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Seismic Response of Structure with Lead Extrusion Damper

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Abstract: Strengthening the strength, stiffness and ductility of structure is the traditional method of designing seismic resisting building. For increasing strength of structure the dimensions of structural member and consumption of materials are expected to be increase which ultimately increase the cost of construction. Also the larger stiffness increase the response of structure in the seismic event of structure. For overcoming this disadvantage different vibration control measures are studied. Dampers are one of the popular vibration control devise of structures, as the damper are safe, effective and economical design. . Lead damper is a passive vibration control system that does not require any external power source for its operation and utilizes the motion of the structure to develop the control forces. In these research to know the performance of structure with and without lead extrusion damper the pushover analysis and time history analysis is done. Also to know the appropriate percentage of damper to be installed in the structure the analysis is done with the varying percent of damper in bays. The study shows that the performance of structure can be increase by increasing percent of dampers in bays. The displacement, shear force, and bending moment can be reduce by installing lead extrusion dampers. While by increasing the percent of dampers it may increase the axial force in the member so it is very important to select the appropriate percentage of damper.

I. INTRODUCTION

The vibration control method can be classified into active control, passive control, hybrid control, semi-active control. Among these The passive control is more studied and applied to the existing buildings than the others due to its advantages like , a passive vibration control system that does not require any external power source for its operation and utilizes the motion of the structure to develop the control forces. Dampers are placed throughout a structure to absorb either kinetic or strain energy transmitted from the ground into the primary system. Damping in structures can significantly reduce the displacement and acceleration responses, and decrease the shear forces, along the height of buildings. Energy dissipation in buildings can be confined mainly to supplemental dampers. Damage to the building can be limited to supplemental dampers which are easier to replace than structural component The use of seismic control system has increased in these resent years but selecting the best damper for reducing vibration in structure in seismic event is necessary. The controlling reduces damage significantly by increasing the structural safety, serviceability and prevents the building form collapse during the earthquake. In 1977 first time Robinson W.H. and Tucker A. G. did the experimental study on lead extrusion damper. There after (1993) W. J cousins and T.E. Porritt suggest some improvement in lead extrusion damper. The lead extrusion damper proved efficient at different temperature. The characteristic of lead extrusion damper have not been affected with the increased number of cycle. C. C. Patel. (2017) investigate the response behaviour of two parallel structures coupled by lead extrusion damper and found effective in seismic response reduction of adjacent structure. Lead damper is a passive vibration control system that does not require any external power source for its operation and utilizes the motion of the structure to develop the control forces. Passive energy dissipation device play a role similar to that of seismic isolators namely to absorb and dissipate a significant portion of the energy input to a building by earthquake shaking. Energy dissipation devices are typically distributed throughout a structure to absorb either kinetic or strain energy transmitted from the ground into the primary system. Damping in structures can significantly reduce the displacement and acceleration responses, and decrease the shear forces, along the height of buildings. Energy dissipation in buildings can be confined mainly to supplemental dampers. Damage to the building can be limited to supplemental dampers which are easier to replace than structural components. Lead Extrusion Dampers work on the principle of extrusion of lead. LED absorbs vibration energy by plastic deformation of lead and thereby mechanical energy is converted to heat. On being expelled lead re-solidifies instantly and recuperates its unique mechanical properties previously next expulsion. The area of force displacement relationship of the damper gives the energy dissipated in the extrusion of lead.

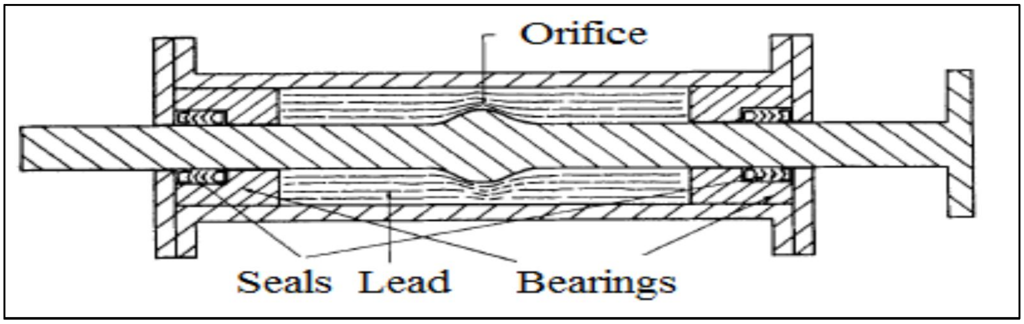

Fig 1 Internal Structure of Lead Extrusion Damper (Robinson and Greenbank, 1976)

II. PUSHOVER ANALYSIS

To know the maximum capacity of building to deform the pushover analysis is performed on the structure. In the pushover analysis we push the building until it reaches its maximum capacity to deform. It helps in understanding the deformation and cracking of structure in case of earthquake. Pushover is static nonlinear analysis method where a structure is subjected to gravity loading and monotonic displacement controlled lateral load pattern. Lateral load may represent any range of base shear induced by earthquake loading.

Output generates a static pushover curve which plots a strength-based parameter against deflection. Results give data about flexible limit of structure framework and demonstrate the structure, load level and deflection at which collapse occur.

Structural Performance Levels and Ranges (FEMA 356) A wide range of structural performance requirements could be desired by individual building owners. The four Structural Performance Levels defined in the FEMA 356 standard have been selected to correlate with the most commonly specified structural performance requirements.

A. Immediate Occupancy Structural Performance Level

Structural Performance Level (IO), Immediate Occupancy, shall be defined as the post-earthquake Damage state that remains safe to occupy, essentially retains the pre-earthquake design strength and stiffness of the structure, and is in compliance with the acceptance criteria specified in the standard for this Structural Performance Level. Structural Performance Level S-1, Immediate Occupancy, means the post-earthquake damage state in which only very limited structural damage has occurred.

The basic vertical- and lateral-force-resisting systems of the building retain nearly all of their pre-earthquake strength and stiffness. The risk of life threatening injury as a result of structural damage is very low, and although some minor structural repairs may be appropriate, these would generally not be required prior to preoccupancy.

B. Life Safety Structural Performance Level

Structural Performance Level Life Safety, means the post-earthquake damage state in which significant damage to the structure has occurred, but some margin against either partial or total structural collapse remains. Some structural elements and components are severely damaged, but this has not resulted in large falling debris hazards, either within or outside the building. Injuries may occur during the earthquake; however, the overall risk of life-threatening injury as a result of structural damage is expected to be low. It should be possible to repair the structure; however, for economic reasons this may not be practical. While the damaged structure is not an imminent collapse risk, it would be prudent to implement structural repairs or install temporary bracing prior to pre-occupancy.

C. Collapse Prevention Structural Performance Level

Structural Performance, Collapse Prevention, means the post-earthquake damage state in which the building is on the verge of partial or total collapse. Substantial damage to the structure has occurred, potentially including significant degradation in the stiffness and strength of the lateral-force resisting system, large permanent lateral deformation of the structure, and to a more limited extends degradation in vertical-load-carrying capacity.

However, all significant components of the gravity load-resisting system must continue to carry their gravity load demands. Significant risk of injury due to falling hazards from structural debris may exist. The structure may not be technically practical to repair and is not safe for re-occupancy, as aftershock activity could induce collapse.

III. CASE STUDY

Study is carried out on 4-storey buildings without and with 20%, 40%, 60% and 80% of bays equipped with lead extrusion damper. The Building selected for analysis is considered in seismic Zone V with medium soil strata. The Importance factor for the building considered is 1 and response reduction factor is

Fig no 2 shows the plan of structure having 5 numbers of bays. Fig No 3, 4, 5, 6, & 7 Shows the elevation of building without and with20%, 40%, 60% and 80 % of bays equipped with lead extrusion damper respectively.

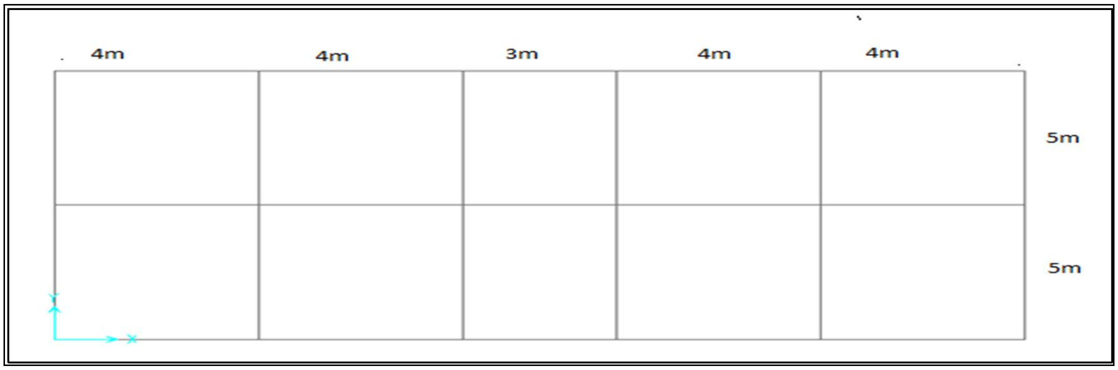

Fig.2 Plan of 4 storey building

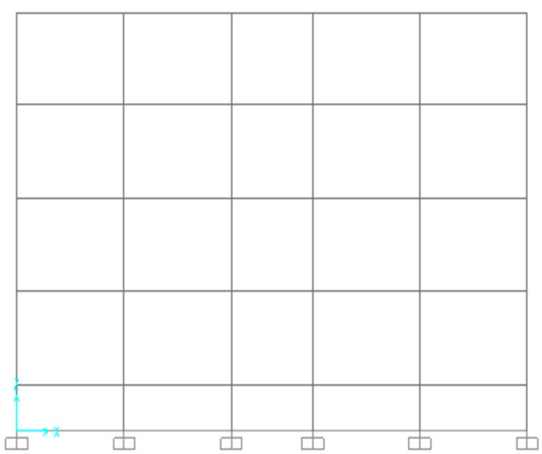

Fig No 3 Structure without damper (0%)

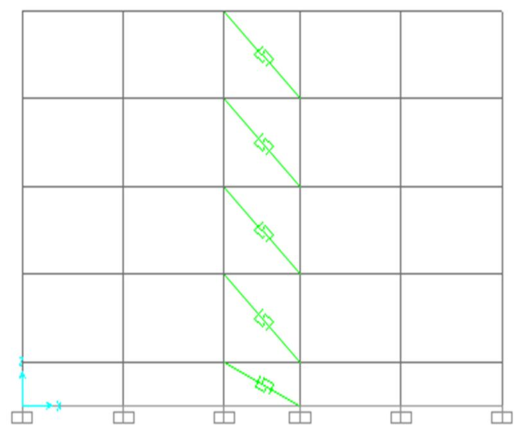

Fig No 4 Structure without damper (20%)

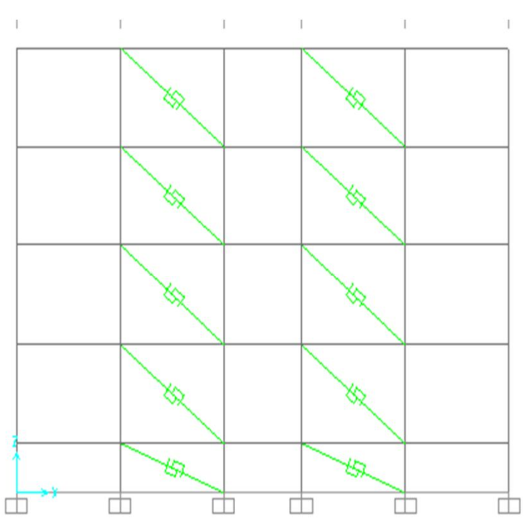

Fig No 5 Structure without damper (40%)

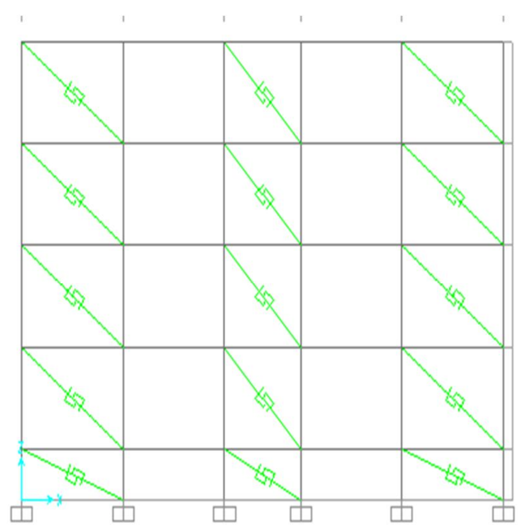

Fig No 6 Structure without damper (60%)

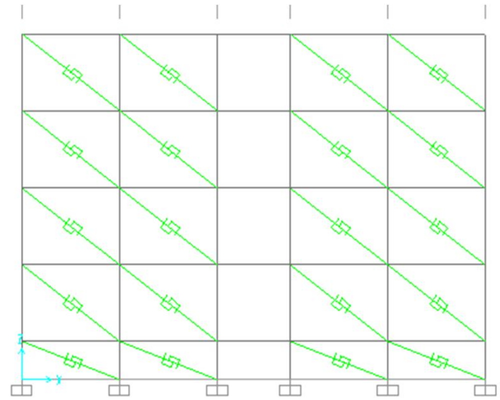

Fig No 7 Structure without damper (80%)

The damper is connected diagonally and the damper properties considered are the same for all dampers. Damper properties were defined as follows [6] Stiffness= 150000 kN/m Yield Strength = 146.46 kN/m yield exponent =15 Post yield Stiffness Ratio= 0 After modal and linear analysis, pushover analysis is performed in X direction under study. The different pushover curves in terms of base shear and roof displacement for models with damper is compared with bare frame model as shown in the following figures. Capacity curves of building models are linear initially, after certain point it start deviating from linearity to non-linearity. Non-linearity comes in picture due to inelastic action start takes place in structural elements and the results are compared. The different performance level area also marked on the graph.

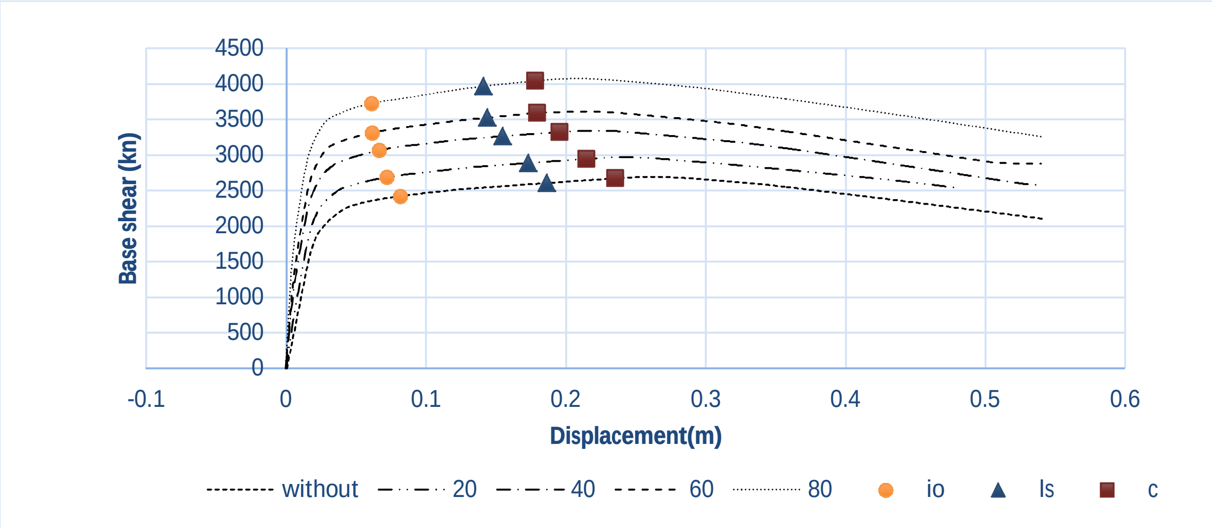

Fig. 10 Pushover Curve without and with varying present of bays equipped with lead extrusion damper

Table 1 Performance level for structure

	Immediate occupancy level		Life Safety		Collapse point	
	Displacement (m)	Base Shear (kN)	Displacement (m)	Base Shear (kN)	Displacement (m)	Base Shear (kN)
without damper	0.08146	2420.86	0.18622	2606.58	0.23536	2673.11
20	0.07181	2687.84	0.17333	2889.52	0.21491	2947.69
40	0.06668	3066.57	0.1547	3265.76	0.19574	3325.39
60	0.06124	3314.25	0.14386	3526.7	0.1795	3591.03
80	0.06111	3727.51	0.14103	3967.07	0.17829	4043.87

Table No 1 shows the values of Displacement and Base Shear at different performance level. The figure and table clearly shows that the Force Caring Capacity of Structure is increased due to lead extrusion damper

Nonlinear Dynamic Analysis of structure

To find the response of structure during different earthquake nonlinear dynamic analysis is performed on the structure. It is known as time history analysis. It is an important technique for structural seismic analysis especially when the evaluating structural response is nonlinear. To perform such analysis, a represented earthquake time history is required for a structure being evaluated. Here the time history analysis is used to determine the seismic response of a structure under dynamic loading of earthquake are Imperial Valley (1979).

Fig.9 and Table 3 shows the displacement at each story with varying percent of bays equipped with damper. The graph shows the reduction in displacement of structure with increased percentage of bays equipped with lead extrusion damper. While Fig 10 and Table 4 shows the shear force at each story with varying percent of bays equipped with damper. Shear force is also reduce with the increased percentage of bays equipped with lead extrusion damper.

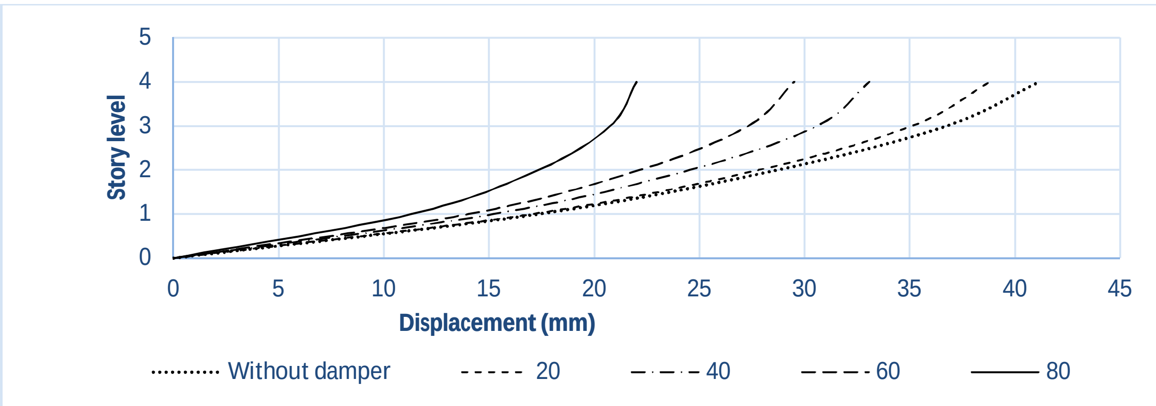

Fig.9 Displacement with varying percentage bays equipped with lead extrusion damper

Table 2 Displacement (mm) At Each Story Level With Varying Percentage Of Bays Equipped With Damper					
Story level	Without damper	20%	40%	60%	80%
0	0	0	0	0	0
1	17.36	17.036	15.203	14.012	11.31
2	28.72	27.814	24.554	22.174	17.362
3	36.761	35.106	30.598	27.329	20.772
4	41.164	38.817	33.079	29.508	22.018

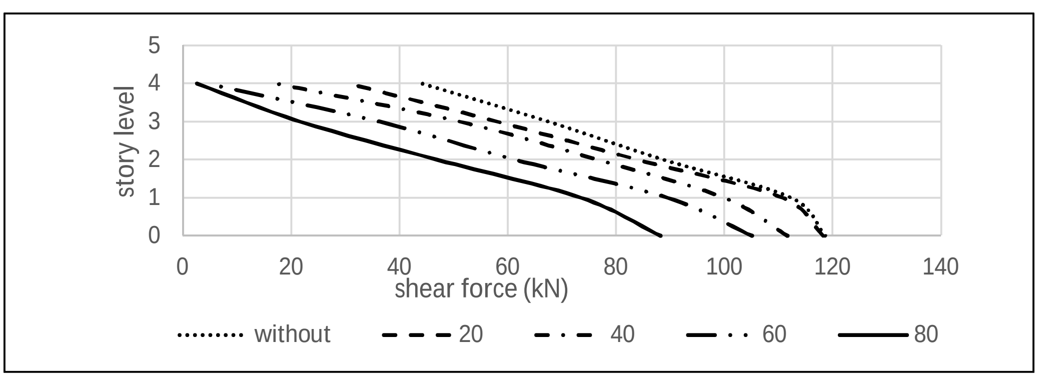

Fig .10 Shear Force with varying percent of bays equipped with lead extrusion damper

Table 4 Shear Force (kN) At Each Story Level With Varying Percentage Of Bays Equipped With Damper					
Story level	Without damper	20%	40%	60%	80%
0	118.625	118.261	111.702	105.142	88.265
1	112.366	110.773	99.931	89.513	73.551
2	88.743	83.955	76.62	61.329	46.954
3	67.488	58.034	51.088	36.229	21.67
4	44.137	30.538	17.167	4.451	2.587

Table 5 and Fig 11 shows the reduction in Bending Moment with increased percentage of lead extrusion damper.

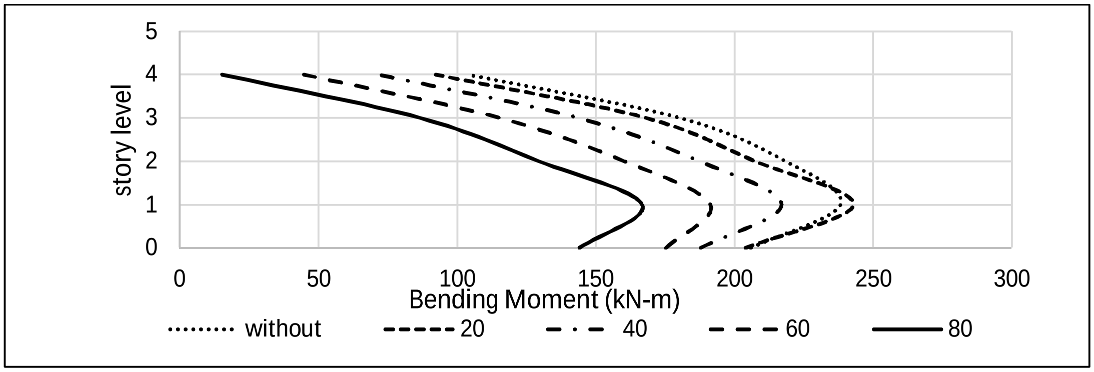

Fig. 11 Bending Moment with varying percent of bays equipped with lead extrusion damper

Table 5 Bending moment (kN-m) in Structure with varying percentage of bays equipped with lead extrusion damper					
Story level	Without damper	20%	40%	60%	80%
0	205.92	203.97	187.85	175.32	144.08
1	238.22	242.92	216.94	191.25	166.67
2	218.38	207.40	187.42	160.29	129.61
3	180.27	168.12	143.68	115.33	86.57
4	103.86	92.27	71.63	44.78	15.244

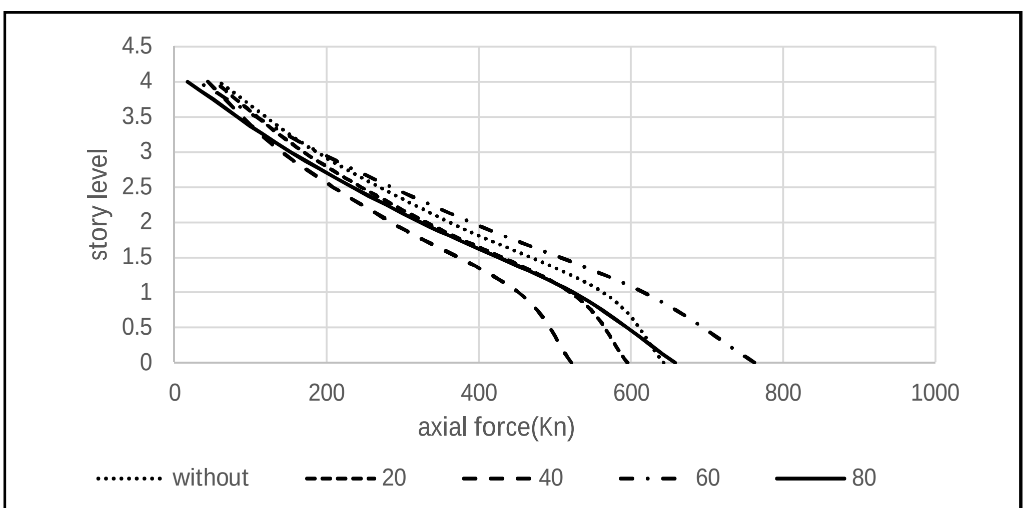

Fig.12 Axial force in structure with varying percentage of bays equipped by lead extrusion damper

Table 6 Axial Force in Structure with varying percentage of bays equipped with lead extrusion damper

story level	without damper	20%	40%	60%	80%
0	643.09	595.41	521.84	762.20	657.97
1	563.45	520.77	452.42	616.97	523.99
2	361.36	330.45	284.69	389.46	323.42
3	186.72	169.96	141.19	189.83	153.03
4	59.051	52.983	43.835	31.312	17.34

Table No. 6 and Fig. No 12 shows the Axial force in varying percentage of bays equipped with lead extrusion damper. The figures shows that axial force in member is reduced in structure where 20% and 40% of bays equipped with lead extrusion damper. But Increased in 60% and 80%. There for it is very important to select the appropriate percentage of bays equipped with damper.

IV. CONCLUSION

A. The performance of reinforced concrete frame was investigated using pushover analysis as a result of the work,

B. The performance is after installing the lead extrusion damper the deformation capacity and force capacity is significantly increase.

C. Capacity of design structure is significantly increase due to use of dampers. Because damper is added stiffness as well as damping to the existing structure without any structural modification.

D. Thus, this can be a one of the method to improve seismic performance of existing structure.

E. The nonlinear structural analysis shows that the displacement, shear force and bending moment in the members are reduce with the increasing number of bays equipped with lead extrusion damper.

F. But the axial force is increased with 60% and 80% of bays equipped with lead extrusion damper and decreased with 20% and 40% of bays equipped with lead extrusion damper.

G. The present study shows that the 40% and 60 % of dampers in bays shows the good results as shear force, bending moment, displacement and axial force are reducing.

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