Seismic Earthquakes Analysis Of High Rise Buildings With Shear Walls At The Center Core Approach

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Abstract- *The usefulness of shear walls in the structural planning of multistory buildings has long been recognized. When walls are situated in advantageous positions in a building, they can be very efficient in resisting lateral loads originating from wind or earthquakes. Incorporation of shear wall has become inevitable in multi-storey building to resist lateral forces. In present work, Fortystorey buildings (120m) have been modeled using software package ETABS for earthquake zone V in India.This paper aims to study the behaviour of reinforced concrete building by conducting dynamic analysis for most suited positions and location of shear wall with opening conditions. Symmetrical openings are provided in shear walls with proper sizes to ensure least interruption to force flow through walls. Estimation of structural response such as; storey displacements, base shear, storey drift is carried out. Dynamic responses under zone V earthquake as per IS 1893 (part 1) : 2002 have been carried out. In dynamic analysis; Response Spectrum method is used.*

I. INTRODUCTION

There has been a considerable increase in the construction of tall buildings both residential and commercial and the modern trend is towards more tall and slender structures. Thus the effects of lateral loads like wind loads, earthquake loads and blast forces area ttaining increasing importance and almost every designer is faced with the problems of providing adequate strength and stability against lateral loads. Shear wall system is one of the most commonly used lateral load resisting system in high rise buildings. Shearwall has high in plane stiffness and strength which canbe used to simultaneously resist large horizontal loads and support gravity loads, which significantly reduceslateral sway of the building and thereby reducesdamage to structure and its contents.When shear wallsare situated in advantageous positions in the building, they can form an efficient lateral force resisting systemby reducing lateral displacements under earthquakeloads. Therefore it is very necessary to determineeffective, efficient and ideal location of shear wall.Modern trends towards high rise buildings increase recently due to the high increase in the number of tall buildings, both residential and commercial. In every parts of the world flat slab construction are widely used in reinforced concrete structures because; this system reduces the costs of form work and construction time and easy installation. Without beams floor slab system directly Supports columns. In comparison with earlier high rise buildings, today's tall buildings are becoming more and more slender and leading to the possibility of more sway. From lateral loads such as wind, seismic loads shear walls provide the stability to the structure. These shear walls transfer the lateral loads to the foundation by their shearing resistance and resistance to overturning. In the present work, summarized the importance of flat slab construction and revealed the relevance of shear wall in a flat slab multi-storied building.

AIM AND OBJECTIVES

In the present study, a typical multi storey building is analyzed using software ETABS by dynamic (Response Spectrum) analysis. All the analyses has been carried out as per the Indian Standard code books. Based on the literature of previous studies most effective positioning of shear walls has been chosen. Analysis is done with model forty storey high and provided with a shear wall at the center core of the building and at the center of each side of the external perimeter with openings. This study is done on RC framed multistory building with RC shear walls with fixed support conditions.

SCOPE

The salient objectives of the present study have been identified as follows:

1) To investigate the seismic performances of the building with two different locations of shear walls in the external perimeter.

2) To evaluate the behaviour of shear wall with openings under seismic loads.

3) To evaluate the effect of openings in shear walls and comparing the results obtained with models without openings.

II. LITERATURE SURVEY

[1] Seismic Damage Evaluation of Concrete-EncasedSteel Frame-Reinforced Concrete Core TubeBuildings

Based on Dynamic CharacteristicsLeiZeng,Yunfeng Xiao, Yiguang Chen, Siqian Jin, Wei Xie and Xianjie Li

To evaluate damage state and residual resistance of concrete-encased steel frame-reinforced

concrete core tube buildings under earthquake actions, a criterion of damage assessment basedon dynamic characteristics is proposed in this paper. Dynamic characterization experiments wereconducted on a 10-story and 1/5 scaled building model using velocity sensors on each floor, andnatural frequencies were obtained based on the measured data. Modal analysis was carried outusing a nonlinear finite element program, and the simulation results of the dynamic characteristicsagreed well with experimental ones. Then, the damage processes under different seismic wave inputswere revealed based on finite element analysis, and the max story drift angle was chosen to reflectthe damage state and to quantify the degree of damage. A criterion of seismic damage assessmentis proposed based on the relationship between the quantitative damage value and the dynamiccharacteristics, in which the higher order modes were considered. Moreover, influencing factors,including earthquake intensity and structural stiffness ratio, were analyzed, and the results indicatedthat the proposed damage index based on dynamic characteristics can account for the higher-ordermodes and provides an innovative approach to evaluate the seismic damage.

[2] Seismic Performance Evaluation of Multistory ReinforcedConcrete Moment Resisting Frame Structure with Shear WallsJunwonSeo , Jong Wan Hu , and BurteDavaajamts

This paper is intended to evaluate the seismic performance of a twelve-storyreinforced concrete moment-resisting frame structure with shear walls using 3D finiteelement models according to such seismic design regulations as Federal EmergencyManagement Agency (FEMA) guideline and seismic building codes including Los AngelesTall Building Structural Design Council (LATBSDC) code. The structure is located inSeismic Zone 4, considered the highest-seismic-risk classification established by the U.S.Geological Survey. 3D finite element model was created in commercially available finiteelement software. As part of the seismic performance evaluation, two standard approachesfor the structure seismic analysis were used; response spectrum analysis and nonlineartime-history analysis. Both approaches were used to compute inter-story drift ratios of thestructure. Seismic fragility curves for each floor of the structure were generated using theratios from the time history analysis with the FEMA guideline so as to evaluate theirseismic vulnerability. The ratios from both approaches were compared to FEMA andLATBSDC limits. The findings revealed that the floor-level fragility mostly decreased forall the FEMA performance levels with an increase in height and the ratios from bothapproaches mostly satisfied the codified limits.

[3] SEISMIC PERFORMANCE OF RC HIGH-RISE BUILDINGS – A CASE STUDY OF 44 STOREY STRUCTURE IN SKOPJE (MACEDONIA), Roberta Apostolska, Golubka

Necevska-Cvetanovska, Jordan Bojadjiev, JulijanaBojadjieva High-rise buildings are designed and constructed by use of modern materials and integral structural systems which are not usual for typical buildings. The existing seismic regulations act as a limiting factor and cannot cover specific behavior of these buildings. Considering the increasing trend in their construction worldwide, additional investigations are necessary, particularly for structures in seismically active areas. It is necessary to elaborate official codes which will clearly prescribe methods, procedures and criteria for analysis and design of such type of structures. The main goal of the paper is to present a review of the existing structural systems, design recommendations and guidelines for high-rises worldwide, as well as selected results from seismic performance of 44 stories RC high-rise building which is a unique experience coming from design and construction of the four high-rise buildings

[4] Effect of shear wall location in buildings subjected to seismic loadsLakshmi K.O.1, Prof. JayasreeRamanujan

here has been a considerable increase in theconstruction of tall buildings both residential andcommercial and the modern trend is towards more talland slender structures. Thus the effects of lateral loadslike wind loads, earthquake loads and blast forces areattaining increasing importance and almost everydesigner is faced with the problems of providingadequate strength and stability against lateral loads.Shear wall system is one of the most commonly usedlateral load resisting system in high rise buildings. Shearwall has high in plane stiffness and strength which canbe used to simultaneously resist large horizontal loads and support gravity loads, which significantly reduceslateral sway of the building and thereby reducesdamage to structure and its contents

[5] Design Optimization and Analysis of ShearWall in High Rise Buildings Using ETABSUmamaheshwara.B1, Nagarajan

The shear wall is a structural element which is used to resist earthquake forces. These wall will consumptives shearforces & will prevent changing location-position of construction & consequently destruction. On other hand, shear wallarrangement must be absolutely accurate, if not, we will find negative effect instead. For example if the shear walls make anincrease distance between mass centre and hardness centre, we cannot expect a good tensional behavior from the structure. Incase of mass centre and hardness centre coincide with each other, at that time the distance of shear wall from the mass centrealso plays an important role in the shear contribution of the shear wall. The bending moment, shear force, torsion, axial forcecontribution by rest of the structural element and the ultimate design of all the structural components also affected by that.A study has been carried out to determine the optimum Structural configuration of a multistory building by changing the shearwall locations. Three different cases of shear wall position for a 15 storey residential building with keeping zero eccentricitybetween mass centre and hardness centre have been analyzed and designed as a space frame system by computer applicationsoftware, subjected to lateral and gravity loading in accordance with IS provisions.Keywords: Skyscraper, exaggeration, Response spectrum, Shear wall.

[6] THE OPTIMUM LOCATION OF SHEAR WALL IN HIGH RISE R.C BULIDINGS UNDER LATERAL LOADING M R Suresh1, AnanthShayanaYadav

Shear walls are the structural system used to increase the strength of R.C.C Structure. In high rise buildings the shear wall are used to resist lateral loads that may be caused by wind and seismic motion. R.C. Shear wall provide large strength and stiffness to the building in the direction of their orientation which considerably reduces lateral sway of the building and there by reduces damage to the structure. If a high rise R.C. Structure is designed without shear wall the beam and column sizes are large and so many problems arises at the joints and due to this it is difficult to place and vibrate the concrete at such places and displacement is more which in turn induces heavy forces on the structure therefore shear wall become essential from the point of view of economy. By providing shear wall the structure become safe and durable and also more stable the function of shear wall is to increase rigidity for wind and seismic load resistance. The use of shear wall gains more popularity in the construction of service apartments or office. In this paper the main aim is to study the optimum location and its effectiveness of shear wall in irregular high rise R.C Building.

[7] PERFORMANCE-BASED SEISMIC DESIGN OFTALL BUILDINGS IN THE U.S.J.P. Moehle

Building codes in the United States contain prescriptive requirements for seismic design as well as an option foruse of alternative provisions. Increasingly these alternative provisions are being applied for theperformance-based seismic design of tall buildings. Application of performance-based procedures requires: Anunderstanding of the relation between performance and nonlinear response; selection and manipulation ofground motions appropriate to the seismic hazard; selection of appropriate nonlinear models and analysisprocedures; interpretation of results to determine design quantities based on nonlinear dynamic analysisprocedures; appropriate structural details; and peer review by independent qualified experts to help assure thebuilding official that the proposed materials and system are acceptable. Both practice- and research-orientedaspects of performance-based seismic design of tall buildings are presented.

[8] SIGNIFICANCE OF SHEAR WALL IN FLAT SLAB MULTI STORIED BUILDING - A REVIEW Athira M. V 1, Sruthi K Chandran

Modern trends towards high rise buildings increases recently due to the high increase in the number of tall buildings, both residential and commercial. In every parts of the world flat slab construction are widely used in reinforced concrete structures because; this system reduces the costs of form work and construction time and easy installation. Without beams floor slab system directly supports columns. In comparison with earlier high rise buildings, today's tall buildings are becoming more and more slender and leading to the possibility of more sway. From lateral loads such as wind, seismic loads shear walls provide the stability to the structure. These shear walls transfer the lateral loads to the foundation by their shearing resistance and resistance to overturning. In the present work, summarized the importance of flat slab construction and revealed the relevance of shear wall in a flat slab multi-storied building.

[9] A comparative Study to Analyze the Effectiveness of Shear Walls inControlling Lateral Drift for Medium to High Rise StructuresJamal Ali 1, Abdul QadirBhatti

2005 Earthquake brought vast destruction in Pakistan which resulted in revision of Building Code of Pakistan (BCP). Inclusion of shear walls adds stiffness to structure and aids in reducing lateral driftunder seismic loads. Important aspects concerning design of shear walls are its placement in structure and thecross section (i.e. width to thickness ratio) keeping in view torsional stresses, economy and ductility ofstructure. A comparative study is carried out using ETABS software by varying location and cross section ofshear wall for Stock Exchange Building, Islamabad. Maximum lateral drift, storey drift, base shear forces andtime period of structure are important parameters considered. Response spectrum analysis has been carriedout on 4 cases depending upon location of shear wall and best possible case is selected which is finallycompared with actual building. It has been concluded that original location with 6in thick shear wall couldhave been more economical and ductile than existing 12in thick wall keeping in view the allowable lateraldrift and base shear forces.

[10] SIGNIFICANCE OF SHEAR WALL IN HIGHRISE IRREGULARBUILDINGSRavikanthCh, Pradeep Kumar Ramancharla

The usefulness of shear walls in the structural planning of multistorybuildings has long been recognized. When walls are situatedin advantageous positions in a building, they can be very efficientin resisting lateral loads originating from wind or earthquakes.Reinforced concrete framed buildings are adequate for resistingboth vertical and horizontal loads acting on them. Extensiveresearch has been done in the design and analysis of shear wallhighrise buildings. However, significance of shear wall in highriseirregular structures is not much discussed in literature. A study onan irregular highrise building with shear wall and without shearwall was studied to understand the lateral loads, story drifts andtorsion effects. From the results it is inferred that shear walls aremore resistant to lateral loads in an irregular structure.

III. MODELING OF BUILDING

3.1 Structural Modeling of Building

To study the effects of openings sizes and locations in shear walls on seismic responses of buildings, three dimensional (3D) geometric models of the buildings were developed in ETABS. Beams and columns were modeled as frame elements. Shear walls were modeled as plate elements. Floor slabs were modeled as rigid horizontal plane. Due to time limitations, it was impossible to account accurately for all aspects of behavior of all the components and materials even if their sizes and properties were known. Thus, for simplicity, following assumptions were made for the structural modeling:

1) The materials of the structure were assumed as homogeneous, isotropic and linearly elastic.
2) The effects of secondary structural components and non structural components such as staircase, masonry infill walls were assumed to be negligible.
3) Floors slabs were assumed rigid in plane.
4) Foundation for analysis was considered as rigid.

3.2 Details of the Building

Mostly in Residential buildings, floor plan will be same for all floors. So the buildings were considered with same floor plan in all floors. Shear walls of same section were used for same height of buildings throughout the height. Centre window openings of size 2m X 1.2m were provided in model. In this paper a high rise multi-storey building is studied for the following cases. Building with Shear Walls provided at the center core and at the center of each side of the external perimeter with openings. The buildings are modeled using software ETABS. Dynamic analysis is carried out for the case. A symmetrical building of plan 24.5m X 22.5m located with location in zone V, India is considered. Seven bays of length 3.5m along X - direction and five bays of length 4.5m along Y - direction are provided.

Table 1: Details of the building

Building parameters	Details
Type of frame	Special RC moment resisting fixed at the base
Building plan	24.5m X22.5 m
Number of storey's	forty
Floor height	3.0 m
Depth of slab	150mm
Size of beam	(230*450)mm
Size of column (exterior)	(400*700)mm
Size of column(interior)	(500*500)mm
Spacing between frames	3.5 m along x – direction 4.5 m along y – direction
Leave load on floor	2kn/m2
Floor finish	1.0kn/m2
Wall load	10kn/m
Grade of concrete	M30 concrete
Grade of steel	Fe- 415
Thickness of shear wall	230mm
Seismic zone	V
Density of concrete	25kn /m3
Type of soil	Medium
Response spectra	As per Is 1893(part 1)-2002
Damping of structure	5 percent

3.3 Layout of the Buildings Building with Shear Walls provided at the centre core and at the center of each side of the external perimeter with openings.

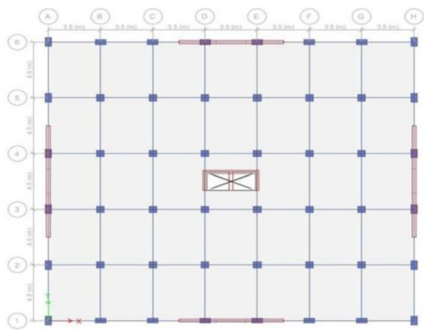


Figure 3: Plan of the building with shear wall openings

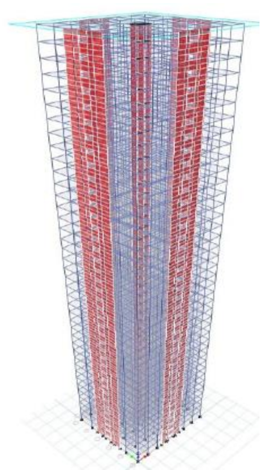


Figure 4:3D view showing openings in shear walls

Figure 5: Elevation view showing shear wall openings of size 2 m X 1.2 m

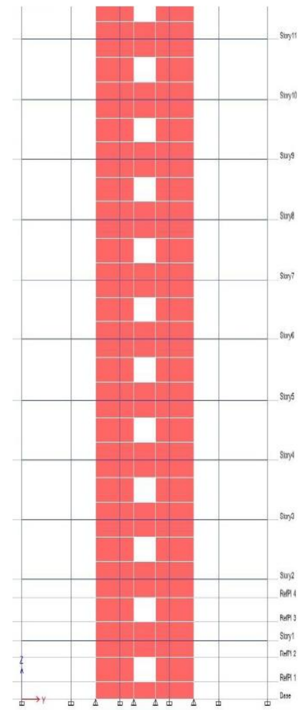


Figure 6: Side view showing shear wall openings of size 2 m X 1.2 m

3.4 Building Design Requirements

The proposed reinforced concrete shear wall buildings are located in zone V, India. Code requirements from IS 456 : 2000, IS 13920 : 1993 and IS 1893 (part 1) : 2002 were used for structural design. In the ETABS design model, modeling was done in order to verify sufficient strength and stiffness. Rigid diaphragms, along with lumped masses, were assigned at each level.

3.5 Load combinations

As per IS 1893 (Part 1): 2002 Clause no. 6.3.1.2, the following load cases have to be considered for analysis:

1.5 (DL + IL)

1.2 (DL + IL ± EL)

1.5 (DL ± EL)

0.9 DL ± 1.5 EL

Earthquake load must be considered for +X, -X, +Y and –Y directions.

3.6 Design of beams

General requirements The flexural members shall fulfill the following general requirements. (IS 13920; Clause 6.1.2)

$b/D \geq 0.3$

In the present study beam of size (230 X 450) mm has been used.

Here, = 230 450= 0.51 > 0.3.
Hence, ok.
As per IS 13920; Clause
6.1.3
b≥ 200 mm
Here b/d = 300 mm ≥ 200 mm
Hence, ok.
As per IS 13920; Clause 6.1.4
The depth D of the member shall preferably be not more than ¼ of the clear span.
Here, D=450 mm and clear span length is 3000 mm.
¼ (clear span) = 3000/4 =750 mm > 450 mm
Hence, ok.

3.7 Check for reinforcement
As per IS 13920; Clause 6.2.1
(b) The tension steel ratio on any face, at any section, shall not be less than
$pmin$ = 0.24 $\sqrt{fck}$ /fy
Therefore, $pmin$ = 0.361 %
As per IS 13920; Clause 6.2.2
The maximum steel ratio on any face at any section, shall not exceed $pmax$ = 0.025 or 2.5 %.

Design was carried out by the software and pt values for critical members were noted down as follows;

Building model	Pt value
Model	1.38

Therefore, the model pass the reinforcement check.

3.8 Design of columns

Check for axial stress As per IS 13920; Clause 6.1.1

The factored axial stress on the member under earthquake loading shall not exceed 0.1fck (=3 Mpa)The factored axial stress values for the most critical member of each model were noted down as follows;
Table 2: Axial stress values of most critical member of model.

Building Model	Axial Stresses (Mpa)
Model	4.01

The model do not satisty the above clause. However, IS 13920 specifies another clause for this case.

3.9 Design requirements

Which have axial stress in excess of 0.1$\boldsymbol{fck}$In the present study, the minimum dimension of the member provided is 500 mm. Also the shortest dimension provided is 500 mm. As per IS 13920; Clause 7.1.2, the minimum dimension of the member shall not be less than 200 mm. Hence the above clause is in fulfillment of the building models.

Two types of columns were provided in the present study.
Column 1 has a cross section of 400 X 700 mm while
Column 2 has 500 X 500 mm Column 1; 400/700 =0.57 > 0.4.
Column 2; 500/500 = 1 > 0.4

As per IS 13920; Clause 7.1.3,

The ratio of the shortest cross sectional dimension to the perpendicular dimension shall preferably not be less than 0.4. Hence, both the columns satisfy the clause. The column section shall be designed just above and just below the beam column joint, and largerof the two reinforcements shall be adopted. This is similar to what is done for design of continuous beam reinforcements at the support. The end moments and end shears are available from computer analysis.

The design moment should include:
(a) The additional moment if any, due to long column effect as per clause 39.7 of IS 456:2000.
(b) The moments due to minimum eccentricity as per clause 25.4 of IS 456:2000. The longitudinal reinforcements are designed as per IS 456 : 2000
3.10 Reinforcement check
Design was carried out by the software and pt values for critical members were noted down as follows;
Table 3: pt values of most critical member of model

Building model	Pt value
Model	2.16

As per IS 456 : 2000; Clause 26.5.3.1(a) the cross sectional area of longitudinal reinforcement, shall not be less than 0.8 % nor more than 6 % of the gross cross sectional area of the column. It should be noted that percentage of steel should not exceed 4 % since it may involve practical difficulties. Therefore, the model pass the reinforcement check.

A. Methods for Seismic analysis of buildings may beclassified as follows:

1) Equivalent Static Analysis (Linear Static)
2) Response Spectrum Analysis (Linear Dynamic)

3) Pushover Analysis (Nonlinear Static)
4) Time History Analysis (Nonlinear Dynamic)

EQUIVALENT STATIC ANALYSIS

In Equivalent static analysis it is assumed that the structure responds in its fundamental mode. The response is read from a design response spectrum, given the natural frequency of the structure. This method works well for low to medium-rise buildings without significant coupled lateral–torsional modes, in which only the first mode in each direction is of significance.

IV. EXPERIMENTAL SET UP

A shear wall is a wall that is used to resist the shear,produced due to lateral forces. Many codes made the shear wall design for high rise buildings a mandatory. Shear walls are provided when the centre of gravity of building area and loads acted on structure differs by more than 30%. To bring the centre of gravity and centre of rigidity in range of 30%, concrete walls are provided i.e. lateral forces may not increase much. These shear walls start at foundation level and extend throughout the building height. The thickness of the shear wall may vary from 150mm to 400mm. Shear walls are oriented in vertical direction like wide beams which carry earthquake loads downwards to the foundation and they are usually provided along both width and length of the buildings. Shear walls in structures located at high seismic regions require special detailing. The construction of shear walls is simple, because reinforcement detailing of walls is relatively straight forward and easy to implement at the site. Shear walls are effective both in construction cost and effectiveness in minimizing earthquake damage to the structural and nonstructural elements also.

1. Shapes or Geometry of Shear

Walls Shear walls are rectangle in cross section, i.e. one dimension is much larger than the other. While rectangular cross-section is frequent, L- and U-shaped sections are also used. Thin-walled hollow RC shafts around the elevator core of the structure also act as shear walls, and should be taken advantage of to resist earthquake forces. The Shear Wall sections are classified as six types.

(a) Box Section
(b) L – Section
(c) U – Section
(d) W – Section
(e) H - Section
(f) T – Section

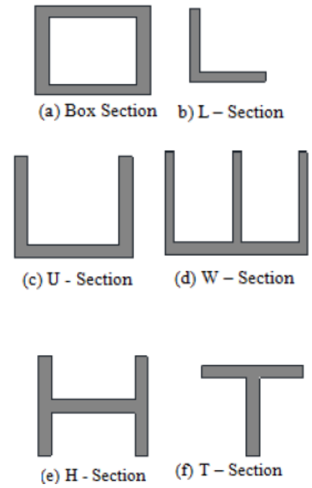


Figure 8: Different shapes or geometries of shear walls

2. Classification according to behaviour

Shear walls can also be classified according to their behaviour also, they are as follows:
a) Shear-shear walls in which strength and deflection are controlled by shear. These types of shear walls are usually constructed in low rise buildings.
b) Ordinary moment shear walls in which deflection and strength are controlled by means of flexure. These are generally used in high rise buildings to resist high winds and cyclones.
c) Ductile moment shear walls are special walls meant for seismic regions and which have good energy dissipation characteristics under reversed cyclic loads.

3. Components of Shear Walls

Reinforced concrete and reinforced masonry shear walls are seldom-simple walls which esist the lateral forces. Whenever a wall has doors, windows, or other openings, the wall must beconsidered as an assemblage of relatively flexible components like column segments and wall piers and relatively stiff elements like wall segments.

a)Column segments:

A column segment is a vertical member whose height exceeds three times its thickness and whose width is less than two and one-half times its thickness. Its load is usually mainly axial. Although it may contribute little to the lateral force resistance of the shear wall is rigiditymust be considered. When a column is built integral with a wall, the portion of the column that project from the face the wall is called a pilaster. Column segments shall be designed according to ACI 318 for concrete.

b)Wall piers:

A wall pier is a segment of a wall whose horizontal length is between two and one-half and six times its thickness whose clear height is at least two times its horizontal length.

c) Wall segments:
Wall segments are components of shear wall that are longer than wall piers. They are the primary resisting components in the shear wall.

4. Seismic Weight

The seismic weight of a structure is the sum of seismic weight of all the floors in the structure. The seismic weight of every floor is the sum of its full dead load and appropriate amount of imposed load, the latter being that element of the imposed loads that may sensibly be pected to be attached to the structure at the time of earthquake movement. It includes the weight of permanent and movable partitions, permanent equipment, a part of the live load, etc. While computing the seismic weight of walls and columns in any storey shall be equally distributed to the floors above and below the storey.

5. Equivalent Static Method

The equivalent static method of finding lateral forces is also known as the static method or the seismic coefficient method. This method is the simplest one and it requires less computational attempt and is based on formulae given in the code of practice. In all the methods of analyzing a multi storey buildings recommended in the code, the structure is treated as discrete system having concentrated masses at floor levels which comprise the weight of columns and walls in any storey should be equally distributed to the floors above and below the storey. In addition, the suitable amount of imposed load at this floor is also lumped with it. It is also assumed that the structure flexible and will deflect with respect to the position of foundation; the lumped mass system reduces to the solution of a system of second order differential equations. These equations are formed by distribution of mass and stiffness in a structure, together with its damping characteristics of the ground motion.

6. Design Seismic Base Shear

The design seismic base shear or total design lateral force (VB) along any principal direction shall be determined by the following expression:

VB = Ah X W

Where, Ah = Design horizontal acceleration spectrum value using the fundamental natural period „T" in the considered direction of vibration

W = seismic weight of the building

$$A_h \;= \frac{Z\,I\,S_A}{2\,R_g}$$

The Ah shall be determined by the following expression:
Provided that for any building with T less than 0.1s, the value of Ah shall not be taken less than Z/2 whatever be the value of I/R. Where,
Z = Zone factor is determined from the following table

Seismic Zone	II	III	IV	V
Seismic intensity	Low	Moderate	Severe	Very severe
Z	0.10	0.16	0.24	0.36

Zone factor given in the above table is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE).

I = I represents the importance factor and it depends upon the functional use of the structures. It is characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value or economic importance. 1.5 is considered for the important structures like hospitals, schools, monumental buildings etc. and the rest of the buildings it is taken as 1. R = It is Response reduction factor which depends on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations of the structure. This ration should not be greater than one. The values for

R are given in Table 7 of IS: 1893. The value for R varies between 3 and 5 with respect to ductile reinforcement detailing.

Sa/g = Average response acceleration coefficient as per clause 6.4.5 of IS 1893:2002 as given by below figure and it is based on the damping and the natural periods of the structures.

7. Time Period

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

T_a = $0.075h^{0.75}$
T_a = $0.085h^{0.75}$

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.

$$T = \frac{0.09\,H}{\sqrt{d}}$$

Where,

H = Height of building in meters (This excludes the basement storey, where basement walls are connected with the ground floor deck or fitted between the columns. But, it includes the basement storey, when they are not connected).

D = Base dimensions of the building at the plinth level, in m, along the considered direction of the lateral force.

4. Results and Discussions Building With Shear Walls Provided At The Centre Core And At The Center Of Each Side Of The External Perimeter With Openings.

Table 4: Storey Maximum Displacement in X and Y directions

4.2 Stress Distribution The stress distribution in shear walls is represented diagrammatically for the models. The stress distribution for shear walls located in the external periphery of the plan of building is studied.

8. Stress distribution in Model

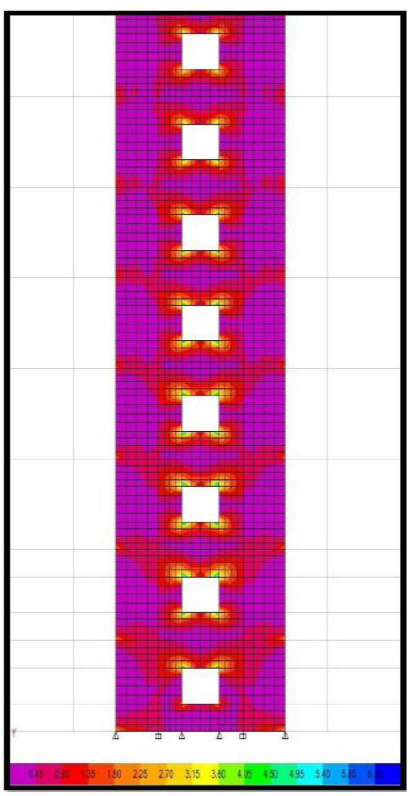


Figure 10: (a) Stress distribution in Model

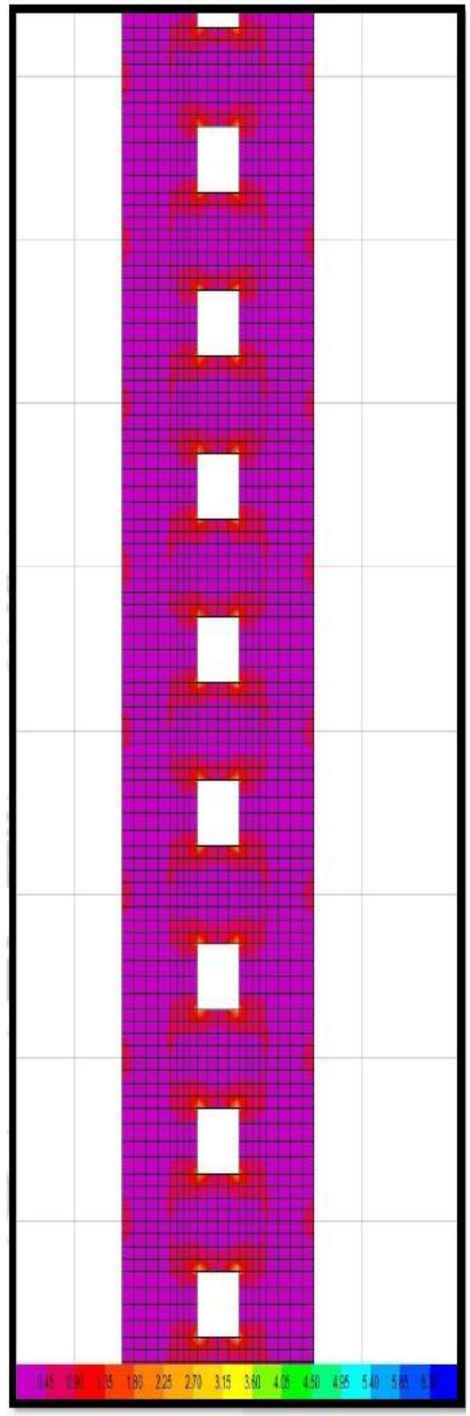
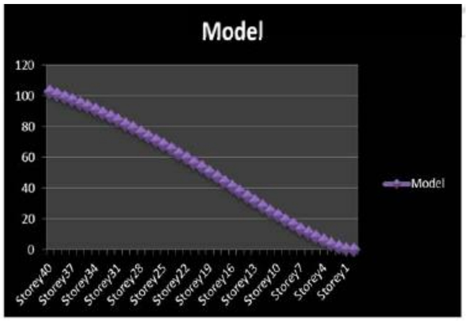


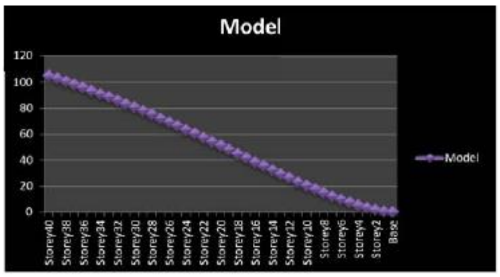
Figure 11: (b) Stress distribution in Model

The variation of stress distribution in this case is 0.45 MPa to 6.30 MPa. The concentration of stress is more at the corners of the openings only. Arresting the high induced stresses at the corners would ensure a low level stress distribution across the shear wall at all storie.

A plot for Displacement at 40 storey levels for the models has been shown here

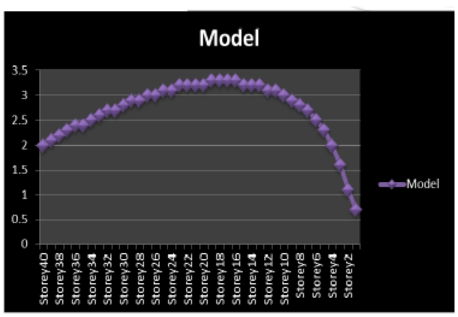


Graph 1: Displacements at various storeys(X-dir)

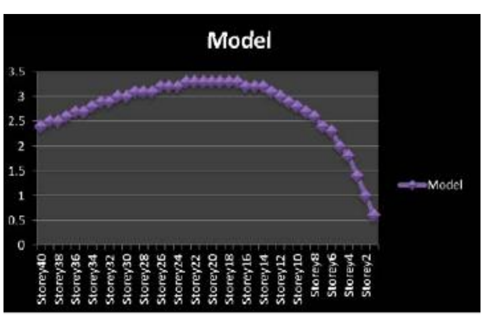


Graph 2: Displacements at various storeys (Y-dir)

The maximum store displacements is less than 5 % i.e, well within the engineering limits. So, it can be safely assumed that displacement wise, the openings provided in shear walls are effective to the extent of shear walls without openings.



Graph 3: Drifts at various storeys (X-dir)



Graph 4: Drifts at various storeys(Y-dir)

As per Indian standard, Criteria for earthquake resistant design of structures, IS 1893 (Part 1) : 2002, the story drift in any story due to service load shall not exceed 0.004 times the story height.

as per IS 1893 (part 1) : 2002 is 0.004 X 3 m = 12 mm. The maximum drift in the models is 6 mm which is well within the limits. 4.4 Base Shears .

Table 6: Base shears in X direction.

Model	Base shears in X (kn)
Model	3599.06

Table 7: Base Shears in Y direction

Model	Base shears in Y (kn)
Model	3676.988

4.5 Modal Results Table 8: Modes and natural periods

Case	Mode	Model
		Period (sec)
Modal	1	4.894
Modal	2	4.875
Modal	3	3.117
Modal	4	1.421
Modal	5	1.36
Modal	6	0.918
Modal	7	0.714
Modal	8	0.657
Modal	9	0.462
Modal	10	0.452
Modal	11	0.407
Modal	12	0.318

According to IS-1893:2002 the number of modes to be used in the analysis should be such that the total sum of modal masses of all modes considered is at least 90 percent of the total seismic mass. Here the minimum modal mass is 93.12 percent.

V. CONCLUSION AND RECOMMENDATIONS

In this paper, reinforced concrete shear wall buildings were analyzed with the procedures laid out in IS codes. The intent of the paper was to investigate the seismic behaviour of Building With shear walls provided at the centre core and center of each side of the external perimeter with openings. From the above results and discussions, following conclusions can be drawn:

1) The location of shear walls in the outermost perimeter considerably reduces the effects of displacements and drifts.
2) Building with shear walls provided at the centre core and center of each side of the external perimeter with openings showed better performance in terms of

maximum storey displacements and storey drifts. Also, the base shear was found to be highest for this case. It was also found that this model exhibited high stiffness.

3) The concentration of stresses in shear walls increases when openings are provided. It was found that the maximum stress induced increased threefold due to openings.

4) The presence of openings in shear walls gave a result with a deviation of approximately 5% with that of shear walls without openings. As mentioned earlier only centre window openings are studied in this thesis. The displacements, drifts and also the base shear values were within the 5% range. So provision shear wall with openings helps to achieve economy.

5) 5.2 Recommendations Different assumptions and limitations have been adopted for simplicity in modeling the proposed structures. In reality, it might affect on results. Thus, all factors which may influence on the behaviour of the structures should be considered in the modeling. For the further study, to obtain the real responses of the structures, the following **recommendations** are made:

1) Since the study was performed for only one type of shear wall, the further investigations should be made for different types of shear walls.

2) Further investigations should be done for shear walls with different aspect ratio (h/L), in frame-shear wall structures.

3) A flexible foundation will affect the overall stability of the structure by reducing the effective lateral stiffness. So the soil structure interaction should be considered in further study.

4) Shear wall structure have been shown to perform well in earthquakes, for which ductility becomes an important consideration. Thus, further study should be made considering geometric and material non-linear behavior of the members concerned.

5) The study was performed for a damping ratio of 5% for the model. Further studies should be carried out for damping ratios of 10%, 15% and so on.

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