International Journal of Research in Advent Technology (IJRAT) Special Issue "ICADMMES 2018"
E-ISSN: 2321-9637
Available online at www.ijrat.org

A Dissertation on Analysis of Shear Wall

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Abstract – Reinforced concrete framed buildings are adequate for resisting both the vertical and the horizontal loads acting on them. However, when the buildings are tall, say, more than twelve storey's or so, beam and column sizes work out large and reinforcement at the beam-column junctions works out quite heavy, Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants; create powerful twisting (torsion) forces. These forces can literally tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints. Shear walls are especially important in high-rise buildings subject to lateral wind and seismic forces. This paper, completely dealt with the analysis of a shear wall under seismic loading. When shear wall is subjected to lateral load (seismic load) the base shear of the shear wall is calculated.

Keywords: Reinforced concrete frame, shear wall, earthquake, seismic loads
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I. INTRODUCTION

On the earth surface everyone is aware that many natural disasters such as earthquakes, Flood, tornadoes, hurricanes, drought, and volcanic eruption occur. Of all natural disasters the least understood and most destructive are earthquakes. The annual losses due to earth quack are very large in many parts of the world. They not only cause great destruction in terms of human casualties, but also have a tremendous economic impact on the affected area. Although the incident of earthquakes of destructives intensity have been confined to a relatively few areas of the world, the castrophic consequences of the new that have struck near centers of population have stressed on the need of provide adequate safety against this most terrible nature's quirks. Structural design of buildings for seismic load though is primarily concerned with structural safety during major earthquakes; serviceability and the potential for economic loss are also of concern. Earthquake is a random phenomenon whose magnitude and intensity cannot be predicted.

Obviously it is impossible to build an earthquake proof structure. The seismic analysis and design of buildings has traditionally focused on reducing the risk of life in the most severe earthquake. Building codes have developed their provisions on the historic performance of buildings and their deficiencies. They have developed provisions for life safety concerns, to prevent collapse under the most intense earthquake expected at a site during the life of a structure.

1. A TYPICAL DAMAGE CAUSED BY THE EARTHQUAKES

The consequences of severe earthquakes are the injury and loss of life of people, the cost of repair of damage to structures and contents, and the costs of disruption of business and other activities. Almost 9,000 people were killed around the world due to earthquakes during 1998, which is close to the long-term average of about 10,000 per year.

Fig.1 Damage Because Of Earthquakes.

1.B SEISMICITY AND SEISMIC ZONING MAPS:

The seismic zone maps are revised regularly to gain more knowledge on the geology, the seismo tectonics and the seismic activity in the country. The Indian standards provided the first seismic zone map in 1962,
which was later revised in 1967 and again in 1970. The map has been revised again in 2002, and it is now has only four seismic zones-II, III, IV and V. the areas falling in seismic zone I in the 1970 version of the map are merged with those of seismic zone II. Also, the seismic zone III as against in zone II in the 1970 version of the map. This 2002 seismic zone map is not the final word on the seismic hazard of the country, and hence there can be no sense of compliancy in this regard. The national seismic Zone Map presents a large-scale view of the seismic zones in the country. Local variations in soil type and geology cannot be represent at that scale. Therefore, for important projects, such as a major dam or a nuclear power plant, the seismic hazard is evaluated specifically for that site. Also for the purpose of urban planning for local variations in geology, local soil profile.

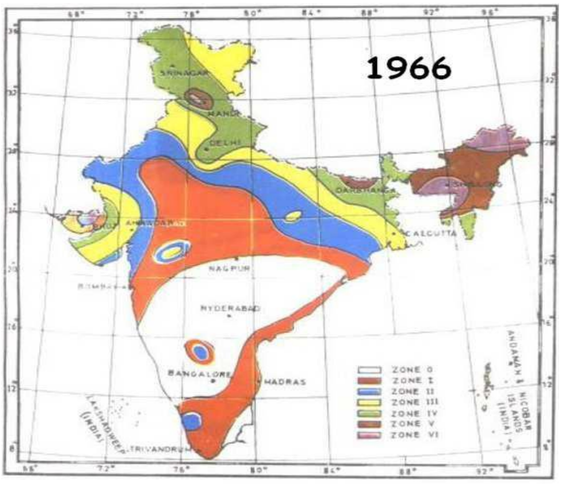


Fig 2 Seismic Zone Map of India in 1966

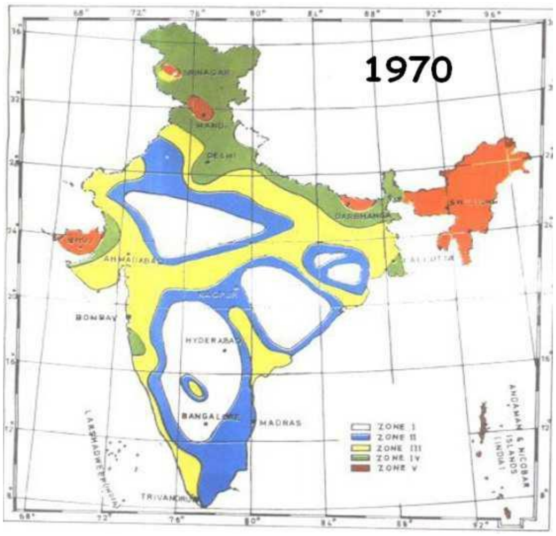


Fig 3 seismic zone map of India 1970

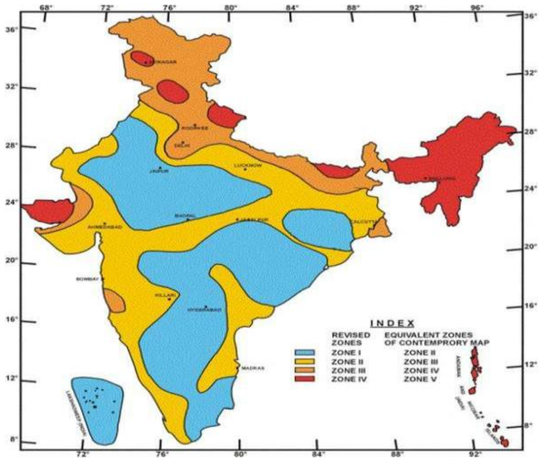


Fig 4 seismic zoning map of India in 2002

II VERTICAL LOAD BEARING MEMBER: Vertical load bearing members are structural elements primarily subjected to axial compressive forces and hence their design is guided by considerations of strength and buckling.. While pedestal, column and wall carry the loads along its length *l* in vertical load bearing direction, the strut in truss carries loads in any direction. The letters *l*, *b* and *D* represent the unsupported vertical length, horizontal least lateral dimension, and the horizontal longer lateral dimension respectively.

II.A COLUMNS

Column is a vertical load bearing member, the effective length of which exceeds three times the least lateral dimension. Column is an upright vertical load bearing member whose cross-sectional dimensions are small relative to its overall length. A vertical load bearing member is a structural element which is subjected (predominantly) to axial compressive forces. Columns are used in buildings to support the floor system and hence pick up the vertical load bearing live loads and dead loads from the floor and transfer them in the foundations. In framed structures, end moments are transferred into the columns from adjacent beams and floor systems. Large column moments and shearing action are produced by horizontal loads which is very important in the case of earthquake.

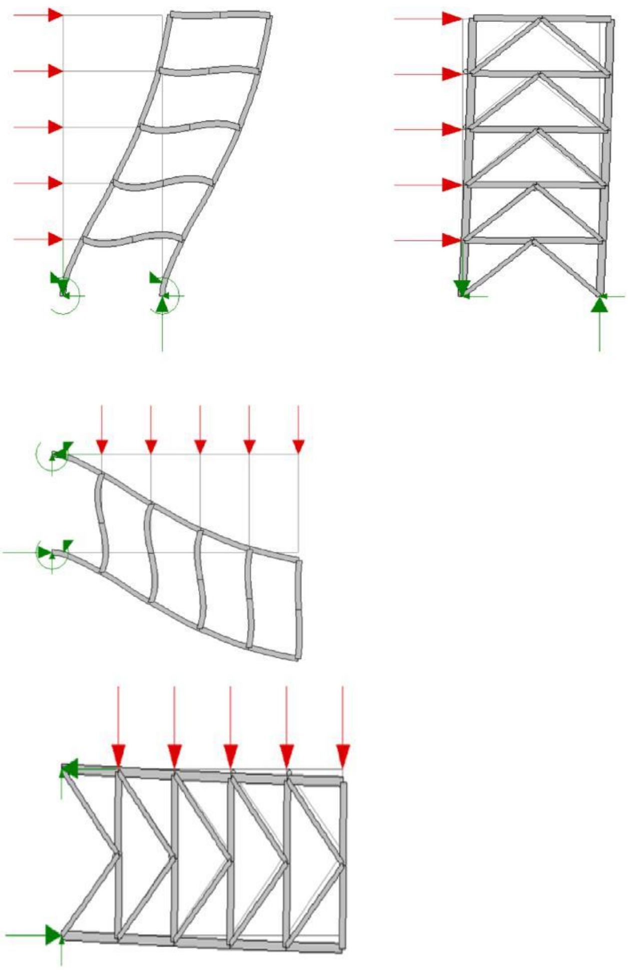
Based on Slenderness Ratios:

Columns are classified into the following two types based on the slenderness ratios:

(i) Short columns

(ii) Slender or long columns

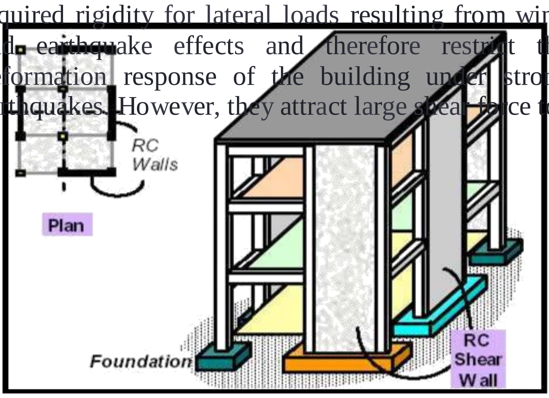
A vertical load bearing member may be considered as short when both the slenderness ratios l_{ex}/D and l_{ey}/b are less than 12, where l_{ex} = effective length in respect of the major axis, D=depth in respect of the major axis, l_{ey} = effective length in respect of the minor axis, and b = width of the member. It shall otherwise be considered as a slender vertical load bearing member.



Comparison of moment resisting frames and braced structures

III STRUCTURAL WALL (SHEAR WALL):

In high-rise buildings, Structural walls provide the required rigidity for lateral loads resulting from wind and earthquake effects and therefore restrict the deformation response of the building under strong earthquakes. However, they attract large shear force to



themselves. The basic criterion for earthquake resistant design is to satisfy strength, stiffness and ductility. These requirements can be satisfied with the provision of properly designed shear walls. Buildings braced by shear walls are invariably stiffer than framed structures. They reduce the excessive deformation under earthquakes. The necessary strength to avoid structural damage under moderate earthquakes can be achieved by proper provision of longitudinal and transverse reinforcement. During a severe earthquake, a shear wall that has very high strength may respond in a fully elastic manner. However, it is uneconomical to construct such walls. Ideally, structural walls should respond in a ductile manner. This can be achieved by proper detailing to make them capable of undergoing large inelastic deformations thereby dissipating seismic energy.

III.A Overall Behavior of Structural wall (shear wall):

Structural walls are like vertical load bearing oriented deep beams that transmit earthquake loads to the foundation (Fig 5). In the case of a solid shear wall, the external lateral loads are being resisted by conventional flexural stress, and shear stress in addition to gravity axial load *P*. Shear wall in buildings must be symmetrically located in plan to reduce ill effect of torsion in buildings. Shear walls are more effective when located along the perimeter of a building. Such a layout increases resistance of a building to torsion (Fig 6).

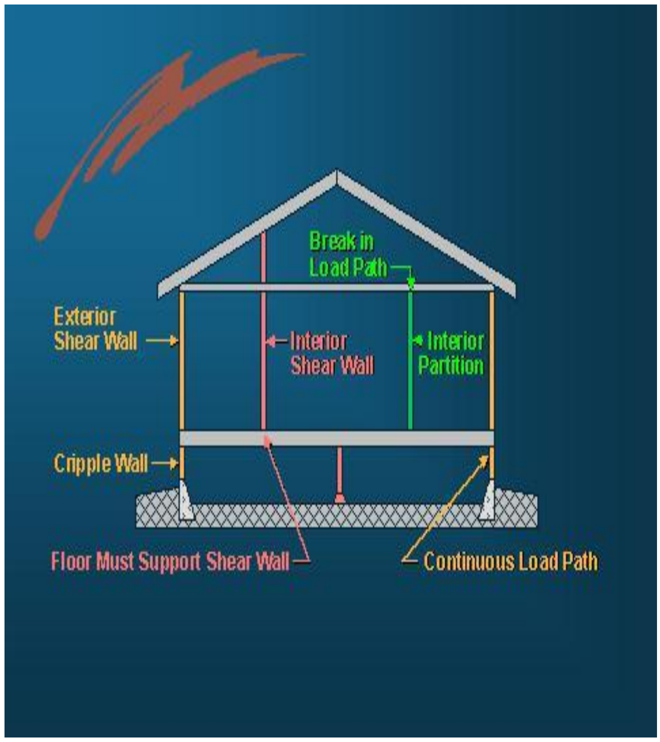


Fig 5 Reinforced concrete shear walls in buildings

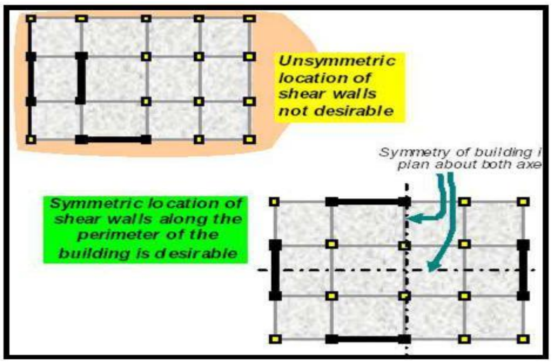


Fig 6 Orientation of shear wall

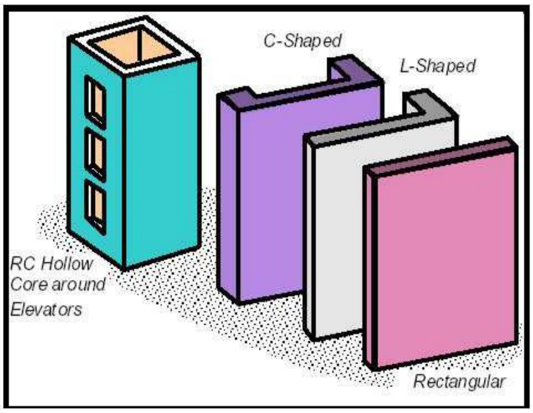
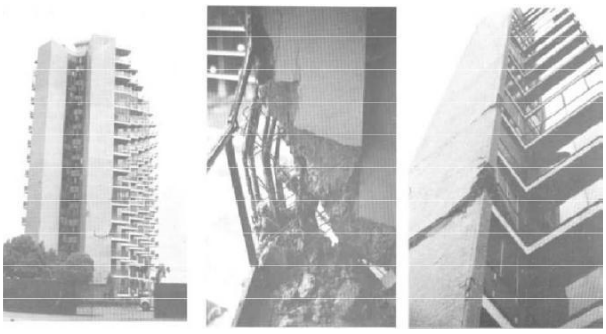


Fig 7 Different shapes of shear wall



Shear wall failure due to earth quake

III.B Why are Buildings with Shear Walls Preferred in Seismic Regions? Ductile Design of Shear Walls:

1.Just like reinforced concrete (RC) beams and columns, Reinforced concrete shear walls also perform much better if designed to be ductile.
2.Overall geometric proportions of the wall, types and amount of reinforcement, and connection with remaining elements in the building help in improving the ductility of walls.
3.The Indian Standard *Ductile Detailing Code* for RC members (IS:13920-1993) provides special design guidelines for ductile detailing of shear walls

III.C Reinforcement Bars in RC Walls:

CURTAINS:
The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called *curtains*.
1. Horizontal reinforcement needs to be anchored at the ends of walls.
2. The minimum area of reinforcing steel to be provided is *0.0025* times the cross-sectional area, along *each* of the horizontal and vertical directions.
3. This vertical reinforcement should be distributed uniformly across the wall cross-section.

IV METHODOLOGY

1)

IV.A Base shear :

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

$$V_b = A_h W \quad (4.1)$$

Here,
A_h = Design horizontal acceleration spectrum value using the fundamental natural period 'T' considered in the direction of vibration.
W = seismic weight of the building

$$A_h = \frac{Z}{2} \frac{I}{R} \frac{S_a}{g} \quad (4.2)$$

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.

2) The approximate fundamental natural period of vibration in seconds of all other, buildings including moment resisting frame buildings with brick infill panels

2 Seismic weight :

The seismic weight of building is the sum of seismic weights 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.

3) *IV.B 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 (IS 1893 (Part 1):2002 (Clause 7.6.1))

$T_a = 0.075h^{0.75}$ for RC frame building (4.3)

$T_a = 0.085h^{0.75}$ for steel frame building (4.4) may be estimated by the following expression. (IS 1893 (Part 1):2002 (Clause 7.6.2))

$$T_a = \frac{0.09\,h}{\sqrt{d}} \quad (4.5)$$

Where

H = Height of building in meters. (This excludes the basement stories where basement walls are connected with the ground floor deck or fitted between the columns. But it includes the basement stories, 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.

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:

$$Q_i = \frac{V_b W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \quad (4.6)$$

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 storey's in the building i.e., number of levels at which masses are located.

The distribution suggested in the code gives parabolic distribution of seismic forces such that seismic shears are higher near top storey's for the same base shear. The assumptions involved in the static procedure reflected in the expression are a)Fundamental mode of the building makes the most significant contribution to base shear, and
b)The total building mass is considered as against the modal mass that would be used in a dynamic procedure.
c)The mass and stiffness are evenly distributed in the building. Connected with the ground floor deck or fitted between the columns. But it includes the basement stories, when they are not connected)
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V ANALYSIS

V.A Load combinations

Geometrical Properties

1. No. of stories of the Building model = 3 (three)
2. Column Sizes: -
   A) Outer periphery columns = 400 mm x 400 mm
3. Beam Size = 300 mm x 300mm
4. Slab thickness = 100mm

Loads

1. Live load
   A) Corridor = 3 KN/m^2
   B) Floor = 2 KN/m^2
2. Dead Load (Floor Finishing) = 1.5 KN/m^2
3. Wall load:
A) 9'' = 12.4 KN/m
B) 41/2'' = 7 KN/m

2. Wind load:

A)Wind Exposure parameters
i)Wind direction angle = 0 Degree
ii)Windward coff. Cp = 0.8
iii)Leeward coff Cp = 0.5

B)Wind coefficients

i)	Wind speed	= 50 KN/m
ii)	Terrain category	= 2
iii)	Structure class	= B

iv) Risk coefficient (k1) = 1

v) Topography (k3) = 1

2.Seismic loading

i) Seismic zone factor (Z) = 0.16

ii) Soil Type = Medium (II)

ii) Response Reduction factor = 5%

CALCULATION OF DESIGN SEISMIC FORCE BY STATIC ANALYSIS METHOD:

Problem statement:

Consider a four storey reinforced concrete office building shown in fig 1.1. The building is located in Shillong (seismic zone v). The soil conditions are medium stiff and the entire building is supported on a raft foundation. The R.C frames are in filled with brick masonry. The lumped weight due to dead loads is 12KN/m^2 on floors and 10 KN/m^2 on the roof. The floors are to cater for a live load of 4 KN/m^2 on floors and 1.5 KN/m^2 0n the roof. Determine design seismic load on the structure as per new code.

SOLUTION:

DESIGN PARAMETERS:

For seismic zone v the zone factor z is 0.36 (As per table 2 of IS 1893). Being an office building, the importance factor, I, is 1.0(Table 6 of IS:1893). Building is required to be provided with moment resisting frames detailed as per IS: 13920-1993. Hence, the response reduction factor R, is 5.(Table 7 of IS:1893 Part 1).

Seismic weights:

The floor area is 15x20=300Sq m.Since the live load class is 4 KN/m^2, only 50% of the live load is lumped at the floors.At roof, no live load is to be lumped. Hence, total seismic weight on the floor and roof is:

FLOORS:

$W_1 = W_2 = W_3$ = 300 x (12+0.5x4).
= 4,200 KN.

ROOF:

W_4= 300x10
w=3000KN.

(Clause 7.3.1 Table 8 of IS 1893 Part 1) Total seismic weight of the structure , $W=\sum W_i$
=3x4,200+3,000
= 15,600 KN.

ADVANTAGES OF SHEAR WALLS IN RC BUILDINGS:

1.Properly designed and detailed buildings with shear walls have shown *very good* performance in past Earthquakes.

2. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarized in the quote: *"We cannot afford to build concrete buildings meant to resist severe earthquakes without shear walls."*

3.Mark Fintel, a noted consulting engineer in USA Shear walls in high seismic regions require special detailing.

4. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse.

5.Shear wall buildings are a popular choice in many earthquake prone countries, like Chile,New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily Implemented at site.

6. Shear walls are efficient, both in terms of construction cost and effectiveness in Minimizing earthquake damage in structural and non structural.

CONCLUSION

Base shear calculations are done for the three storied buildings for earthquake loads for Zone (II) following the IS 1893 provisions Base shear of the building: $V_B = A_{h\,x\,W}$ Where V_B = Base shear of the building A_h = Seismic coefficient, W = Seismic weight of the building. The V_B calculated is 1440 KN.

The present work deals with the analysis of a shear wall under seismic loading. When shear wall is subjected to lateral load(seismic load) the base shear of the shear wall is calculated.

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