Performance Based Analysis of Multistoried Confined Masonary Building Using ETABS Software

Vikram Thakur[1] Ankit Sethi[2]
[1,2]Department of Civil Engineering
[1,2]WCTM Farukhnagar, Gurugram, Haryana, India

Abstract— There are several damage reports 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.

Keywords: Confined Masonry Building (CM), Seismic Analysis, Base Shear, RCC Frame, Response Spectrum Method, Static Loading Method

I. Introduction

A. 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 behavior 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 is 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.

B. 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.

C. 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.

D. Similar Building technologies in use:

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

2) RC frames having masonry infill walls:

Both finished CM and RCC buildings looks alike. However, both techniques are differing 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

E. Components of CM buildings [11]:

- RC floor and roof slabs – transfer gravity and lateral loads to the walls.
- Confined masonry walls – transfer lateral and gravity load 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.
– RC plinth band – transfers the loads from walls to the foundation system and reduces differential settlement.
– 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.
– RC tie-columns: columns are then casted. The entire panel height is usually constructed in two 1.2 to 1.5 m high lifts.
– RC tie-beams: are constructed atop the walls once the wall construction is completed up to the total storey soffit level.

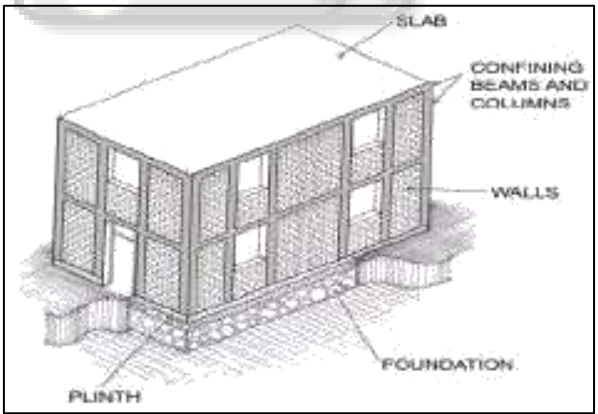

Fig. 3: confined masonry building [10]

F. Comparison of RC frame construction and confined masonry:

	Confined masonry construction	Reinforced masonry frame construction
Superstructure construction sequence	1. Masonry walls are constructed first. 2. Subsequently, tie-columns are cast in place. 3. Finally tie-beams are constructed on top of the walls, simultaneously with the floor/roof slab construction.	1. The frame construction is adopted first. 2. Masonry walls are not load bearing because they cast after the construction of column and beam.
Gravity and lateral load resisting system	Masonry walls are the main load bearing elements and are expected to resist the both gravity and lateral loads. Confining elements are significantly smaller in size than reinforced concrete beam and column,	Reinforced concrete frames resist both gravity and lateral loads through their relatively large beams, columns, and their connections. Masonry infill is non load bearing walls.
Foundation construction	Strip footing beneath the wall and the reinforced concrete plinth band.	Isolated footing beneath each column.

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

G. Advantages:

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

H. 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.

II. 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. This 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.

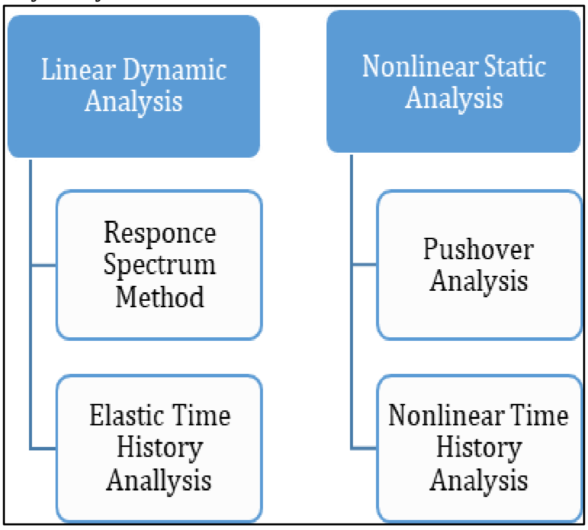

Chart 1: Methods of seismic analysis

III. Methodology

A. 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).

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.

2) Fundamental Natural Time Period (Ta)

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

$T_a = 0.075\, h^{0.75}$

$T_a = 0.085 h^{0.75}$ -RC frame

-Steel frame

The approximate time or period of vibration (Ta), 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) The design horizontal seismic coefficient (Ah):

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 ≤ 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.

IV. Problem Statement

Reinforced Concrete Frame of G+3 building, with plan size 16.37 m x 7.84 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.

A. Designed Information about Statement.

1) RCC Building Plan

Sr. no.	Description	Information
1	Plan size	16.37 m x 7.84 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	M20, fck= 20 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 tie column	230 mm x 230 mm
20	Size of tie beam	230 mm x 230 mm
21	Thickness of slab	125 mm
22	Floor to floor height	3 m
23	Plinth level height above ground level	1 m
24	Imposed load	1.6 KN/m^2
25	Wall thickness	230 mm

Table 2: Data of RCC frame

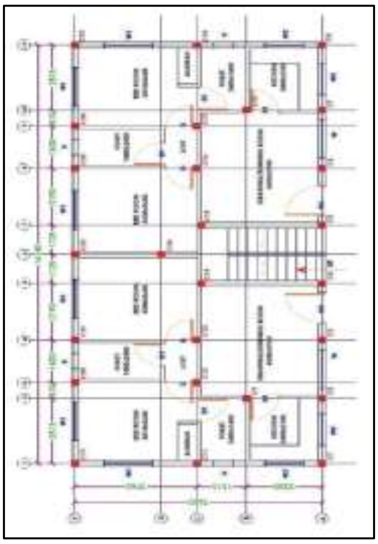

Fig. 4: Plan of RCC Building

2) Confined Masonry Building:

Sr. no.	Description	Information
1	Plan size	16.37 m x 7.84 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	M20, fck= 20 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	2.5
18	Brick Density	10.5 kN/m3
19	Size of column near wc and bath	230 mm x 115 mm
20	Size of tie column	230 mm x 230 mm
21	Size of tie beam @ sill level	230 mm x 230 mm
22	Size of tie beam @ lintle level	230 mm x 230 mm
23	Thickness of slab	125 mm
24	Floor to floor height	3 m
25	Plinth level height above ground level	1 m
26	Imposed load	1.6 KN/m2
27	Wall thickness (with plaster)	230 mm

Table 3: Data of CM building

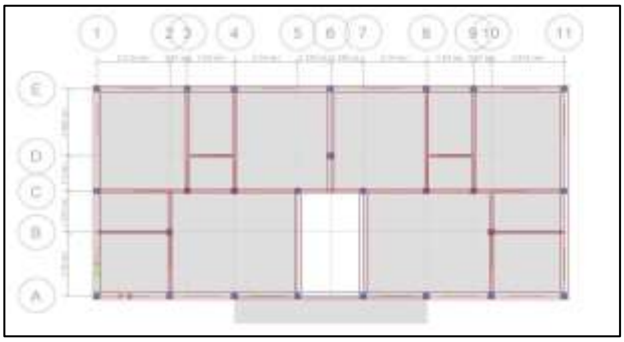

Fig. 5: confined masonry building

B. Static Method for Confined Masonry Building:

LOAD CALCULATION FOR CM BUILDING

Total Weight, W = Wall+ Tie Beam+ Tie Column+ Slab+ Reduced LL Wall Weight = (41.58) X 19 = 790.0523 KN

Tie Beam Weight = (92.075*0.23*0.23) X 25 = 121.769 KN

Lintel Beam Weight = (92.075*0.23*0.23) X 25 = 121.769 KN

Tie Column Weight = (3*0.23*0.23) X 25 X 25 = 99.18 KN

Slab = (16.37*7.84*0.125) X 25 + (1*6.63*0.125) X 25 = 421.78

Therefore, Total Weight of 1 floor = 1748 KN

For simplicity, assuming equal weight at each floor. So, total building Weight = 1748*4 = 6992 KN

1) Calculation of base shear (VB):

– 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} = 0.385

– Horizontal Seismic Coefficient (A_h):

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

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

$$A_h = 0.12$$

– Design Base Shear (V_B):

$$V_d = A_h \times W$$

$$V_d = 0.12 \times 6992$$

$$V_d = 839.04 \text{ KN}$$

C. Static Method for RCC Frame Building:

Q4 = $(839*1748*12^2) / (1748*12^2 + 1748*9^2 + 1748*6^2 + 1748*3^2)$ = 447.46 KN

Q3 = $(839*1748*9^2) / (1748*12^2 + 1748*9^2 + 1748*6^2 + 1748*3^2)$ = 251.7 KN

Q2 = $(839*1748*6^2) / (1748*12^2 + 1748*9^2 + 1748*6^2 + 1748*3^2)$ = 111.86 KN

Q1 = $(839*1748*3^2) / (1748*12^2 + 1748*9^2 + 1748*6^2 + 1748*3^2)$ = 27.96 KN

S. No.	Load Combination
1	1.5 DL + 1.5 LL
2	1.2 DL + 1.2 LL + 1.2 EQ-X
3	1.2 DL + 1.2 LL + -1.2 EQ-X
4	1.2 DL + 1.2 LL + 1.2 EQ-Y
5	1.2 DL + 1.2 LL + -1.2 EQ-Y

6	1.5 DL + 1.5 EQ-X
7	1.5 DL + -1.5 EQ-X
8	1.5 DL + 1.5 EQ-Y
9	1.5 DL + -1.5 EQ-Y
10	0.9 DL + 1.5 EQ-X
11	0.9 DL + -1.5 EQ-X
12	0.9 DL + 1.5 EQ-Y
13	0.9 DL + -1.5 EQ-Y

Table 4: Load calculation for RCC building

1) *Calculation of base shear (VB):*

– Fundamental Natural time Period (Ta) in X and Y direction:

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

Tax = 0.26, Tay = 0.385

– Horizontal Seismic Coefficient (Ah):

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

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

$$A_h = 0.06$$

– Design Base Shear (VB):

$$V_d = A_h \times W$$

$$V_d = 0.06 \times 6992$$

$$V_d = 419.52\ \text{KN}$$

D. *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.

Storey	ETABS	NUMERICALLY
Story4	0.267	0.3116
Story3	0.347	0.2225
Story2	0.357	0.1335
Story1	0.297	0.0445

Table 5: Comparison of max. Drift

E. *Wall Density*

Wall density is a key indicator for the safety of confined masonry buildings subjected to seismic and gravity loads. Wall density (Wd) can be defined as the total cross-sectional area of all walls, Aw (product of wall thickness and wall length), in each direction divided by the plan area, Ap

$$WV_d\ (\%) = \frac{Aw}{Ap} \times 10$$

Now, for above plan minimum wall density required for confined masonry building located in seismic zone
IV is 4%.

Wd = { [(0.23*16.37) + (0.115*16.37) + (0.23*13.2)] / [16.37*7.84] } * 100 = 6.7 % (in X Direction)

Wd = { [(0.23*7.84*2) + (0.115*7.84*2) + (0.115*3.65*2) + (0.23*3.65) + (0.23*3.7*2)] /[16.37*7.84] } * 100 = 6.8% (in Y Direction)

Wall density in X direction = 6.7% > 4%, OK

Wall density in Y direction = 6.8% > 4%, OK

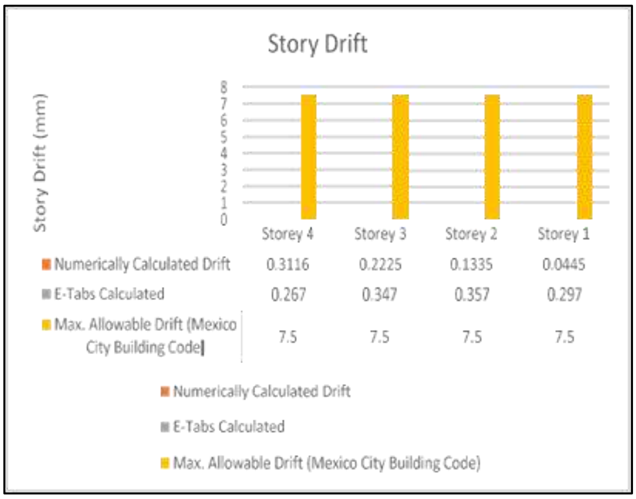

Chart 2: Lateral Storey Drift (mm)

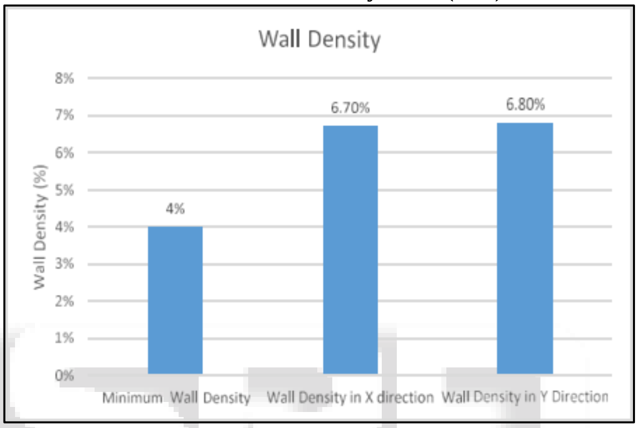

Chart 3: Wall Density (%)

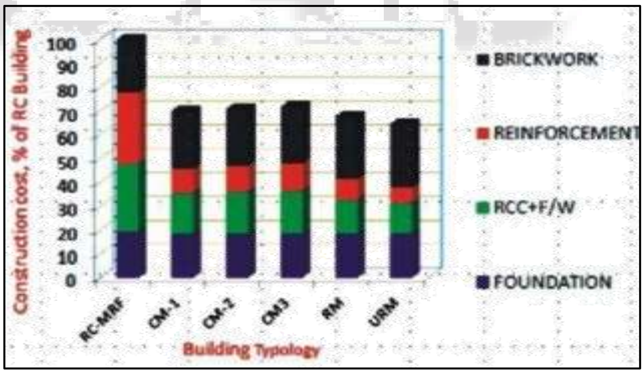

Chart 4: Average Construction Cost of Masonry Buildings with reference to RC Framed Structure

V. 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 these buildings give 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.

REFERENCES

[1] Dogangun, A., Ural and R. Livaoglu "SEISMIC PERFORMANCE OF MASONRY BUILDINGS DURING RECENT EARTHQUAKES IN TURKEY." (October 12- 17, 2008)
[2] Ajay Chourasia, Sriman K. Bhattacharyya, Pradeep K. Bhargava, Navratan M. Bhandari "Influential aspects on seismic performance of confined masonry construction." (23 July 2013)
[3] Angelo Marrinilli and Enrique Castilla "Experimental evaluation of confined masonry wall with several confined columns." (August 1-6, 2004)
[4] IS 1893:2002 CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURE.
[5] IS 13920 (1993): Ductile detailing of reinforced concrete structures subjected to seismic forces- Code of practice [CED 39: Earthquake Engineering.
[6] IS 4326:1993 Earthquake Resistant Design and Construction of Buildings - Code of Practice.
[7] K. Desai, S. B. Patel and V. V. Agrawal "Confined Masonry - Analysis, Design and Comparison."
[8] Ramesh A. M, Sivan P.P. and Dr. Sunilaa George ijesird "A Study of Confined Masonry Buildings over Unconfined Masonry Buildings."(MAY 2018)
[9] Sudhir K. Jain, Dhiman Basu, Indrajit Ghosh, Durgesh C. Rai, Svetlana Brzev, and Laxmi Kant Bhargava, "Application of confined masonry in major project in India." (July 21-25, 2014)
[10] Svetlana Brzev, Roberto Meli "International Guideline for Seismic Design of Low-Rise Confined Masonry Buildings in Regions of High Seismic Risk."15WCEE LISBOA 2012
[11] T. M. Hart and S. Brzev "The confined masonry networks design and construction guideline." (July 21-25, 2014)
[12] Vishnu J., Mathew C. S., Leny Thomas, Deepu R, Praveen A. "Unconfined Masonry and Confined Masonry Construction: A Comparative Study." (April 2016)
[13] Ramesh A. M, Sivan P.P. and Dr. Sunilaa George ijesird "A Study of Confined Masonry Buildings over Unconfined Masonry Buildings."(MAY 2018)
[14] Sudhir K. Jain, Dhiman Basu, Indrajit Ghosh, Durgesh C. Rai, Svetlana Brzev, and Laxmi Kant Bhargava, "Application of confined masonry in major project in India." (July 21-25, 2014)
[15] Svetlana Brzev, Roberto Meli "International Guideline for Seismic Design of Low-Rise Confined Masonry Buildings in Regions of High Seismic Risk."15WCEE LISBOA 2012
[16] T. M. Hart and S. Brzev "The confined masonry networks design and construction guideline." (July 21-25, 2014)
[17] Vishnu J., Mathew C. S., Leny Thomas, Deepu R, Praveen A. "Unconfined Masonry and Confined Masonry Construction: A Comparative Study." (April 2016)