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Effect of Shear Wall Area on Seismic Bheavior of Multisoried Builiding Tube in Tube Structure

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.**Abstract**-*The advances in three-dimensional structural analysis and computing resources have allowed the efficient and safe design of taller structures. Tubular structures are common structural system for tall buildings over past few years. The tubular structures are of different types in which tube in tube structures are more suitable for high rise buildings. A tube in tube structure is formed by outer framed tube and inner core tube connected by floor slab. It is act like a huge tube (i.e. Peripheral tube) with a smaller tube (i.e., core tube) in middle of it. The load is transfer between these two tubes. In which a strong center tube of high strength concrete is the main load carrying structure. Presence of shear walls imparts a large stiffness to the lateral force resisting system of the RC building. One of the major parameters influencing the seismic behavior of shear wall frame buildings is the shear wall area ratio. Thus an analytical study is performed to evaluate the effect of Shear Wall Area to floor area ratio (SWA/FA %) on the seismic behavior of multistoried RC structures. For this purpose, 30 stories with SWA/FA % is considered. Then, the behavior of these building models under earthquake loading is examined by carrying out Static and Response Spectrum Analysis using structural analysis software E-TABS. Static and Response Spectrum Analysis is done according to seismic code IS 1893:2002.*

INTRODUCTION

1.1 GENERAL

In the last few decades, shear walls have been used extensively in countries especially where high seismic risk is observed. The major factors for inclusion of shear walls are ability to minimize lateral drifts, inter storey displacement and excellent performance in past earthquake record. Shear walls are designed not only to resist gravity loads but also can take care overturning moments as well as shear forces. They have very large in plane stiffness that limit the amount of lateral displacement of the building under lateral loadings. Shear walls are intended to behave elastically during moderate or low seismic loading to prevent non-structural damage in the building. To minimize loss after earthquakes, the experimental and analytical studies on seismic design approaches encourage use of shear walls for earthquake-resistant design.The shear wall area to floor area ratio (also referred to as shear wall ratio), the wall aspect ratio, shear wall ratio is also accepted as an essential parameter affecting the global performance of a building under severe ground motions. The tube is a structural engineering system that is used in high-rise buildings, enabling them to resist lateral loads from wind, seismic pressures and so on. It acts like a hollow cylinder, cantilevered perpendicular to the ground. The tube system can be constructed using concrete, steel or a composite of both. In its simplest form, closely-spaced columns are tied together with deep spandrel beams through moment connections as part of the external perimeter of the building. The rigid frame that this assembly of columns and beams forms results in a dense and strong structural 'tube' around the exterior. Tube-in-tube system is also known as 'hull and core' and consists of a core tube inside the structure which holds services such as utilities and lifts, as well as the usual tube system on the exterior which takes the majority of the gravity and lateral loads. The inner and outer tubes interact horizontally as the shear and flexural components of a wall-frame structure. They have the advantage of increased lateral stiffness.

METHODOLOGY AND BUILDING MODELING

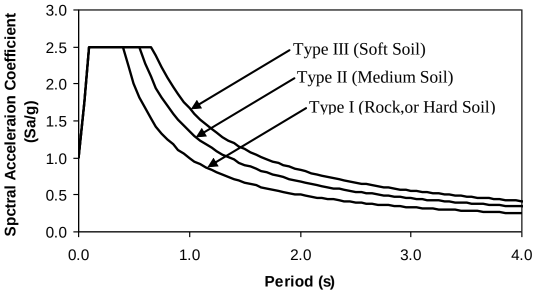
A number of methods are available for the earthquake analysis of buildings; two of them are presented here:

- Equivalent Static Lateral Force Method (pseudo static method)
- Dynamic analysis
  Response spectrum method.

BASE SHEAR

According to IS 1893(part1): 2002, the base shear V_b is given by the following formula:

$$V_b = A_h W \quad \text{eq. 3.1}$$



Here,

A_h = Design horizontal acceleration spectrum value using the fundamental natural period ‘T’ in the considered direction of vibration

W = seismic weight of the building

$$A_h = \left(\frac{Z}{2}\right)\frac{I}{R}\frac{S_a}{g} \quad \text{eq. 3.2}$$

Z= Zone factor as per table 2 of IS: 1893

I= Importance factor as per table 6 of IS: 1893

= 1.5 for important structures

= 1.0 for all other buildings

R= Response reduction factor as per table 7 of IS: 1893 value varies between 3 and 5 with respect to ductile reinforcement detailing

Sa/g= Average response acceleration coefficient as per clause 6.4.5 of the Indian Standard IS 1893:2002.

SEISMIC WEIGHT

The seismic weight of building is the sum of seismic weight of all the floors. The seismic weight of each floor is its full dead load plus appropriate amount of imposed load. While computing the seismic weight of columns and walls in any story shall be equally distributed to the floors above and below the story.

TIME PERIOD

The approximate fundamental natural period of vibration T_a in seconds, of a moment resisting frame building without brick infill panels may be estimated by the following empirical formula

$T_a = 0.075h^{0.75}$ for RC frame building

$T_a = 0.085h^{0.75}$ for steel frame building

The approximate fundamental natural period of vibration in seconds of all other, buildings including moment resisting frame buildings with brick infill panels may be estimated by the following expression.

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

As per IS 1893: 2002 in clause 7.7.1 mentioned that the force thus obtained shall be distributed along the height of the building as per the following expression:

$$Q_i = \frac{V_b \, W_i \, h_i^2}{\sum W_j \, h_j^2}$$

Where

Q_i = Design lateral force at floor i,

W_i =seismic weight of floor

h_i = height of floor measured from base, and

n = number of storeys in the building i.e., number of levels at which masses are located.

Load Combinations

The analysis results obtained for the following load combinations (IS 1893:2002)

COMB1 = 1.5(DL+LL) *COMB2 = 1.5(DL+EQX)* *COMB3 = 1.5(DL-EQX)*

COMB4 = 1.5(DL+EQY) *COMB5 = 1.5(DL-EQY)* *COMB6 = 1.2(DL+LL+EQX)*

COMB7 = 1.2(DL+LL-EQX) *COMB8 = 1.2(DL+LL+EQY)* *COMB9 = 1.2(DL+LL-EQY)*

COMB10 = 1.5(DL+SX) *COMB11= 1.5(DL-SX)* *COMB12= 1.5(DL+SY)*

COMB13= 1.5(DL-SY) *COMB14= 1.2(DL+LL+SX)* *COMB15=1.2(DL+LL-SX)*

COMB16=1.2(DL+LL+SY)   COMB17=1.2(DL+LL-SY)

Here, DL ≡ Dead load, IL ≡ Live load, and EL ≡ Earthquake Load. The dead load and the live load are taken as per IS 875..

DYNAMIC ANALYSIS

Dynamic analysis may be performed either by the time history method or by the response spectrum method. However, in either method, the design base shear (V_B) shall be compared with a base shear (V_b) calculated using a fundamental period t. where V_B is less than V_b, all response quantities (for example member forces, displacements, storey forces, storey shears and base reactions) shall be multiplied by V_B/V_b

Response spectrum analysis

The base shear calculated from the response spectrum analysis $(\bar{V}_B)$ is less than the design base shear (V_B), the response quantities (member forces, displacements, storey shears and base reactions) have to be scaled up by the factor $V_B/\bar{V}_B$.

The response spectra are given by the following equations

For type I soil (Rock or Hard Soil sites) $$\frac{S_a}{g}=\begin{cases}1+15T; 0.00\le T\le 0.10\\ 2.50 \quad 0.10\le T\le 0.40\\ \dfrac{1}{T} \quad 0.40\le T\le 4.00\end{cases}$$

For type II (Medium soil) $$\frac{S_a}{g}=\begin{cases}1+15T; 0.00\le T\le 0.10\\ 2.50 \quad 0.10\le T\le 0.55\\ \dfrac{1.36}{T} \quad 0.55\le T\le 4.00\end{cases}$$

For type III (Soft soil) $$\frac{S_a}{g}=\begin{cases}1+15T; 0.00\le T\le 0.10\\ 2.50 \quad 0.10\le T\le 0.67\\ \dfrac{1.67}{T} \quad 0.67\le T\le 4.00\end{cases}$$

Response quantities (member forces, displacements, storey forces, storey shears and base reactions) for each mode of response shall be combined by either the SRSS (square root sum of squares) or the CQC (complete quadratic combination) rule.

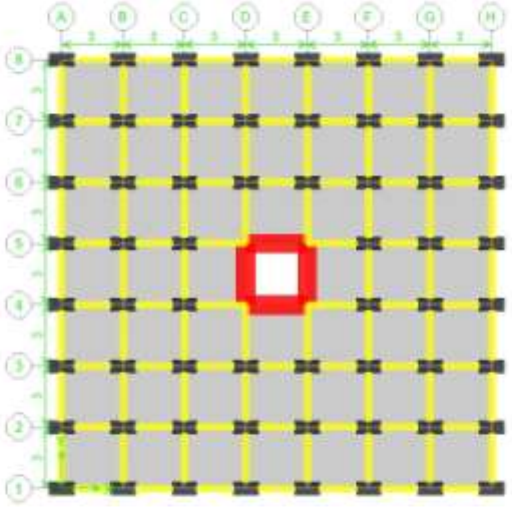
MODELLING AND ANALYSIS

Material propertiesThe material properties of concrete include mass, unit weight, modulus of elasticity, Poisson's ratio, shear modulus and coefficient of thermal expansion. The modulus of elasticity of reinforced concrete as per IS 456:2000 is given by

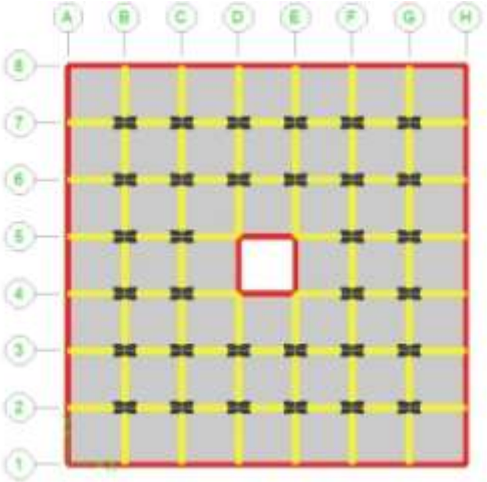
$$E_c = 5000\sqrt{f_{ck}}$$

where f_{ck} ≡ characteristic compressive strength of concrete at 28-days in MPa. For the steel rebar, the necessary properties are yield stress and modulus of elasticity.

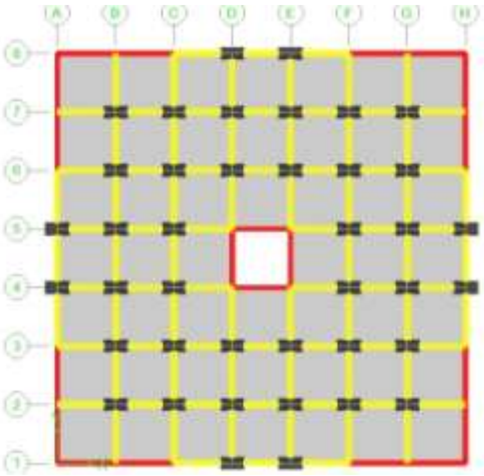
Modelling of Shear Wall and core wall



Model-1 (M1)



Model-2 (M2)



Model-3 (M3)

Building Description

a)Constant Parameters

Number of storeys :G+2 9 storeys (H=90m)
Height of typical floor : 3 m
Column size : 600 mm X 1200 mm
Beam size : 300 mm X 600 mm
Plinth beam size : 300 mm X 600mm
Slab thickness : 150 mm
Shear wall thickness : 900 mm
Masonry wall thickness : 230 mm
Depth of foundation : 3 m
Characteristic strength of concrete, f_{ck} : 40 Mpa
Grade of Steel : Fe 415
Density of Concrete : 25 KN/m^3
Modulus elasticity of concrete, E_c :5000√f ck =25000Mp a = 25000X10^3 KN/m^2
Poisson's ratio of concrete, µ : 0.20
Density of brick masonry, ρ : 20 kN/m^3(Including plastering)
Modulus of elasticity of brick masonry, E_{me} : 1.8 X10^6 kN/m^2
Poisson's ratio of brick masonry : 0.20
Earth quake Zone : III (z=0.16)
Importance factor : 1.00

Response reduction factor	: 3
Damping ratio	: 5 %

LOAD CALCULATIONS

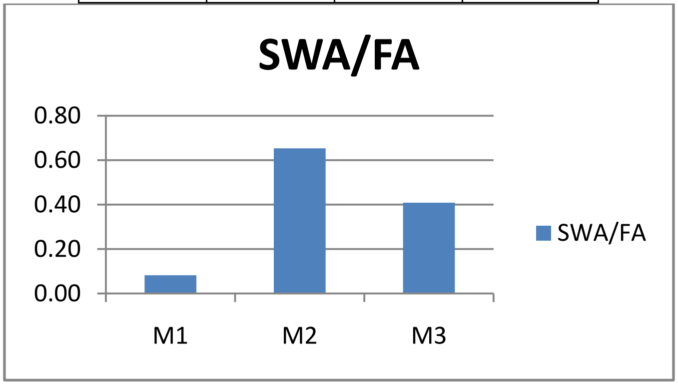
Seismic weight calculations

The weight of columns and walls in any story shall be equally distributed to the floors above and below the story. Following reduced live loads are used for analysis: zero on terrace, and 25% on other floors [IS:1893 (Part 1):2002, Clause 7.4]

RESULTS AND DISCUSSION

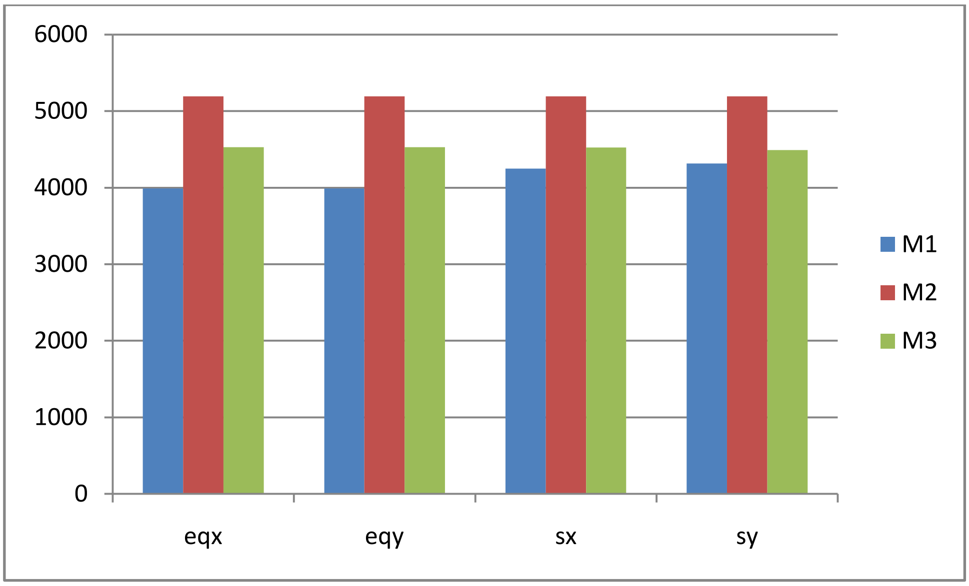
Shear wall to Floor area ratio:

MODEL	SWA	FA	SWA/FA
M1	36	441	0.08
M2	288	441	0.65
M3	180	441	0.41



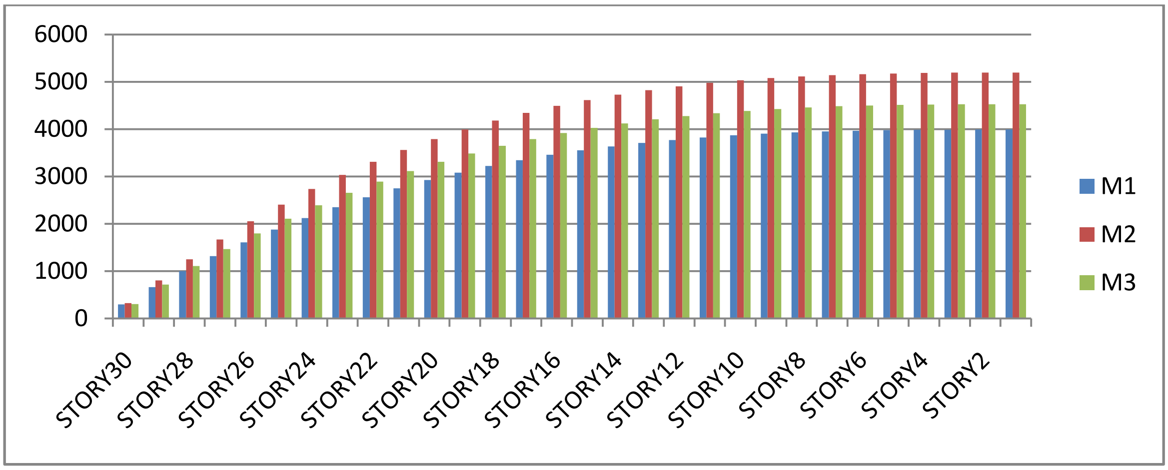
BASE SHEAR:

MODEL	eqx	eqy	sx	sy
M1	3991.49	3991.49	4249.84	4317.91
M2	5195.65	5195.65	5192.98	5191.7
M3	4528.89	4528.89	4524.91	4491.57

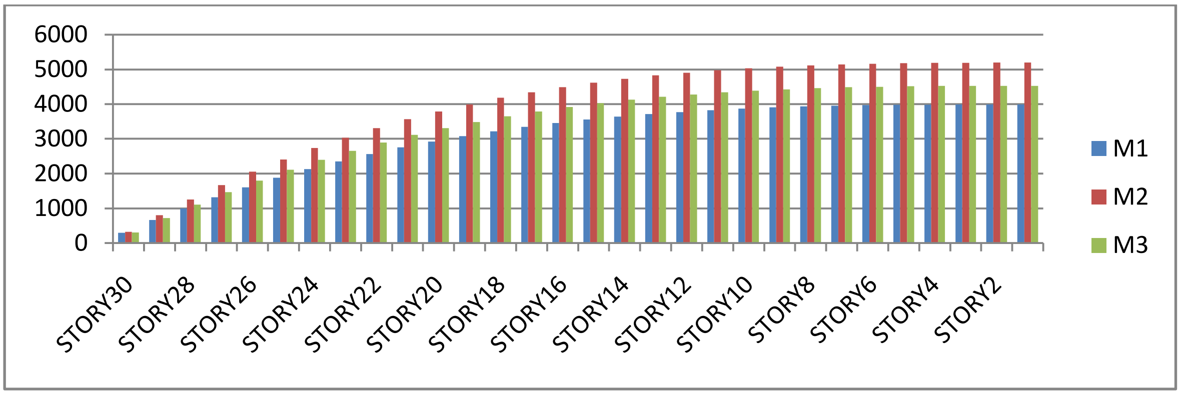


Base shear

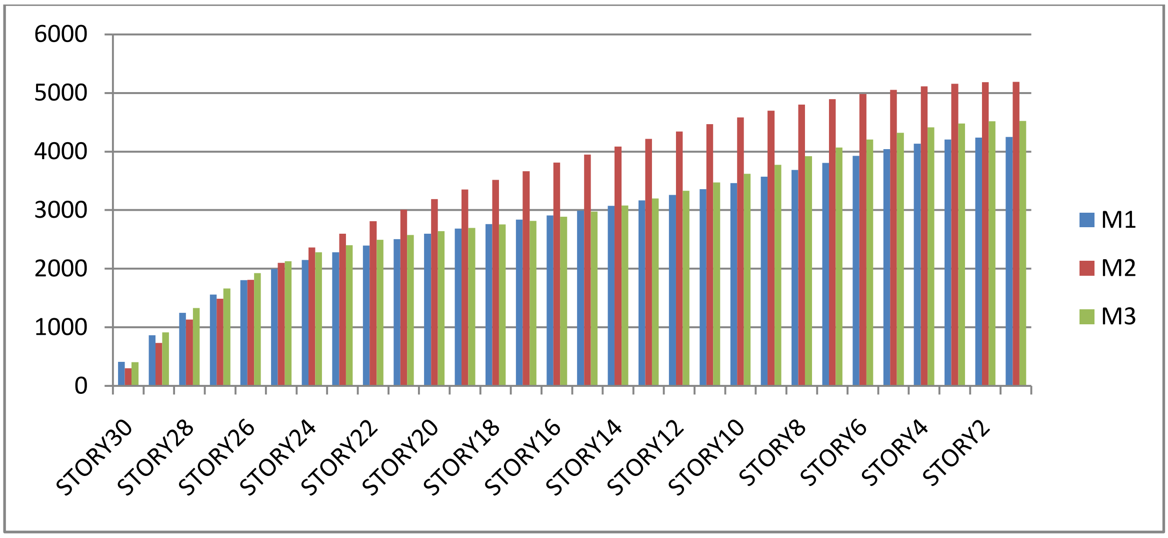
Story shear in X-direction For Static earthquake analysis:



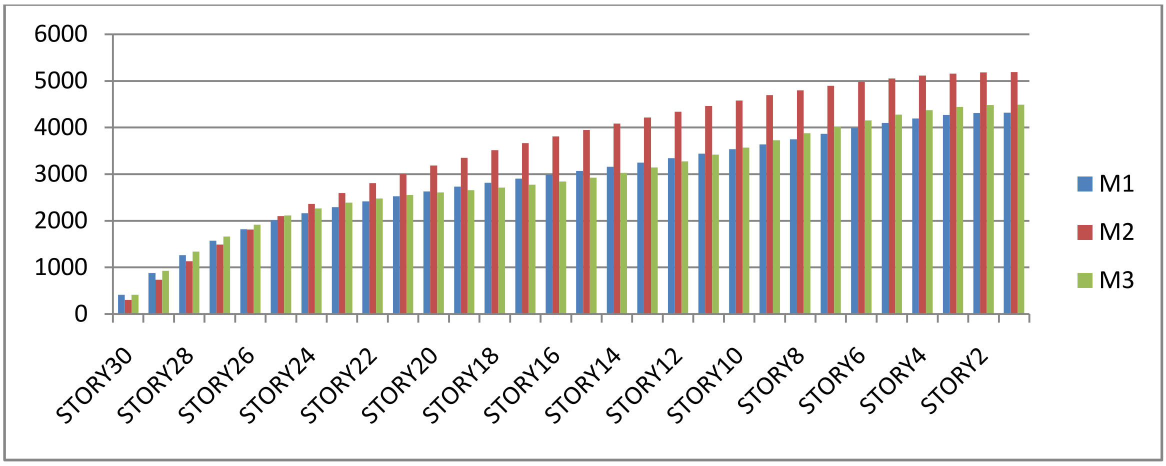
Story shear in Y-direction For Static earthquake analysis



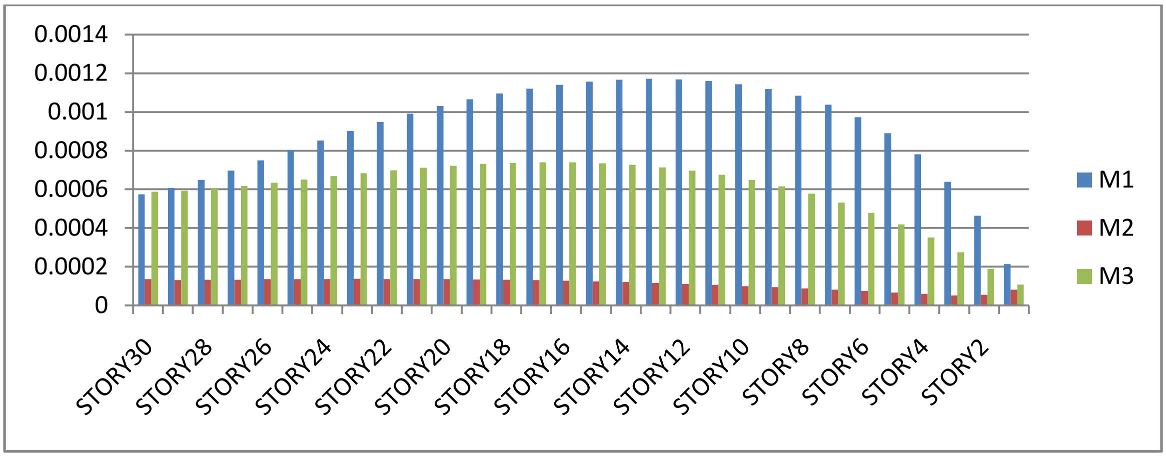
Story shear in X-direction For Response Spectrum analysis



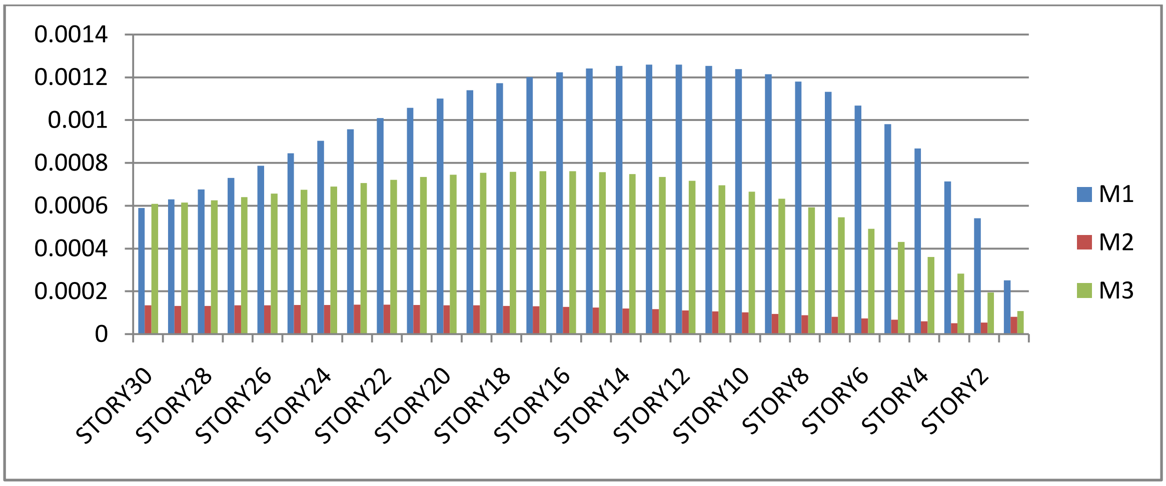
Story shear in Y-direction For Response Spectrum analysis



Story Drift:
Story Drift in X direction

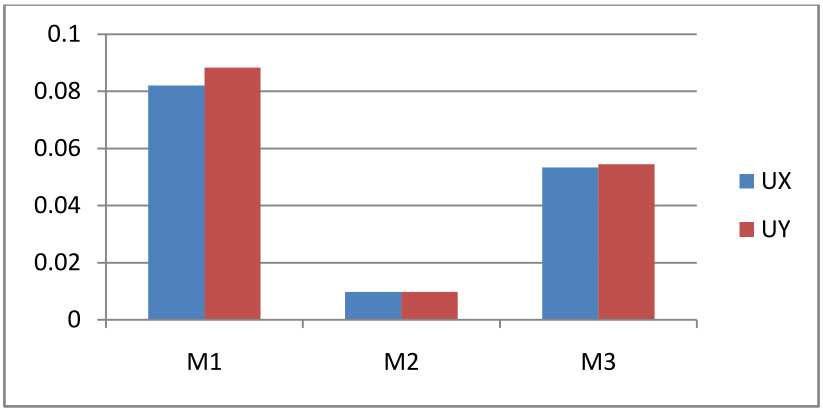


Story Drift in Y direction



Maximum Displacement of the structure:

MODEL	UX	UY
M1	0.0821	0.0883
M2	0.0097	0.0097
M3	0.0534	0.0545



CONCLUSION

On the basis of the results of the analytical investigation of 30 storey RC building models, which are having the different Shear wall area to floor area ratio of tube in tube structure, the following conclusions are drawn:

- M1 model considered as 8% Shear wall area, M2 as 65% and M3 as 41% Shear wall area to the floor area
- In static Earthquake analysis, the base shear in both X and Y direction are Similar for individual models. The M1 model is showing the minimum and where as M2 and M3 are showing the base shear 30% and 13.5% more than the M1 model
- In Response Spectrum analysis, the base shear in both X and Y direction are Similar for individual models. The M1 model is showing the minimum and where as M2 and M3 are showing the base shear 22% and 6.5% more than the M1 model
- As the shear wall area increased for M2 and M3 model when comparing to the M1 model. Due to the self weight of the shear wall, the base shear is increased.
- At maximum story drift in both X and Y direction, it is observed that for M2 and M3 model story drift is reduced by 86.5% and 40% respectively when comparing with M1 model.
- Maximum displacement for M2 and M3 models is reduced by 88% and 38% when comparing to the M1 model.
- By the above investigations, as the shear wall area increases, even though the base shear increases the displacement and story drift of the structure decreases.

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