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Seismic Behaviour of Steel Braced Base Isolated Reinforced Concrete Building Frame

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Abstract - *In constructions and industries traditional methods for seismic design of buildings are constrained. To overcome this, many structural control measures found to be remarkable advances. Low rise building is considered in this paper which is having low damping and flexibility, constructed as light as possible and makes structure safe to unwanted vibration. This vibration creates problem to reliability requirements of structure also reduces structural integrity, having possibilities of failure. In this paper G+4 storey RCC structure is taken for seismic analysis evaluation. This RCC building is analyzed with some structural control systems such as bracing & base isolator with use of SAP 2000, consequently different ground motion data is assigned to the building model as per codes to assess the worth of structural response. Response spectrum analysis is carried out for this low-rise building model with each control system and combination of both control systems, results of seismic response of control system is compared with conventional building and some other control systems. Response spectrum analysis reveals that building with cross bracing shows minimum displacement but maximum base shear and time period, building with LRB shows less base shear but more displacement and time period, combination of both structural control system minimizes displacement, base shear & time period.*

Key Words: *Seismic performance, cross bracings, lead rubber bearing isolator, base isolation, response spectrum analysis.*

1. INTRODUCTION

Structural control is a system having a wide range of study in different fields. It is one of the major recent areas of current research aims, to minimize vibrations of the structure during loadings such as earthquakes and strong winds. In various vibration absorption methods, structural control is split into active control, passive control, hybrid control and semi-active control. Base isolation comes under passive vibration control system in which any external power source for its operation is not required. The motion of the structure is utilized to develop the control forces.

1.1 Bracing System

Bracing system effectively reduces the lateral displacements. Several types of bracing systems such as concentric bracing, eccentric bracing and knee bracing systems have been used over years. Bracing is more efficient and economical method for lateral stiffness the framed structures. Bracing is efficient due to working of diagonal bracing in axial stress hence the minimum member size provides the stiffness and strength against horizontal shear, thus under seismic loading bracing system reduces lateral movement as well as torsional motion of the structures.

1.2 Base Isolation

Base isolation separates substructure from superstructure changing of fixed joint with flexible one. Base isolation is a passive control system in which there is no need of any external force or energy for its activation. Increasing of flexibility is done by the insertion of isolators known as isolators. Therefore, vibrations of soil to upper structure are drastically reduced. But in case of isolated building as the ground moves, inertia have tendency to keep structure in place, resulting in the enforcing of structure with large displacement in different stories. For base isolation structure the situation is quite different. In such cases, the superstructure gets displaced (which naturally remains in limits) and the relative displacement of different stories is so small which leads the structure to withstand a comparatively high seismic shocks with a low seismic loading in safe, efficient and economic manner.

2. Response Spectrum Method

This method is useful for those type of structures where modes except the primary one affect significantly the response of the structure, in this method the response of multi degree of freedom system is determined by the superposition of modal response, each of the modal response is being determined from spectral analysis of single degree of freedom system, which are then combined to find out the total response. This method is mostly usually used in industries. Response spectrum method is linear dynamic method in which estimates structural response for short, nondeterministic and transient dynamic events, earthquake and shocks are examples of such events. It can be obtained by CQC or SRSS method. If frequency is widely spaced SRSS method is applicable while if closely spaced frequency is there then CQC is preferred. It works in linear range to obtain the peak structural response of building. That linear range is used to find lateral forces evolved in structure due to ground motions and earthquake thus it make possible to earthquake resistant design of structures.

3. Structural Model Considered

Table -1: Model Data

Storey	G+4
Height of Building (m)	18.6
Plan Area (m2)	400
Plan Dimension (m)	20*20
Column size (mm)	400*400(Below Plinth) & 300*300
Thickness of slab (mm)	150
Beam size (mm)	250*300
Concrete grade	M20, M25, M30
Steel grade	fe 500
Seismic zone	V
Importance factor	1
Response reduction factor	5
Type of soil	III
Unit weight of Concrete (kN/m^3)	25
Live Load (kN)	2
Floor Finish (kN)	1
Roof Live (kN)	1.5
Roof Treatment (kN)	1

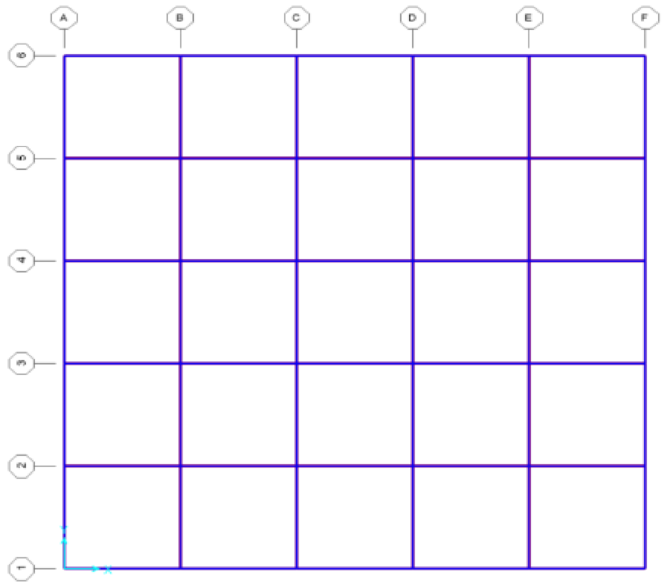

Fig -1 Floor Plan of building (From SAP 2000 window)

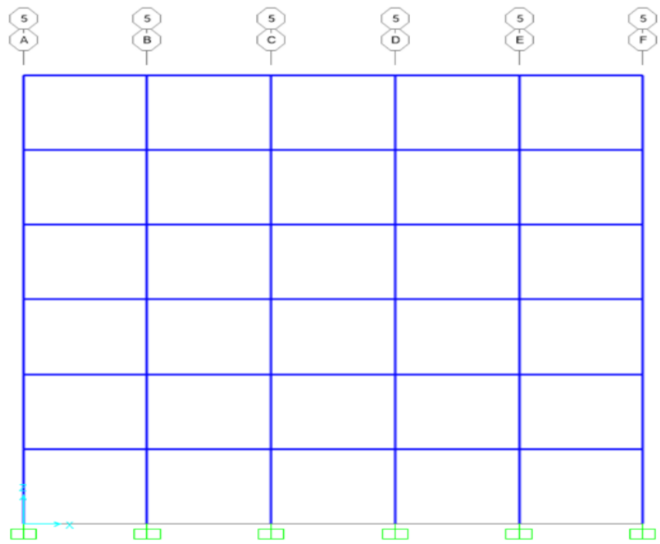

Fig -2 Elevation of building (From SAP 2000 window)

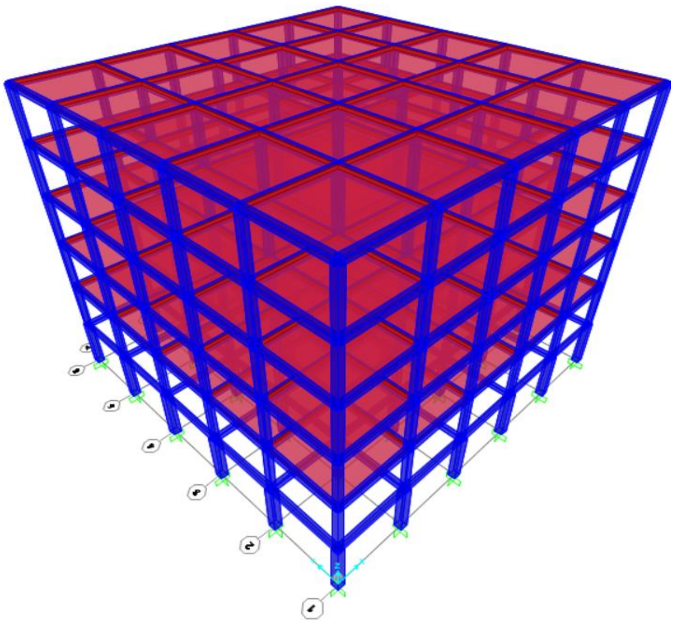

Fig -3 3D Structural model (From SAP 2000 window)

4. Types of Bracing System

(A) Concentric Bracings

In this type the bracing members intersects diagonally at a mid-point of sections. These bracing improves lateral stiffness of the frame along with increasing the natural frequency and decreasing the lateral drift.

(B) Eccentric Bracings

In this type of bracings members are linked at distinct points on the beam/girder. These bracings not only minimize the lateral stiffness of the system but also helps to improve the energy dissipation capacity. When beams are connected to eccentric bracing system, the lateral stiffness of the system is based on flexural stiffness of the beams and columns, results in mitigation of the lateral stiffness of the frame.

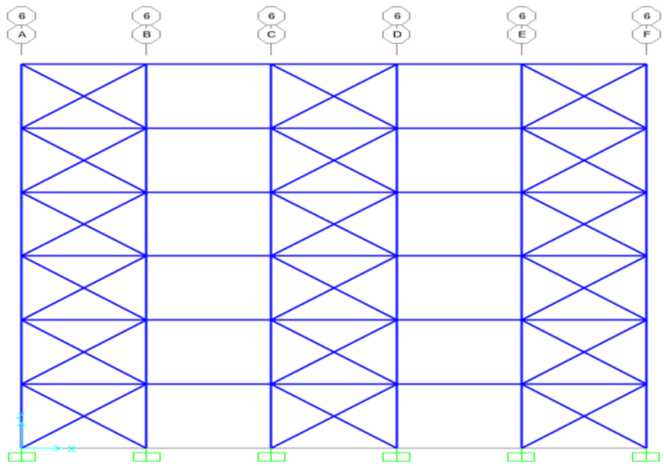

Fig -4 Steel braced frame in XZ direction (From SAP 2000 window)

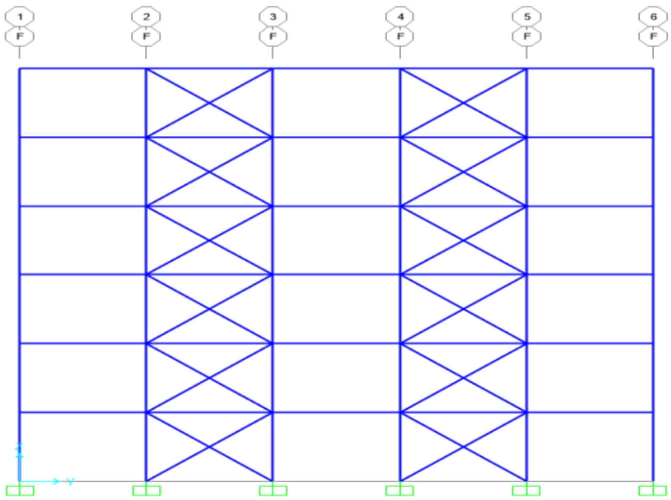

Fig -5 Steel braced frame in YZ direction (From SAP 2000 window)

Table -2: Bracing Sections

Storey	Size of Single Angle Section Cross Bracings	
	XZ Direction	YZ Direction
Base	130*130*15	150*150*18
1	130*130*15	150*150*15
2	130*130*15	130*130*15
3	130*130*15	150*150*15
4	110*110*12	150*150*15
5	110*110*12	110*110*12

4.1 Mode shapes of RCC frames:

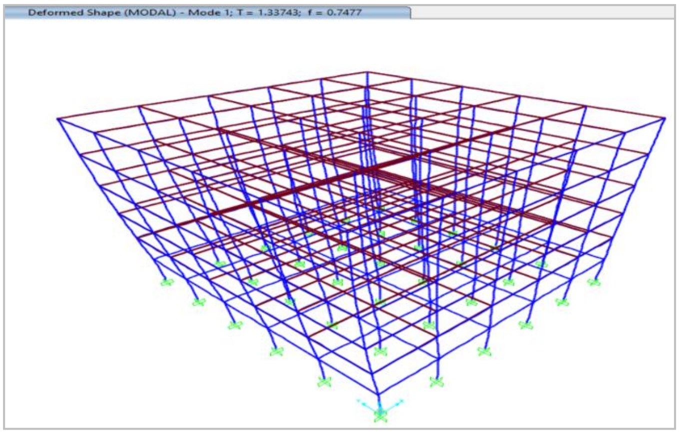

Fig -6 Deformed shape in X-direction (from SAP 2000 window)

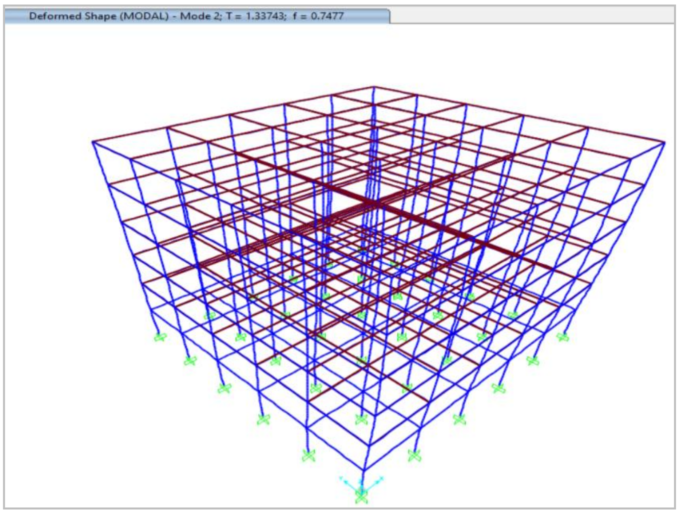

Fig -7 Deformed shape in Y-direction (from SAP 2000 window)

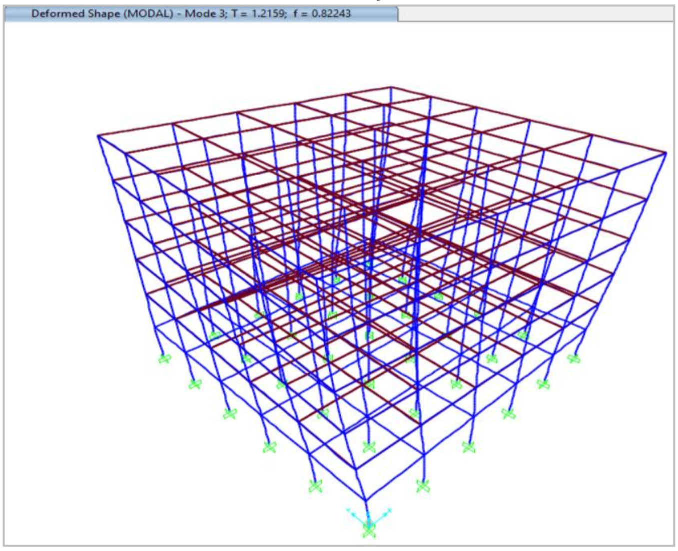

Fig -8 Deformed shape in torsion (From SAP 2000 window)

4.2 Mode shapes of steel braced frames:

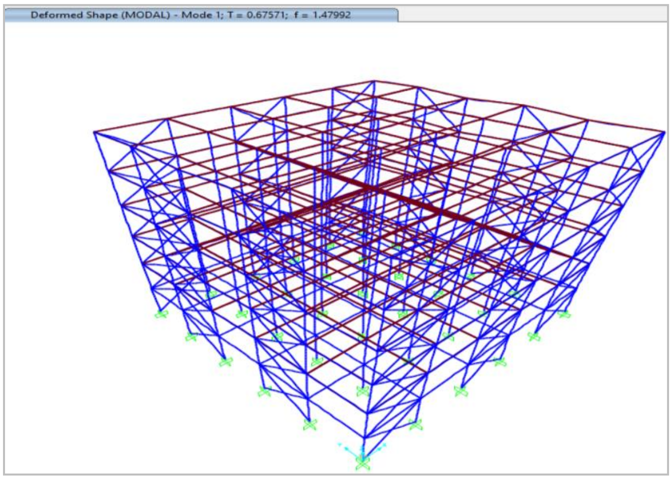

Fig -9 Deformed shape in X-direction (from SAP 2000 window)

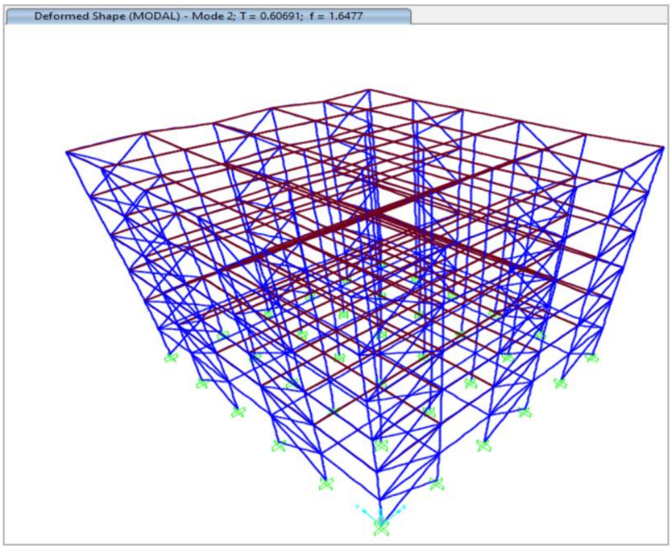

Fig -10 Deformed shape in Y-direction (from SAP 2000 window)

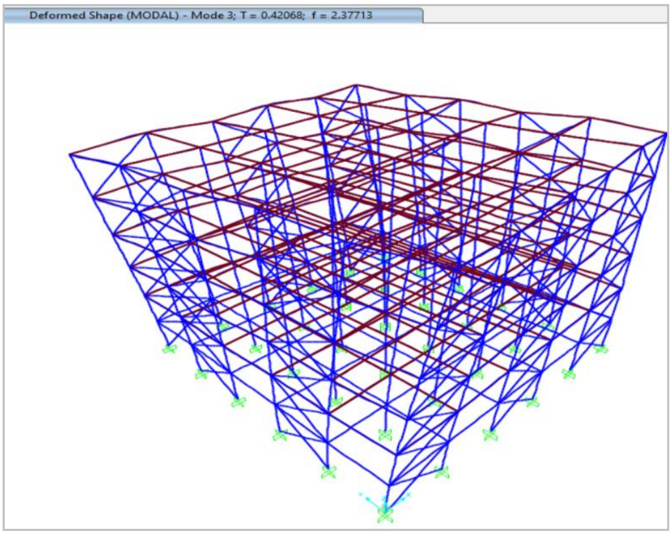

Fig -11 Deformed shape in torsion (from SAP 2000 window)

5. Lead Rubber Bearing Isolator

LRB isolators are having cylindrical rubber bearing, which are strengthened with the steel shims. These steel shims are assigned at alternate layers and steel plates are also provided at the two ends of the isolator. For better stiffness of structure under vertical loads and flexibility under horizontal loads steel shims are used which boosts load carrying capacity of structure. Isolator is used to increase the natural period of overall structure which leads to decrease its acceleration response to earthquake generated vibrations. Further decrease in response occurs with addition of damping. Increase in period together with damping can markedly reduce effect of earthquake so that less damaging loads and deformations are imposed on structure and its contents. To investigate the effect of superstructure characteristics on isolation performance a low rise and midrise reinforced concrete moment resisting frame buildings have been considered. Ideal base isolation that completely isolates structural building from its moving base has not been yet gained, in this study we only trying to reduce effect of earthquake on structures by using base isolation system. Hence proper characteristics of superstructure, lead rubber bearing isolator, sub soil properties and characteristics of earthquakes are considered. Maximum vertical load of column is considered for design of LRB isolator which is suitable for all columns. For design of LRB isolator book of author J M Kelly is referred, required data for design is taken from UBC 97 code for base isolation.

Table -3: Inputs of LRB isolator for SAP 2000

Description	Values	Unit
Rotational Inertia	0.00208	kN/m
Effective Stiffness for U1	3381237.756	kN/m
Effective Stiffness for U2 & U3	3381.237756	kN-m
Effective Damping for U2 & U3	0.05	%
Post yield stiffness to Pre-yield stiffness ratio (n) for rubber	0.1	$n = k_2/k_1$
Distance from End-J for U2 & U3	0.003199386	m
Stiffness for U2 & U3	31158.10592	kN/m
Yield Strength for U2 & U3	35.21225307	kN

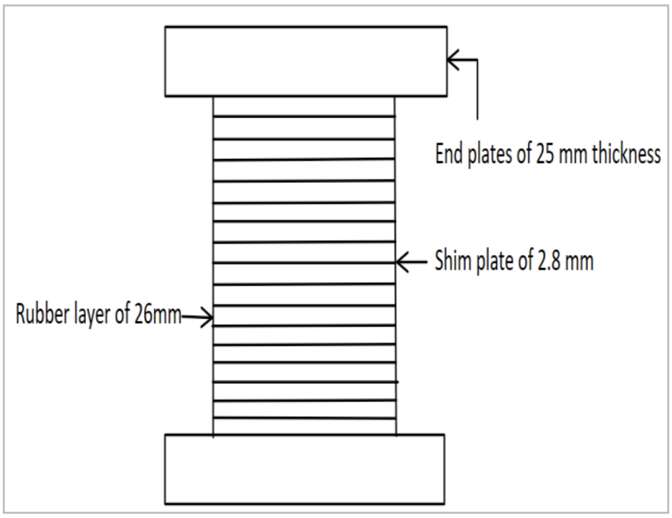

Fig -12 Assigned cross section of LRB Isolator

5.1 Mode shapes of LRB isolator frames:

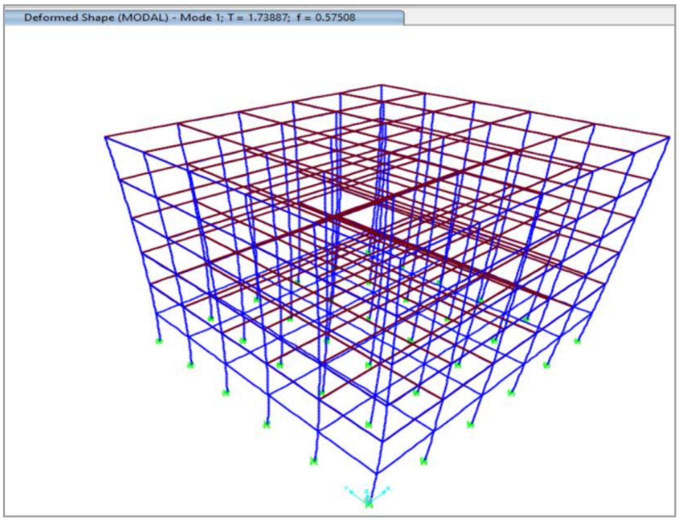

Fig -13 Deformed shape in X-direction (from SAP 2000 window)

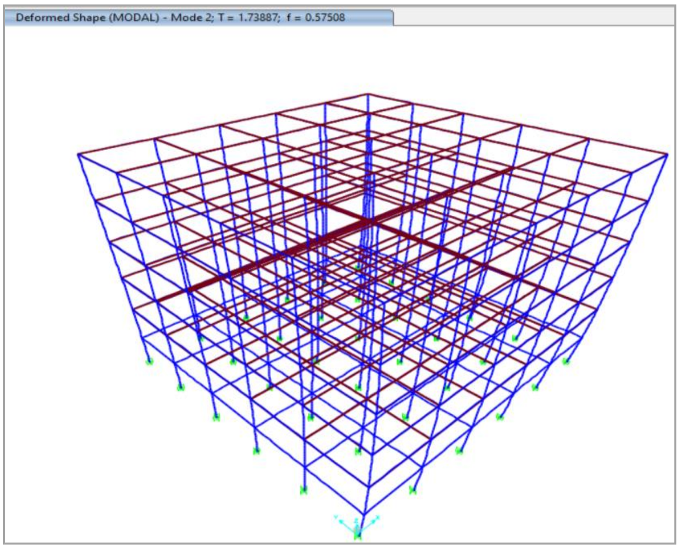

Fig -14 Deformed shape in Y-direction (from SAP 2000 window)

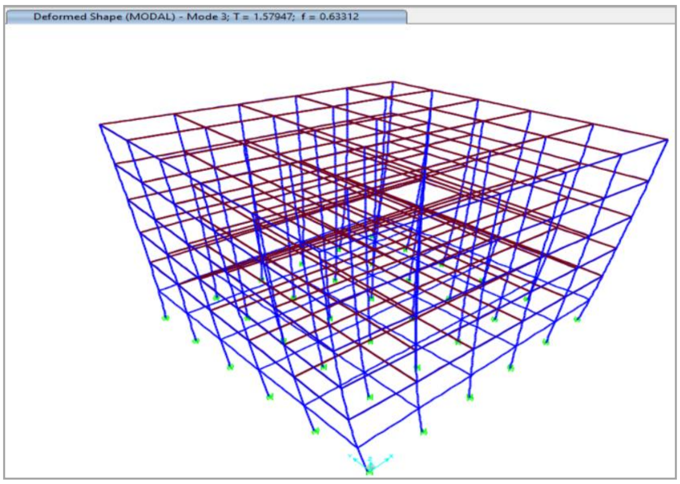

Fig -15 Deformed shape in torsion (from SAP 2000 window)

5.2. Mode shapes of base isolated steel braced frames:

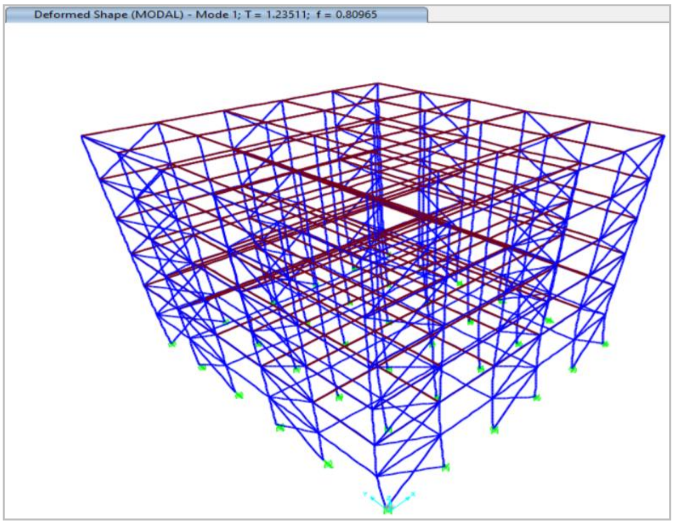

Fig -16 Deformed shape in Y-direction (from SAP 2000 window)

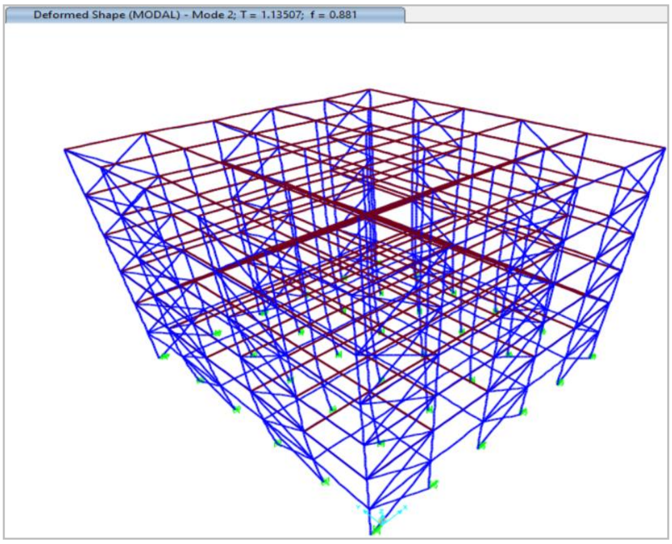

Fig -17 Deformed shape in X-direction (from SAP 2000 window)

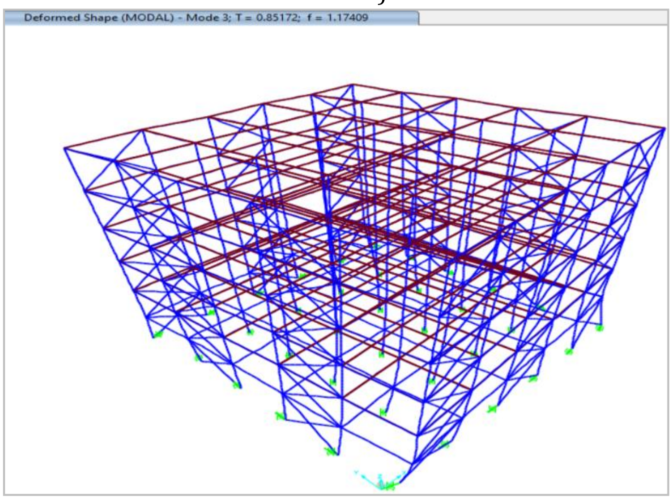

Fig -18 Deformed shape in torsion (from SAP 2000 window)

6. Results:

Table -4: Time Period

Frame Type	Mode No.	Time Period (sec)
RCC	1 (X-Direction)	1.337431
	2 (Y-Direction)	1.337431
	3 (Tortional)	1.215905
Bracing	1 (X-Direction)	0.683005
	2 (Y-Direction)	0.606633
	3 (Tortional)	0.423181
LRB Isolator	1 (X-Direction)	1.738874
	2 (Y-Direction)	1.738874
	3 (Tortional)	1.57947
Bracing with LRB	1 (Y-Direction)	1.235107
	2 (X-Direction)	1.135069
	3 (Tortional)	0.85172

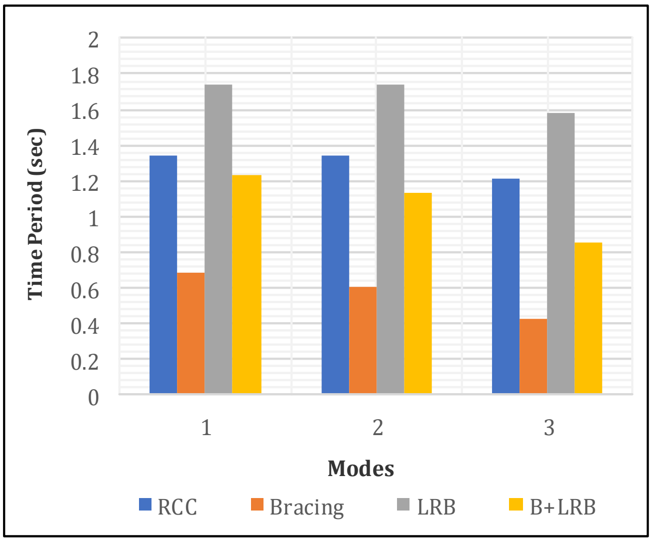

Chart -1: Time period for the frames with and without protective systems

Table -5: Base Shear

Frame Type	O/p Case	Base Shear (kN)
RCC	EQ X	1541.197
	EQ Y	1541.197
Bracing	EQ X	1660.915
	EQ Y	1660.915
LRB Isolator	EQ X	1274.731
	EQ Y	1274.731
Bracing with LRB	EQ X	1349.661
	EQ Y	1349.661

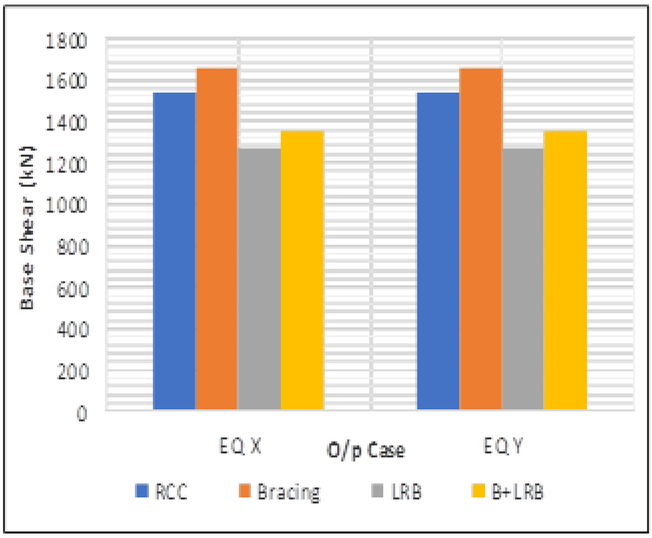

Chart -2: Base shear for the frames with and without protective systems

Table -6: Storey Displacement

Strorey	Displacement (mm)			
	RCC	Bracing	LRB	B+LRB
Base	6.8	1.6	31.9	23.2
1	21.6	4.1	48.9	25
2	34	7.2	60.6	27.4
3	43.9	10.5	69.6	29.7
4	51.1	14.1	75.9	32.1
5	55.10	17.10	79.30	34.10

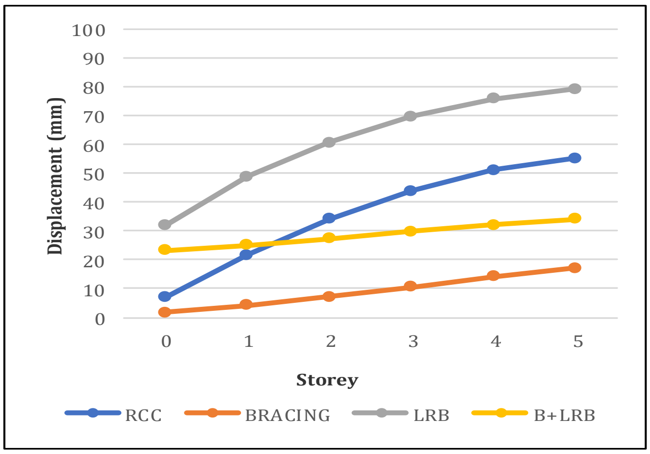

Chart -3: Displacements for the frames with and without protective systems

Table -7: Storey Drifts

Storey	Storey Drift (mm)			
	RCC	Bracing	LRB	B+LRB
Base	0.00037	0.00008	0.00172	0.00125
1	0.0008	0.00013	0.00091	0.00009
2	0.00067	0.00017	0.00063	0.00013
3	0.00053	0.00018	0.00048	0.00012
4	0.00039	0.00019	0.00034	0.00013
5	0.00022	0.00016	0.00018	0.00011

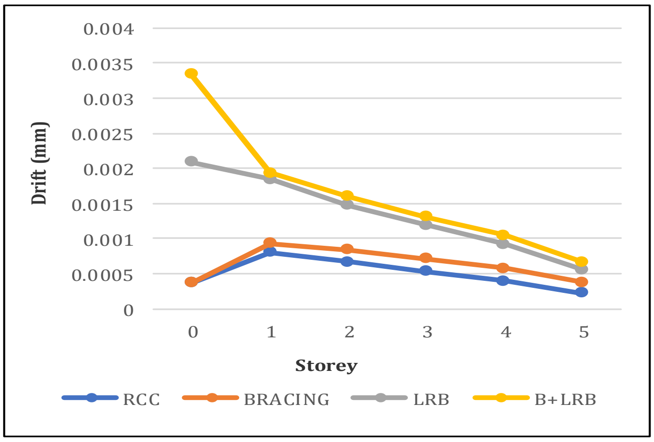

Chart -4: Storey drift for the frames with and without protective systems

7. Conclusions:

1. Due to application of bracings, there is increase in seismic weight of structure so might be results in more value of base shear during the earthquake.
2. It is observed that storey displacement was reduced during the earthquake in base isolation. Hence forth LRB is used as an alternative, which will not increase the seismic weight of structure.
3. Time period is increased due to LRB, hence might results in less value of spectral acceleration, resulting in less base shear.
4. Combination of LRB isolator & Bracing shows increase in base shear but decrease in time period than conventional RCC building and LRB isolated building.
5. In high seismic zone use of LRB for low rise building is optimal solution to prevent impact of earthquake and ground motions.

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