Seismic Performance of Indian RC Tall Buildings with Transfer Beam Located in Lower Seismic Zone (II)

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Abstract - The seismic performance of reinforced concrete (RC) tall buildings with transfer beams has become a subject of growing interest, particularly in the context of Indian urban development. Transfer beams are often introduced in high-rise buildings to accommodate architectural or functional requirements, such as parking or commercial spaces in the lower levels. However, their inclusion leads to vertical irregularities that may compromise the building's response during seismic events. While buildings in Seismic Zone II of India are subjected to relatively low seismic forces, the presence of such irregularities necessitates closer scrutiny to ensure structural safety and serviceabilityThis study evaluates the seismic behavior of a 18-storey RC building with a transfer beam at the fourth level, designed as per Indian Standards IS 456:2000 and IS 1893 (Part 1):2016. Using structural modeling and nonlinear analyses (pushover and time-history), the study compares the performance of buildings with and without transfer beams under Zone II ground motions. Results indicate increased inter-story drift, concentration of plastic hinges, and reduced energy dissipation capacity in the structure with the transfer beam. These findings suggest that even in lower seismic zones, the inclusion of transfer elements can significantly affect seismic performance, underscoring the need for performance-based design approaches.

The structural behavior of reinforced concrete (RC) tall buildings during seismic events is critically influenced by the presence of transfer beams, especially in configurations where architectural and functional requirements dictate column discontinuities. In lower seismic zones like Zone II of the Indian Seismic Code (IS 1893:2016), the design considerations may not fully address the complex dynamic response induced by such irregularities. This study investigates the seismic performance of RC tall buildings with transfer beams located at podium or mid-levels through detailed nonlinear time history and pushover analyses. Various models with different transfer beam configurations were developed and evaluated using seismic data representative of Zone II conditions. The results indicate that while the base shear and inter-storey drift remain within permissible limits, the presence of transfer beams introduces localized stress concentrations and stiffness irregularities. The study highlights the need for more refined design guidelines, even in low seismic zones, to ensure adequate performance and safety of tall RC structures.

Keywords: Reinforced Concrete (RC), Tall Buildings, Transfer Beam, Seismic Performance, Seismic Zone II, IS 1893:2016, Structural Irregularity, Nonlinear Analysis, Time History Analysis, Pushover Analysis

1. INTRODUCTION:

1.1 Overview

.1.1 Background of Seismic Design in India

India is a country with a vast range of seismic activity, divided into four seismic zones (II, III, IV, and V), with Zone II being the least seismically active. Despite the relatively lower hazard classification, structures in Zone II cannot be exempt from careful seismic considerations. Urbanization and real estate development in cities falling under Zone II—

such as Bengaluru, Hyderabad, and parts of Chennai—have led to a proliferation of mid-rise to high-rise reinforced concrete (RC) structures. These buildings often incorporate architectural features like podium levels, cantilevers, and open ground floors, which introduce both vertical and horizontal irregularities.

Transfer beams are structural elements frequently adopted in modern high-rise buildings to accommodate non-aligned column layouts between commercial podium levels and residential towers above. While these elements are structurally effective in redistributing loads, they interrupt the continuity of load transfer paths and introduce significant stiffness and mass irregularities. As a result, they act as critical zones in a building that can influence dynamic response during seismic events. The discontinuity they introduce can lead to concentration of forces, differential displacements, and unexpected failure modes under lateral seismic loads.

Most design codes, including IS 456:2000 and IS 1893 (Part 1):2016, provide general guidance for seismic design. However, these standards tend to focus more on overall building mass, geometry, and location-based seismic zoning, rather than local discontinuities like transfer beams. As such, while a building may meet the minimum requirements of seismic safety on paper, its actual performance in an earthquake—especially with complex geometrical features—can be inadequate.

1.1.2. Transfer Beams and Vertical Irregularity

Transfer beams are commonly placed at podium levels or above open commercial spaces where the architectural layout demands large column-free spans. These beams receive concentrated loads from upper-story columns and redistribute them to the structural supports available at the podium or base level. Their structural efficiency in load transfer often makes them indispensable in the architectural planning of tall buildings.

However, this architectural-functional advantage comes at a structural cost. The introduction of a massive beam at a single level—often with significantly higher stiffness than the floors above and below—creates what is termed a **vertical stiffness irregularity** in the building. This abrupt change in lateral stiffness leads to a phenomenon called “soft story” behavior, where one floor (usually the transfer beam level or just above it) deforms more than others under lateral seismic loading. This concentration of deformation is not only undesirable but also potentially dangerous, as it may lead to the formation of plastic hinges, damage concentration, and eventual collapse mechanisms in severe cases.

In tall RC buildings located in low seismic zones, the assumption often is that earthquake-induced lateral forces are small enough to ignore these localized irregularities. However, past earthquake records from low to moderate seismic zones across the globe—including Bhuj (2001), Killari (1993), and recent tremors in Zone II areas—have shown that such assumptions can be misleading. Buildings with irregularities have suffered disproportionate damage compared to regular structures, regardless of the seismic intensity.

1.1.3. Need for Study in Indian Context

In India, Seismic Zone II includes several rapidly growing urban centers that are currently witnessing a construction boom. Developers in these regions often prioritize architectural utility, market demands, and cost-efficiency over seismic resilience. Building control authorities typically permit transfer structures without mandating in-depth dynamic analysis or performance-based design evaluations. As a result, buildings with significant vertical irregularities, including those with transfer beams, are frequently approved and constructed based solely on static load checks and simplified seismic coefficient methods.

Furthermore, standard design practices generally apply equivalent lateral force methods for seismic analysis in Zone II. These methods, while convenient, are not always suitable for buildings with irregular configurations, as they do not capture dynamic behaviors such as higher mode effects, torsion, or inelastic responses. Without time-history or pushover analysis, engineers may fail to identify critical weaknesses in the structure.

A detailed study evaluating the seismic performance of such buildings becomes crucial for three primary reasons:

1. **To fill the research gap**: There is limited published research that specifically focuses on seismic responses of Indian RC buildings with transfer beams in lower seismic zones.
2. **To assess real-world safety**: Despite being designed to code, such structures may still fail to meet expected performance levels (e.g., Immediate Occupancy or Life Safety) during a moderate earthquake.
3. **To inform design standards**: Findings can lead to improvements in national design codes by providing recommendations on modeling, detailing, and analysis practices for transfer systems in tall buildings.

1.1.4. Implications of Poor Seismic Performance

The failure of a building during an earthquake has far-reaching consequences. In addition to loss of life and property, it damages public trust in engineering practices and has economic ramifications for local governments and insurance sectors. While major earthquakes are infrequent in Zone II, the risk of even one damaging event over the life cycle of a building is not negligible—especially given the increasing vulnerability from urban densification and aging infrastructure.

Moreover, post-disaster reconstruction is far more expensive than initial safe design. Retrofitting of buildings with severe vertical irregularities is also technically complex and often infeasible without major disruptions. Thus, integrating seismic resilience from the design stage is both cost-effective and socially responsible.

This study recognizes that the seismic zone classification should not be the sole determinant of design rigor. Instead, the presence of structural irregularities, building height, and occupancy type must also govern the level of analysis and detailing. Through this research, the aim is to demonstrate the importance of accounting for transfer beam behavior even in lower seismic zones and to recommend best practices for enhancing structural safety in the evolving Indian urban context.

1.2 Motivation and Objectives

1.2.1 Motivation:

Despite being classified as a low seismic risk zone, Seismic Zone II regions in India are home to millions of residents and a rapidly growing inventory of high-rise structures. Structural failures during past earthquakes in other parts of the country have highlighted that design irregularities—not just seismic intensity—contribute significantly to damage. With transfer beams becoming a common feature in modern RC buildings, it is crucial to understand their influence on seismic behavior, even in supposedly "safe" zones.

In particular, failure to address vertical irregularities may lead to soft story mechanisms, excessive inter-story drift, or localized failures near the transfer level. There is a pressing need to evaluate whether such buildings, while code-compliant under static and minimum seismic load checks, can achieve desirable performance levels during actual seismic events.

1.2.2 Objectives:

- To analyze the seismic behavior of RC tall buildings with and without transfer beams in Seismic Zone II.
- To identify the influence of transfer beams on parameters such as base shear, drift, plastic hinge distribution, and displacement.
- To assess whether current Indian design standards (IS 456:2000 and IS 1893:2016) adequately address performance issues arising from transfer systems.

- To recommend possible design improvements or detailing guidelines for better seismic performance in low-risk zones.

2. Literature Reviews:

1. **Cinitha, P. K. Umesha,Nagesh R Iyer1,N. Lakshmanan (2015)** This paper presents a typical 6-storey reinforced concrete structural frame analyzed and designed for four load cases, taking into account three revisions of IS: 1893 and IS: 456. A conceptual framework and detailed steps for performance evaluation of buildings with reinforced concrete frame are presented using the explicit force-based method described in the Indian Code of Practice. The modeling process describes issues related to capacity curve generation, damage , and vulnerability index. Based on studies, a simple formula has been proposed for estimating the global damage index in the hardening and elasto-plastic regions of the capacitance spectrum.
2. **Lin Shibin1, Xie Lili1, Gong Maosheng, and Li Ming(2010)** This paper presents a performance-based methodology for assessing building seismic vulnerability and capacity of . The vulnerability assessment methodology is based on the HAZUS methodology and the improved capacity requirement diagram method. The spectral shift (Sd) of performance points on the capacitance curve is used to estimate the damage level of the building. The relationship between Sd and peak ground acceleration (PGA) has been established and the new vulnerability function is represented in PGA. In addition, the expected value of seismic performance index (SCev) is provided to estimate the seismic performance of buildings based on the probability distribution of damage levels and the corresponding seismic performance index . The results show that the proposed vulnerability methodology can directly and quickly assess the seismic damage to large numbers of building stocks after the earthquake. SCev provides an effective index for measuring the seismic resistance of buildings, showing the relationship between the seismic resistance of buildings and the effects of earthquakes. The estimation results are compared with the damage survey of Dujiangyan City and Jiangyu in the M8.0 Wenchuan earthquake, and show that the earthquake risk assessment and decision-making method is accepted. Describes the main reasons for the discrepancy between the estimation results and the damage report.
3. **S. Choudhury • S. M. Singh(2013)** Here we report on a uniform design approach for RC moment resistant frame buildings . It takes into account both the design deviation and the intended performance level of the component. Rays are proportional to from the theoretical processing corresponding to the target. The proposed method was validated by designing a building with two plans, different height and different performance goals . The proposed method was found to be sufficient to achieve a elastic RC frame building with a given performance goal of under a given hazard level.
4. **Rahul Rana, Limin Jin and Atila Zekioglu (2004)** tries to performed push over analysis on a nineteen story, slender concrete tower building located in San Francisco having 430,000 sq. ft. gross area. Building having concrete shear wall for lateral load resistance. Push over analysis was performed to check the intent of life safety performance under design earthquake. Software used are ETABS version 7 and SAP2000 version 7. For all lateral member, cracked section stiffness is assumed to be 50% of gross section.
5. **Dr. Rehan (2014)** A Khan1 Research is an attempt to understand a performance-based design approach. Here we use STAAD.Pro to design a five-story symmetrical building and follow the N2 method using a simple computer-based pushover analysis technique using SAP 2000, a product of Computers and Structures International. Performs performance-based seismic design. This method compares the structural capacitance of the MDOF system (the form of the pushover curve) with the structural requirements (the form of the inelastic response spectrum of a one-degree-of-freedom system). This method is formulated in the acceleration distance format. The graphical intersection of the two curves approaches the performance point of the structure. The proposed method determines seismic performance points of a five-story reinforced concrete building in Zone IV symmetrically in Plan (designed according to IS 456: 2002), which is exposed to three different PGA levels as input floor movements. Indicated by. A large parametric study has been conducted to investigate the impact of many important parameters on the credit score. The parameters individually include the effect of soil movement entered on performance points, changes in the proportion of rebar in the columns, and column and beam sizes. Analysis results are compared in terms of base thrust and floor.
6. **Devendra Sardiwal, Rekha Shinde,and Oshin Victor** This post presents the latest literature review of performance-based seismic analysis of nonlinear multi-story buildings using Soft Storey. Performance-based seismic design is an elastic design technique, also known as “Performance-based plastic design”. The total load capacity of a

structure depends on the strength and deformation capacity of the individual components of the structure. A soft floor, known as a weak floor, is defined as a building floor that is less rigid or less ductile to withstand an earthquake triggered within the building. A soft bullet is a bullet with a lot of free space.

7. **Ashish R. Akhare1, Abhijeet A. Maske (2015)** in This paper uses standard pushover and modal pushover analyzes to investigate power -based seismic designs for buildings with planning irregularities. Nonlinear Time Analysis is performed to check the accuracy of both methods. In this study, the "L", "C", and "T" building models of (G + 6) floor regular and irregular buildings are computer program ETAB. (Version 9.7.3) Generated. The floor plan building shapes are selected at so that the total floor plan area is the same, so the deadload and payload values are about the same. Various parameters such as pushover curve, power point, plastic hinge mechanism, twist, etc. are examined. The results show that the standard pushover analysis gives the same results as the modal pushover analysis and the time-lapse analysis of regular buildings, but for irregular buildings, the modal pushover analysis is higher. Considering gives a fashion effect gives better results. Also, the twist in irregular buildings is almost 20% higher than in normal buildings, so in irregular buildings the effects of twist should be considered. The power-based seismic design obtained by method above also meets the tolerance criteria for immediate occupancy and lifetime safety limit state for specific seismic intensities.

8. **Irshad Timmapur1, Prof. Vikhyat Katti (2018)** This paper introduces power-based seismic design methods. The three-dimensional design method of the building is carried out under the modified movement of the seismic floor. The Performance Based Design (PBD) method is the 's new and evolving perfection for the future of seismic design. The PBD is a direct design method for this method. The nonlinear analysis involves determining the damage that can be done to the structure, the performance objects are precomputed, and the elements of the frame are refined to the intended flow. Mechanisms and structures that must operate in the event of an earthquake caused by an earthquake with a required limit of its.

9. **Pranali S Mehare1, Joshi M 2020** This study aims to determine the performance of buildings under earthquake using performance-based seismic design. In this study, in order to study the performance of a building due to seismic force, we will create various sets of reinforcements at various levels and finally provide the optimum combination of reinforcements. Occupancy. The second is to find the performance points of the building and compare the seismic response of the building in terms of ground thrust, floor drift, spectral acceleration, floor displacement, and spectral displacement. Second, if the resulting roof displacement is compared to the target displacement and the resulting displacement is less than the target displacement, the design is based on a performance-based seismic design. Finally, compare the performance-based design with the code-based design.

10. **Mathieu Gil-oulbé*, Fouad Adnan Noman Abdullah Al-Shaibani, Abass Saad Lina (2020)** The purpose of this work is to implement a performance-based seismic design (PBSD) approach on a concrete building. A new concept in seismic design of structures, PBSD is a reliable approach that can provide more detailed information about performance level for both structural and non-structural elements. Method. In this study, seismic designs based on performance were used for irregular reinforced concrete frames. A pushover analysis was performed for this purpose. A floor drift ratio of was selected as the deformation limit to define the performance level for a particular seismic hazard level . The results of this study show that the 's performancebased seismic design provides structures with better seismic performance, and the meets its performance and economic goals. It is also possible to conclude that the PBSD obtained by the above method meets the tolerance criteria for immediate occupancy of various seismic intensities and life safety limits.

11. **Vasileios Vatsikas and Prof. Yong Lu(2001)** The main purpose of this project was to compare the Eurocode 8 based design with the design obtained from the proposed performance-based method. The comparison was related to the design life of 50 years and was made with reference to: • Acquisition cost: Immediate construction cost, related to material, content, and labor costs. • Lifecycle Cost: Take into account the potential damage costs of seismic events that can occur during the design life of the structure.

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3. METHODOLOGY:

3.1 Methodology

An overview of the methodology adopted to know the seismic performance of tall buildings with TB and to comment on their appropriateness in seismic zone II is shown in Figure 3.1. The first two steps, i.e. the selection of buildings and the step-by- step procedure of building design, Once the building design is complete, the buildings are assessed using the Linear Time History Analysis (LTHA) method. The performance of buildings due to eleven ground motions adopted in LTHA is discussed in detail to outline the recommendations.

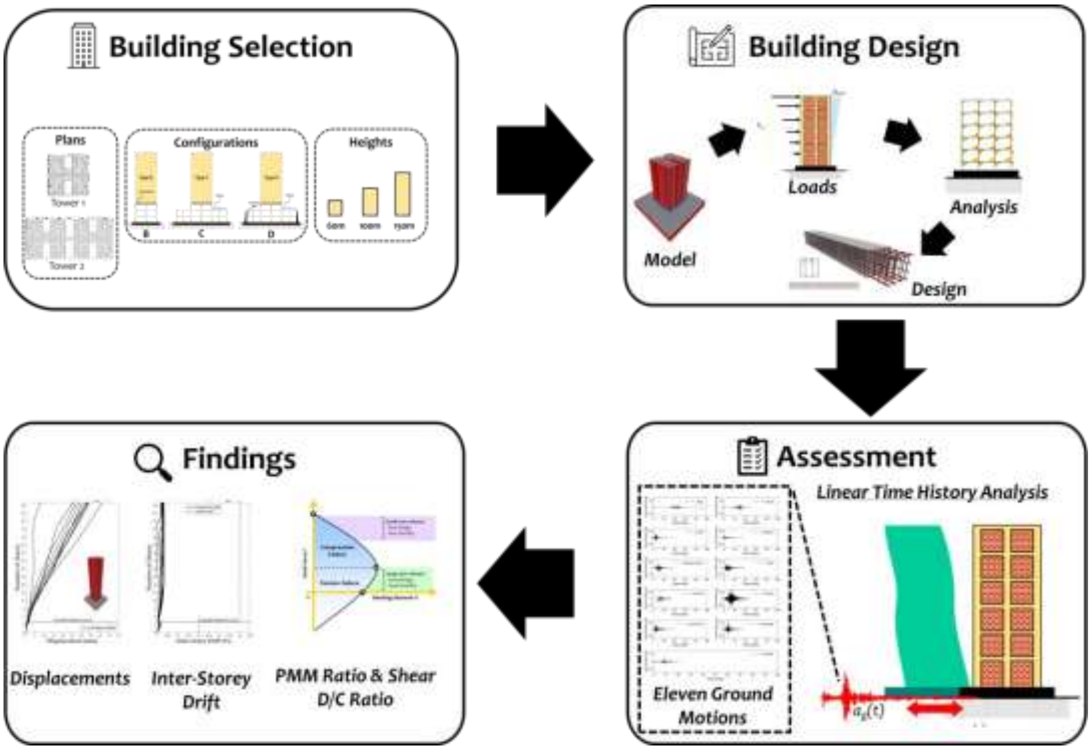

Figure 3.1: Methodology of current work

3.1.1 Linear Time History Analysis (LTHA)

In a LTHA, the structural behaviour is assumed to be elastic, i.e. the stiffness and strength of the structure do not change during the earthquake. It involves selecting ground motions and applying them to a structural model to compute there sponse of buildings in terms of forces and deformations.

a) Ground Motions

For the present study, eleven ground motions are chosen. Ideally, ground motions are selected to represent the time history that the building is likely to experience at its location. In other words, as a first step, ground motions should be selected to have similar source mechanism, magnitude, focal depth, epicentral distance, characteristics of the path through which the seismic waves travel, and soil strata on which the structure is founded. However, the current study focuses on zone II, which is spread over a larger region; hence, narrowing down to these factors representing the entire zone II is difficult. Further, only a limited number of large Indian earthquakes are recorded and publicly available. Therefore, except for the Bhuj earthquake, significant earthquakes that occurred outside India are chosen for this study. Table 3.1 gives details of all these ground motions along with their characteristics, viz., amplitude, predominant period, and significant duration. The signature and Fast Fourier Transform (FFT) of all these ground motions are plotted in Figure 3.2 and Figure 3.3, respectively.

Table 3.1: Details of ground motions considered and their characteristics

SrNo.	*Name of Earthquake (Country)*	*Station*	*Date*	*Peak Ground Acceleration (g)*	*Predominant Period (sec)*	*Significant duration (sec)*
1	Bhuj (India)	Ahmedabad	January 26, 2001	0.1060	0.07-1.23	16.97
2	Chi-Chi (Taiwan)	TCU045	September 20, 1999	0.3610	0.81-1.78	11.78
3	Friuli (Italy)	TOLMEZZO(000)	May 06,1976	0.3513	0.47-0.53	04.24
4	Hollister (USA)	USGS STATION 1028	April 09,1961	0.1948	0.37-1.37	16.53
5	Imperial Valley (USA)	USGS STATION 5115	October 15, 1979	0.3152	0.43-0.61	08.92
6	Kobe (Japan)	KAKOGAWA (CUE90)	January 16, 1995	0.3447	1.14-2.05	12.86
7	Kocaeli (Turkey)	YARIMCA (KOERI330)	August 17, 1999	0.3490	1.14-5.12	15.62
8	Landers (USA)	000SCE STATION 24	June28,1992	0.7803	0.07-0.10	13.73
SrNo.	*Name of Earthquake (Country)*	*Station*	*Date*	*Peak Ground Acceleration (g)*	*Predominant Period (sec)*	*Significant duration (sec)*
9	Loma Prieta (USA)	090 CDMG STATION 47381	October 18,1989	0.3674	1.08-2.56	11.37
10	Northridge(USA)	090 CDMG STATION 24278	January 17,1994	0.5683	0.68-0.91	09.06
11	Trinidad (USA)	090 CDMG STATION 1498	August 24,1983	0.1936	0.27-0.40	07.80

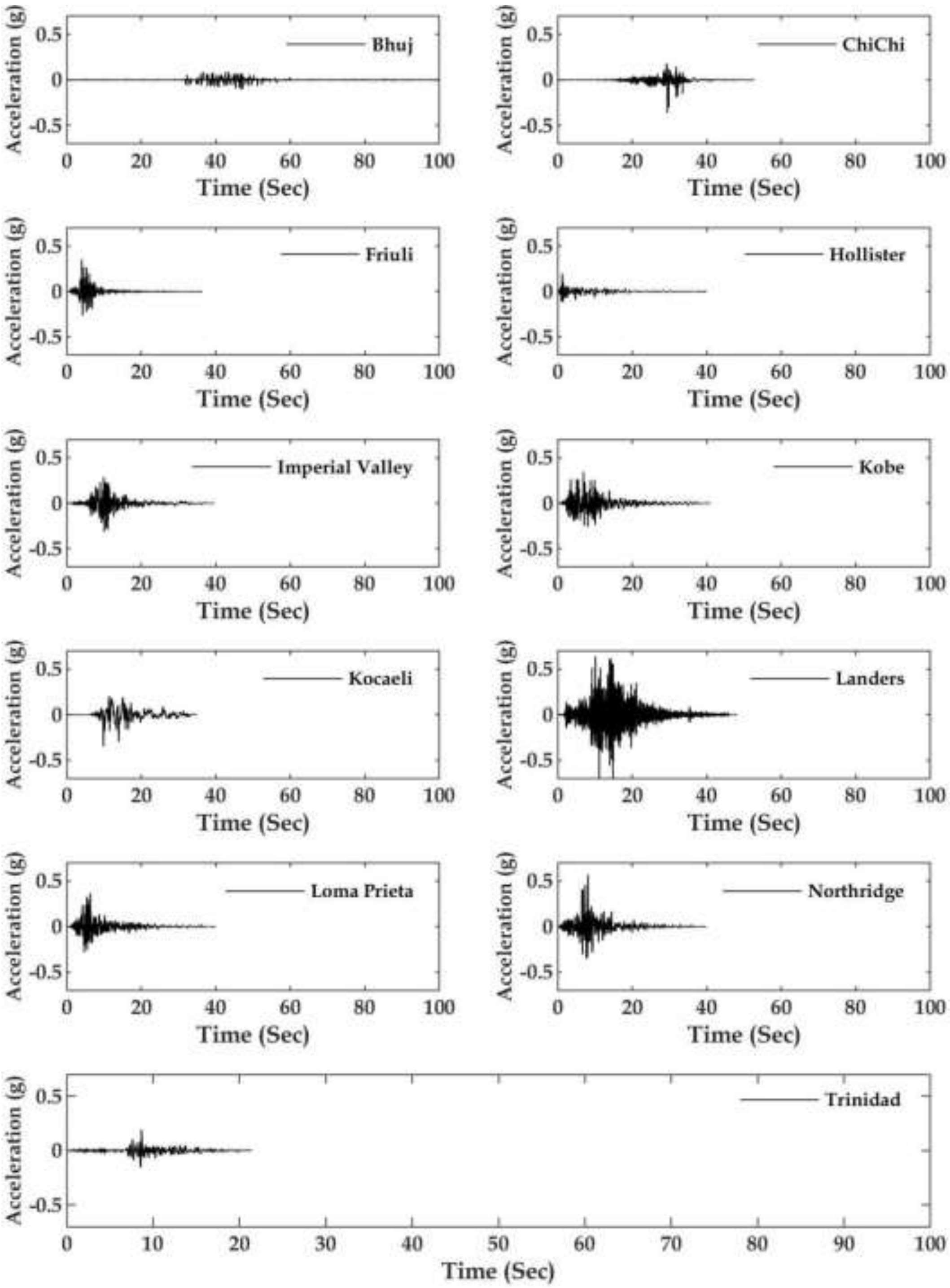

Figure 3.2: Time history plots of all Ground Motions

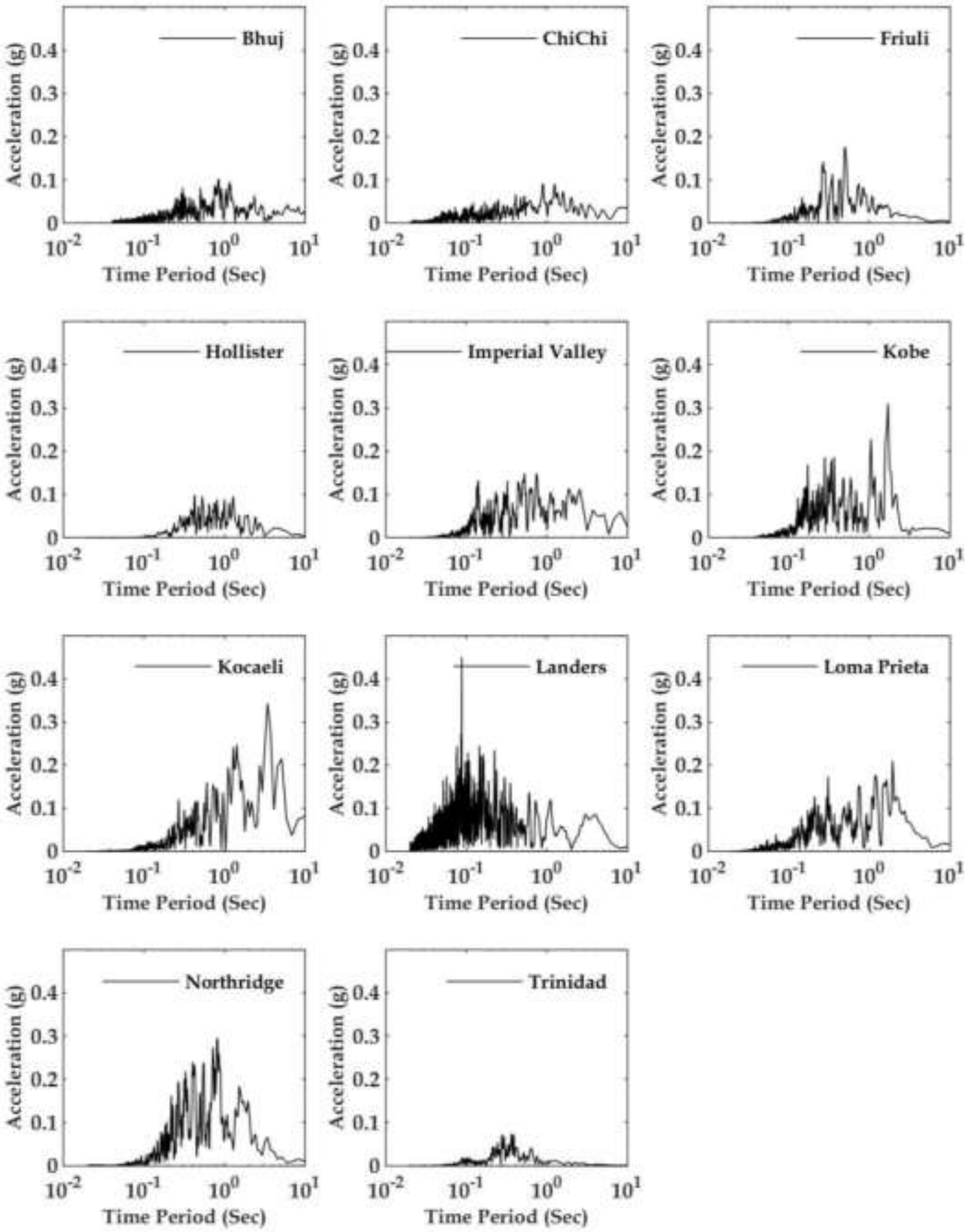

Figure 3.3: Fourier Spectrum Plots of all the Ground Motions

b) Ground motion scaling

Clause 7.7.4 of IS 1893 (IS 1893(Part 1):2016, 2016) indicates that the designer shall choose an appropriate ground motion. The same clause defines appropriate ground motion as preferably compatible with the design acceleration spectrum in the desired range of natural periods. Apart from this, the code is silent on giving further details. In the absence of guidelines from BIS, ASCE 7-16 (ASCE 7-16, 2016) guidelines are followed to make eleven ground motions appropriate. The spectral matching method is adopted to modify ground motions such that they become compatible with the design acceleration spectrum (Figure 3.4 a) for medium soil as given in IS 1893. This technique consists of using different modification factors for different periods and, in some cases, adding or subtracting additional energy wavelets to the ground motions so that the response spectra of the modified ground motions more or less match the target spectra. A Seiso Match (Seismo soft, 2020) tool is used to perform this task, and modified ground motions compatible with the design spectra are shown in Figure 3.4b.

Ground motions are matched for a specific period ranges that ensure the selected ground motions accurately represent the design hazard at the building's fundamental response period. To do this, ASCE7-16 gives two formulae for upper bound and lower bound periods. The upper bound period consists of two times the maximum fundamental lateral natural period as per equation 4-1. The modification factor two is applied to capture the period elongation effects during the earthquake. And the lower bound period is selected based on the minimum of the lateral period needed for 90% modal mass participation. However, this value can not exceed 20% of the minimum fundamental lateral natural period (equation 4-2). This lower bound period captures the higher mode response.

$$T_{upper} \geq 2\{T_{x1}, T_{y1}\}_{max} \qquad 4\text{-}1$$

$$T_{lower} = \{T_{xi}, T_{yi}\}_{min,90\%\ modal\ mass} \leq 0.2\{T_{x1}, T_{y1}\}_{min} \qquad 4\text{-}2$$

Table 3.2: Spectral matching period range as per ASCE7-16 (ASCE7-16,2016)

ModelID	***PPeriod(Sec)***		***ModelID***	***PPeriod(Sec)***	
	Upper bound	***Lower bound***		***Upper bound***	***Lower Bound***
T1ZIIB60	2.144	0.083	T2ZIIB60	2.090	0.060
T1ZIIC60	2.100	0.120	T2ZIIC60	2.066	0.070
T1ZIID60	1.970	0.069	T2ZIID60	1.858	0.063
T1ZIIB100	4.202	0.167	T2ZIIB100	4.194	0.172
T1ZIIC100	3.770	0.265	T2ZIIC100	4.166	0.117
T1ZIID100	4.070	0.101	T2ZIID100	3.800	0.047
T1ZIIB150	6.322	0.043	T2ZIIB150	6.652	0.158
T1ZIIC150	6.350	0.130	T2ZIIC150	6.680	0.114
T1ZIID150	6.314	0.060	T2ZIID150	6.280	0.047

The upper and lower bound periods for all buildings are tabulated in Table 3.2. The same has been plotted in Figure 3.5. The comparison of the upper bound and lower bound periods for the building with the same height indicates that the influence of podium configurations (*type C* & *D*) is negligible. This is inevitable since the fundamental lateral natural periods were more or less the same, and so is the case with modal mass participation, which resulted in a similar lower bound period with an insignificant difference.

Hence the upper and lower bound period has been computed for each building, the eleven ground motions for each building are modified. Figure 3.6 summarises the spectral matching procedure from the computation of period range to the outcome of modified ground motions.

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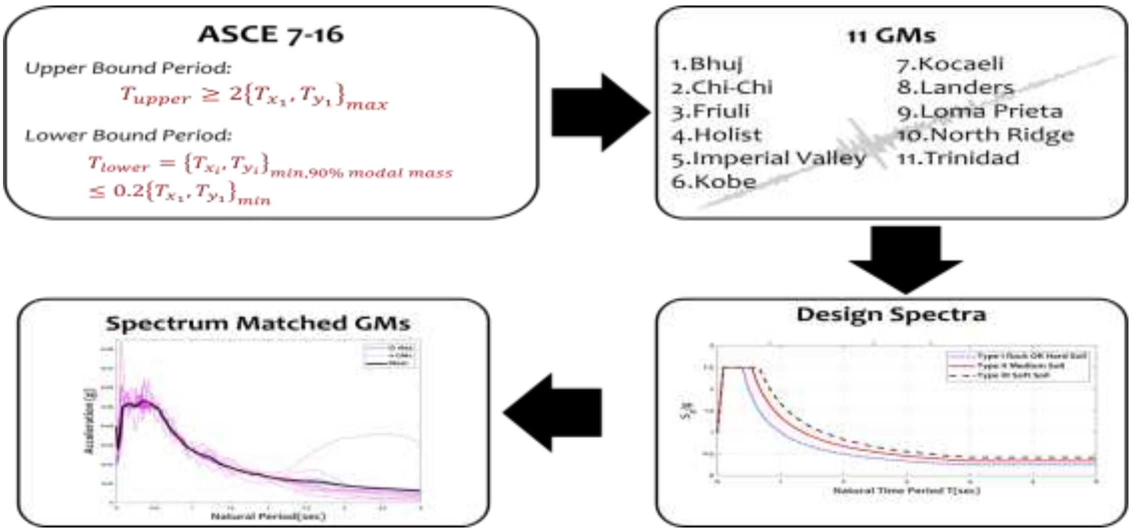


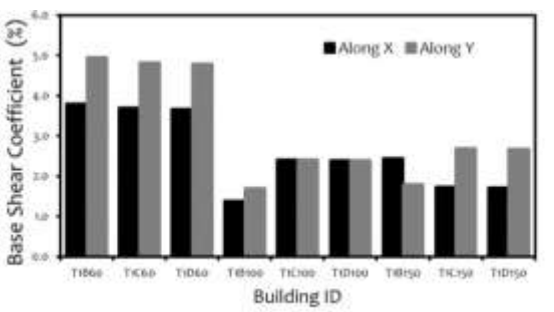
Figure 3.6: Overview of Ground Motion Scaling Procedure

4. Results

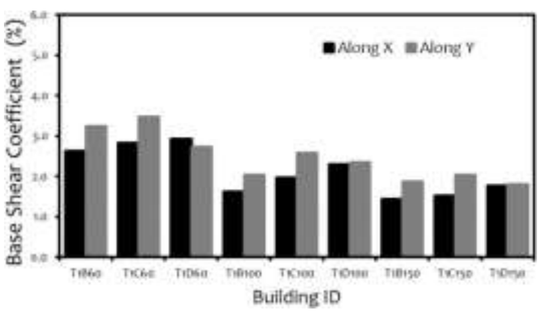
4.1. Base Shear

Figure 3.7 and Figure 3.8 illustrates the difference between the design base shear from RSA and the maximum base shear obtained from LTHA for Tower 1 and 2 buildings, respectively. Figure 3.7c and Figure 3.8c shows the ratio of seismic demand (LTHA) to capacity (RSA) base shear. For Tower 1 buildings, these values range from 0.57 to 1.19, whereas for *Tower 2* buildings, they range from 0.53 to 1.32. The variation in the base shear among various ground motions and between LTHA base shear and RSA base shear is obvious since, despite the modification of ground motion based on the response spectrum matching procedure, there will be a slight uniqueness of each ground motion. This leads to a difference in the base shear between the RSA and LTHA methods.

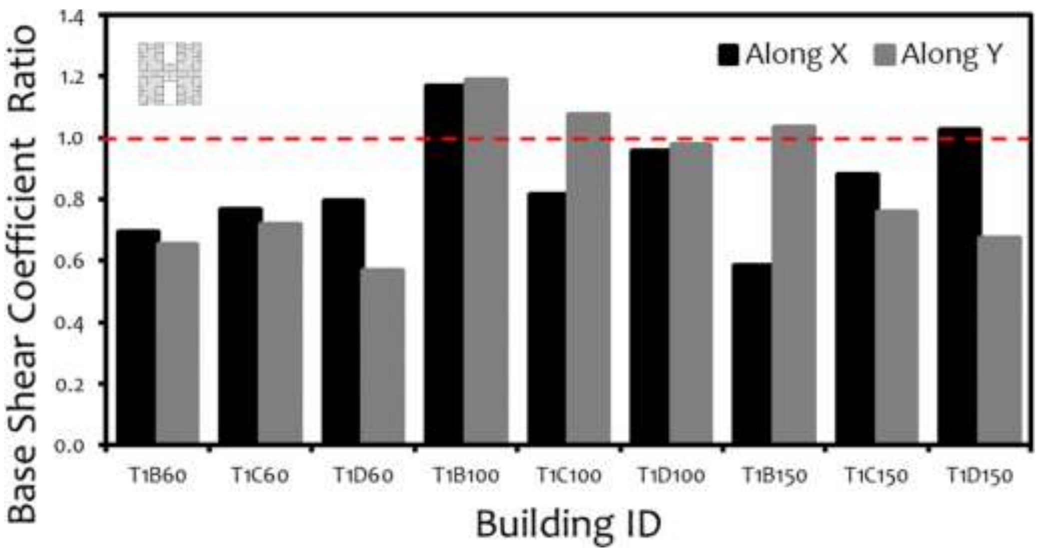
Out of eighteen buildings, only seven have a ratio greater than one. The values less than one indicate the possibility of the building performing better during earthquake shaking since they are designed for higher seismic base shear. However, the distribution of base shear, also known as storey shear, does influence the performance of the building, hence few more indicators of the performance of buildings are discussed in further subsections. The values of Figure 4.7 and Figure 4.8 are listed in Table 4.3, Table 4.4 and Table 4.5.



Capacity: Design Base Shear (RSA)

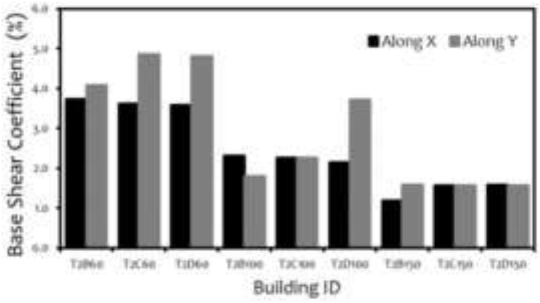


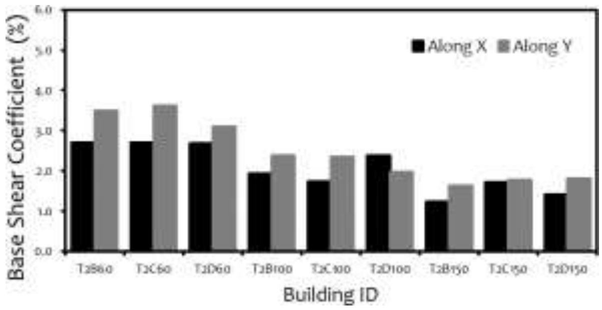
(b) Demand: Max. LTHA Base Shear

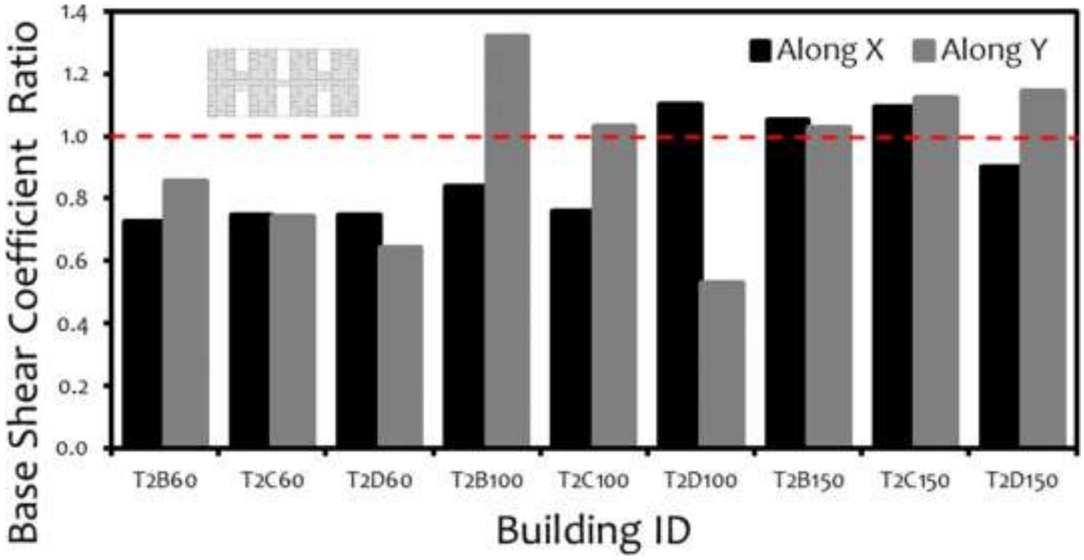


© Base Shear Demand /Capacity Ratio

Figure 4.7: Design (RSA) and LTHA base shear for *Tower1* buildings







(a) Capacity: Design Base shear

(b) Demand: Max. LTHA Base Shear

© Base Shear Demand/Capacity Ratio

Figure 4.8: Design (RSA) and LTHA base shear for *Tower* buildings

Table 4.3: Maximum LTHA base shear

coefficient

Model ID	*Max. LTHA Base Shear Coefficient(%)*		*Model ID*	*Max. LTHA Base Shear Coefficient (%)*	
	X	*Y*		*X*	*Y*
T1ZIIB60	2.6	3.2	T2ZIIB60	2.7	3.5
T1ZIIC60	2.8	3.5	T2ZIIC60	2.7	3.6
T1ZIID60	2.9	2.7	T2ZIID60	2.7	3.1
T1ZIIB100	1.6	2.0	T2ZIIB100	1.9	2.4
T1ZIIC100	2.0	2.6	T2ZIIC100	1.7	2.3
T1ZIID100	2.3	2.3	T2ZIID100	2.4	2.0

Table 4.4: Design base shear coefficient (RSA)

Model ID	*Design (RSA) Base Shear Coefficient(%)*		*Model ID*	*Design (RSA) Base Shear Coefficient(%)*	
	X	*Y*		*X*	*Y*
T1ZIIB60	3.8	5.0	T2ZIIB60	3.7	4.1
T1ZIIC60	3.7	4.8	T2ZIIC60	3.6	4.9
T1ZIID60	3.7	4.8	T2ZIID60	3.6	4.8
T1ZIIB100	1.4	1.7	T2ZIIB100	2.3	1.8
ModelID	*Design(RSA)BaseShear Coefficient(%)*		*ModelID*	*Design(RSA)BaseShear Coefficient(%)*	
	X	*Y*		*X*	*Y*
T1ZIIC100	2.4	2.4	T2ZIIC100	2.3	2.3
T1ZIID100	2.4	2.4	T2ZIID100	2.2	3.7
T1ZIIB150	2.4	1.8	T2ZIIB150	1.2	1.6
T1ZIIC150	1.7	2.7	T2ZIIC150	1.6	1.6
T1ZIID150	1.7	2.7	T2ZIID150	1.6	1.6

Table 4.5: Base shear Demand (LTHA) to Capacity (RSA) Ratio

ModelID	*BaseShear Demand/Capacity Ratio*		*ModelID*	*BaseShear Demand/Capacity Ratio*	
	X	*Y*		*X*	*Y*
T1ZIIB60	0.7	0.7	T2ZIIB60	0.7	0.9
T1ZIIC60	0.8	0.7	T2ZIIC60	0.7	0.7
T1ZIID60	0.8	**0.6**	T2ZIID60	0.7	0.6
T1ZIIB100	**1.2**	**1.2**	T2ZIIB100	0.8	**1.3**
T1ZIIC100	0.8	**1.1**	T2ZIIC100	0.8	1.0
T1ZIID100	1.0	1.0	T2ZIID100	**1.1**	**0.5**
T1ZIIB150	0.6	1.0	T2ZIIB150	**1.1**	1.0
T1ZIIC150	0.9	0.8	T2ZIIC150	**1.1**	**1.1**

T1ZIID150	1.0	0.7	T2ZIID150	0.9	**1.1**

5. CONCLUSIONS:

The following conclusions can be drawn from the present study:

1) Analysis:

a. Complete elimination of stiffness irregularity by bringing the stiffness difference between two consecutive floors to less than 30% is quite challenging. However, continuing a few structural walls other than the core walls down to the foundation level will be beneficial.

b. The contribution of stiffness increase due to *type C* is relatively less. A significant increase in stiffness occurs when *type D* configuration is present. However, the percentage of increase in stiffness depends on the number and orientation of walls continuing from the top to the foundation.

c. Mass irregularity occurs between level below TB level and TB level due to a large mass of TB level due to TB. If necessary, this irregularity can be eliminated by modelling podium configurations.

2) LTHA behaviour:

a. The increase in base shear demand due to LTHA did not cause any significant change in performance parameters such as displacements and IDR.

b. Building displacements are minimal, and the effect of podium configurations on displacements is insignificant.

c. IDR demands are also well within the code specified limits. Further, IDR can better capture the influence of podium configuration in a better manner. The amplitude of maximum IDR tends to reduce from configuration *B* to *D*.

d. The transfer column PMM capacity ratios are in the interaction curve's lower third, indicating column failure's non-brittle nature.

e. The effect of podium configurations on transfer column shear demand to capacity ratio is insignificant, and upto 50-60% of shear capacity is reserved for transfer columns.

3) Design Provisions:

a. Even after qualifying for several irregularities, the building performance was satisfactory under LTHA, thus eliminating the need to revise the code limits for inter storey drift ratio.

4) Other:

a. Residential buildings with RC transfer beams can perform well inseismic zone II when all analysis and design criteria are properly followed.

b. The impact of podium configurations (*Type C* and *Type D*) on the seismic resistance of buildings is negligible. Thus, architects and structural engineers can choose whether or not to include a separation joint based solely on functional and execution requirements.

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