

EARTHQUAKE RESPONSE OF REINFORCED CONCRETE MULTI STOREY BUILDING WITH BASE ISOLATION

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Abstract

A seismic base isolation is an earthquake resistant design method that is based on reducing the seismic demand and also the ductility demand. The basic concept of base isolation system is to increase the natural time period of the fixed base building and to protect the structure from the seismic effect. The main purpose of this work is to study the dynamic response of structure when subjected to different isolators. For this purpose, a three dimensional response spectrum analysis and time history analysis is performed using a commercial structural analysis software package called as SAP 2000 to study the influence of isolation damping on building. The main objective is to make a comparison between the fixed base building and various isolation systems such as friction pendulum isolator, lead rubber bearing (LRB) isolator and high damping rubber isolator, subjected to strong earthquakes to achieve an optimal design of the base isolation system. SAP 2000, a popular large scale explicit finite element analysis software used to stimulate the behavior of base isolated structure. In the present work, it was found that base isolation substantially increases the time period of structure and hence correspondingly reduces the base shear. The top displacement for fixed and isolated cases conspicuously shows the reduction in the case of isolated frame. The study shows that the bending moment and shear force values are reduced for base isolated frame when compared to fixed base building. From design consideration the steel requirement is reduced in base isolated structures when compared to fixed base building.

Key Words: Isolators, SAP2000

1. INTRODUCTION

The previous Earthquake data provides enough evidence for behavior of different types of structures under different seismic conditions and foundation aspects has become stuff for Engineers and Scientists. This has given various types of innovative techniques to save structures from seismic effects. Among those, Base Isolation is one of the recent technique. The main aim of base isolation is to provide flexibility and dissipation of energy by incorporating the isolated devices so called isolators, which is provided between the foundation and the super structure. Thus, base isolation essentially dissociates the building from the ground during seismic excitation. The use of flexible layer by base isolation systems at the base of the structure will allow relative displacements between the foundation and the superstructure. Addition of isolation layer elongates the fundamental time period of the structure so as to move away from the ascendant time periods of motion of ground, it means that decreasing the acceleration induced in the structure.

1.1 Basic Concept of Base Isolation

The basic concept of base isolation is to protect the structure from the damage caused due to seismic forces by establishing a support isolating the building from the ground movement. In simple way, the structure is isolated from its foundations. Due to seismic forces, there will be movement in ground and this ground movement tends to damage the

structure. So, the concept is literal to isolate the structure from the ground. So that we can control the movement of building. By using the Base isolation systems, such as sliding and rubber isolator bearing systems, reduces the response of structure, but there will be increase in base displacements in near-fault motions.

To limit the bearing displacement nonlinear passive dampers are provided; however, this enhances the forces in the superstructure. The base isolation concept is explained by an example of building resting on frictionless roller. When the ground moves, the rollers freely roll, but the superstructure will not move. Because of this no force is transmitted to the superstructure due to the movement of the ground; literally, the superstructure does not experience the seismic forces. Now, if the same structure is rested on adjustable pads which is having resistance against lateral movements, then some effect of the ground movement will be transferred to the above building. If the adjustable pads are properly chosen, the forces induced by the ground movement will be a few times lesser than that experienced by the structure built directly on ground, namely a fixed base building. The adjustable pads are called base-isolators.

Therefore, the structures secured by means of these devices are called base-isolated buildings. The important feature of this technic is that it introduces flexibility in the structure. As a result, a medium-rise masonry building or reinforced concrete building becomes extremely flexible. These isolators are also designed to absorb energy by that damping is added to the system. This helps in further decrease the

earthquake response of the building. Many commercial brands of base isolators are widely available, and many of them look like large rubber pads, although there are other types that are based on sliding of one part of the building relative to the other. A peer study is required to select the most suitable type of device for a specific building. Also, base isolation is not acceptable for all buildings. Base isolation are more acceptable for low to medium-rise buildings rested on hard soil. But not for High-rise buildings or buildings rested on soft soil.

1.2 Types Of Isolation Components (Isolators)

a) Lead-Rubber Bearings

A lead-rubber bearing is one of the type of elastomeric bearing. The lead core provides rigidity under service loads and energy dissipation under high lateral loads. The entire bearing is encased in cover rubber to provide environmental protection. When subjected to low lateral loads, the lead rubber bearing is stiff both laterally and vertically. The lateral stiffness results from the high elastic stiffness of the lead plug and the vertical rigidity results from the steel-rubber construction of the bearing

b) High-Damping Natural Rubber Bearings

The high damping rubber bearing is one of the type of elastomeric bearings where the elastomer used (either natural or synthetic rubber) provides a significant amount of damping. This type of bearing consists of thin layers of high damping rubber and steel plates built in alternative layers. Here rubber reinforced with steel plates provides stable support for structures. Using this type of system seismic vibrations is converted to low speed motion. The outcome of this system is after earthquake the building will regain its original position.

c) Friction Pendulum System

Friction pendulum (FP) isolators is one of the special type of sliding isolator, which executes the same principle of simple pendulum. The isolator setup consists of a concave sliding surface and an articulated slider that is coated with a low friction composite material. When the concave spherical bearings are placed at a particular support point, there will be a sway in a structure same like a gentle pendulum motion at the time of shaking of ground. This system is featured as substantial under severe environmental conditions and insensitivity to the frequency content of ground motion.

2. NUMERICAL EXAMPLE

2.1 Structural Models Considered

In this analytical study, three-dimensional RC building considered, incorporated with different base isolation devices under each column which have been investigated. Building considered is as shown in Fig 1, is an actual eight-storey RC building of 21 m × 26.4 m in plan (x and y axes) dimensions and 29.7m in height (z axis). This building is connected with a total number of 50 base isolation devices under each column. For the analysis, structural analysis software SAP version 14.2.0 is used. By using this software,

each floor slab is modeled as a rigid diaphragm, so that each floor is represented by three degrees of freedom: two lateral degrees of freedom in the x and y directions and a rotational degree of freedom about the vertical axis. These degrees of freedoms are located at the center of the floor mass, which is the same at every floor. Here the structural models used are having symmetric floor plans. The analysis is carried out using response spectrum and time history analysis. According to variations in the design parametric characteristics the relative effectiveness of the isolation systems is investigated.

2.2 Dimensions of 3d Frame

Isometric view & Top view of reinforced cement concrete, C-shaped 8 storey frame is as shown in the Fig.1 & Fig.2 respectively.

Storey height= 3.4m is being modeled in SAP-2000.

Sizes of the structural members are as follows:

Beam size1: 230 mm x 350 mm.

Beam size2: 230 mm x 400 mm.

Column size1: 230 mm x 900 mm.

Column size2: 230 mm x 1000 mm.

Roof slab: 125 mm thick.

The beam & column sizes are kept same for both fixed and isolated frame.

Isometric view & Top view of reinforced cement concrete, C-shaped 8 storey frame are as shown in the figures.

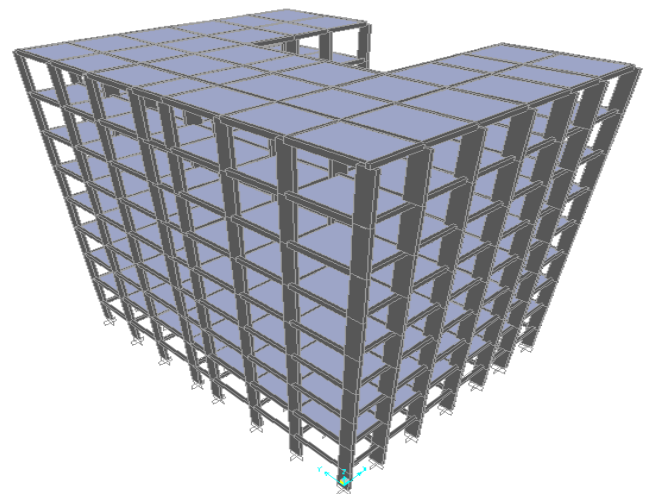


Fig -1: Isometric view of C-shaped frame

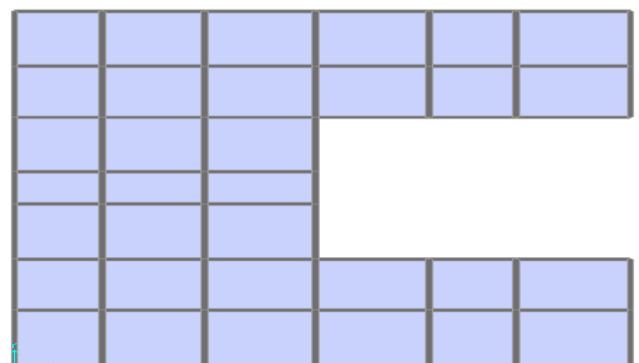


Fig -2: Top view of the C-shaped frame

The modelling of base isolators has been done in SAP using Joint 2 link element type are,

Type I: Friction pendulum isolator frame with all isolators of uniform stiffness.

Type II: Rubber Isolated frame with all isolators of uniform stiffness.

Type III: Friction isolator frame with outer columns of one stiffness and inner columns of another stiffness.

Type IV: High damping rubber Isolated frame with all isolators of uniform stiffness.

The seismic isolators in the system are defined as NL link components 0.5m in length placed between the fixed base and the columns. The parameters selected to define the utilized isolators in the SAP2000 program are as follows:

Table -1: Isolator properties

	Type I	Type II	Type III	Type IV
K ₁	15000000	1500000	15000000,5000000	350.4
K ₂	15000	2500	15000,2000000	9.32
K ₃	15000	2500	15000, 2000000	9.32
KE ₂	750	800	750,150	0.83
KE ₃	750	800	750, 150	0.83
FY ₂	0.03	80	0.03,0.04	-
FY ₃	0.03	80	0.03,0.04	-
RK ₂	0.05	0.1	0.05,0.1	-
RK ₃	0.05	0.1	0.05,0.1	-
A ₂	40	-	40,900	-
A ₃	40	-	40,900	-
R ₂	2.23		2.23,0.0	
R ₃	2.23		2.23,0.0	

Where,

- K₁ spring stiffness along axis 1(Axial)
- K₂ Initial Spring stiffness along axis 2
- K₃ Initial Spring stiffness along axis 3
- KE₂ Spring Effective stiffness along axis 2
- KE₃ Spring Effective stiffness along axis 3
- FY₂ Yield Force along axis 2
- FY₃ Yield Force along axis 3
- RK₂ Post-Yield stiffness ratio along axis 2
- RK₃ Post-Yield stiffness ratio along axis 3
- A₂ Coefficient controlling friction axis 2
- A₃ Coefficient controlling friction axis 3
- R₂ Radius of Contact 2 direction
- R₃ Radius of Contact 3 direction

The joint local 1- 2-3 coordinate system is normally the same as the global X- Y-Z coordinate system.

2.3 Seismic Loading:

For response spectrum analysis, the response spectrum given in IS 1893-2002

Zone V, Z= 0.36

Importance factor I= 1.0

Response reduction factor R= 5.

Soil type: Type II (medium)

$$\text{Time period } T = \frac{0.09 \cdot h}{\sqrt{D}} = \frac{0.09 \cdot 29.7}{\sqrt{21}} = 0.5833 \text{ sec.}$$

Table -2: Total base shear values (KN)

Structural Model	Response Spectrum			Time History		
	Base	Top (Abs.)	Top (Rel.)	Base	Top (abs.)	Top (rel.)
FBB	0	11.7423	11.7423	0	11.7423	11.7423
TYPE I	1.86587	1.86587	0	1.86587	1.86587	0
TYPE II	1.86587	1.86587	0	1.86587	1.86587	0
TYPE III	3.51074	3.51074	0	3.51074	3.51074	0
TYPE IV	1.86586	1.86586	0	1.86586	1.86586	0

Damping in analysis for both fixed base & base isolated structure is taken as 5 % as the default value in IS 1893-2002 response spectrum. Linear isolator is being used so no additional damping will be there due to the damping of isolator.

3. RESULTS OF ANALYSIS CARRIED OUT:

General:

The four structural models under consideration are analyzed in SAP 2000 (Ver. 14.2) for Response Spectrum (IS 1893-2002) & Time History (EL-Centro, NS-Component 1940) and analysis results are given in following tables (Table -2 to Table -20).

Table -3: Fundamental time period in sec.

Structural Model	Response Spectrum		Time History	
	X	Y	X	Y
FBB	5978.962	6410.898	5978.962	6410.898

TYPE I	1191.809	1405.681	560.344	672.842
TYPE II	886.001	1048.611	384.337	409.453
TYPE III	501.617	596.730	143.099	120.089
TYPE IV	731.684	866.277	265.665	269.142

The total base shear is given in Table -2, for both response spectrum & Time History analysis.

Table -4 Base and top displacements (in mm):

Structural Model	Response Spectrum	Time History
FBB	0.29259	0.29267
TYPE I	2.76796	2.76918
TYPE II	2.68007	2.68007
TYPE III	3.30933	3.30933
TYPE IV	2.63119	2.63019

Compares the fundamental time periods which is obtained from modal analysis, for the 4 cases under consideration.

Compares the base & top displacements, obtained from SAP for both response spectrum & Time History analysis. For each case the nodal displacement value which gives maximum top relative and absolute displacement are compared.

Table -5: Bending Moment in Columns (KN-m):

Column Bending Moment Values in KN-m					
COL NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
C1	542.213	2.796	2.827	2.819	2.902
C2	578.173	2.829	2.837	2.85	2.855
C3	696.828	3.714	3.662	3.668	3.527
C4	490.705	2.998	2.979	3.013	2.935
C5	424.125	2.861	2.9	2.896	3.003
C6	541.717	2.697	2.782	2.705	2.892
C7	695.333	3.603	3.585	3.585	3.533
C8	706.416	3.81	3.767	3.78	3.65
C9	712.818	4.004	3.968	3.974	3.856
C10	714.492	3.759	3.713	3.71	3.59

The bending moment values for ground storey columns for response spectrum analysis are given in above Table -5.

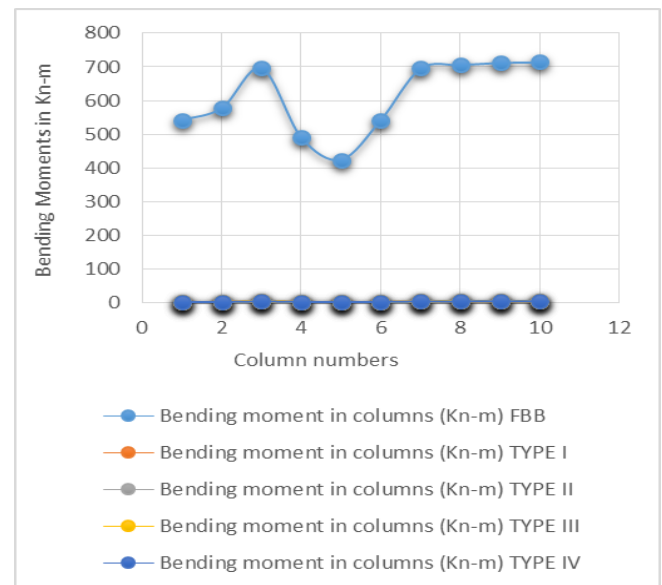


Chart -1: Bending Moment Values of Ground Storey Column

The above chart shows the bending moment values for ground storey columns. From the chart we can see that the bending moment values for base isolated buildings is much lesser than that of the fixed base building. The bending moment values for base isolated buildings are almost having same values.

Table -6: Column B.M Values (KN-m) w.r.t FBB:

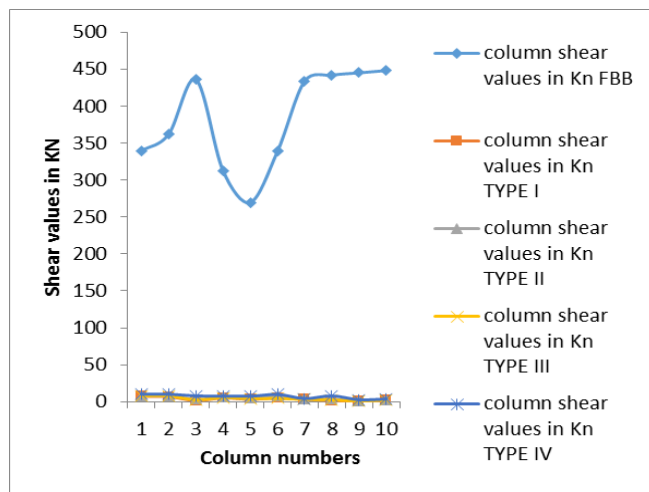
Column Bending Moments (KN-m) Values w.r.t Fixed Base Building				
COL NO	TYPE I	TYPE II	TYPE III	TYPE IV
C1	-539.417	-539.386	-539.394	-539.311
C2	-575.344	-575.336	-575.323	-575.318
C3	-693.114	-693.166	-693.16	-693.301
C4	-487.707	-487.726	-487.692	-487.77
C5	-421.264	-421.225	-421.229	-421.122
C6	-539.02	-538.935	-539.012	-538.825
C7	-691.73	-691.748	-691.748	-691.8
C8	-702.606	-702.649	-702.636	-702.766
C9	-708.814	-708.85	-708.844	-708.962
C10	-710.733	-710.779	-710.782	-710.902

- - ve indicates that bending moment decreases.
- + ve indicates that bending moment Increases

Table -7: Column shear Values (KN):

Column Shear Values In KN					
COL NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
C1	339.373	7.085	8.014	7.949	10.425
C2	361.659	6.992	7.943	7.866	10.376
C3	436.003	1.689	3.253	2.668	7.977
C4	312.612	5.164	5.8	5.64	7.704
C5	269.708	3.334	4.435	4.13	7.53
C6	338.7	4.967	7.281	4.564	9.978
C7	433.895	3.161	3.455	3.226	4.371
C8	441.803	1.684	3.274	2.687	8.013
C9	444.997	1.023	1.369	1.103	2.741
C10	448.054	2.173	2.459	2.238	3.812

Base shear values in columns for response spectrum analysis are given in the above Table -7.

**Chart -2:** Column shear values of ground storey**Table -8:** Column shear Values (KN):

Column Shear Values (KN) w.r.t Fixed Base Building				
COL NO	TYPE I	TYPE II	TYPE III	TYPE IV
C1	-332.288	-331.359	-331.424	-328.948
C2	-354.667	-353.716	-353.793	-351.283
C3	-434.314	-432.75	-433.335	-428.026
C4	-307.448	-306.812	-306.972	-304.908
C5	-266.374	-265.273	-265.578	-262.178
C6	-333.733	-331.419	-334.136	-328.722
C7	-430.734	-430.44	-430.669	-429.524
C8	-440.119	-438.529	-439.116	-433.79
C9	-443.974	-443.628	-443.894	-442.256
C10	-445.881	-445.595	-445.816	-444.242

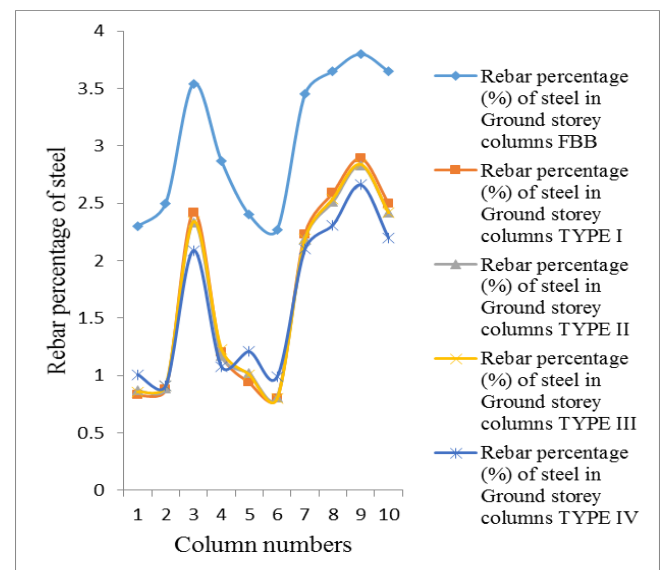
Table -9: Rebar Percentage of Steel in Column

Rebar Percentage (%) Of Steel In Ground Storey Columns					
COL NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
C1	2.3	0.83	0.87	0.86	1.01
C2	2.5	0.88	0.89	0.91	0.91
C3	3.54	2.42	2.33	2.34	2.09
C4	2.87	1.2	1.17	1.23	1.08
C5	2.4	0.94	1.02	1.01	1.21
C6	2.27	0.8	0.81	0.8	0.99
C7	3.45	2.23	2.19	2.19	2.1
C8	3.65	2.59	2.51	2.54	2.31
C9	3.8	2.89	2.83	2.84	2.66
C10	3.65	2.5	2.42	2.42	2.2

Table -10: Rebar Percentage of Steel in Column

Rebar Percentage (%) Of Steel In Columns w.r.t FBB				
COL NO	TYPE I	TYPE II	TYPE III	TYPE IV
C1	-1.47	-1.43	-1.44	-1.29
C2	-1.62	-1.61	-1.59	-1.59
C3	-1.12	-1.21	-1.2	-1.45
C4	-1.67	-1.7	-1.64	-1.79
C5	-1.46	-1.38	-1.39	-1.19
C6	-1.47	-1.46	-1.47	-1.28
C7	-1.22	-1.26	-1.26	-1.35
C8	-1.06	-1.14	-1.11	-1.34
C9	-0.91	-0.97	-0.96	-1.14
C10	-1.15	-1.23	-1.23	-1.45

The above Table -9 gives rebar percentage of steel in column for ground storey columns w.r.t Fixed base building.

**Chart -3:** Rebar Percentage of Steel in Columns.

The above Chart shows the rebar percentage of steel for ground storey columns. From the Chart we can see that the rebar percentage of steel for base isolated buildings is much lesser than that of the fixed base building. The rebar percentage of steel for TYPE I isolator is more, when compared to other isolators.

Table -11: Column Steel in Kg

Column Longitudinal Steel In Kg					
COL NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
C1	99.77	30	31.44	31.08	36.51
C2	108.44	31.81	32.17	32.89	32.89
C3	153.56	87.48	84.22	84.58	75.55
C4	112.05	39.04	38.06	40.01	35.14
C5	93.70	30.58	33.17	32.86	39.37
C6	98.47	28.91	29.28	28.91	35.78
C7	149.65	80.61	79.16	79.16	75.91
C8	158.33	93.62	90.73	91.81	83.5
C9	164.83	104.47	102.3	102.66	96.15
C10	158.33	90.37	87.48	87.48	79.52

The column steel for ground storey columns are compared for all 4 cases in the above Table -11

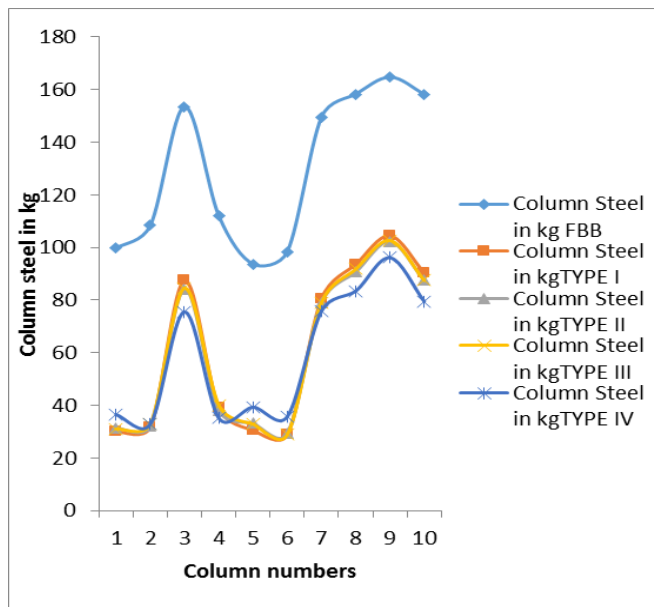


Chart -4: Column Steel Values

The above chart shows the steel values (Kg) for ground storey columns. From the above chart, we can see that the steel values for base isolated buildings is much lesser than that of the fixed base building. The steel values for TYPE I isolator is more, when compared to other isolators.

Table -12: Column Steel in Kg w.r.t FBB

Column Longitudinal Steel In Kg w.r.t FBB				
COL NO	TYPE I	TYPE II	TYPE III	TYPE IV
C1	-69.77	-68.33	-68.69	-63.26
C2	-76.63	-76.27	-75.55	-75.55
C3	-66.08	-69.34	-68.98	-78.01
C4	-73.01	-73.99	-72.04	-76.91
C5	-63.12	-60.53	-60.84	-54.33
C6	-69.56	-69.19	-69.56	-62.69
C7	-69.04	-70.49	-70.49	-73.74
C8	-64.71	-67.6	-66.52	-74.83
C9	-60.36	-62.53	-62.17	-68.68
C10	-67.96	-70.85	-70.85	-78.81

The column steel for ground storey columns w.r.t fixed base building is given in Table -12

Table -13: Column Steel In Kg/m³

Column Longitudinal Steel In Kg /M ³					
COL NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
C1	180.745	65.225	68.369	67.583	79.371
C2	196.462	69.155	69.941	71.512	71.512
C3	278.19	190.175	183.103	183.889	164.242
C4	225.542	94.302	91.948	96.656	84.887
C5	188.604	73.877	80.141	79.382	95.099
C6	178.388	62.868	63.654	62.868	77.799
C7	271.118	175.244	172.101	172.101	165.028
C8	286.835	203.535	197.248	199.606	181.531
C9	298.622	227.11	222.395	223.181	209.036
C10	286.835	196.462	190.175	190.175	172.887

The column steel for ground storey columns are compared for all 4 cases in the above Table -13

Table -14: Column Steel In Kg/m³ w.r.t FBB

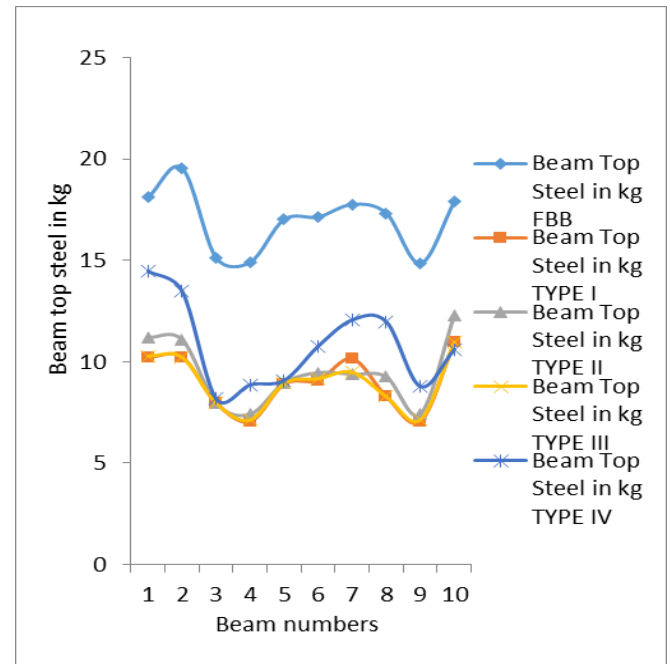
Column Longitudinal Steel In Kg /M ³ w.r.t fixed base building				
COL NO	TYPE I	TYPE II	TYPE III	TYPE IV
C1	-115.52	-112.376	-113.162	-101.374
C2	-127.307	-126.521	-124.95	-124.95
C3	-88.015	-95.087	-94.301	-113.948
C4	-131.24	-133.594	-128.886	-140.655
C5	-114.727	-108.463	-109.222	-93.505
C6	-115.52	-114.734	-115.52	-100.589
C7	-95.874	-99.017	-99.017	-106.09
C8	-83.3	-89.587	-87.229	-105.304
C9	-71.512	-76.227	-75.441	-89.586
C10	-90.373	-96.66	-96.66	-113.948

The above Table-14 gives the column steel for ground storey columns w.r.t fixed base building.

Table -15: Beam Top Steel in Kg

Beam Top Steel In Kg					
BEAM NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
B1	18.103	10.226	11.209	10.288	14.468
B2	19.551	10.236	11.091	10.223	13.488
B3	15.128	7.969	7.969	7.968	8.179
B4	14.906	7.052	7.414	7.128	8.868
B5	17.026	8.908	8.969	8.938	9.081
B6	17.144	9.089	9.466	9.169	10.771
B7	17.764	10.159	9.386	9.486	12.068
B8	17.327	8.291	9.259	8.281	11.978
B9	14.85	7.061	7.423	7.142	8.786
B10	17.899	10.948	12.296	10.968	10.612

The beam top steel for ground storey beams are compared for all 4 cases in the above Table -15

**Chart -5:** Beam Top Steel Values.

The chart shows the beam top steel. From the chart, we can see that the beam top steel for base isolated building is reduced when compared to fixed base building. The steel values for TYPE IV isolator is more, when compared to other isolators.

Table -16: Beam Top Steel in Kg

Beam Top Steel In Kg w.r.t fixed base building				
BEAM NO.	TYPE I	TYPE II	TYPE III	TYPE IV
B1	-7.877	-6.894	-7.815	-3.635
B2	-9.315	-8.46	-9.328	-6.063
B3	-7.159	-7.159	-7.16	-6.949
B4	-7.854	-7.492	-7.778	-6.038
B5	-8.118	-8.057	-8.088	-7.945
B6	-8.055	-7.678	-7.975	-6.373
B7	-7.605	-8.378	-8.278	-5.696
B8	-9.036	-8.068	-9.046	-5.349
B9	-7.789	-7.427	-7.708	-6.064
B10	-6.951	-5.603	-6.931	-7.287

Table -17: Beam top Steel in Kg/m³

Beam Top Steel In Kg/M ³					
BEAM NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
B1	47.992	27.112	29.713	27.269	38.361
B2	51.831	27.139	29.402	27.092	35.784
B3	43.272	22.798	22.798	22.789	23.386
B4	52.903	24.982	26.321	25.312	31.483
B5	55.66	29.121	29.329	29.213	29.691
B6	56.046	29.712	30.958	29.956	35.182
B7	56.583	32.358	29.895	30.218	38.424
B8	49.563	23.723	26.481	23.668	34.267
B9	52.707	25.103	26.329	25.331	31.236
B10	47.452	29.024	32.596	29.074	28.139

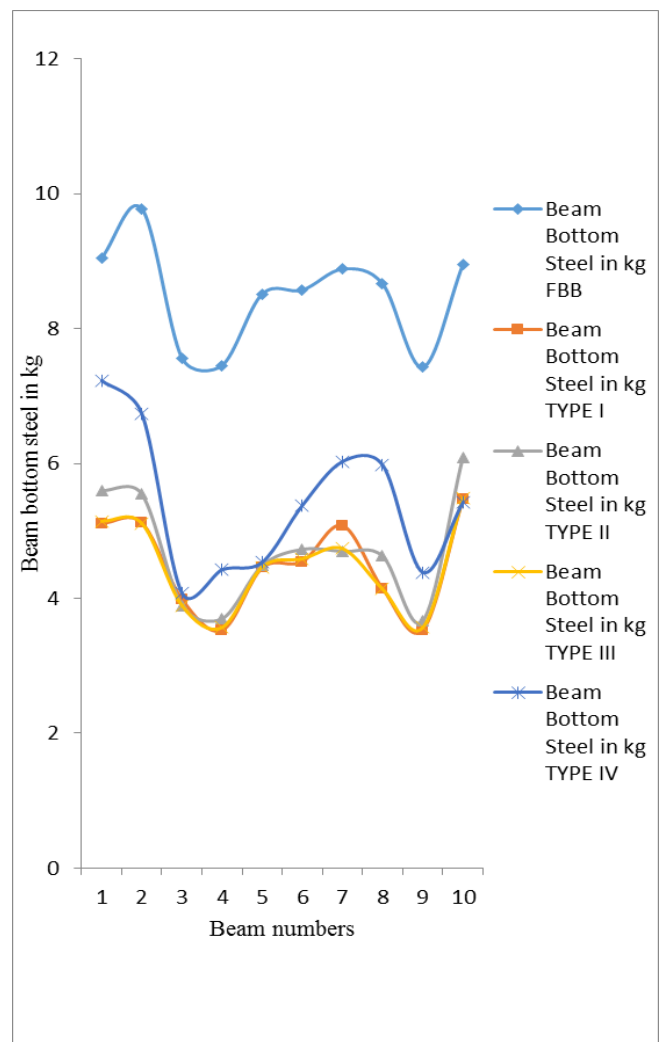
Table -18: Beam top Steel In Kg/m³ w.r.t FBB

Beam Top Steel In Kg/M ³ w.r.t FBB				
BEAM NO	TYPE I	TYPE II	TYPE III	TYPE IV
B1	-20.88	-18.279	-20.723	-9.631
B2	-24.692	-22.429	-24.739	-16.047
B3	-20.474	-20.474	-20.483	-19.886
B4	-27.921	-26.582	-27.591	-21.42
B5	-26.539	-26.331	-26.447	-25.969
B6	-26.334	-25.088	-26.09	-20.864
B7	-24.225	-26.688	-26.365	-18.159
B8	-25.84	-23.082	-25.895	-15.296
B9	-27.604	-26.378	-27.376	-21.471
B10	-18.428	-14.856	-18.378	-19.313

Table -19: Beam Bottom Steel in Kg

Beam Bottom Steel In Kg					
BEAM NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
B1	9.051	5.113	5.598	5.146	7.251
B2	9.775	5.118	5.545	5.112	6.736
B3	7.564	3.985	3.895	3.894	4.078
B4	7.453	3.526	3.698	3.568	4.425
B5	8.513	4.454	4.485	4.465	4.536
B6	8.572	4.544	4.726	4.586	5.378
B7	8.882	5.08	4.694	4.738	6.028
B8	8.664	4.145	4.627	4.137	5.978
B9	7.425	3.531	3.665	3.566	4.386
B10	8.95	5.474	6.091	5.487	5.421

The beam bottom steel for ground storey beams are taken from SAP analysis results for each case are compared for all 4 cases in the above Table 19

**Chart -6:** Beam Bottom Steel Values

The chart -6 shows the beam bottom steel. From the chart we can see that the beam bottom steel for base isolated building is reduced when compared to fixed base building. The steel values for TYPE IV isolator is more, when compared to other isolators.

Table -20: Beam Bottom Steel in Kg

Beam Bottom Steel In Kg w.r.t FBB				
BEAM NO	TYPE I	TYPE II	TYPE III	TYPE IV
B1	-3.938	-3.453	-3.905	-1.823
B2	-4.657	-4.23	-4.663	-3.039
B3	-3.579	-3.669	-3.67	-3.486
B4	-3.927	-3.755	-3.885	-3.028
B5	-4.059	-4.028	-4.048	-3.977
B6	-4.028	-3.846	-3.986	-3.194
B7	-3.802	-4.188	-4.144	-2.854
B8	-4.519	-4.037	-4.527	-2.686
B9	-3.894	-3.76	-3.859	-3.039
B10	-3.476	-2.859	-3.463	-3.529

Table -21: Beam Bottom Steel in Kg/m³

Beam Bottom Steel In Kg/m ³					
BEAM NO	FBB	TYPE I	TYPE II	TYPE III	TYPE IV
B1	23.996	13.555	14.861	13.642	19.183
B2	25.916	13.568	14.701	13.542	17.886
B3	21.636	11.398	11.397	11.396	11.687
B4	26.452	12.515	13.158	12.652	15.731
B5	27.831	14.561	14.668	14.611	14.843
B6	28.023	14.856	15.478	14.978	17.586
B7	28.291	16.179	14.013	15.112	19.212
B8	24.781	11.857	13.241	11.832	17.129
B9	26.353	12.537	13.169	12.671	15.613
B10	23.726	14.512	16.301	14.532	14.372

3. CONCLUSIONS

The highly functional structures like Bridges, power plants, buildings can be protected from a technology called Base isolation. The main purpose of this work is to study the dynamic response of structure when subjected to different isolators and cost of base isolated structure when subjected to strong seismic forces in order to pursue an optimal design of the system. For the analysis of different isolation systems, three-dimensional RC building, with base isolation devices

under each column have been investigated.

According to the analytical study following conclusions were drawn:

1. The Base isolation substantially increases the time period of the building & hence correspondingly reduces the base shear. As observed in Table -2 & Table -3 the time period is being increased upto 9.4 times & base shear is reduced upto 1/5th of that of fixed one.
2. By considering the bending moment values in Table -5 it is clearly observed that for isolated cases the maximum bending moment is reduced as that of fixed case. So considering bending moment also, the high damping rubber isolated frame is performing better as compared to the other isolator stiffness.
3. The shear force values in Table -7 shows that the ground storey columns are reduced for isolated frame when compared fixed base building.
4. From the analytical results, it is observed that how effective seismic isolation works by considering various aspects such as: base shear, maximum bending moments, & column shears, etc. Analysis results of the study suggest that high damping rubber isolators are better option as compared to other isolators.

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