ANALYSIS OF DYNAMIC FORCES ON ASYMMETRICAL BUILDINGS WITH COMBINED USE OF FLUID VISCOUS DAMPER & LEAD RUBBER BEARING

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Abstract : The present research is done to understand seismic behavior of asymmetrical structure with fixed base, with fluid viscous damper (FVD) & base isolated (LRB) and structure with commingle use of LRB base with FVD. While designing the structure to resist earthquake most of the designers plan the building as symmetrical shape, so to meet the current architectural demand along with the seismic need we have taken asymmetrical building plan to work on it accordingly. In this thesis, two different types of asymmetrical structures which include G + 15 storeyed normal plan and live project plan with different plan area are considered and analyzed. The analysis of structure is done by Response spectrum method & Time history method(TH). The ETABS18 software is used to model. The building is to be considered in seismic zone V (IS 1893: 2016 Part 1) and on medium soil condition. For analysis of fixed based structure procedure is repeated for (FVD), base isolator (LRB) and combined use of LRB with FVD structures. So we would be able to easily compare it in all parameters. The results would be analyzed of storey displacement, Max modal time period, base shear forces etc. and obtained results are presented.

Index Terms: Response spectrum method(RS), Seismic, Fluid viscous damper(FVD), Base isolator, Lead rubber bearing(LRB), ETABS18.

I. INTRODUCTION

In India generally the constructed buildings have not been induced with any tools to resist Earthquake, or resist Earthquake until people move out of the building safely, so due to this we would have to suffer extensive damage or even collapse due to earthquake. The improvement in the seismic field will be helpful to counteract during severe earthquakes. The product of the building mass and ground accelerations equivalent proportional to the inertia forces causes Earthquakes. So as the mass of the building and ground acceleration being equivalent to the inertia forces of the earthquake we need to to increase the mass of the building to counteract the inertia forces caused due to earthquake. But as it is being not practically possible to increase the strength of the building infinitely. The forces causing acceleration in building are equivalent to the gravitational forces or sometimes even doubling the gravitational force (g) in huge seismic zones. To counteract these loads in which the buildings can be sided and horizontal without damage we need to increase its capacity. To minimize the potentiality of earthquake forces to transmitting it to the structure is achieved by installation of flexible base that is making it like rubber at the base of the structure. So that it can resist the horizontal forces by damping in that direction materials somewhat like to shock absorbers. Recently, this technology has been come to light as a practical and economic solution to conventional seismic strengthening. This concept has encountered expanded the academic and professional attention and its been familiar to a broad range of civil engineering structures. In this modern time there are many buildings in America, Japan, Auckland, India which are been using the principles of seismic isolation & technology for their seismic design. We all know rubber as a flexible material hence it is a boon that the rubber being elastic material its foundation is actually working to minimize earthquake damage to buildings, to counteract this massive forces on these buildings must experience in a major quake. Hence concept of isolating a base to counter the seismic forces is to point at a outstanding reduction of dynamic loads induced by the earthquake at the base of the structure itself. Isolating the base separates the structure from the injurious motions of the ground by providing pliability and energy's self indulgence capability through the sliding of the isolated device are called isolators between the foundation and the building structure. There are many regions in world from low to medium earthquake risk region. There are many places even at the Midwestern areas in USA (Southern Illinois, Kentucky, Southern Indiana etc). Hence, to construct building in these zones, base should be isolated and this can be the accurate Solution as it guards flexibility of building and turn down the impact of lateral forces in a desperate manner, especially in such buildings as important buildings, museums, data centers, library, etc. Now, the operation of isolator being very familiar all over the world, yet there is a yet lot to discover to implement the device practically mainly in low to medium seismic zone near Himalayan mountain especially for general buildings at capital of Bangladesh region according to the general requirements. So, this discussion is a very ignited matter to get knowledge. Specific Site of earthquake data are also exceptionally important in seismic design. The study seeks an attention for the detail revision of seismic isolation system, properties of various device of different categories, recognize along with its intensity on building structures.

II. AIM & OBJECTIVE

1 To Analyse the Asymmetrically shapes structure and design it with fixed base and provide fluid viscous damper.

2 To design base isolators of lead rubber bearing os asymmetrical structure and model it in ETABS18

3 To analyse and design Asymmetrical building with fixed base, by its commingle effect by using Lead & rubber as a bearing and fluid viscous damper.

4 To perform various analysis such as response spectrum analysis, time history analysis of asymmetrical building with fixed base, fluid viscous damper, lead rubber bearing each and the commingle use of LRB and FVD.
5 To provide results of seismic response of storey displacement, drift, acceleration, base shear, modal time period.

III. LITERATURE REVIEW

According to Xiaohan Wu et al. (2018), sesismic efficiency analysis of linked multitower analysis of friction pendulum system and viscous damper was investigated. To achieve a better effect of seismic reduction, a set of measurements must be used to determine FPS parameters. In comparison to the friction pendulum, the viscous damper dissipates less energy. The viscous damper, on the other hand, can reduce the horizontal slip displacement of the friction pendulum and keep it within the design value. According to Rincy et al. (2015), in a comparative analysis on RC framed buildings with isolators and dampers, storey drift and storey displacement was reduced to a greater degree in base isolated structures. Elif Cagda Kandemir Mazanoglu (2017) In his paper stated that Effect of base Isolator to be compared with fluid viscous damper in adjacent building shows that base isolation affects the flexibility in Response Spectrum. Roof displacement is greater in flexible buildings when compared to the base. Budhi Ram Chaudhary and colleagues (2019) published a research paper. According to a review paper on a comparative analysis of fixed base, base isolation, and damper systems in RC buildings, the base isolated building had better bending capability than the fixed base and shear wall systems, even in the settled density along the fault line. As compared to FVD and bracing, the LRB method allows for the most sifting time. In their paper, Mithun et al. (2017) compare the seismic response of irregular structures with lead rubber bearing and friction pendulum bearing base isolation systems. In both foundation isolated and fixed base structures, the time span in the Composite structure is the longest as compared to RCC and steel structures. As compared to fixed base structures, base isolation reduces base shear.

IV. TERMINOLOGY

1. Base Isolation System

It is a system that enlarges the fundamental time period of earthquake shakes so that the structure is induced to lesser amount of earthquake forces. Hence due to the increase in time period it results in increment of displacement of the structure, it becomes necessary to provide pliable base which can withstand the longer period. The basic elements for base isolation are :

1. A isolator with pliable base enlarges the period of vibration of the building so it can decrease the force.
2.It should absorb the earthquake forces and compensate the energy by damper. Due to it the relative deflections across the flexible base has limitations over practical design level.
3. It should definitely provide rigidity under lower loads.

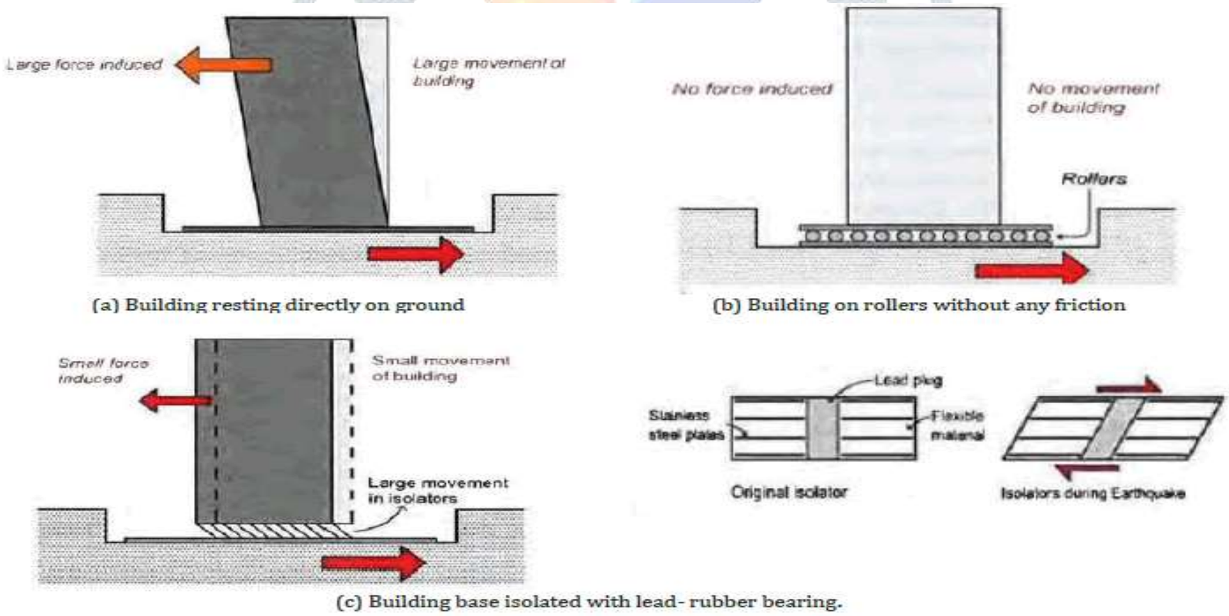
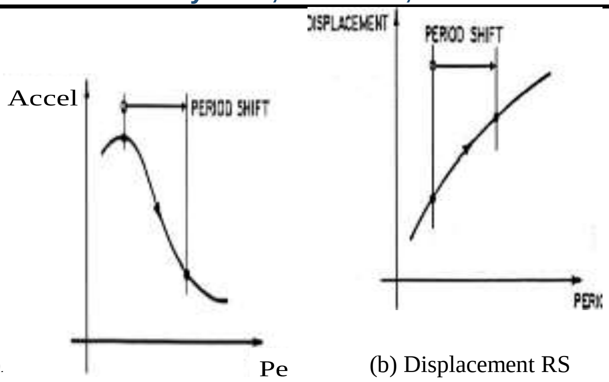
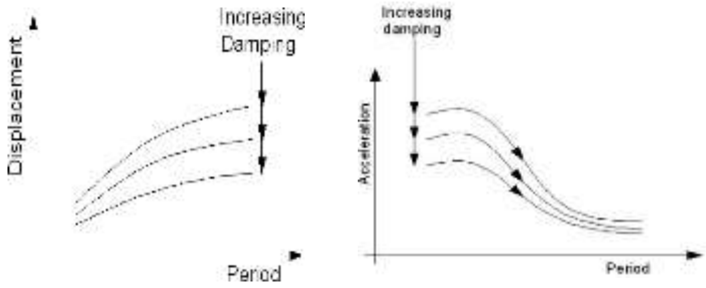


Figure 1 – Base Isolated Structure with Lead rubber Bearing.



(a). (b) Displacement RS

Figure 2 – Periodic Shift



(a)Acceleration RS (b) Displacement RS

Figure 3 – Damping

a) **Isolators:-** The devices which are designed to sepearate as the flexible base to isolate the structures from the base to dissipate the inertia forces caused by earthquake are called isolators. The properties to make the perfect base isolation are to be discussed and the one which is taken for use is LRB

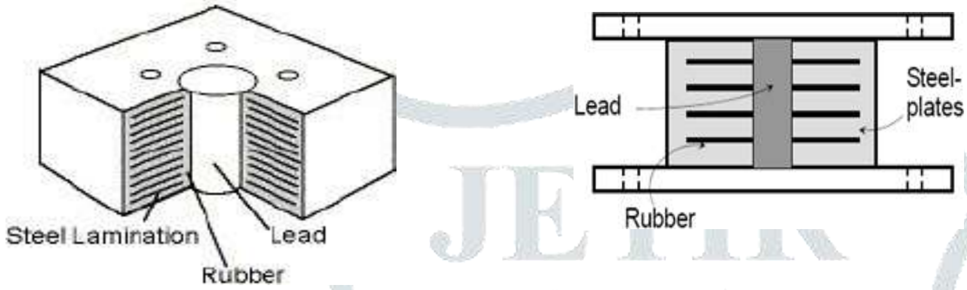


Figure 4 – Cross Section of Lead Rubber Bearing.

b) **Lead Rubber Bearing(LRB):-** Flexible bearing is a device with layers indulged of rubber for elasticity and steel or lead for resisting forces both are combined in one cylinder and placed alternately to act as a spring to resist lateral as well as vertical forces to safeguard the structure from earthquake and act as a shield by compensating the forces by elongation and contraction. When this bearing are placed below the structure the base below the structure oscillates acting as a spring. The LRB was invented in 1975 and been in use in America, Auckland, Japan to fight against earthquake. The steel plates act as a lead plug to compensate shear forces and produces damping. LRB has to be maintained after strong Earthquakes, with appropriate durability and reliability.

2. **Dampers**

a) **Energy Dissipation System (Dampers) :-** It is a device in which it Mechanically dissipate earthquake energy into special kind of devices which disfigure or bend during earthquake. The enhancement of energy dissipator in a structure to which they are installed so that it compensates the energy and the structure has to face lesser amount of earthquake forces. This dampers dissipates the seismic forces induced on the building and hence acts as a shield between the members of the building by damping. When seismic waves shakes the ground, the building also gets shaked, but due to inertia it tries to regain its position hence it get damaged especially at the joints and it bends at the top end as being fixed at the base and hence due to this bending from this side to another side like oscillations of pendulum, than collsapse, hence Dampers compensate it by controlling the oscillations of the building placed inside the structures.

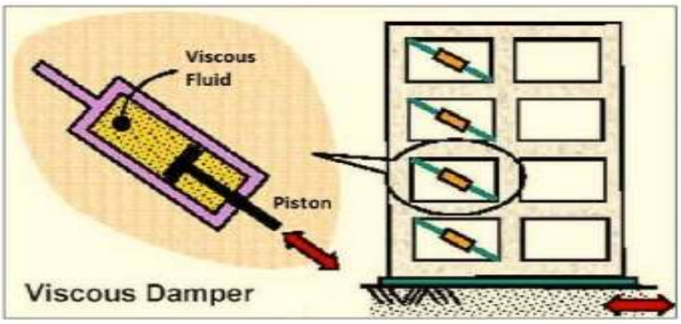


Figure 5 – Fluid Viscous Damper

b) **Fluid viscous Damper(FVD) :-** For damping phenomena, viscous damping is the source in which viscous damping force is shown as a result of volume, shape, and velocity of an object crossing through a real fluid with viscosity. An examplar of viscous damping in mechanical systems can be demonstrated as :-

We have seen oil films between two steels of abrasion surfaces, as well as fluid flowing between the steel piston and cylinder surface, Also the Fluid flowing through an orifice, Fluid flow within a journal bearing. Nowadays, there are many things in which fluid viscous phenomena is used in many areas such as hydraulic lifts.

Generally, they regain by moving by providing a force or torque opposing motion proportional to the velocity. This may be accomplished by fluid flow or similar magnetic principle used in magnetic structures. The deliberate impact is to improve the damping ratio.

V. METHODOLOGY

1. The irregular RC frame structure is modelled in ETABS18
2. The codes used are IS 456 :2000, IS 1893 (PART I) 2016.
3. Provisions published by FEMA-273, 356, 456 (Federal Emergency Management Agency).
4. The loads are applied as per code provisions of IS 875 (Part II) Reaffirmed in 2008 for live load and IS 875 (Part I) for dead load. And IS 875 (Part III) for Wind Loads.
5. Analysis of Response spectrum is done for the fixed base structure. As the analysis of a fixed base structure is done the maximum axial load is noted from support reaction results of External columns and maximum axial load of internal columns.
6. Then properties of Lead rubber bearing are calculated and these properties are used as link properties for base isolation structure.
7. Then properties of fluid viscous damper are taken from standard availability chart and these properties as used as link properties for fluid viscous damper structure as Damper Exponential.
8. Then the structure with Base isolation, Fluid viscous damper & combined LRB Base with FVD will be analysed and compared each with fixed base too.

VI. MODELS

1. **Live Project Plan**
   G+15 storey
   Plan area = 516.1231 m^2

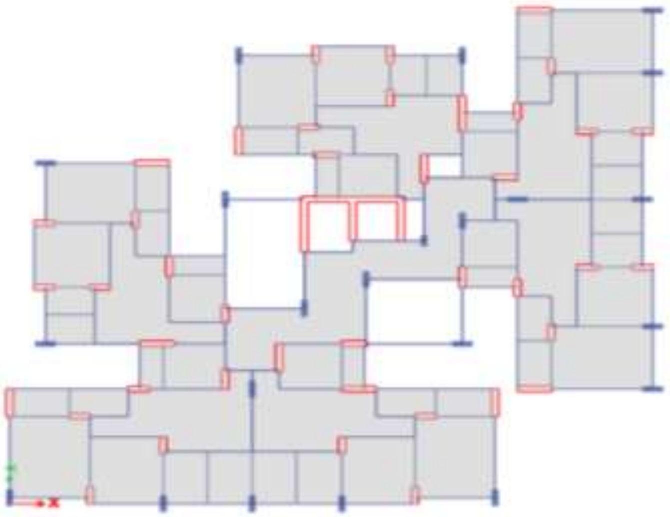


Figure 6 – Plan of Live Project

2. **Normal project plan.**
   G+15 storey
   Plan area = 203.87 m^2

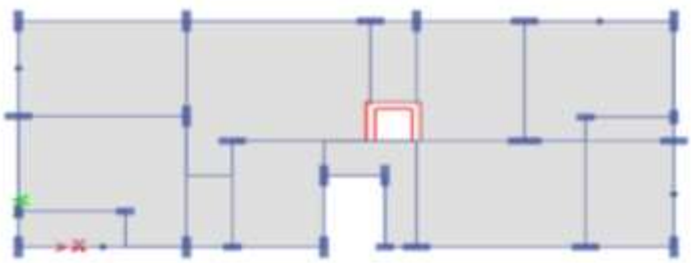


Figure 7 – Plan of Normal Project (Idea generated plan)

VII. RESULTS

1. Max Time Period

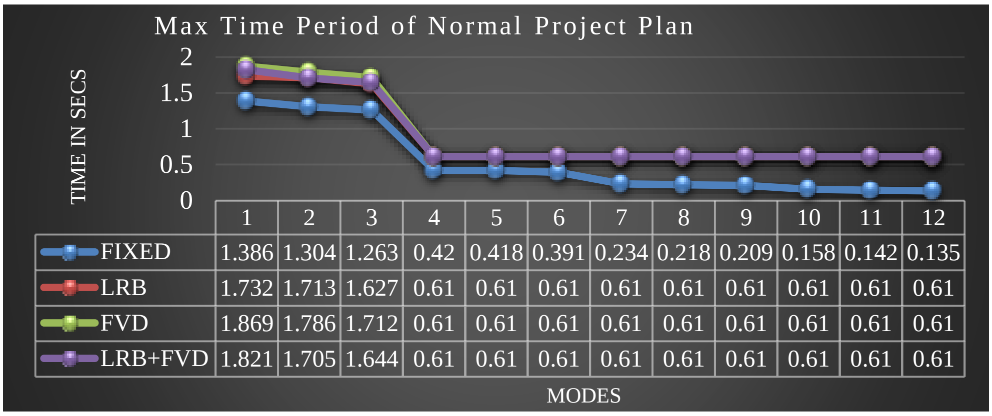


Figure 8 – Graph 1 – Max Time Period of Normal Project Plan

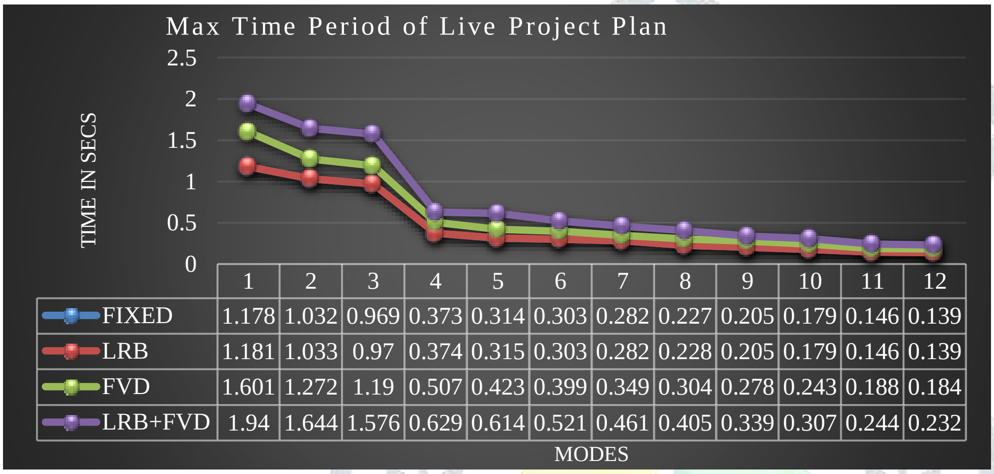


Figure 9 – Graph 2 – Max Time Period of Live Project Plan

2. Base Shear

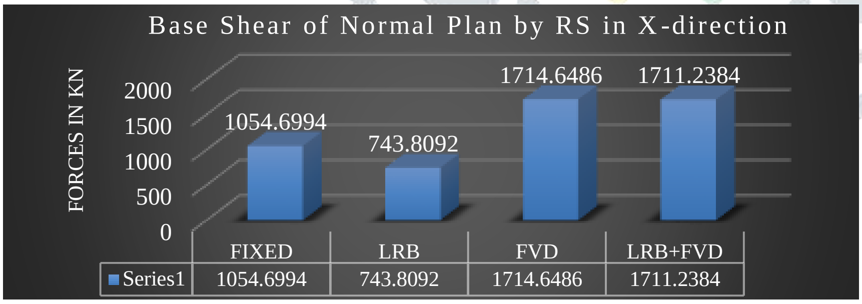


Figure 10 – Bar Chart 1 – Base Shear of Normal Plan by RS in X-direction

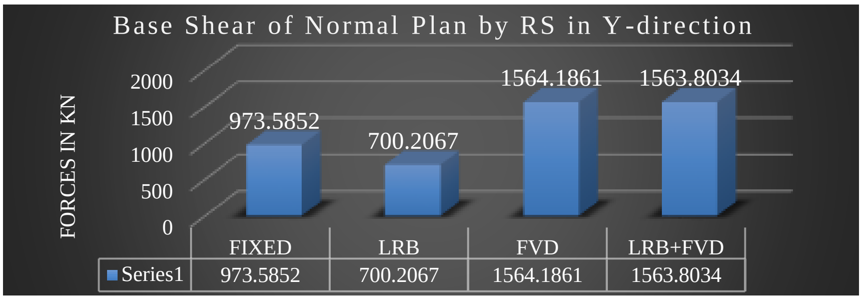


Figure 11 – Bar Chart 2 – Base Shear of Normal Plan by RS in Y-direction

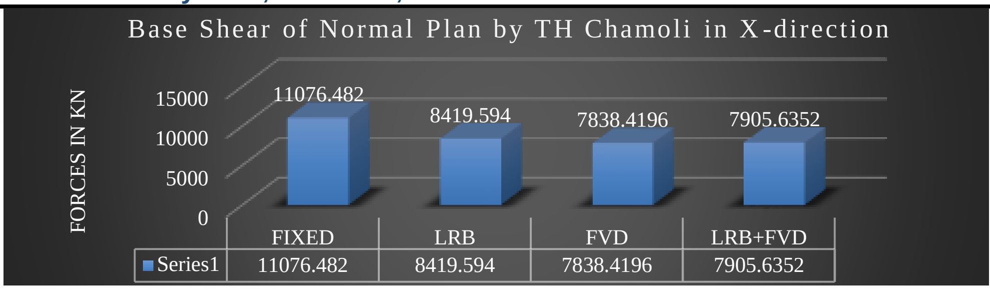


Figure 12 – Bar Chart 3 – Base Shear of Normal Plan by TH Chamoli in X-direction

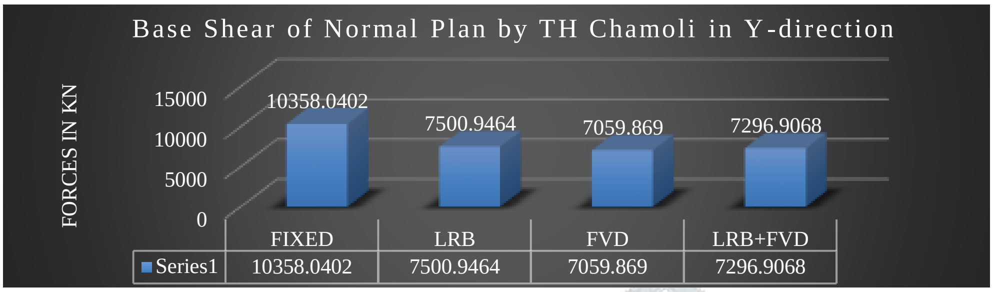


Figure 13 – Bar Chart 4 – Base Shear of Normal Plan by TH Chamoli in Y-direction

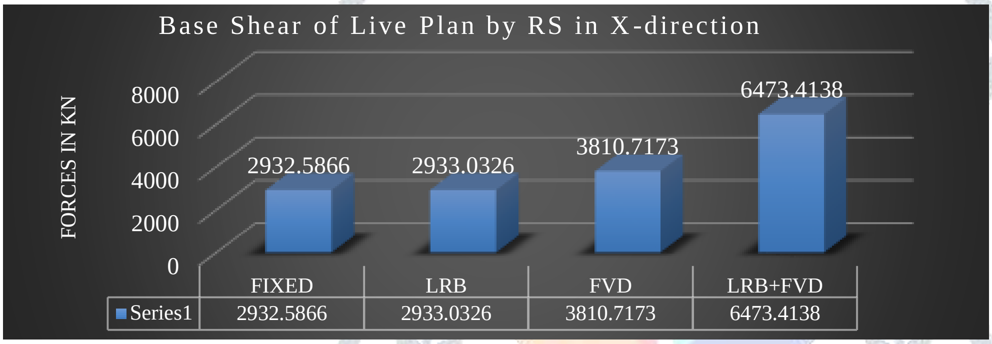


Figure 14 - Bar Chart 5 – Base Shear of Live Plan by RS in X-direction

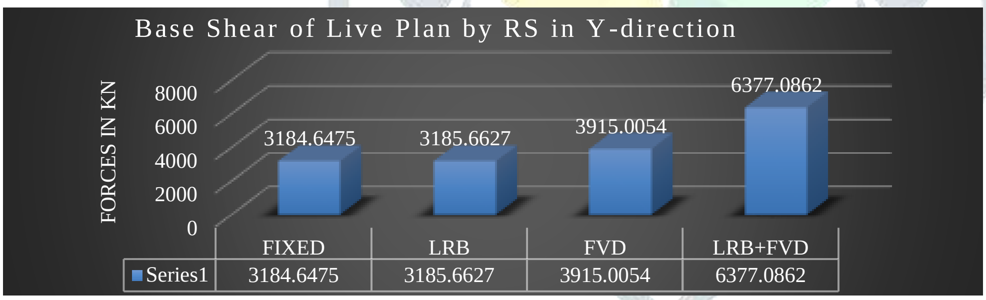


Figure 15 - Bar Chart 6 – Base Shear of Live Plan by RS in Y-direction

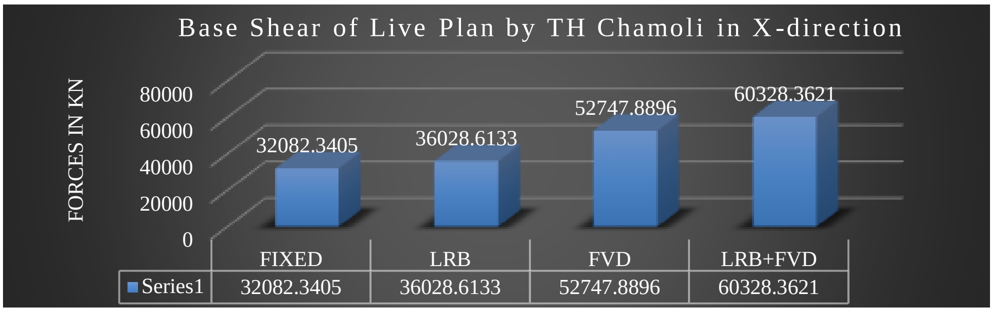
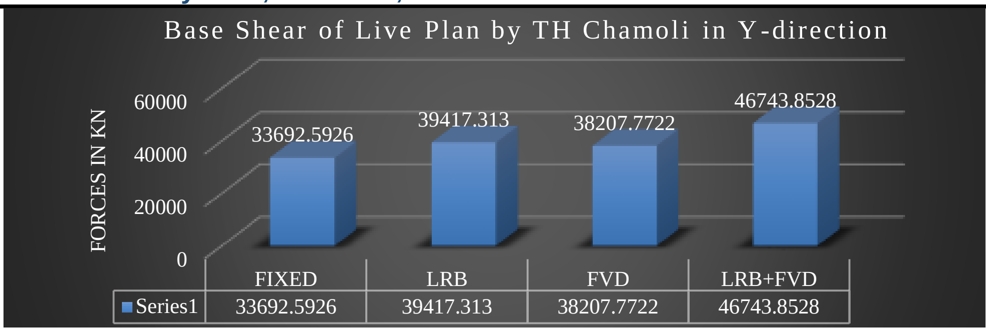


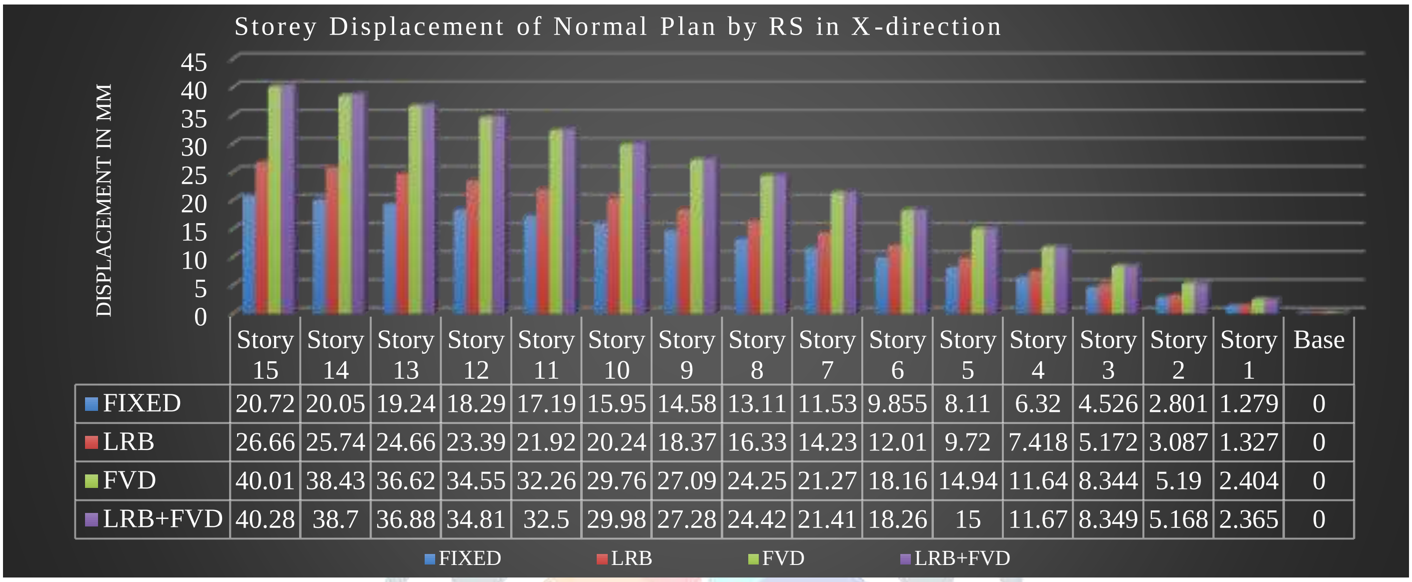
Figure 16 - Bar Chart 7 – Base Shear of Live Plan by TH Chamoli in X-direction



	FIXED	LRB	FVD	LRB+FVD
Series1	33692.5926	39417.313	38207.7722	46743.8528

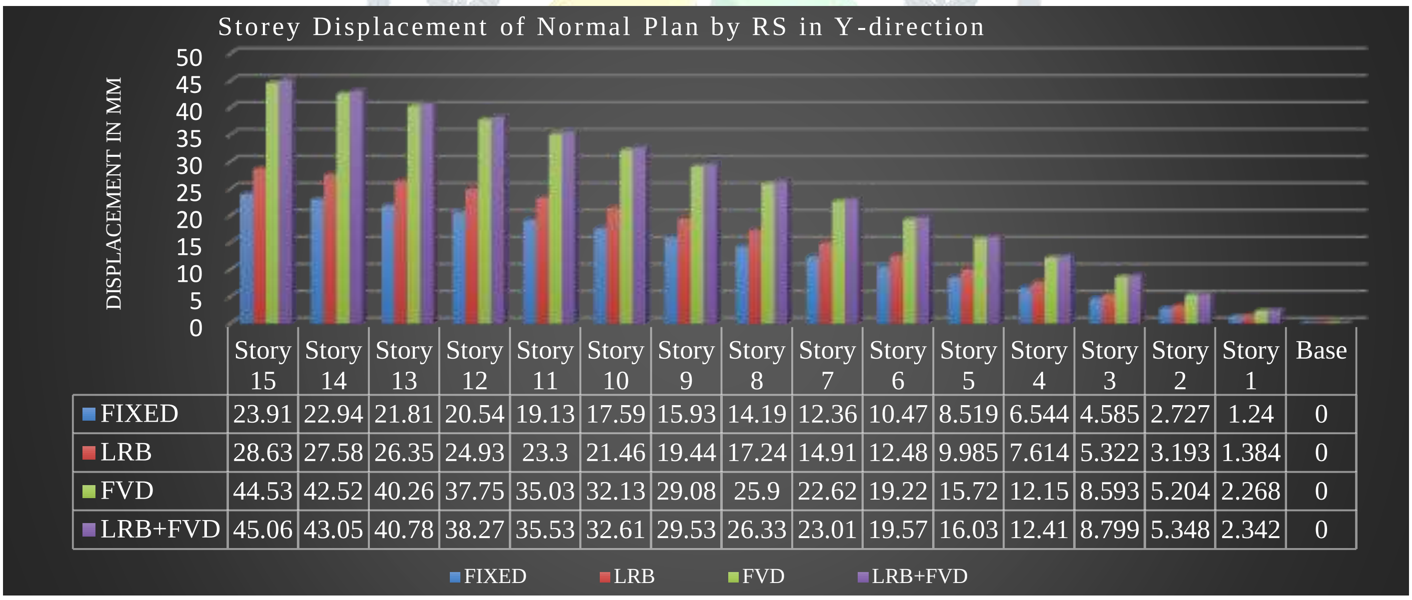
Figure 17 – Bar Chart 8 – Base Shear of Live Plan by TH Chamoli in Y-direction

3. Storey Displacement



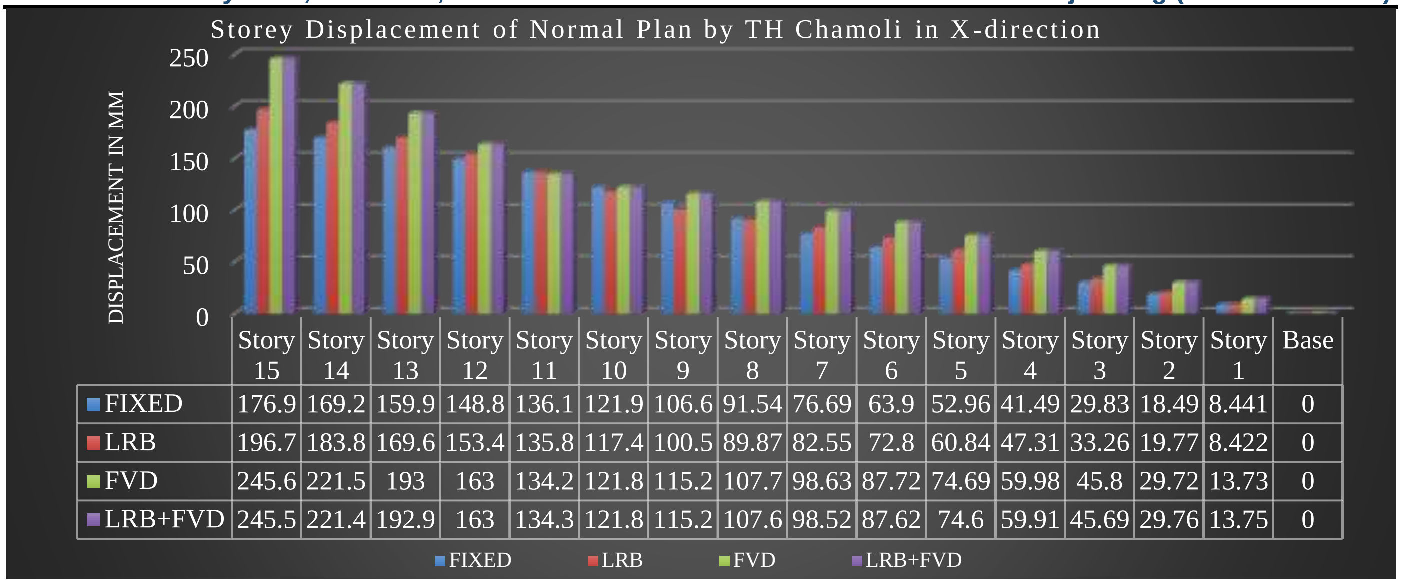
	Story 15	Story 14	Story 13	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1	Base
FIXED	20.72	20.05	19.24	18.29	17.19	15.95	14.58	13.11	11.53	9.855	8.11	6.32	4.526	2.801	1.279	0
LRB	26.66	25.74	24.66	23.39	21.92	20.24	18.37	16.33	14.23	12.01	9.72	7.418	5.172	3.087	1.327	0
FVD	40.01	38.43	36.62	34.55	32.26	29.76	27.09	24.25	21.27	18.16	14.94	11.64	8.344	5.19	2.404	0
LRB+FVD	40.28	38.7	36.88	34.81	32.5	29.98	27.28	24.42	21.41	18.26	15	11.67	8.349	5.168	2.365	0

Figure 18 – Bar Chart 9 Storey Displacement of Normal Plan by RS in X-direction



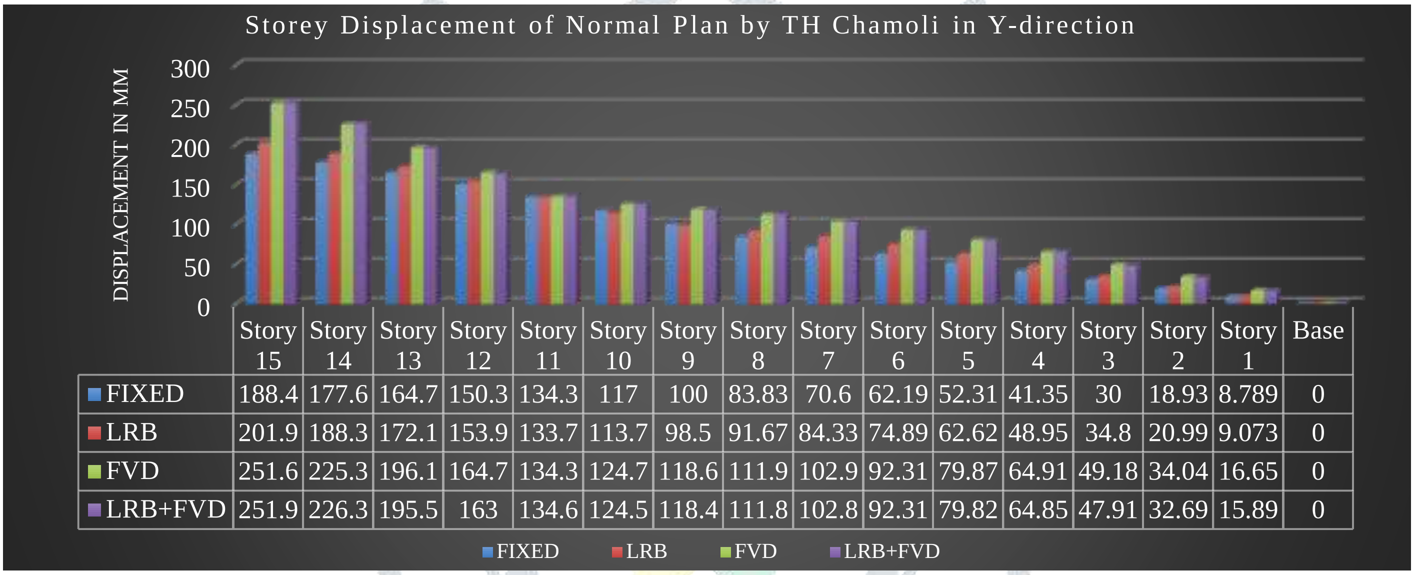
	Story 15	Story 14	Story 13	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1	Base
FIXED	23.91	22.94	21.81	20.54	19.13	17.59	15.93	14.19	12.36	10.47	8.519	6.544	4.585	2.727	1.24	0
LRB	28.63	27.58	26.35	24.93	23.3	21.46	19.44	17.24	14.91	12.48	9.985	7.614	5.322	3.193	1.384	0
FVD	44.53	42.52	40.26	37.75	35.03	32.13	29.08	25.9	22.62	19.22	15.72	12.15	8.593	5.204	2.268	0
LRB+FVD	45.06	43.05	40.78	38.27	35.53	32.61	29.53	26.33	23.01	19.57	16.03	12.41	8.799	5.348	2.342	0

Figure 19 – Bar Chart 10 Storey Displacement of Normal Plan by RS in Y-direction



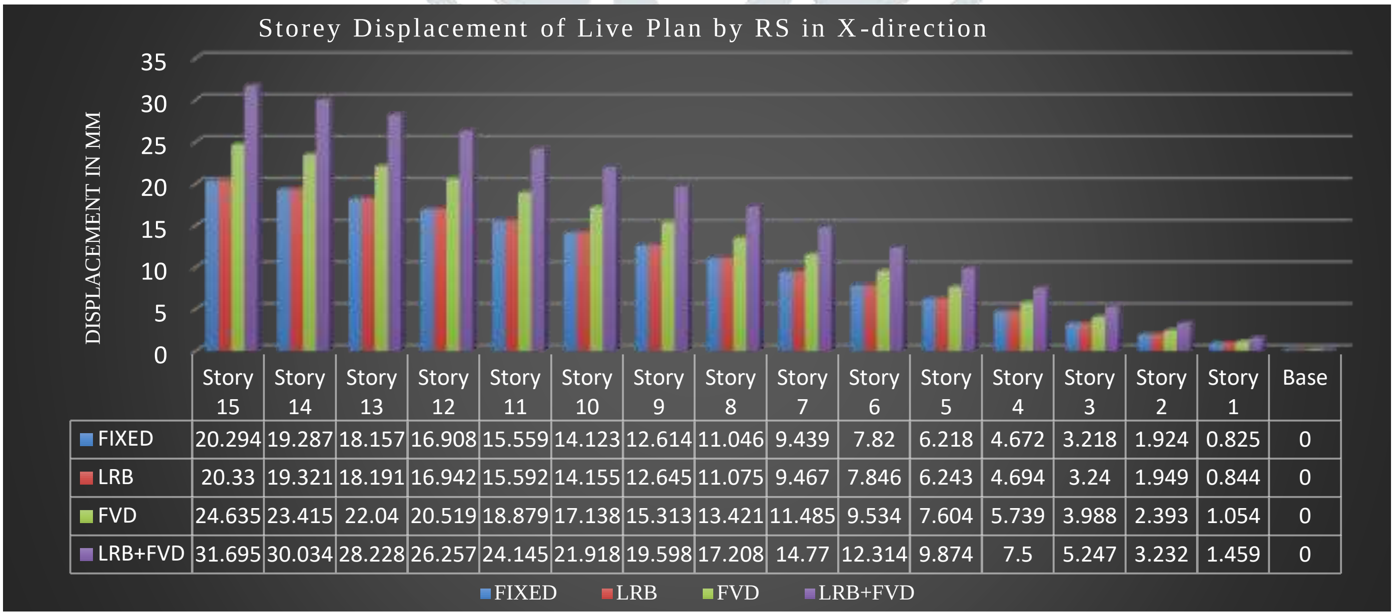
	Story 15	Story 14	Story 13	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1	Base
FIXED	176.9	169.2	159.9	148.8	136.1	121.9	106.6	91.54	76.69	63.9	52.96	41.49	29.83	18.49	8.441	0
LRB	196.7	183.8	169.6	153.4	135.8	117.4	100.5	89.87	82.55	72.8	60.84	47.31	33.26	19.77	8.422	0
FVD	245.6	221.5	193	163	134.2	121.8	115.2	107.7	98.63	87.72	74.69	59.98	45.8	29.72	13.73	0
LRB+FVD	245.5	221.4	192.9	163	134.3	121.8	115.2	107.6	98.52	87.62	74.6	59.91	45.69	29.76	13.75	0

Figure 20 – Bar Chart 11 Storey Displacement of Normal Plan by TH Chamoli in X-direction



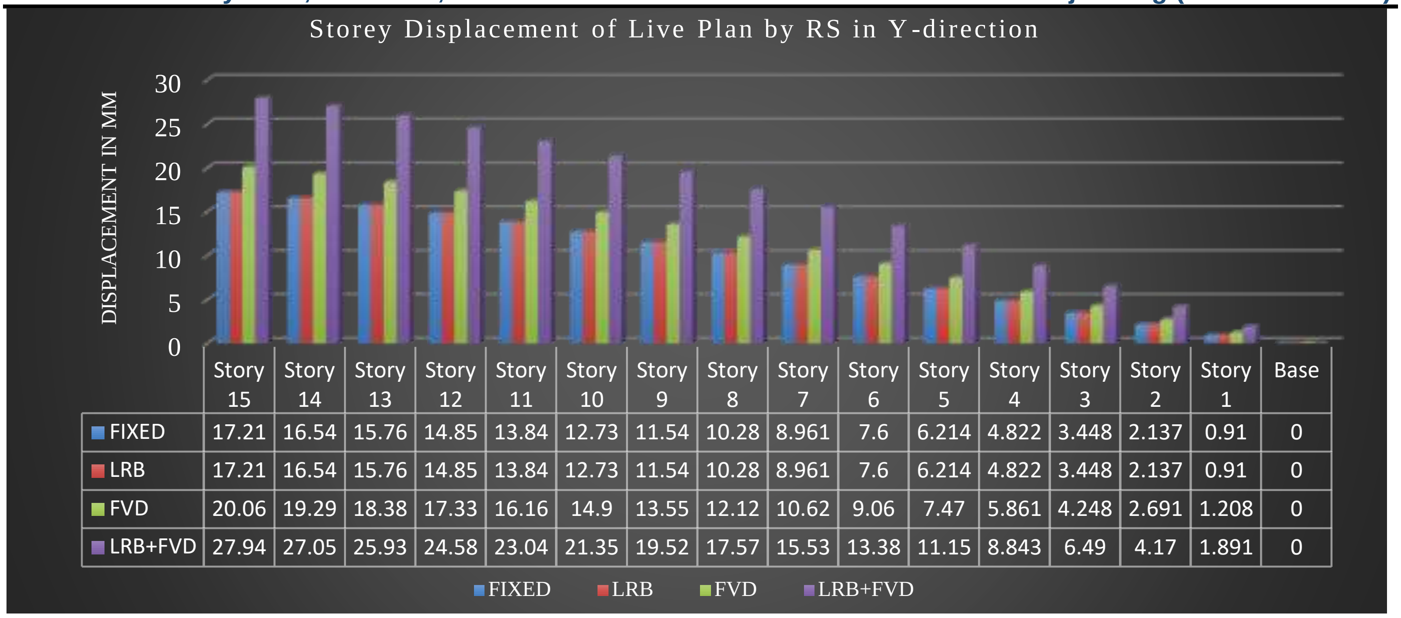
	Story 15	Story 14	Story 13	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1	Base
FIXED	188.4	177.6	164.7	150.3	134.3	117	100	83.83	70.6	62.19	52.31	41.35	30	18.93	8.789	0
LRB	201.9	188.3	172.1	153.9	133.7	113.7	98.5	91.67	84.33	74.89	62.62	48.95	34.8	20.99	9.073	0
FVD	251.6	225.3	196.1	164.7	134.3	124.7	118.6	111.9	102.9	92.31	79.87	64.91	49.18	34.04	16.65	0
LRB+FVD	251.9	226.3	195.5	163	134.6	124.5	118.4	111.8	102.8	92.31	79.82	64.85	47.91	32.69	15.89	0

Figure 21 – Bar Chart 12 Storey Displacement of Normal Plan by TH Chamoli in Y-direction



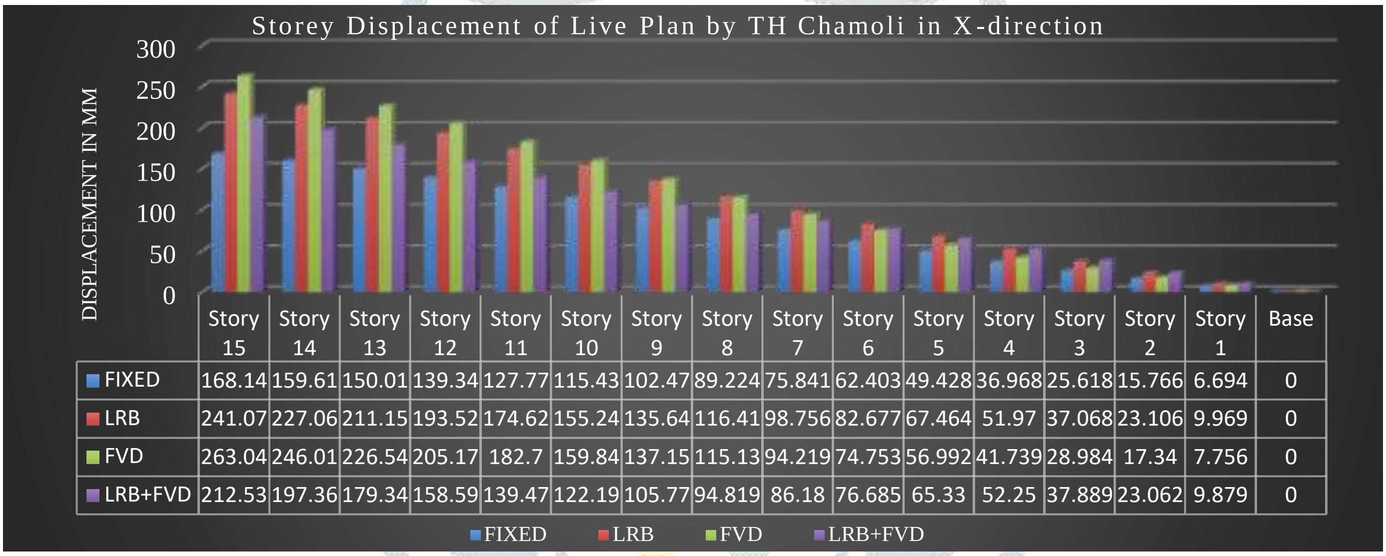
	Story 15	Story 14	Story 13	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1	Base
FIXED	20.294	19.287	18.157	16.908	15.559	14.123	12.614	11.046	9.439	7.82	6.218	4.672	3.218	1.924	0.825	0
LRB	20.33	19.321	18.191	16.942	15.592	14.155	12.645	11.075	9.467	7.846	6.243	4.694	3.24	1.949	0.844	0
FVD	24.635	23.415	22.04	20.519	18.879	17.138	15.313	13.421	11.485	9.534	7.604	5.739	3.988	2.393	1.054	0
LRB+FVD	31.695	30.034	28.228	26.257	24.145	21.918	19.598	17.208	14.77	12.314	9.874	7.5	5.247	3.232	1.459	0

Figure 22 – Bar Chart 13 Storey Displacement of Live Plan by RS in X-direction



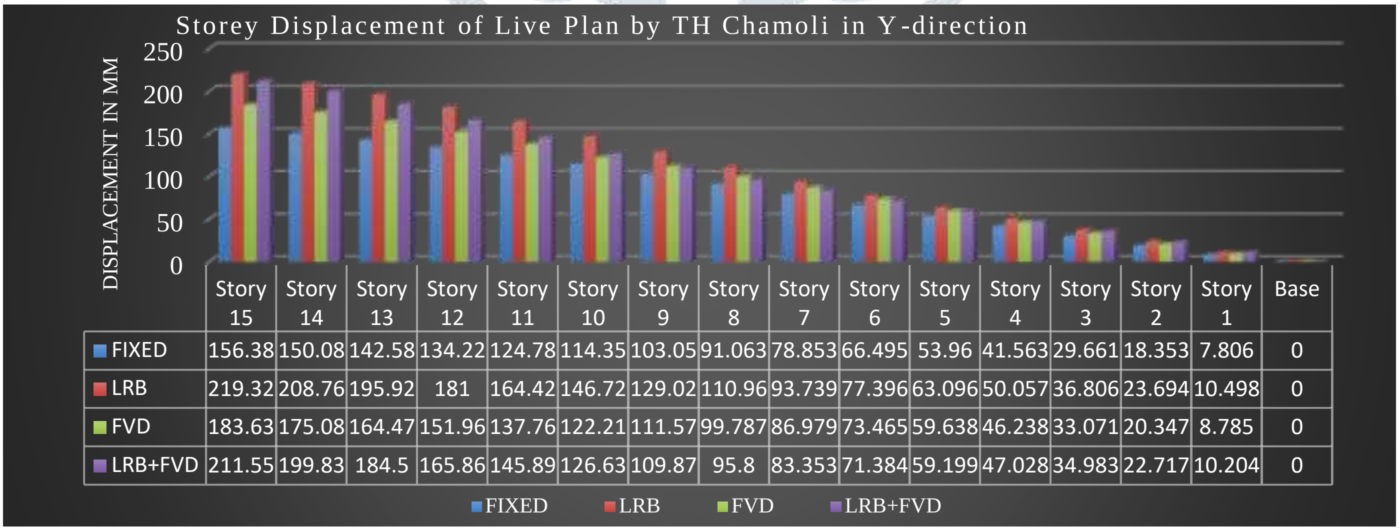
	Story 15	Story 14	Story 13	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1	Base
FIXED	17.21	16.54	15.76	14.85	13.84	12.73	11.54	10.28	8.961	7.6	6.214	4.822	3.448	2.137	0.91	0
LRB	17.21	16.54	15.76	14.85	13.84	12.73	11.54	10.28	8.961	7.6	6.214	4.822	3.448	2.137	0.91	0
FVD	20.06	19.29	18.38	17.33	16.16	14.9	13.55	12.12	10.62	9.06	7.47	5.861	4.248	2.691	1.208	0
LRB+FVD	27.94	27.05	25.93	24.58	23.04	21.35	19.52	17.57	15.53	13.38	11.15	8.843	6.49	4.17	1.891	0

Figure 23 – Bar Chart 14 Storey Displacement of Live Plan by RS in Y-direction



	Story 15	Story 14	Story 13	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1	Base
FIXED	168.14	159.61	150.01	139.34	127.77	115.43	102.47	89.224	75.841	62.403	49.428	36.968	25.618	15.766	6.694	0
LRB	241.07	227.06	211.15	193.52	174.62	155.24	135.64	116.41	98.756	82.677	67.464	51.97	37.068	23.106	9.969	0
FVD	263.04	246.01	226.54	205.17	182.7	159.84	137.15	115.13	94.219	74.753	56.992	41.739	28.984	17.34	7.756	0
LRB+FVD	212.53	197.36	179.34	158.59	139.47	122.19	105.77	94.819	86.18	76.685	65.33	52.25	37.889	23.062	9.879	0

Figure 24 – Bar Chart 15 Storey Displacement of Live Plan by TH Chamoli in X-direction



	Story 15	Story 14	Story 13	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1	Base
FIXED	156.38	150.08	142.58	134.22	124.78	114.35	103.05	91.063	78.853	66.495	53.96	41.563	29.661	18.353	7.806	0
LRB	219.32	208.76	195.92	181	164.42	146.72	129.02	110.96	93.739	77.396	63.096	50.057	36.806	23.694	10.498	0
FVD	183.63	175.08	164.47	151.96	137.76	122.21	111.57	99.787	86.979	73.465	59.638	46.238	33.071	20.347	8.785	0
LRB+FVD	211.55	199.83	184.5	165.86	145.89	126.63	109.87	95.8	83.353	71.384	59.199	47.028	34.983	22.717	10.204	0

Figure 25 – Bar Chart 16 Storey Displacement of Live Plan by TH Chamoli in Y-direction

VIII. CONCLUSION

LRB & FVD together increases the time period enormously. LRB slightly increases the time period and provides flexibility to structure. LRB slightly increases the displacement at base of structure which increases the time period by 22-0%. FVD causes damping which results in increase in time period by 40-38%. Commingle LRB & FVD extends the time period by 32-65%.

LRB divides the superstructure from base. Hence very less forces are transmitted to the building as a result base shear slightly decreases by 29.5-0%. But in case of plan with Shear wall it does not shows effect. In FVD it increases the base shear due to induced load of damper on each floor by 62.7-30%. Commingle LRB & FVD enlarges base shear by 62.3-120% with respect to LRB structure.

LRB gives flexibility to the base by either decreasing displacement or slightly increasing the displacement by 29-0%. FVD dampers increases the displacement and provides a flexible displacement to the structure as it provides damping in the structure 93-21%. LRB isolator with FVD increases displacement by 100-51% as collate to fixed base/LRB. Hence it provides better control/more flexibility on movement during earthquake. Similarly, for drift as it is the ratio of two consecutive displacements. Storey drift is less for LRB as compared to FVD.

As LRB separates the superstructure from the base. Hence it decreases the storey forces in normal plan by 48.5-0%, but in case of live plan with shear walls it doesn't gives much impact. FVD increases the storey forces by 38-20%, but provides flexibility to it. The commingle use of LRB & FVD reduces the storey forces by 38-89% than fixed base.

LRB lessens the storey acceleration by 50-0%, FVD lessens the storey acceleration by 60-12% individually. But Storey acceleration is majorly lessen by the acceleration from the commingle use of LRB & FVD by 55-22%.

It has been noticed that LRB effect is minimal in shear walls in live plan.

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