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Seismic Analysis of Confined Masonry Building and RCC Building.

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Abstract - *There are several damage report because of the unreinforced structures. Further, there is need to develop another option for regular RCC frame structure such as confined masonry structures. In this paper I want to discuss about seismic analysis of confined masonry building. This will help to compare equivalent RCC frame to confined building. For this purpose software like ETABS is used as well as manual calculation has been done. These building types are compared based on base shear, storey drift, lateral displacement etc.*

Key Words: confined masonry building (CM), Seismic analysis, base shear, RCC frame, response spectrum method, static loading method.

1. INTRODUCTION

1.1. Confined Masonry Building:

CM is nothing but masonry confined with columns and beams. Reinforced frame plays an important role in this type of buildings. It confines the masonry and hence increase the ductility of the structure. Walls are used as a form work for placing reinforced frame. Walls are confined by tie beam and tie column frame while wall intersections are jointed with RC column by providing toothing to the walls. It engages wall and column in each other.

CM buildings are the combination of unreinforced and RC frame. walls of CM building carries seismic load and RC members confines wall. This behaviour of building is exactly opposite to RCC building. CM building uses commonly known materials and its process of construction is simple one. This type of building is not practiced in India. It can be used upto four storey buildings. In this structure vertical members are called as tie column whereas horizontal member are called as tie beam. This paper deals with study of seismic analysis of CM building. IIT Gandhinagar and IIT Kanpur did study on these buildings and tries to make them famous in India.

1.2. IS Code Used

For calculating lateral load acting on the structure and base shear IS1993:2002 (part 1) is used. It is standard code for designing earthquake resisting structure. It gives all required provision for earthquake resisting structure. IS 4326:1993 is the code for earthquake resistant design and construction of building used for designing CM building.

1.3. How Does Confined Masonry Building Works?

Confined masonry act exactly opposite to RCC frame. RC frame and confined wall are constructed in such a way that they act together. Whole structure is the combination of shear panel, which is subjected to shear forces during seismic action. In construction process first step is to construct wall with the tooting at the ends. Wall is constructed in part of about 1-1.5m in height. Then after tie column and tie beams are constructed. Wall used as formwork for placing RC members. Steel used in tie column and beam is less than the regular RC member. Therefore is simply less than in an earthquake resistant seismic frame. The amount of concrete and bricks is similar in both cases i.e. in CM and RCC building.

1.4. Similar Building technologies in use:

1.4.1. Reinforced masonry

In this type reinforcement is provided to increase strength and ductility of masonry walls. Usually hollow bricks made up of clay or concrete are used. Vertical bars are placed in hallow holes of bricks. These holes are then filled with the grout and it protect it from corrosion.

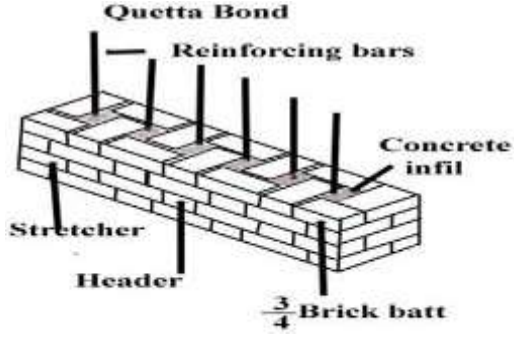

Fig. 1- Reinforced masonry wall

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1.4.2. RC frames having masonry infill walls:

Both finished CM and RCC buildings looks alike. However both techniques are differ from each other in many points. Main difference is its construction process and another one is how they carries gravity and seismic load. In RC frame load is carried by column and beam system where in CM load is carried by masonry walls.

Fig. 2- RC frames with masonry infill walls

1.5. Components of CM buildings [11] :

1. RC floor and roof slabs – transfer gravity and lateral loads to the walls.
2. Confined masonry walls – transfer lateral and gravity loads from floor and roof slabs down to the foundations. The masonry walls are enclosed on all sides by horizontal and vertical RC confining elements, known as tie-beams and tie-columns. These RC elements provide confinement to the masonry walls and protect them from collapse in major earthquakes. Sequence of first making the masonry walls and then pouring in-situ the RC vertical elements and horizontal bands. This choice of construction sequence is responsible for enhancing the integrity of the masonry units and mortar in Confined Masonry.

- Type of bond used in masonry: Use of a regular grid of walls in both directions with RC vertical members at all wall junctions and in straight walls of longer lengths are necessary. These items together confine the wall segments and prevent them from dilating along the length direction of the wall and from falling out-of-plane along the thickness direction of the wall. As the regular grid pattern is required use Flemish bond. Do not use English bond. Provide 10 mm mortar joint between masonry courses.

3. RC plinth band – transfers the loads from walls to the foundation system and reduces differential settlement.
4. Foundation – transfers the load to underlying soil. RC confining elements are critical for the earthquake safety of a confined masonry building. These elements are effective in enhancing the stability, integrity and ductility of masonry walls subjected to in-plane and out-of-plane seismic excitation. They are expected to lead to enhanced seismic performance of confined masonry buildings compared to unreinforced masonry construction.
5. RC tie-columns: columns are then casted. The entire panel height is usually constructed in two 1.2 to 1.5 m high lifts.
6. RC tie-beams: are constructed atop the walls once the wall construction is completed up to the total storey soffit level.

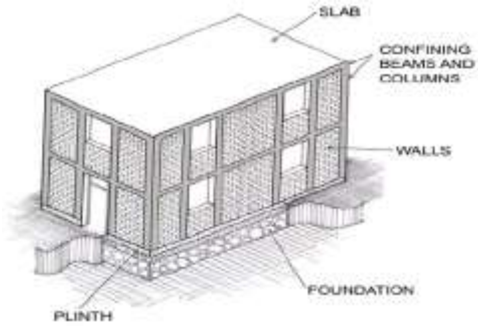

Fig. 3- confined masonry building [10]

1.6. Comparison of RC frame construction and confined masonry:

Table -1: Comparison of RC frame construction and confined masonry [7]

Parameter	Confined masonry construction	RC frame construction
Gravity and lateral load resisting system	Masonry walls are the main elements to resist gravity and lateral loads.	RC frames resist lateral load and gravity and lateral loads with larger beams, columns, and their connections. Masonry infills are not load-bearing walls.
Foundation constructio n	Strip footing below the wall and the RC plinth band	Isolated footing below each column
Superstruct ure constructio n sequence	1. First masonry walls are constructed. 2. Parallel, tie-columns are cast in place. 3. Finally, tie-beams are constructed on top of the walls, in parallel to floor/roof slab construction.	1. First construction of frame is carried out. 2. Masonry walls are constructed at a later stage and are not bonded to the frame members; these are non-structural, that is, non-load bearing walls.

1.7. Advantages:

1. Due to confinement disintegration of structure get prevented.
2. It improve out of plane stability.
3. It improve in plane deformability.
4. It help to increase ductility of structure.
5. It required less amount of steel as compare to normal RCC frame.

1.8. Disadvantage

1. It required high construction cost.
2. This technique required demolition of wall.
3. Architectural appearance of these building is not good as other.

2. METHODS OF SEISMIC ANALYSIS

Confined masonry building is a masonry building hence its analysis is done as per masonry building seismic analysis. For these purpose book by pankaj Agrawal on earthquake resisting design of structure is used for reference. For shear force calculation IS1993:2002 is used. There are several methods for analysing structure.

Analysis process is divided on the basis of external action, behaviour of structure, and type of model. On the basis of external action it divided into two method called static analysis and second is dynamic analysis. On the basis of behaviour there are two types, one is elastic analysis and second one is elastic plastic analysis. Model of building are of type 1D, 2D, 3D. These analysis can be carried out with different methods.

Linier static analysis can be carried out for regular structure of limited height. Linear dynamic analysis can be carried out either with the help of response spectrum method or elastic time history analysis. Nonlinear static analysis is an improvement over static analysis. This can be carried out with the help of pushover analysis and nonlinear time history analysis.

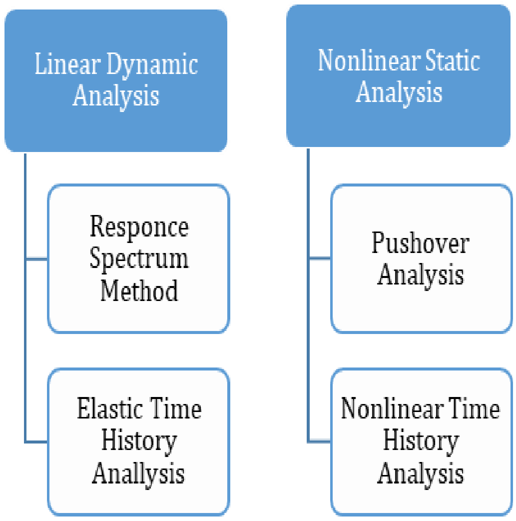

Chart 1- Methods of seismic analysis

3. METHODOLOGY

3.1. Base Shear Calculations as per IS 1993:2002 (part1):[4]

Lateral load calculation and design base shear can be found with the help of following equation described in IS1993:2002 (part 1).

3.1.1. Design seismic base shear:

$$V_d = A_h \times W$$

Where,
Ah = Design horizontal acceleration spectrum value as per clause 6.4.2 using the fundamental natural period *Ta* as per clause 7.6 in the considered direction of vibration.
W= Seismic weight of the building as per clause 7.4.2.

3.1.2. Fundamental Natural Time Period (T_a)

The approximate time or period of vibration (T_a), in seconds for mrf building without brick infill panel is given by

$$T_a = 0.075\, h^{0.75} \text{-RC frame}$$

$$T_a = 0.085 h^{0.75} \text{-Steel frame}$$

The approximate time or period of vibration (T_a), in seconds for mrf building with brick infill panel is given by

$$T_a = \frac{0.09\, h}{\sqrt{d}}$$

Where, h = Total height of a building.
d = base dimension of the building at the plinth level in m, along the considered direction of the lateral force.

3.1.3. The design horizontal seismic coefficient (A_h):

Ah for a structure shall be determined by the following expression:

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{Sa}{g}$$

Where, For any structure with $T \leq 0.1$ is the value of Ah will not be taken less than Z/2 whatever be the value of I/R

Where,

Z = Zone factor, is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. – (Table 2 of IS 1893:2002)

I = Importance factor, depending upon the functional use of the structures,

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. – (Table 7 of IS 1893:2002)

Note: the ratio (I/R) shall not be greater than 1.0.

Sa/g = Average response acceleration coefficient.

4. PROBLEM STATEMENT

Reinforced Concrete Frame of G+3 building, with plan size 19 m x 14 m, with heights of 12 m above plinth level respectively are modelled and analysed by manual calculation and by using software ETABS. Both RCC and CM buildings are analysed and comparing both of them results should made.

4.1. Designed Information about Statement.

4.1.1. RCC Building Plan

Table -2: Data of RCC frame

Sr. no.	Description	Information
1	Plan size	19 m x 14 m
2	Building height above plinth level	12 m
3	Number of storeys above ground	4
4	Number of basements below ground	0
5	Type of structure	RCC Frame
6	Type of building	Regular frame without open ground storey
7	Open ground storey	No
8	Grade of concrete	M25, fck= 25 MPa, Density = 25 kN/m3
9	Steel used	Fe415
10	Software used	ETABS
11	Soil type	Type II (medium soil)
12	Seismic zone	Severe, zone IV
13	Zone factor	0.24
14	Damping	5%
15	Support Conditions	Fixed
16	Importance Factor, I	1
17	Response Reduction Factor, R	5 (SMRF)
18	Brick Density	20 kN/m^3
19	Size of column	500 mm x 300 mm
20	Size of beam	400 mm x 300 mm
21	Thickness of slab	160 mm
22	Floor to floor height	3 m
23	Plinth level height above ground level	1 m
24	Imposed load	1.5 KN/m^2
25	Wall thickness	250 mm

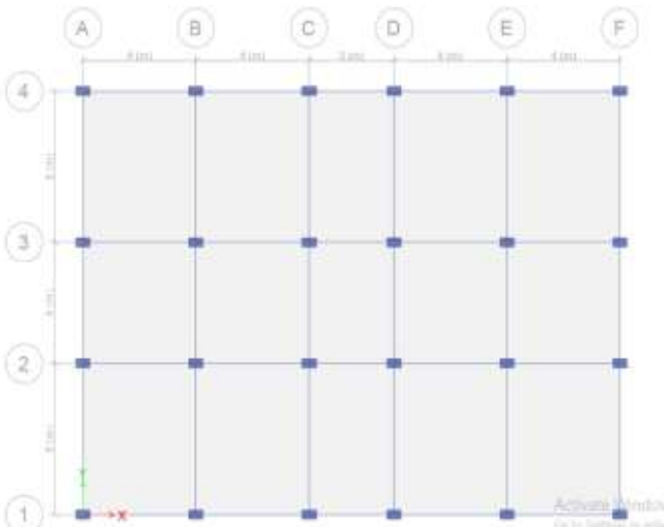

Fig. 4- Plan of RCC Building

4.1.2. Confined Masonry Building:

Table -3: Data of CM building

Sr. no.	Description	Information
1	Plan size	19 m x 14 m
2	Building height above plinth level	12 m
3	Number of storeys above ground	4

4	Number of basements below ground	0
5	Type of structure	Confined masonry building
6	Type of building	confined frame without open ground storey
7	Open ground storey	No
8	Grade of concrete	M25, fck= 25 MPa, Density = 25 kN/m3
9	Steel used	Fe415
10	Software used	ETABS
11	Soil type	Type II (medium soil)
12	Seismic zone	Severe, zone IV
13	Zone factore	0.24
14	Damping	5%
15	Support Conditions	Fixed
16	Importance Factor, I	1
17	Response Reduction Factor, R	3
18	Brick Density	20 kN/m^3
19	Size of column	250 mm x 250 mm
20	Size of column near wc and bath	250 mm x 150 mm
21	Size of tie column	250 mm x 115 mm
22	Size of tie beam @ sill level	250 mm x 100 mm
23	Size of tie beam @ lintle level	250 mm x 150 mm
24	Size of beam	400 mm x 300 mm
25	Thickness of slab	160 mm
26	Floor to floor height	3 m
27	Plinth level height above ground level	1 m
28	Imposed load	1.5 KN/m^2
29	Wall thickness (with plaster)	250 mm

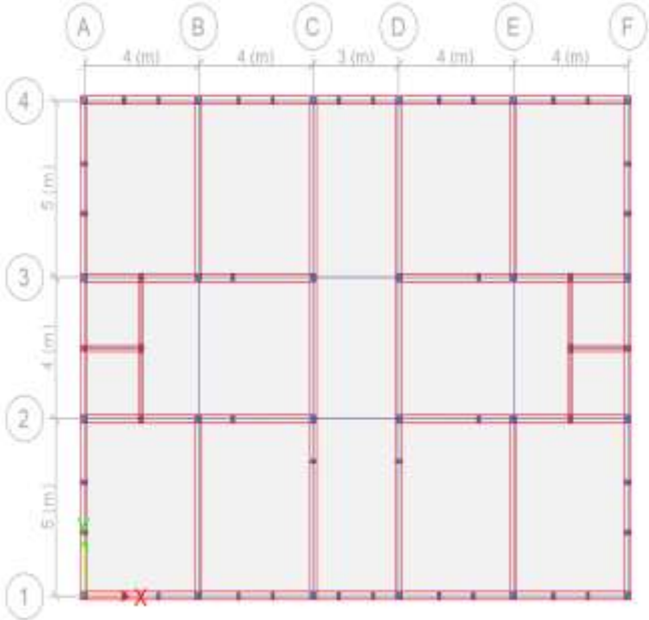

Fig. 5- confined masonry building

4.2. Static Method for Confined Masonry Building:

Table -4: Load calculation for CM building

Storey	Slab	Beam	Column	Wall	L.L.	Total
4	1064	631.3	104.16	1149	-	2948.46
3	1064	631.3	208.31	2298	99.75	4301.36
2	1064	631.3	208.31	2298	99.75	4301.36
1	1064	631.3	208.31	2298	99.75	4301.36
Plinth	-	631.3	104.16	1149	-	1884.46
					Total	17737

4.2.1. Calculation of base shear (V_B):

- Fundamental Natural time Period (T_a) in X and Y direction:

$$T_a = \frac{0.09\,h}{\sqrt{d}}$$

$$T_{ax} = 0.26,\ T_{ay} = 0.312$$

- Horizontal Seismic Coefficient (A_h):

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{Sa}{g}$$

$$A_h = \frac{0.24}{2} \times \frac{1}{3} \times 2.5$$

$$A_h = 0.1$$

- Design Base Shear (V_B):

$$V_d = A_h \times W$$

$$V_d = 0.1 \times 17737$$

$$V_d = 1774\ KN$$

4.2.2. Lateral load calculation along height of the building:

Table 5: Lateral load calculation of CM building

Storey level	Wi (KN)	Hi (m)	$Wihi^2$ x 10^3	$\frac{WiHi^2}{\sum WiHi^2}$	Q_i	Lateral force X	Lateral force Y
4	2948.46	13	498.29	0.411	728.99	728.99	728.99
3	4301.36	10	430.14	0.356	631.43	1359.72	1359.72
2	4301.36	7	210.77	0.175	310.39	1670.11	1670.11
1	4301.36	4	68.82	0.057	101.1	1771.21	1771.21
Plinth level	1884.46	1	1.8846	0.00156	2.8	1774.01	1774.01
		Total	1209.90				

4.3. Static Method for RCC Frame Building:

Table -6: Load calculation for RCC building

Storey	Slab	Beam	Column	Wall	L.L.	Total
4	1064	480	135	1149	-	2828
3	1064	480	270	2298	99.75	4211.75
2	1064	480	270	2298	99.75	4211.75
1	1064	480	270	2298	99.75	4211.75
Plinth	-	480	135	1149	-	1764
					Total	17227.25

4.3.1. Calculation of base shear (V_B):

- Fundamental Natural time Period (T_a) in X and Y direction:

$$T_a = \frac{0.09\,h}{\sqrt{d}}$$

$T_{ax} = 0.26$, $T_{ay} = 0.312$

- Horizontal Seismic Coefficient (A_h):

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{Sa}{g}$$

$$A_h = \frac{0.24}{2} \times \frac{1}{5} \times 2.5$$

$A_h = 0.06$

- Design Base Shear (V_B):

$V_d = A_h \times W$

$V_d = 0.06 \times 17227.25$

$V_d = 1033.635$ KN

4.3.2. Lateral load calculation along height of the building:

Table 7: Lateral load calculation of RCC building

Storey level	Wi (KN)	Hi (m)	$Wihi^2$ x 10^3	$\frac{WiHi^2}{\sum WiHi^2}$	Q_i	Lateral force X	Lateral force Y
4	2828	13	477.93	0.406	419.66	419.66	419.66
3	4211.75	10	421.18	0.358	370.04	789.7	789.7
2	4211.75	7	206.37	0.176	181.92	971.62	971.62
1	4211.75	4	67.39	0.057	58.92	1030.54	1030.54
Plinth level	1764	1	1.764	0.0015	1.55	1032.09	1032.09
		Total	1174.63				

4.4. ETABS software result for base shear along each storey:

Table -8: ETABS software result for base shear

Storey	CM building		RCC building	
	By calculation	Etabs result	By calculation	Etabs result
4	728.99	728.26	419.66	423.85
3	631.43	636.23	370.04	375.55
2	310.39	311.75	181.92	184.02
1	101.1	101.79	58.92	60.089
Plinth	2.8	3.1013	1.55	1.9346

In this study results are made based on the comparison of results based on storey drift, base shear, lateral maximum displacement and manual and software based base shear calculation. From the bellowed table we can say that software gives analytical results with manual calculations. These results are obtained for RCC building and CM buildings.

4.5. ETABS Software Result for Base Shear along each Storey:

Table -9: Comparison of Base Shear

Storey	CM building		RCC building	
	By calculation	Etabs result	By calculation	Etabs result
4	706.47	705.7237	411.15	414.55
3	607.263	611.4304	360.76	364.8728
2	295.93	299.6009	176.35	178.7877

1	97.5	97.8289	57.44	58.3797
Plinth	2.644	2.9162	1.51	1.8649

4.6. Comparison Based on Storey Maximum Displacement

Effect of confinement on storey displacement shows drastic change. Displacement of CM building is less compare to the RCC building in both the cases i.e. static and response spectrum analysis.

Table -10: Comparison of max storey displacement

Storey	RCC Building		CM Building	
	Static Loading	response spectrum	Static Loading	response spectrum
Story4	0.286	0.211	0.001503	0.001922
Story3	0.235	0.179	0.001091	0.001878
Story2	0.164	0.131	0.000739	0.001704
Story1	0.089	0.074	0.000391	0.001568
plinth	0.018	0.015	7.75E-05	0.000932

4.7. Comparison Based on Storey Maximum Drift

Following table shows the comparison of storey drift. Storey drift of a CM building is less than RCC building due confinement of walls of building. Drift of storey get reduction in its value.

Table -11: Comparison of max. Drift

Storey	RCC Building		CM Building	
	Static Loading	response spectrum	Static Loading	response spectrum
Story4	1.70E-05	1.10E-05	1.52E-07	7.27E-08
Story3	2.40E-05	1.60E-05	1.18E-07	8.54E-08
Story2	2.50E-05	1.90E-05	1.18E-07	9.70E-08
Story1	2.40E-05	2.00E-05	1.05E-07	2.13E-07
Plinth	1.80E-05	1.50E-05	7.49E-08	9.91E-08

4.8. Comparison Based on Storey Shear

Storey shear is shown in bellowed table for both buildings who has equivalent design.

Table -12: Comparison of storey shear

Storey	Rcc Building		CM Building	
	Static Loading	Response spectrum	Static Loading	Response spectrum
Story4	-414.55	235.4931	-666.945	31.9495
	-414.55	235.4931	-705.724	381.4795
Story3	-779.4228	525.3659	-1294.21	420.7976
	-779.4228	525.3659	-1317.15	761.1175
Story2	-958.2105	736.9488	-1605.51	790.9151
	-958.2105	736.9488	-1616.75	1121.202
Story1	-1016.5901	859.8946	-1710.91	1139.629
	-1016.5901	859.8946	-1714.58	1457.702
plinth	-1018.455	872.5517	-1717.5	1459.884
	-1018.455	872.5517	-1717.5	1459.884

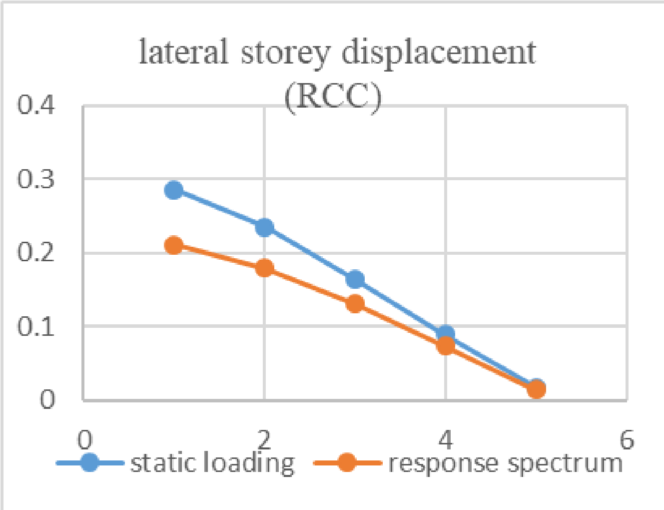

Chart 2- Lateral storey displacement (RCC)

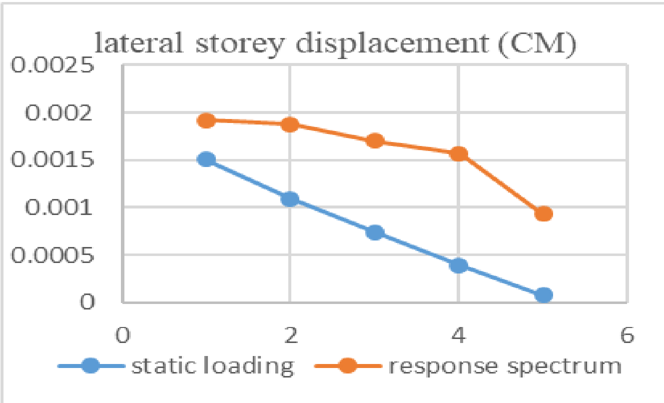

Chart 3- Lateral storey displacement (CM)

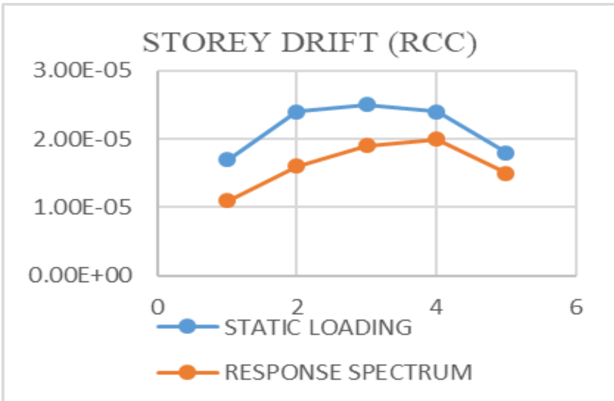

Chart 4 - Lateral storey drift (RCC)

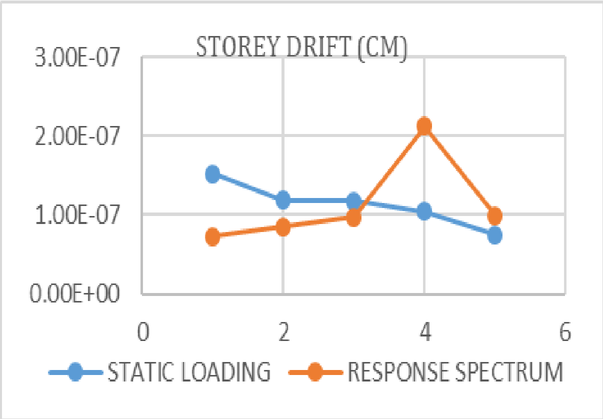

Chart 5- Lateral storey drift (CM)

5. CONCLUSIONS

In India use of RCC buildings are commonly used for construction but there are many other methods that can give comparative strength. For seismic regions there is need to find out another construction method that can help to reduce cost of construction and also give resistant to earthquake. This can be done with CM building. As per IS 1893:2016 confined buildings can be constructed in any type of region. From the above study we can conclude that this buildings gives less max storey displacement compare to RCC building.

There are some advantages as well as disadvantages of these buildings i.e. confinement increases overall strength of structure. Massive column and beam sizes can get reduced. But its not easy to give idea about construction to mason complex creation process compare to RCC buildings. Proper confinement is required.

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