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IMPLEMENTATION OF EARTHQUAKE RESISTANT NORMS IN ENGINEERED BUILDING CONSTRUCTION

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ABSTRACT

Earthquakes are a destructive force of nature that we cannot control and in such a situation, the main cause of failure of multi-storey multi-bay reinforced concrete frames during seismic motion is the soft storey sway mechanism or column sway mechanism. If the frame is designed on the basis of strong column-weak beam concept the possibilities of collapse due to sway mechanisms can be completely eliminated. The tall structures of the Shear wall are very well suited for construction in earthquake-prone areas and become economical when lateral forces affect the design and proportioning of the beam–column structures. The skyscrapers up to 163 story's have been built using shear walls.

The aim of the investigation of this study is the response of RCC Framed buildings with different plans by response spectrum method during an earthquake. Building with simple geometry in the plan has performed well during strong past earthquakes but Building with +,H,V,U and channel-shaped structures in the plan have sustained significant vertically irregular buildings frames.

An RCC-framed building of 10 storied with regular and irregular plans has been selected to explain the analysis of the coupling beam and shear wall as per the literature available on the coupled shear wall structure. The building is analyzed by using STAAD Pro V8i software with a shear wall. The result of the analysis is presented in terms of displacement, drift and moment. Under horizontal loading, the wall deflects and shears forces are induced in the coupling beam. The present analysis helps in understanding the behavior of coupling beams and shear walls rationally.

Keywords: Modeling by STAAD Pro, Special Moment Resisting Frames, Diff. types of Plans, Seismic Analysis.

1. INTRODUCTION

India has been proactive in addressing seismic threats through earthquake engineering advancements. The development of seismic zone maps and the implementation of earthquake-resistant features for buildings are crucial steps towards enhancing resilience. However, as you rightly point out, the escalating risk necessitates continued innovation and investment in earthquake preparedness.

Integrating earthquake-resistant design principles and construction techniques from the outset of a project is indeed vital. While achieving absolute earthquake-proof structures may be challenging, focusing on enhancing resilience can substantially reduce the impact of seismic events on both lives and infrastructure. Prioritizing seismic safety measures and leveraging advancements in earthquake engineering are pivotal strategies for protecting India's population and assets from the devastating effects of earthquakes.

India's long history of earthquake engineering, coupled with formal teaching and research dating back to the late 1950s, provides a solid foundation for further progress. However, recent moderate earthquakes resulting in significant loss of life highlight the pressing need for continuous improvement and adaptation to evolving seismic risks. By remaining proactive and innovative in earthquake preparedness efforts, India can better mitigate the potential impact of future seismic events.

Reinforced Concrete (R.C.C) shear walls are structural elements designed to resist lateral loads such as wind, seismic forces, or other horizontal forces. They are an integral part of building systems, particularly in regions prone to earthquakes.

Shear walls can be classified based on various criteria:

Based on Location:

Exterior Shear Walls: These are located at the perimeter of a building and often contribute significantly to the building's lateral resistance.

Interior Shear Walls: Positioned within the building's interior, these walls also provide lateral resistance but might have different design considerations compared to exterior walls.



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Based on Shape:

Rectangular Shear Walls: These are straight walls with a rectangular cross-section.

T-Shaped Shear Walls: These walls have a T-shaped cross-section and are often used at building corners or other locations where additional stiffness or strength is needed.

L-Shaped Shear Walls: Similar to T-shaped walls, these have an L-shaped cross-section and are used in corners or intersections of buildings.

Based on Structural System:

Coupled Shear Walls: These are shear walls closely spaced and interconnected by beams or slabs to form a structural unit.

Uncoupled Shear Walls: These are independent walls without significant horizontal connections, each providing lateral resistance individually.

Based on Material:

Reinforced Concrete Shear Walls: These are made of reinforced concrete and are the most common type.

Steel Shear Walls: These walls are made of steel, offering high strength and ductility but are less common in traditional construction compared to reinforced concrete.

Based on Behavior:

Flexural Shear Walls: These walls primarily resist lateral loads through flexural action, where bending moments develop in the wall due to lateral forces.

Axial Shear Walls: These walls primarily resist lateral loads through axial action, where shear forces are resisted by the axial strength of the wall.

Based on Boundary Conditions:

Fixed Shear Walls: These walls are rigidly connected to the foundation and roof, providing maximum resistance to lateral loads.

Pinned Shear Walls: These walls are allowed to rotate at their base, offering less resistance compared to fixed shear walls but are easier to construct.

Each classification has its advantages and is chosen based on the specific requirements of the structure, the prevailing building codes, and the environmental conditions of the location.

2. LITERATURE REVIEW

Coull and Choudhary [1] gave one simple method of analysis which was produced by assuming that the discrete system of connections, formed by lintel beams or floor slabs, may be replaced by an equivalent continuous medium. By assuming that the cross beams have a point of contra flexure at mid span, and do not deflect axially, the behavior of the system can be expressed as a single second order differential equation, enabling a general closed solution to the problem to be obtained. Experiments on model structures yield results in good agreement with the values given by the theory. Developed a technique in which the beams formed by vertically arranged uniform openings in a wall were replaced by infinitesimal elastic laminas of an equivalent stiffness. The analogy permitted the solution to be reduced to a differential equation which yielded the required static quantities, displacement, rotations, or stresses as a continuous function of distance from the top or bottom of the structure.

Heidebrecht and Swift [2] presented a method of analysis which was not restricted to planar walls, nor to walls connected by rigid diaphragms. A matrix stiffness method was used in which a shear wall element was developed based on thin walled beam theory. The connecting beams were considered as slender elastic members with full capacity to develop axial, flexural, shear and torsional resistance.

3. RESULT AND DISCUSSION

Calculation of Coupling Ratio

In STAAD Master, just base shear (V),) is gotten. Shear at each floor is determined physically as underneath:

$$Q_i = \frac{W_{i h_i^2}}{\sum W_{i h_i^2}}$$

Where,

Qj=lateral force at floor I,

Wi= seismic load at floor I,



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H_i =height estimated from the foundation of story. For a two-wall framework, the coupling proportion is characterized as:

$$CR = \frac{L \sum V_{beam}}{L \sum V_{beam} + \sum m_i} \frac{-L \sum V_{beam}}{OTM} \quad \dots$$

Structural engineering concepts related to coupled shear walls and coupling beam design. The equations and explanations provided suggest an analysis of how coupling beams distribute shear forces between coupled walls based on the coupling ratio (CR). Here's a breakdown of the provided information:

Vbeam is the accumulation of coupling beam shears acting at the edge of one wall.

L is the lever arm between the centroids of the wall.

mi is the overturning moment resisted by wall i.

And you've described three scenarios based on the coupling ratio (CR):

a) **CR** = 0: This implies that coupling beams develop no end moments, suggesting either the absence of beams or that they are pinned links, resulting in no coupling action.

b) CR = 50%: In this scenario, the coupling action resists half of the imposed overturning moments, while the remaining half is resisted by individual wall pier moment reactions.

c) CR = 100%: This represents the theoretical case where the two wall piers effectively behave as a single pier, with the length of the coupling beam trending towards zero.

Based on research by El-Tawil et al. (2002b), coupling ratios ranging from 30% to 45% performed optimally in terms of structural performance and economy, requiring less steel and concrete materials.

You mentioned a formula for obtaining the coupling beam shear force (Vbeam), but it seems that the formula is missing. If you provide the formula, I can help you understand how to calculate the coupling beam shear force.

$$V_{beam} = W \frac{H}{l} x \frac{1}{\mu} x k_3 x h'$$

w=weight of the shaft at which we are working out the V beam.

H=Total level of the structure.

h'=story level.

k3=is acquired from fig and furthermore rely on worth of (1-x/H)

$$\mu = 1 + \frac{AI}{A_1 A_2 l^2}$$

Where,

l= Distance between the centroid tomahawks of walls

I=Moment of inactivity of the wall

A1=Cross sectional region of the wall 1.

A2=Cross sectional region of the wall 2



Figure 1: Variation of connecting beam stress factor K_3 for triangular distributed load



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Discussing structural engineering principles related to shear forces and bending moments in beams likely represents a mathematical expression for determining the intensity of shear forces in a continuous connecting medium, and graph1 likely provides data or a curve from which coefficients are obtained.

To summarize your statements:

- 1. The intensity of shear forces in the equivalent continuous connecting medium is the coefficient required in equation is obtained from graph1.
- 2. The shear force in any particular beam is calculated by finding the area underneath the curve between half-storyheight levels above and below the beam position.
- 3. The given curves enable the maximum value of the shear force to be determined easily.
- 4. The maximum bending moment in any connecting beam is then calculated using the formula 1/2Qb, where Q is the shear force and b is the width of the beam.

These principles are fundamental in analyzing and designing structural elements to ensure they can withstand the loads placed upon them safely. If you need further clarification or assistance with any specific aspect.

Analysis of Coupling Beam:

a. First of all we calculate the coupling ratio (CR) according to equation 3.1.

- b. Now calculate the over turning moment (OTM) according to method mention above.
- c. Now calculate the Tension (T) and Compressive (C) forces in coupling beam according to formula:

$T/C = \frac{CR \times OTM}{L}$

Where, L is centroid distance between the walls.

Flexibility is the capacity of a material to go through twisting after its underlying yield with no critical decrease in yield strength.

The elements which influence the pliability of a design are as per the following :-

a) The Flexibility increments with expansion in shear strength of cement for little hub compressive pressure between 0-1 MPa. The varieties is straight in nature.

b) The Flexibility differs straightly up to the moment that pivotal compressive pressure becomes equivalent to the compressive pressure at adjusted disappointment.

c) The Flexibility figure increments with increment extreme kind of cement. Accordingly repression of substantial increments flexibility.

d) The malleability increments with expansion in substantial strength and diminishes with the expansion in yield strength of steel.

e) The impact of sidelong support is to upgrade the malleability by forestalling the shear disappointment .It additionally controls the pressure support from clasping.

Calculation and Software Analysis

Regular Section





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Table 1: Calculation of seismic weights of Regular section.

Weight of Brick wall	0.12 x 4 x (30-15-2 x 0.5) x (3-0.6) x 20 = 322.56
Weight of primary beam at each floor	32 x7.5x0.5 x 0.6 x 25 = 1800 KN
Weight of secondary beam at each floor	16 x 7.5 x 0.35 x 0.45 x 25 = 472.5 KN
Weight of column for each floor	21 x 3 x 0.5 x 0.5 x 25 =393.75 KN
Weight of shear wall at each floor	4 x [14.5 x 1 x 0.25 x 25 + 10 x 2 x0.25 x 25] = 862.5 KN
Weight of slab for each floor	30.5 x 30.5 x 0.14 x 25 = 3255.88 KN
Live Load coming on each floor	30.5 x 30.5 x 3 x 0.25 = 697.7 KN

Wi= 322.56+ 1800+ 472.5+ 393.75+ 862.5+ 3255.88 =7107.19 KN

Similarly, W1=W2=W3=W4=W5=W6=W7=W8=W9=7107.19 KN

Dead weight of columns and walls for the top floor

 $\frac{393.75}{2} + \frac{322.56}{2} + 0.85(197/1.5) + 28.5x4x0.12x0.85x20 = 702.5 \text{ KN}$

Dead weight of shear wall =362.5/2 = 431.25 KN

So, Lumped mass at floor W10 = 2272.5+3255.88+702.5+431.25 = 6662.13 KN.

For regular structure

Table 2 Story shears and Lateral forces for Regular Section

Storey	Wt. of Floor (KN)	Ht. (m)	$W_i \mathbf{x} h^2_i$	Storey Shear (KN)	FxH (KNm)
0	7107.19	0	0	0	0
1	7107.19	3	63964.71	6.904511177	20.7135335
2	7107.19	6	255858.84	27.61804471	165.708268
3	7107.19	9	575682.39	62.14060059	559.265405
4	7107.19	12	1023435.4	110.4721788	1325.66615
5	7107.19	15	1599117.8	172.6127794	2589.19169
6	7107.19	18	2302729.6	248.5624024	4474.12324
7	7107.19	21	3134270.8	338.3210477	7104.742
8	7107.19	24	4093741.4	441.8887153	10605.3292
9	7107.19	27	5181141.5	559.2654053	15100.1659
10	6662.13	30	5995917	647.2143146	19416.4294
			$\Sigma = 24225859$		$\Sigma = 61361.3348$

Overturning moment (OTM) = 61361.33 KN





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Calculation of Coupling Ratio (CR)

$$\mu = \mathbf{1} + \frac{A1}{A1A2l2}$$

 A_1 = area of wall 1 = 2.25x.25=0.5625m² A_2 = area of wall 2 =2.25x.25=0.5625m² $A = A_1 + A_2 = 0.5625 + 0.5625 = 1.125m^2.$ $l_1 = l_2$ = Moment of inertia of each wall $= \frac{1}{12} \times 250 \times 2250^3 = 2.37 \ 3 \times 10^{11} \ mm^4$ $I = l_1 + l_2 = 4.746 \text{ x } 10^{11} \text{ mm}^4$ $\mu = 1 + \{ (1.125 \text{ m}^2 \text{ x} 2.373 \text{ x} 10^{11} \text{ mm}^4) / (0.5625 \text{ m}^2 \text{ x} 0.5625 \text{ m}^2 \text{ x} 9500 \text{ mm} \text{ x} 10^6) \}$ Base moment of regular sectioned calculated from STAAD Pro. M = 61361.33 KN, $M = (WH^2/3),$

 $W = (3M/H^2)$, W = 204.54 KN



Figure. 4: Equivalent Load on Coupled shear wall for Regular Section Table 3: Shear and Moment in Coupling beam

Beam No.	h'(m)	x(m)	(1-x/H)	К3	Qi(KN)	moment(KN-m)
0	1.5	28.5	0.05	0.06	58.679	132.0274481
1	3	27	0.1	0.13	254.28	572.1189417
2	3	24	0.2	0.23	449.87	1012.210435
3	3	21	0.3	0.27	528.11	1188.247033
4	3	18	0.4	0.285	557.45	1254.260757
5	3	15	0.5	0.275	537.89	1210.251607
6	3	12	0.6	0.225	440.09	990.2058606
7	3	9	0.7	0.235	459.65	1034.21501
8	3	6	0.8	0.215	420.53	946.1967112
9	3	3	0.9	0.18	352.07	792.1646884
10	1.5	1.5	0.95	0.17	166.26	374.0777695
					∑= 4224.9	∑= 9505.976261



Coupling Ratio (CR) = $\frac{L \sum V beam}{OTM} x 100 = \frac{9.5x3116.297}{61361.33} x 100 = 48\%$ Cross Section :



Figure 6: Plan view of the Cross Section

Table 4 : Calculation of Seismic Weights of Cross Section.

Weight of brick wall	0.12x4x (30- 15-2x0.5) x (3 - 0.6) x20 =322.56 KN
Weight of primary beam at each floor	24x7.5x0.5x0.6x25 =1350 KN
Weight of secondary beam at each floor	12x7.5x0.35x0.45x25 =354.38KN
Weight of columns for each floor	17x3x0.5x0.5x25 =318.75KN
Weight of shear wall at each floor	4x [14.5x1x0.25x25+10x2x0.25x25] -862.5KN
Weight of slab for each floor	30.5x30.5x0.14x25-4(7.5X7.5X.14X25) =2468.38KN
Live load coming on each floor	[(30.5x30.5)-(4X7.5X7.5)] x3x0.25 =528.94KN

W1=322.56+1575+354.38+318.75+862.5+2468.38+528.94=6205.51 KN

W1=W2=W3=W4=W5=W6=W7=W8=W9= 6205.51 KN

Dead weight of columns and walls for the top floor

$$= \frac{318.75}{2} + \frac{322.56}{2} + 0.85(\frac{197}{1.5}) + 28.5x4x0.12x0.85x20 = 664.88 \text{ KN}$$

Dead wt. of shear wall =
$$\frac{862.5}{2}$$
 = 431.25 KN

So, Lumped mass at floor W10 = 1350+354.38+2468.38+664.88+431.25=5268.89 KN

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4. CONCLUSION

The following broad conclusions can be drawn on Based on the limited study in this investigation

- ◆ For RCC framed building with shear wall and columns system, almost entire lateral load due to earthquake is taken by shear walls.
- \div The moments and shears induced in the coupling beam are mainly due to earthquake loading and moments and shears due to DL and IL are very small.
- The analysis proposed can be used to calculate the shear force and end moment in the coupling beams. *
- * The structural action on a coupling beam resulting from earthquake lateral loads on the wall is to cause differential movement between the supporting ends. As a result of flexural deformation, the reinforcement should consist of equal area of steel in the top and bottom.
- * Regular buildings with plan performed well during earthquake as compared to buildings with irregular plan.
- ◆ For performance with plan irregular, it was observed that Cross (+) Section structure performed better than Channel Section.
- ✤ For regular building in plan, shear wall can be curtailed at 40-50 percent of height above base. For irregular plan shapes the curtailment of shear wall will be at 50-60 percent of height above base.
- * There is a lack of awareness in the earthquake disaster mitigations. Avoiding non-engineered structures with unskilled labor even in unimportant temporary constructions can help a great way.

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