame.

Youssef et.al. worked on the performance evaluation of reinforced concrete frame building with steel bracing system. An experimental investigation evaluated the performance of metallic X brace element. Two RC frames were modeled one with moderate ductility and other with braces in accordance with International Building Code (IBC) and ACI 318-02. Two cyclic load test were conducted on moment resisting frame and braced frame. The RC frame had four stories in it. The braces were connected to the RC frame with the help of gusset plate welded together. A pushover analysis was conducted on the cast specimen and the results revealed that bracings reduced ductility demands on the primary structural members. Bare frame starts yielding at a load of 45kN and failed at 55kN load. Whereas the braced frame yielded at a load of 105kN and failed at a load of 140kN.

Sarno and Elnashi studied the seismic performance of steel moment resisting frame and frame with bracing system. Three types of bracing system used are Special Concentrically Braces (SCBF's), Buckling Restrained Braces (BRB's) and Mega Braces (MBF's). A nine storey steel building was modeled with insufficient lateral stiffness so that the code drift limitations in high seismicity zone are not satisfied. Retrofitting of the structure was carried out with the help SCBF's, BRB's and MBF's. An inelastic time history analysis was carried out to access the performance of the modeled structure. Comparative results were accessed in the form of plastic rotation of the member, interstorey drift and roof storey displacement. Results concluded that the roof storey displacement of the Mega Brace Frame is 70% lower than Moment Resisting frame and 50% lower than Special Concentrically Brace Frame. Further investigation stated that Buckling Restrained Mega Brace Frame are superior than Mega Brace Frame. To find the yield point and formation of hinges pushover analysis should also be carried out.

A. *Bracing System*

Any structures which is to be constructed in earthquake prone areas must be designed to resist lateral forces due to wind and seismic forces. The lateral force resisting systems employed to resist these forces include rigid frames, steel plate shear walls and bracing systems. Conventional bracing systems are simple to design and provide effective and economical lateral force resisting systems. Bracing systems can be constructed in many different configurations, often established by specific clearance constraints or to behave in predetermined fashion. Bracing configurations include tension compression cross braces, chevron and inverted chevron tension compression braces. These systems may be designed and detailed as concentrically or eccentrically braced frames. Sizing of the brace member is normally a simple task as the section is designed only to resist an axial tension or a compressive force.

II. Dynamic Analysis

The time history analysis determines the response of a structure due to forces, displacements, velocities or accelerations that vary with time. There are two versions of this method, first is direct integration and the second, modal superposition. Modal superposition is only suitable for linear analysis, whereas direct integration can be used also for nonlinear analysis. The direct integration utilizes a step-by-step solution of Equation of motion, which is generally described as:

$$M\ddot{U} + C\dot{U} + KU = F(t)$$

Where, M,C,K are the mass, the damping, and the stiffness matrices, respectively

For this purpose ground acceleration records, Imperial Valley, Loma Prieta and North Ridge earthquake are used as the disturbing ground motion.

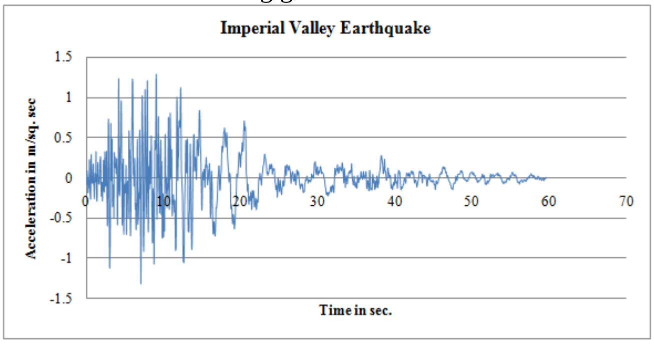

Fig. 1: Time History for Imperial Valley Earthquake

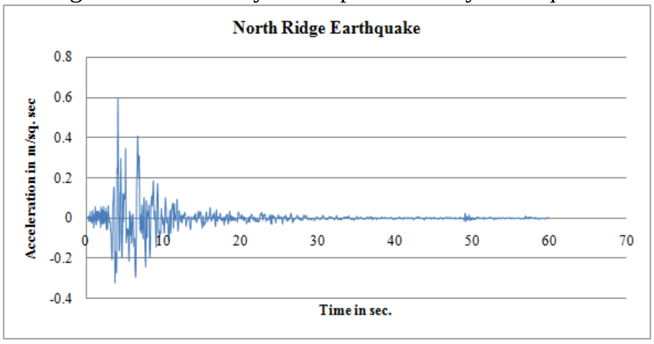

Fig. 2: Time History for North Ridge Earthquake

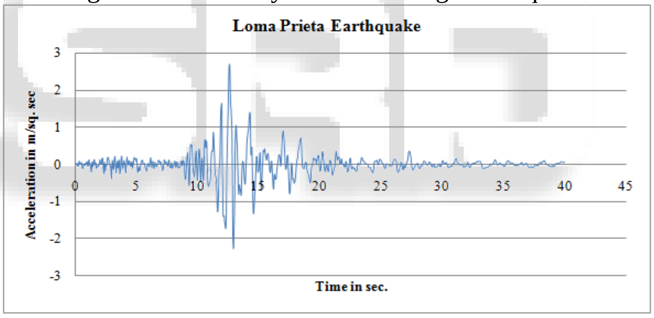

Fig. 3: Time History for Loma Prieta Earthquake

III. Methodology of Research Work

This study comprehensively investigates the seismic response of 8 storey RC structures with bracing system. Considering the imposition any one earthquake record on the building structure, the effects of the three bracing system used were investigated.

IV. Description of the Investigated Structures

The data assumed for the problem to be analyzed in SAP 2000 is as follows.

Columns Notation	Size (mm)	Beams Notation	Size (mm)
C1	350 X 400	B1	300 X 350
C2	450 X 500	B2	350 X 400

Table 1: Columns and Beams sizes

Building	=	G + 7
Slab Depth	=	150 mm
Live Load	=	3 kN/m^2
Floor Finish	=	1 kN/m^2
Grade of Concrete	=	M20

Concrete Density	=	25 kN/m^3
Grade of Steel	=	Fe415
Software	=	SAP 2000
Excitation Used	=	Imperial Valley, Loma Prieta Northridge
Properties and Material of Bracing		
Section Used	=	ISMC100
Material Used	=	MILD STEEL

Table 2: Description

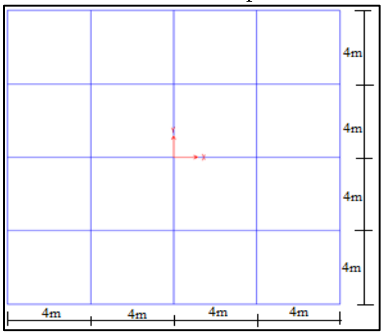

Fig. 4: Plan of RC Building

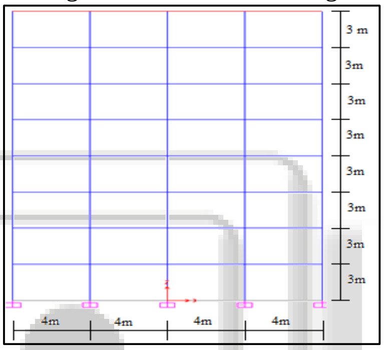

Fig. 5: Elevation of RC Building

V. RESULT AND OBSERVATION

A comparative study is presented between the performances of different passive energy dissipation devices elements for the application of different three earthquakes.

Floor Level	Bare Frame (mm)	X Brace (mm)	V Brace (mm)	IV Brace (mm)
North Ridge Earthquake				
1	8.22	2.66	5.23	2.75
2	20.14	5.83	12.6	6.12
3	29.99	8.73	16.91	9.09
4	37.08	11.25	20.93	11.47
5	42.49	13.29	24.32	13.17
6	46.04	14.83	27.02	14.31
7	49.34	16.04	29.01	15.34
8	51.76	17.06	31.00	16.32
Imperial Valley Earthquake				
1	45.84	25.26	43.24	15.58
2	117.32	56.03	112.66	35.05
3	185.51	84.86	148.17	53.24
4	244.17	109.71	178.60	68.70
5	298.30	129.07	201.79	80.43
6	340.59	152.05	222.44	89.86
7	367.67	171.08	248.40	98.75
8	382.34	185.63	265.61	105.47
Loma Prieta Earthquake				
1	67.08	20.95	27.62	28.36
2	170.11	46.61	67.03	63.23
3	269.60	71.31	90.95	96.00
4	363.80	93.76	117.02	125.28
5	441.40	113.56	144.28	150.01
6	495.51	130.23	169.81	169.61
7	526.62	143.91	190.71	187.87
8	541.22	153.62	204.47	201.91

Table 2: Storey Displacement for X, V and IV bracing System

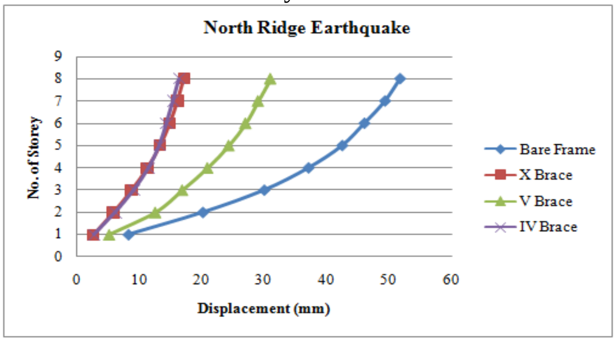

Fig. 6: Storey Displacement for Various Bracing System For Northridge Earthquake

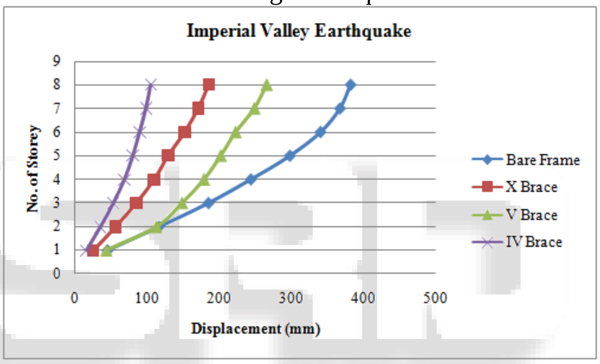

Fig. 7: Storey Displacement for Various Bracing System For Imperial Valley Earthquake.

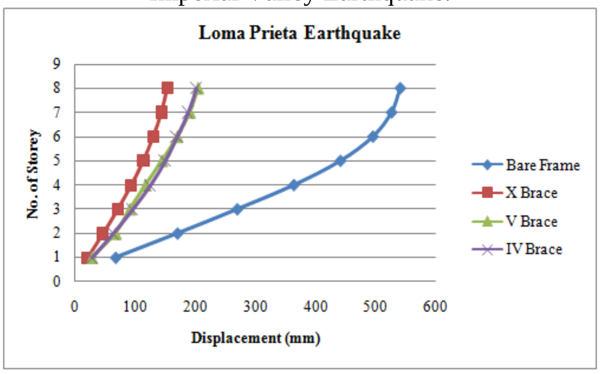

Fig. 8: Storey Displacement for Various Bracing System For Loma Prieta Earthquake.

Floor Level	Bare Frame (mm)	X Brace (mm)	V Brace (mm)	IV Brace (mm)
North Ridge Earthquake				
1	8.22	2.66	5.23	2.75
2	11.92	3.17	7.37	3.37
3	9.85	2.90	4.31	2.97
4	7.09	2.52	4.02	2.38
5	5.40	2.04	3.39	1.70
6	3.55	1.54	2.70	1.14
7	3.30	1.21	1.99	1.03

8	2.42	1.02	1.78	0.98
Imperial Valley Earthquake				
1	45.84	25.26	43.24	15.58
2	71.48	30.77	69.42	19.47
3	68.19	28.83	35.51	18.19
4	58.66	24.85	30.43	15.46
5	54.13	19.36	23.19	11.73
6	42.29	22.98	20.65	9.43
7	27.08	19.03	25.96	8.89
8	14.67	14.55	17.21	6.72
Loma Prieta Earthquake				
1	67.08	20.95	27.62	28.36
2	103.03	25.66	39.41	34.87
3	99.49	24.70	23.92	32.77
4	94.20	22.45	26.07	29.28
5	77.60	19.80	27.26	24.73
6	54.11	16.67	25.53	19.6
7	31.11	13.68	20.90	18.26
8	14.6	9.71	13.76	14.04

Table 3: Storey Drift for X, V and IV bracing System

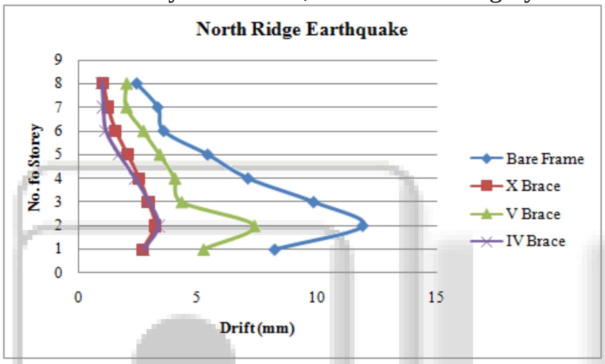

Fig. 9: Storey Drift for Various Bracing System Northridge Earthquake.

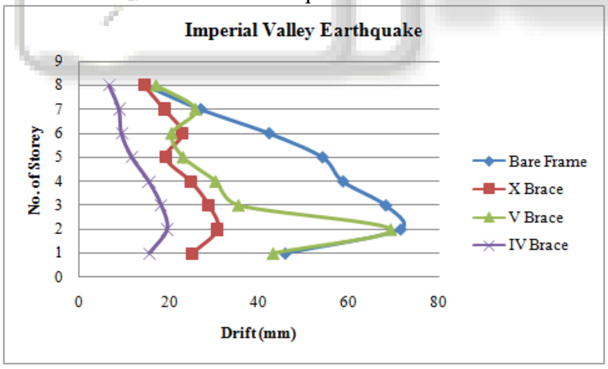

Fig. 10: Storey Drift for Various Bracing System Imperial Valley Earthquakes.

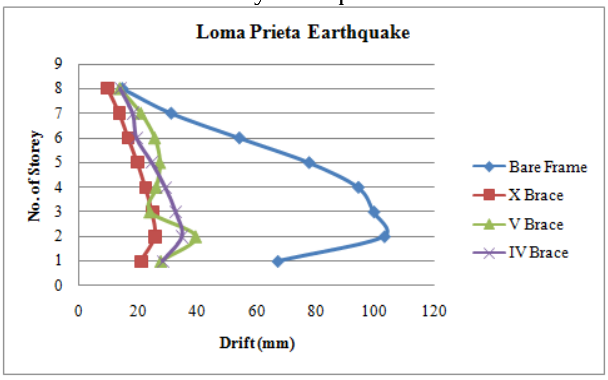

Fig. 11: Storey Drift for Various Bracing System Loma Prieta Earthquake.

VI. Conclusion

Imparting bracing elements to the building reduce the response of building curtailing storey displacement and storey drift. The top storey displacement of X brace system is found to be 69% lower than bare frame and 44.9% lower than V bracing system in case of Imperial Valley Earthquake and a similar kind of trend is followed for rest of earthquake. The storey displacement is found to be least for X and inverted V bracing system dissipating significant amount of energy. Maximum storey drift was found at second storey level. X bracing system reduce the maximum storey drift by a margin of 56.9% . The whole of the work conclude that imparting bracing system significantly improve the energy absorbing capacity of structure and X bracing configuration of bracing is best for it.

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