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Shear Concentration in Shear Walls Immediately above the Transfer Floor in Tall Buildings under Seismic Loading

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Abstract: Shear concentration in shear walls is a critical factor in the seismic design of tall buildings. In structures incorporating transfer floors, the redistribution of storey shear forces plays a significant role in governing overall stability and structural performance. A comprehensive understanding of this behaviour is therefore essential for enhancing both the safety and efficiency of tall buildings. This study examines shear concentration in shear walls located immediately above the transfer floors in a series of planar symmetric rectangular tall building models subjected to seismic loading conditions representative of Sri Lanka. Five three-dimensional finite element models were developed, with transfer floors modelled using solid elements while varying both depth and vertical position. The findings reveal that an optimal transfer floor depth minimises storey shear demand in the shear walls directly above, whereas both shallower and deeper slabs increase these forces. Additionally, positioning the transfer floor at a higher elevation is shown to reduce shear concentrations in the overlying walls. A comparative assessment of Time History Analysis (THA) and Response Spectrum Analysis (RSA) further demonstrates that. However, the THA reveals localised deformations in the transfer slab that RSA fails to capture, highlighting its importance for more realistically assessing behaviour. These findings provide practical guidance for seismic design, particularly in moderate to low seismicity regions where transfer structures are commonly employed.

Keywords: Core Wall, Response Spectrum Analysis (RSA), Seismic Loading, Shear Wall, Time History Analysis (THA), Transfer Floor, Vertical Irregularity

1. Introduction

Typically, the upper floors of tall buildings are designated for residential areas or office functions, while the lower floors accommodate parking facilities and commercial spaces. To meet these functional requirements, hybrid structural systems are often employed, combining moment-resisting frames and core walls in the lower zones with shear walls in the upper zones. Many contemporary tall buildings adopt this form of vertical irregularity, necessitating the use of a transfer structure to address the discontinuity between the moment-resisting frame system below and the shear wall-core wall system above. For instance, a typical residential development in Hong Kong consists of six 34-storey buildings supported by a thick transfer plate resting on columns and core walls. A transfer structure redistributes loads from shear walls in upper zones to the supporting elements in the lower zone (Li et al., 2006) [1].

A transfer structure generally comprises deep beams, truss systems, or thick transfer floors designed to channel vertical and lateral loads from the superstructure to the substructure.

The primary challenge in this configuration is the abrupt change in lateral stiffness at the transfer level, where a rigid shear-core wall system above transitions into a comparatively flexible beam-column system below. This discontinuity makes tall buildings incorporating transfer structures particularly susceptible to lateral forces, with seismic loading forcing a critical design concern.

The transfer structure in tall buildings generally exhibits substantially greater lateral stiffness compared to other structural components. These systems play a pivotal role in redistributing seismic loads from the upper zones of a building to its lower zones. During

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seismic events, inertial forces induce deformations through the structure. Since inertial force is proportional to the product of mass and acceleration, the concentration of mass at the transfer level generates disproportionately large inertial forces, thereby amplifying seismic demand on the transfer system and adjacent structural elements.

Experimental and numerical studies have further highlighted the critical role of transfer structures in seismic behaviour. Xu et al. [2], through a shaking table test on a 27-storey building with transfer beams at the 7th floor, observed abrupt changes in shear distribution across structural elements. While storey shear forces were relatively consistent between shear walls and core walls in the upper stories, a significant redistribution occurred in the vicinity of the transfer level. Specifically, storey shear forces in core walls were transferred to exterior shear walls, resulting in a pronounced concentration of storey shear demand. Below the transfer structure, however, the supporting columns carried storey shear forces comparable to those in the walls, with the core wall resisting only a limited portion of seismic load.

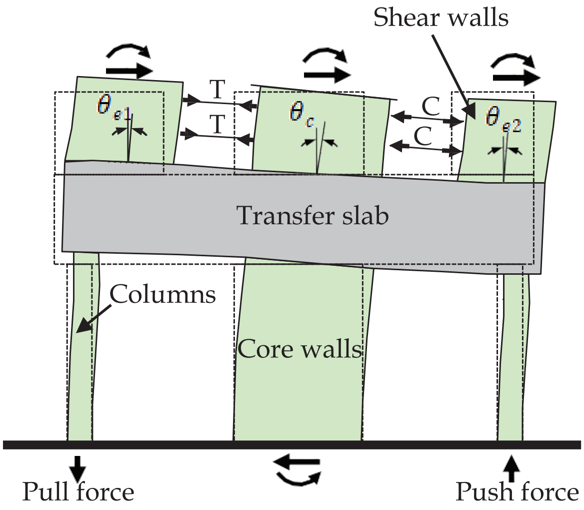

Figure 1 - Local deformation of transfer slab [5]

As illustrated in Figure 1, local deflection of the transfer floor induces pull-push actions at the base of the supporting columns, which in turn generate a rotational incompatibility between the exterior shear walls and the core wall during seismic excitation. Owing to the monolithic connection between the transfer floor and the core wall, however, both elements are forced to rotate similarly at their interface. This constraint gives rise to significant in-plane tensile and compressive forces in connecting slabs, as the structure attempts to accommodate the differential rotational demands between the core wall and the exterior shear walls.

Li et al. [1] investigated the seismic performance of a scaled tall building model featuring a 2.7 m thick transfer floor at the third level and 34 typical floors. The model was subjected to minor, moderate, major, and supermajor earthquake excitations to represent conditions in moderate seismic regions. As shown in Figure 2, the majority of the damage was concentrated immediately above the transfer floor. Similarly, Gómez-Bernal et al. [3] examined the behaviour of transfer floor systems in medium-rise buildings in Mexico by applying cyclic loading in both vertical and horizontal directions. Their study revealed that an increase in mass on the transfer floor significantly amplifies the shear forces experienced by the load-bearing walls at that level.

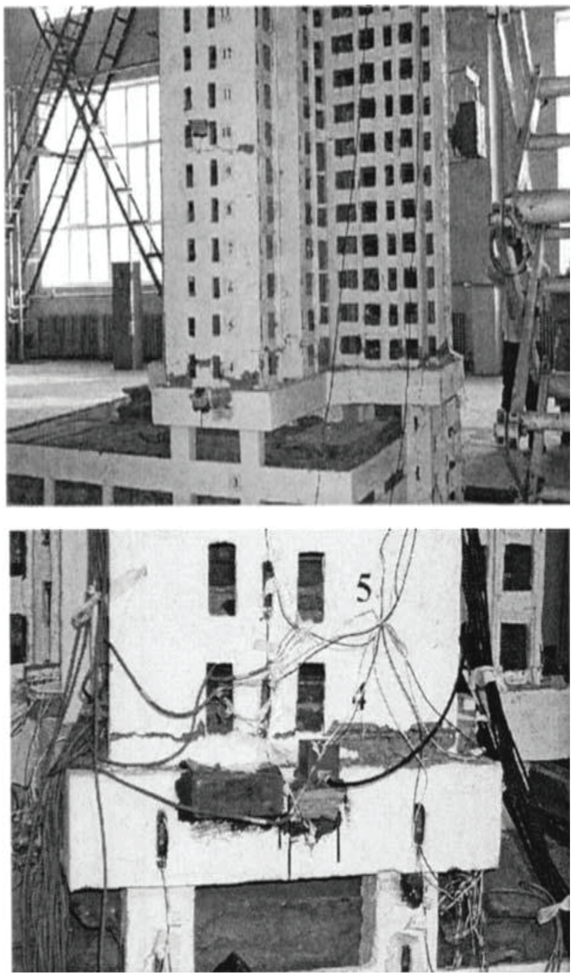

Figure 2 - Damage observed in the test model by Li et al. [1]

Ye et al. [4] concluded that introducing floor openings above the transfer structure can mitigate the storey shear concentration in shear walls by disrupting the load paths. In another analysis, Su and Cheng [5] conducted a parametric analysis of several two-dimensional building models, varying parameters such as transfer beam depth, stiffness of shear walls and core walls, size of supporting columns, storey height above the transfer structure and the vertical position of the transfer beam. The severity of the concentration was quantified using a factor named Shear Concentration Factor. Their findings highlighted the importance of accurate numerical modelling, recommending the use of elements that can incorporate the flexibility in beams, plates or even solid elements to capture structural behaviour realistically. The study also revealed that the storey shear concentration in exterior shear walls decreased with an increase in storey height above the transfer structure. Furthermore, positioning the transfer structure at a lower level, typically below the fifth floor, effectively controls local rotation in the core wall. However, this effect showed limited insensitivity to the stiffness of the shear and core walls. Conversely, when the transfer structure is located at a higher level, the storey shear concentration effect becomes more pronounced. In another study, Elawady et al. [6] further observed that positioning the transfer floor at a lower-level results in an increase in base shear compared to configurations where it is placed at a higher level.

Although several numerical studies have explored the shear concentration of shear walls above the transfer structures, most have relied on simplified models, such as a two-dimensional representation or finite element models or using shell or plate elements instead of solid elements, which more accurately capture the flexibility and shear stress variation through the depth of thick slabs such as transfer floors. Moreover, no prior research has compared Time History Analysis (THA) and Response Spectrum Analysis (RSA) in this context, particularly under the moderate seismic conditions relevant to Sri Lanka. In practice, transfer structures are often located in regions of moderate or low seismicity, whereas they are prohibited in the high-seismic areas. In standard practice, in such buildings, some shear walls are typically continued down to the ground; however, in this study, the upper zone was modelled with walls only, and the lower zone with a moment resisting frame only, as this arrangement allows maximum stiffness discontinuity at the transfer level, and it captures the worst-case scenario. Similar modelling approaches have been employed in several previous research studies (Li et al., [1]; Su and Cheng, [5]; Abdlebasset et al., [7]), which aimed to evaluate the effect of stiffness irregularities in buildings with transfer systems.

This paper addresses the aforementioned gaps by conducting a detailed parametric study that evaluates the severity of storey shear concentration in shear walls immediately above a transfer structure owing to the changes in both transfer floor depth and vertical location, using solid finite element modelling, while also comparing THA and RSA to improve the reliability of seismic performance assessment for buildings with transfer floors.

The importance of studying the context in this study is further strengthened by several observations from prior research. First, Senevirathne et al. [8] concluded that seismicity around Sri Lanka cannot be ignored, emphasising the necessity of incorporating seismic analysis into engineering designs, such as transfer structures in tall buildings. Several other studies have been conducted regarding Sri Lankan seismicity. For instance, Weerasinghe et al. [9] applied the Deterministic Seismic Hazard Assessment (DSHA) to determine the Peak Ground Acceleration in major cities in the country. Uduweriya et al. [10] conducted a Probabilistic Seismic Hazard Assessment (PSHA), incorporating seismic data from South India.

This present study primarily investigates the effects of storey shear concentration in seismicity specific to Sri Lanka. By varying the depths of transfer floors and their vertical positions, the study aims to better understand how severe these factors influence the behaviour of tall buildings with transfer floors. The goal is to highlight the importance of seismic design in buildings with transfer floors. To achieve this, five 3-D building models with transfer floors have been analysed using time histories and response spectra.

2. Structural Configuration

In this study, five primary building models, detailed in Table 1, were developed in the CSI SAP 2000 and evaluated using both THA and RSA. Analysis inputs included seven ground motion time histories and corresponding response spectra that match the design elastic response spectrum of Sri Lanka's seismicity for a 2500-year return period, representing moderate seismic conditions relevant for Sri Lanka. These time history records, sourced from the PEER ground motion database, span durations of around 25 to 100 seconds and peak ground accelerations between 0.22 and 0.38 g (see Figure 3). Each record was scaled to match the target design response spectrum (see Figure 4), ensuring alignment with the local seismic hazard.

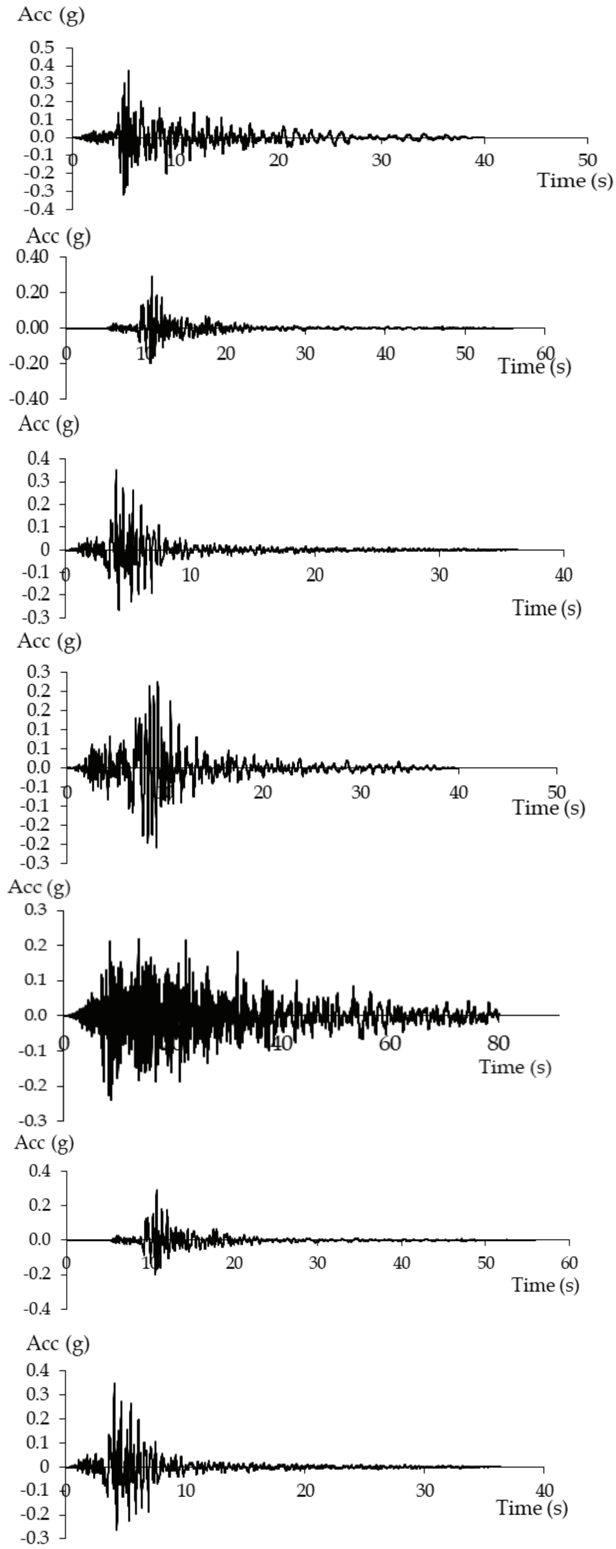

Figure 3 – The scaled seven-time histories

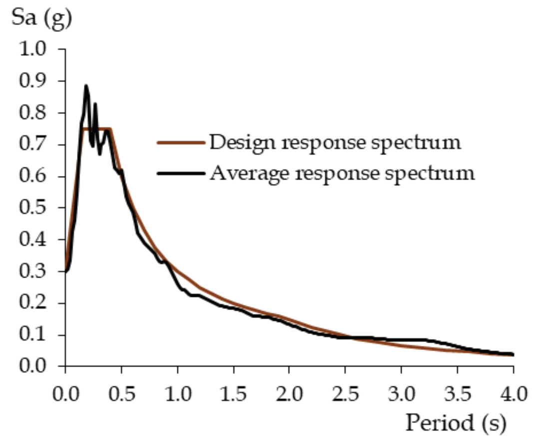

Figure 4 – The design elastic response spectrum for Sri Lanka, along with the average response spectrum relevant to the seven-time histories

The Response Spectrum Analysis (RSA) captures the dynamic behaviour of structural systems by considering several equivalent single-degree-of-freedom (SDOF) oscillators and their corresponding peak response (*Response Spectrum Analysis Theory*, [11]). The spectral acceleration varies with the natural period of the oscillator, and the peak spectral acceleration represents the highest point on the response spectrum curve. It indicates the maximum acceleration that any structure with a specific natural period would experience during the seismic event.

According to Figure 4, the effective peak ground acceleration is 0.3 g, as it is defined as the spectral acceleration at zero seconds (ACI 350.3-06; OFFICE OF NUCLEAR REGULATORY RESEARCH, [12]). At zero period, the oscillator's natural period is effectively zero, meaning it responds almost instantaneously to the ground motion, essentially behaving like the ground itself. In this limit, the spectral acceleration at zero period corresponds to the peak ground acceleration.

In addition, contemporary seismic design codes derive their elastic response spectra from spectral acceleration values, which may be reduced using behaviour or response modification factors to reflect the effects of inelastic deformation (Eurocode 8, 2004; Bangladesh National Building Code, 2020). Importantly, the fundamental periods of the analysed buildings are greater than 1.5 sec (see Table 4). At these periods, the corresponding spectral acceleration values are significantly lower than the peak ground acceleration, indicating that the expected base shear experienced by the structures is moderate. Therefore, although the applied response spectrum has a peak spectral acceleration around 0.7-0.8 g, the actual dynamic response of the buildings under their modal characteristics is lower.

Table 1 - Building models

Model	Description
A	1.0 m deep transfer floor at the 5th floor level
B	1.5 m deep transfer floor at the 5th floor level
C	2.0 m deep transfer floor at the 5th floor level
D	1.5 m deep transfer floor at the 3rd floor level
E	1.5 m deep transfer floor at the 7th floor level

Table 2 - Element details

Section	Dimensions
Column	450 × 450 mm
Coupling Beam	300×400 mm
Typical floor slab	150 mm
Podium floor slab	200 mm
Core wall	200 mm
Shear wall	200 mm
Storey height	3000 mm
Number of stories	20

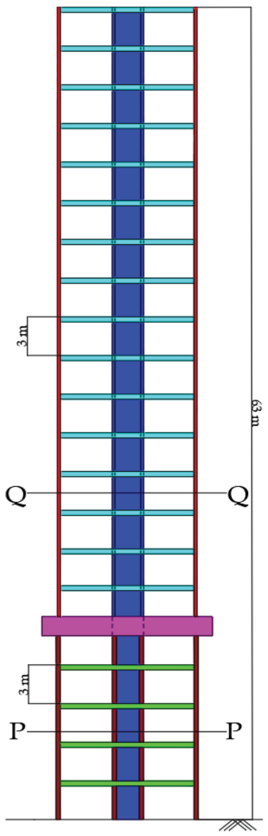

Figure 5 – Elevational view of a building

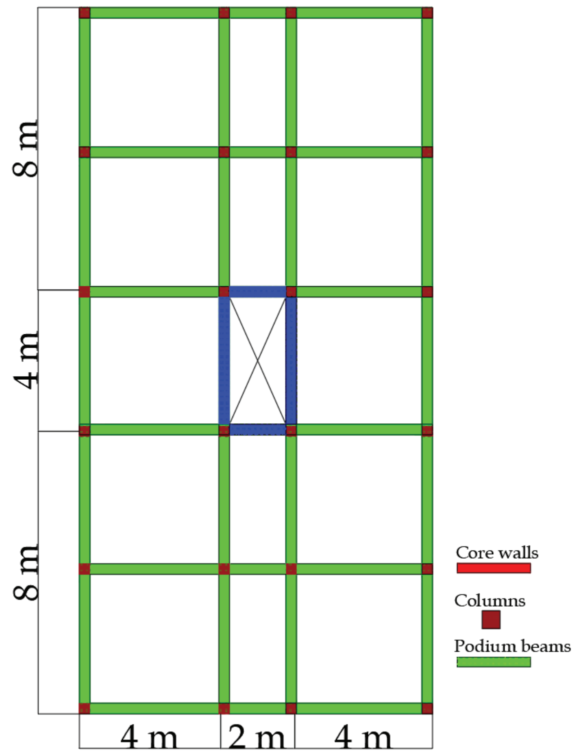

Figure 6 – Section P-P

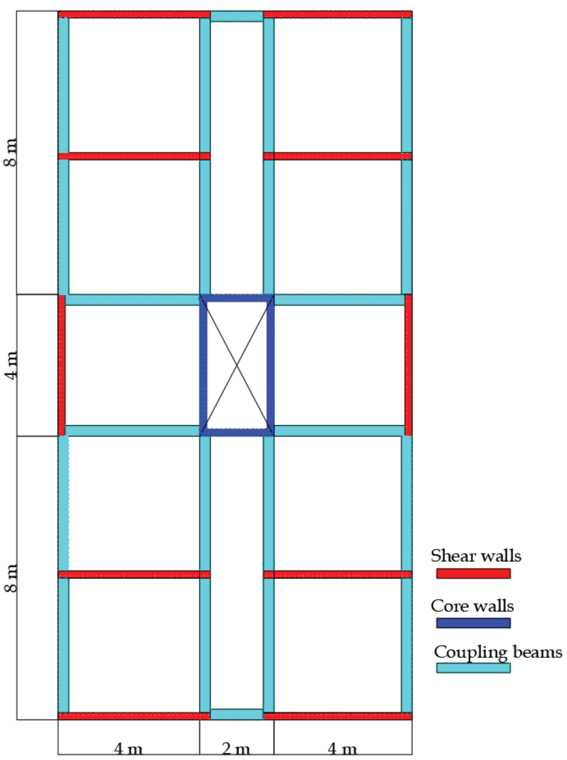

Figure 7 – Section Q-Q

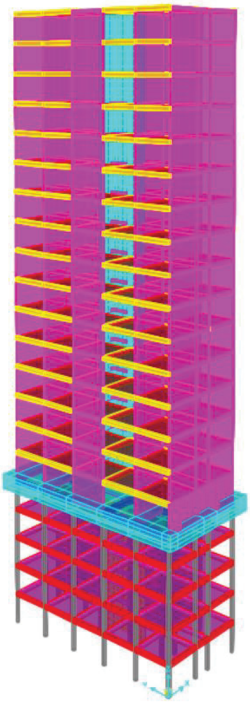

Figure 8 - Model B

As illustrated in Figures 5, 6, 7 and 8, all building models feature a rectangular plan layout and rise to a total height of 63 meters, comprising 20 stories, including a transfer floor. The structural system incorporates both a central core wall and a system of shear walls.

Moreover, based on conclusions drawn by Abdlebasset et al. [7], particular attention is given to the deformation of the transfer floor under seismic loading, highlighting its critical influence on the overall seismic performance of the structure.

All the models feature a regular rectangular plan and a centrally located core wall, which maintains planar symmetry and facilitates clear observation of shear concentration phenomena. Furthermore, the shear walls were arranged symmetrically around the building's centre to minimise torsional irregularities and ensure a balanced distribution of lateral forces. More shear walls were placed along the more flexible direction, which exhibits the longest fundamental period.

The arrangement aligns with the findings of Khand et al. [13], who reported that walls near the centroid help reduce shear forces and promote uniform load distribution, while walls farther from the centroid are subjected to higher seismic responses. In this study, the central core provides stability and reduces base shear, whereas the intermediate and exterior walls, positioned farther from the centroid, help redistribute lateral forces across the building and improve stiffness along the weaker axis.

In the current study, walls are located above the transfer floor without any additional columns, while a frame system occupies the space below, representing a simplified frame-wall configuration. While representing the worst-case scenario, further, this approach isolates the effects of the transfer floor and vertical stiffness irregularity directly.

The exclusion of framing elements in the upper zone was also intentional, as their presence could introduce alternative load paths, allowing a portion of the seismic forces to be absorbed by the columns and thereby reducing the actual shear forces transferred to the shear wall system. Moreover, the podium level incorporates both the continued central core wall and full column beam frame system, representing a typical arrangement in tall buildings. In fact, this configuration reflects common architectural and functional needs at lower levels, such as open floor spaces for parking or commercial use, where continuous shear walls are often not feasible. Therefore, the resulting discontinuity in stiffness and load path at the transfer level serves as a critical point for the redistribution of seismic forces in such buildings.

3. Model Validation

All the building models were subjected to unidirectional seismic loading (along the X direction) using both THA and RSA.

To isolate the most severe localised effect of the transfer floor, the time history records and response spectrum records were applied in the most flexible direction, representing unidirectional ground motion, which is the X direction. In fact, in the model, the X-direction is parallel to the building's width. Despite most of the shear walls being oriented along this direction, it was the most flexible direction of the building, as the first mode of vibration was in that direction. Consequently, this approach magnifies the localised effects, such as pull-push forces and local rotations in the transfer floor. Since the structures were symmetric in plan, further isolating the system to highlight the phenomenon is viable. Therefore, 30% of the live load was also ignored from the analysis.

Accordingly, this study focuses on the behaviour of transfer structures under moderate seismic conditions of peak ground acceleration (0.3 g), which are representative of Sri Lanka. In the models considered, the moment resisting frame system extends up to the transfer floor, while the wall system is located above the transfer floor, representing a worst-case scenario.

These modelling strategies provide clear insight into the phenomenon in isolation. However, their generalisation to other buildings should consider differences in height, low-moderate seismicity, and structural configurations.

Several key steps in model validation are outlined in the following section, specifically for model B. First, the base shear obtained using the elastic design spectrum (Figure 4) in the X-direction was 8,362 kN. The dead weight of the model was 4,646.5 tons. Then, the period of the first mode of vibration in the X direction was 1.96 seconds, while the second mode in the X direction was 0.55 seconds. The translational modal mass participation in the X direction for the first and the second modes was 0.66 and 0.28, respectively. The corresponding spectral accelerations for the first and second modes in the X direction were 0.15 g and 0.52 g, respectively.

Based on these values, the expected base shear contributions from the first and second modes in the X direction were 4513 kN and 6637 kN, respectively. The resultant base shear in the X direction $V_b = \sqrt{V_{b1}^2 + V_{b2}^2}$ = 8026 kN. The percentage error is 4 %, which was within the acceptable limit of 5 %. Therefore, the model was adequate for further analyses.

Table 3 - Validation of each model

Model	Percentage error (%)	Remark
A	4.0	Ok
B	4.0	Ok
C	4.0	Ok
D	3.7	Ok
E	4.2	Ok

According to Table 3, all the models exhibit a percentage error of less than 5 %.

4. Results and Discussion

A detailed investigation of each model led to several key observations. Initially, as shown in Figures 9, 10 and 11, which depict storey shear force variation in shear walls, core walls and supporting columns with the storey number (referring to the vertical storey level of the building, starting from the ground), the storey shear force variation in shear walls generally exhibited a consistent and gradual variation up to a certain storey level. However, at the transfer floor level, an irregular variation in shear forces in both shear walls and core walls was observed in both THA and RSA. Most importantly, a notable concentration of storey shear force was found in the overlying shear walls in the transfer level. This phenomenon arises from redistributing shear forces from the core wall to the shear walls owing to the in-plane tension and compression forces within the floor slabs induced by the localised deformations in the transfer floor under seismic excitation. Moreover, according to Figures 9 and 10, the supporting columns resist a smaller portion of the storey shear, while the core wall carries the majority of the shear force beneath the transfer floor. This is because the core walls are stiffer and more continuous than the supporting columns; they attract and resist a larger share of lateral load within the lower zone. The columns, being relatively flexible and discontinuous above the transfer level, contribute less lateral stiffness to the system, resulting in lower shear demand.

In Figures 12 and 13, the overall shear variation in all models under the design response spectrum is presented. According to Figure 12, it is evident that the model with the 1.5 m deep transfer floor (model B) indicates the lowest storey shear immediately above the transfer floor. Figure 13 further shows that, when the transfer floor is located at higher vertical elevations, the overall shear demand reduces and the variation becomes more consistent, whereas when the transfer floor is located at lower levels, the variation becomes more irregular.

Table 6 indicates the average shear force in shear walls immediately above the transfer floor evaluated by averaging the storey shear forces from the seven time histories and response spectra for all the building models. It was observed that the shear force distributions obtained from both RSA and THA were relatively similar; however, the values from THA were up to 13% higher than those from RSA at the level immediately above the transfer floor.

Table 4 – Period of the first mode and Model Participating Mass Ratio (MPMR) of each model

Model	Period of the first mode (s)	MPMR
A	1.97	0.67
B	1.96	0.66
C	1.94	0.65
D	1.79	0.60
E	2.15	0.73

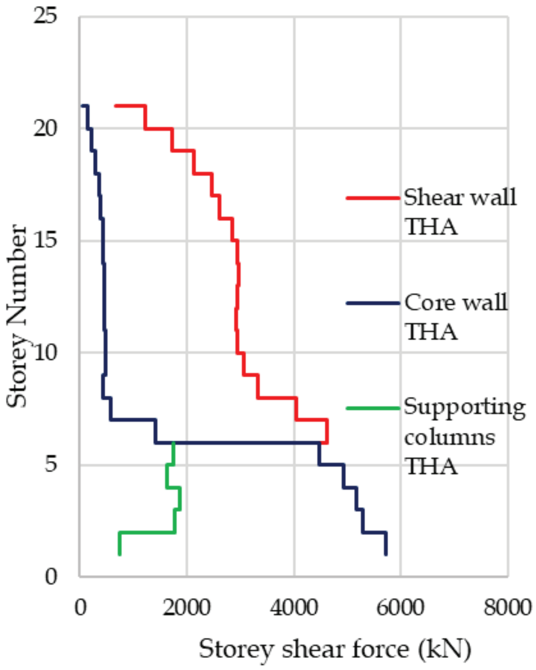

Figure 9 - Shear distribution in core walls & shear walls from THA in model B

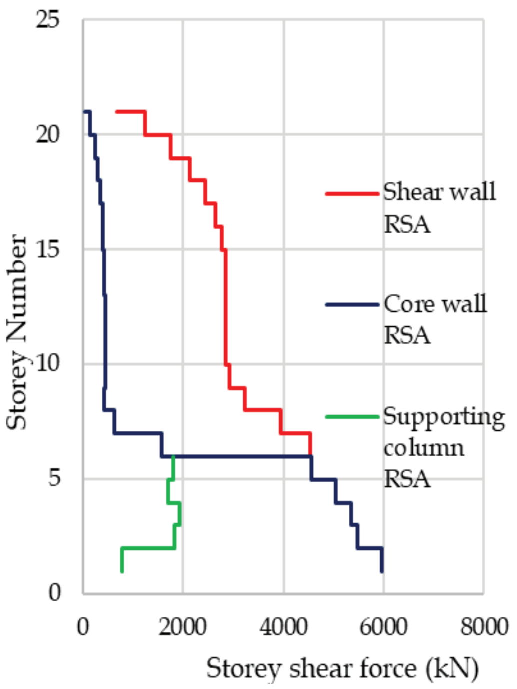

Figure 10 - Shear distribution in core walls & shear walls from RSA in model B

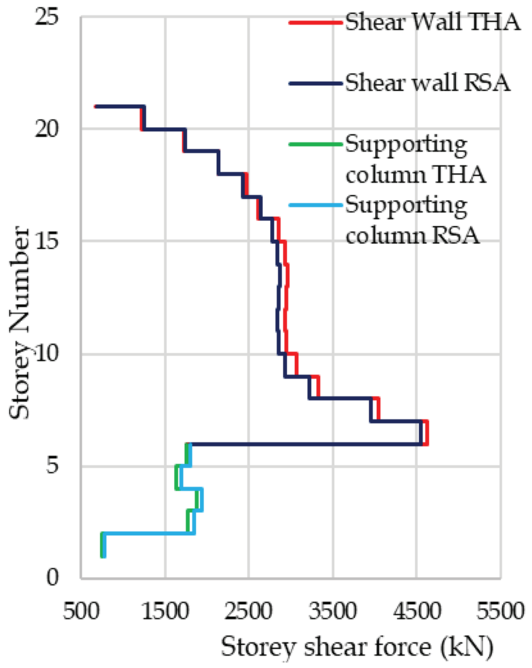

Figure 11 - Shear distribution in shear walls from THA & RSA in model B

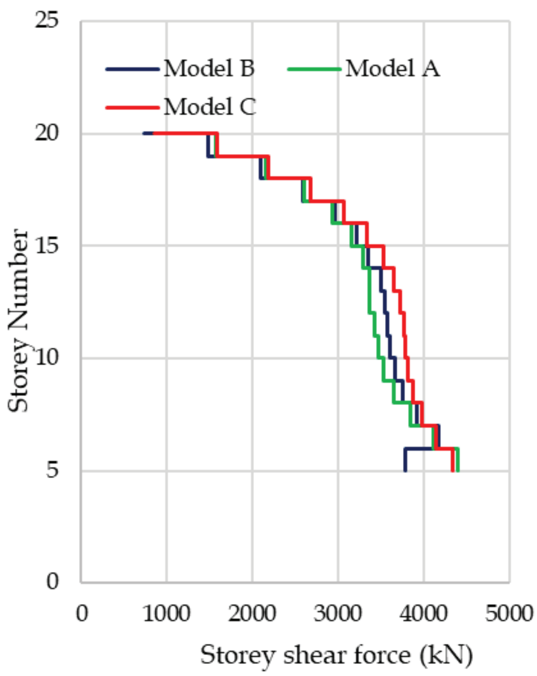

Figure 12 – Overall storey shear distribution in design RSA for Sri Lanka in models A, B & C

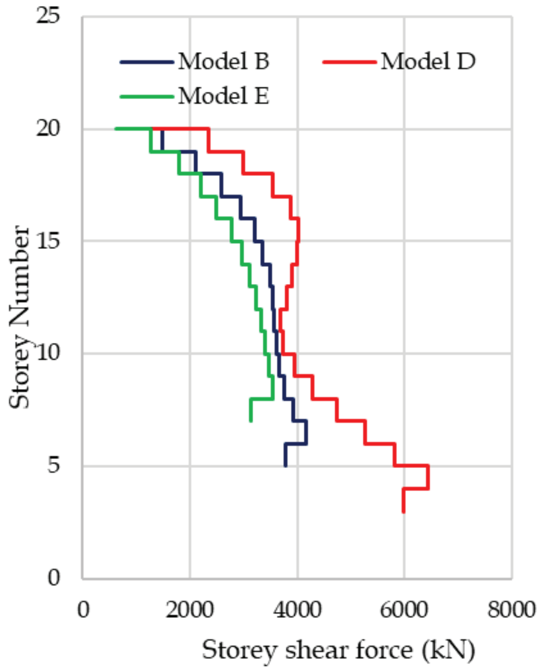

Figure 13 – Overall storey shear distribution in design RSA for Sri Lanka in models B, C & D

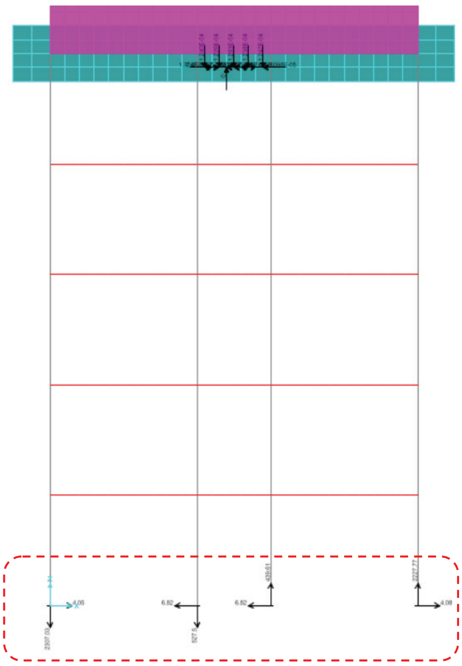

Figure 14 - Base reactions in supporting columns under THA in model B

Most importantly, as shown in Figures 14 and 15, push-pull forces were only observed in the THA, while the base reactions in RSA are unidirectional. This highlights that THA is more effective in capturing the realistic behaviour of the transfer floor system under seismic loading.

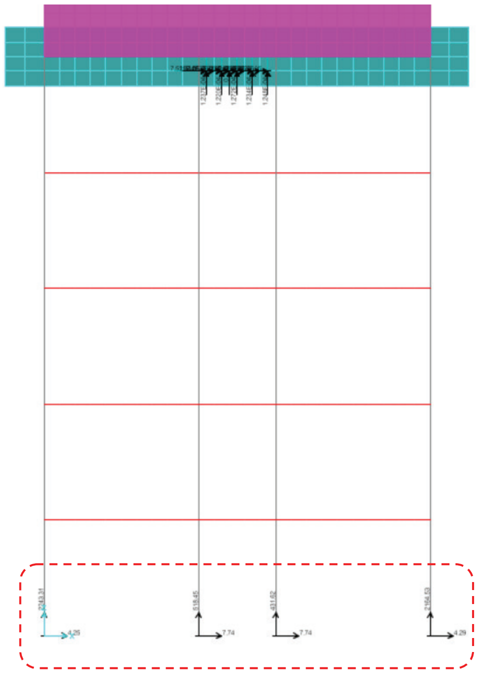

Figure 15 - Base reactions in supporting columns under RSA in model B

This difference may have arisen because the Time History Analysis (THA) solves the dynamic equilibrium equation:

$$M\ddot{u} + C\dot{u} + Ku = -M\ddot{u}_g \quad .... (1)$$

where M, C and K are the mass, damping, and stiffness matrices, respectively, u is the displacement vector, and $\ddot{u}_g$ is the ground acceleration. This approach accounts for all dynamic components over time.

RSA captures the dynamic nature of the system by considering several equivalent SDOF oscillators. Therefore, it does not reflect the full time-dependent interactions of the structure.

These push-pull forces, which result from localised floor rotations and dynamic interactions between columns and slabs, play a critical role in understanding shear force redistribution immediately above the transfer floor. They significantly amplify the in-plane tension and compression forces within floor slabs above the transfer floor, causing a transformation of shear forces from the core wall to the outer shear walls. Since RSA does not replicate these dynamic load transfer and rotations, it tends to underestimate shear concentrations in walls. Therefore, THA offers a more realistic representation of structural behaviour in buildings with vertical stiffness irregularity. Additionally, the present study proposes the development of a correlation or adjustment method to align the outcomes of RSA with those of THA. Figure 16 illustrates the variation in average shear force in the shear

walls immediately above the transfer floor for models A (1.0 m deep), B (1.5 m deep), and C (2.0 m deep), based on all seven time history records and corresponding response spectra. Notably, Figure 16 shows that the shear force in the shear walls is lower when the transfer floor depth is 1.5 meters compared to other depths.
When the transfer floor is 1 meter deep (relatively flexible), it tends to rotate significantly under seismic forces. This rotation induces higher shear force transmission from the core wall to the exterior shear walls through the typical floor slabs in an effort to reduce rotational incompatibility. This may explain the higher shear forces observed just above the transfer floor in this scenario. Conversely, with a 2.0-meter-deep transfer floor, the system behaves similarly to a rigid diaphragm, limiting in-plane deformation but increasing shear transfer to the walls. In contrast, a 1.5-meter-deep transfer floor offers a balance between stiffness and deformation compatibility, resulting in lower shear force transmission to the shear walls compared to the other two configurations.

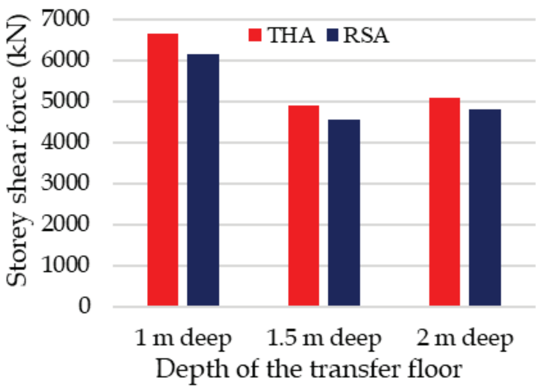

Figure 16 - Shear force on top of the transfer floor in shear walls from THA & RSA

Table 5 – Period of the second mode and Model Participating Mass Ratio (MPMR) of each model

Model	Period of the first mode (s)	MPMR
A	1.65	0.62
B	1.52	0.55
C	1.57	0.58
D	1.62	0.55
E	1.55	0.65

According to Table 6, the comparison between RSA and THA across the five models reveals that THA consistently predicts slightly higher storey shear forces in shear walls immediately above the transfer floor.

Table 6 - Average shear force in shear walls immediately above the transfer slab

Model	Analysis	Average shear force in X direction (kN)	Δ %
A	THA	6652	8.4 %
	RSA	6139	
B	THA	4884	7.5 %
	RSA	4543	
C	THA	5078	5.9 %
	RSA	4794	
D	THA	6650	13.0 %
	RSA	5887	
E	THA	3511	4.7 %
	RSA	3351	

The percentage increase under THA compared to RSA ranged from approximately +4.7% to +13%, with the highest deviation observed in the model with the transfer floor located at the 3rd-floor level (Model D). Although Models B, D, and E all had 1.5 m deep transfer floors, the variation in shear force differences highlights the importance of transfer floor elevation in addition to its stiffness. Therefore, while RSA provides a simplified and generally conservative estimate, THA remains essential for capturing the most realistic dynamic behaviour, particularly in buildings with vertical irregularities. As the depth of the transfer floor increases from 1.0 m to 2.0 m, the structure's fundamental periods of first and second modes reduce from 1.97 s to 1.94 s and 1.65 s to 1.57 s, respectively, indicating increased stiffness. This period shortening leads to higher spectral acceleration and, consequently, higher base shear. While the first mode mass participation ratio slightly decreases from 0.67 to 0.65, the second from 0.62 to 0.55 (see Table 4 and Table 5), the structures still respond primarily in their fundamental mode, and the rise in base shear is mainly attributed to the reduced period and increased global stiffness. According to Table 4 and Table 5, the model properties strengthen the conclusions made by Elawady et al. [6]. As seen in this study, Model D, with a transfer floor at a lower level (3rd floor), has a shorter fundamental period (1.79 s) and lower MPMR (0.60), reflecting a more complex, multi-modal seismic response. This complexity likely contributes to the higher discrepancy (+13%) between RSA and THA results. In contrast, model E, with its transfer floor at the 7th level, exhibits a longer period (2.15 s) and higher MPMR (0.73) for the first mode, indicating a fundamental mode-dominated behaviour. This results in a smaller difference between RSA and

THA (+4.7%). These findings confirm that both the stiffness and vertical location of transfer floors significantly affect seismic behaviour, especially the accuracy and consistency of analysis methods like RSA compared to THA.
Via models B (5th level), D (3rd level), and E (7th level), the shear force variation in shear walls was estimated by varying the vertical location of the transfer floor. Both the THA and RSA were done on each model to record the shear force values immediately above the transfer floor, and then the variation of shear force with transfer floor level is indicated in Figure 17.

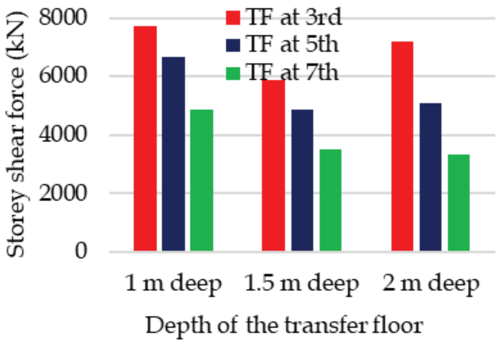

Figure 17 – The average shear force on top of the transfer floor in shear walls from THA when the transfer slab (TS) is at different levels

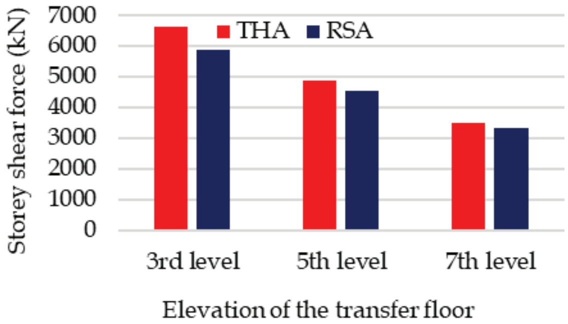

Figure 18 - Shear force variation in shear walls on top of the transfer floor from THA & RSA

According to Figure 18, a reduction in shear force is observed in the shear walls immediately above the transfer floor as its elevation increases, from the 3rd floor (model D) to the 7th floor (model E). This can be attributed to both mass distribution and structural discontinuity effects. In fact, in model D, the transfer floor is at a lower level, resulting in a higher mass above it. This mass may have been the cause of the increasing shear force on the shear walls immediately above the transfer floor. In contrast, Models B and E have higher transfer floor levels, reducing shear forces. Thus, elevating the transfer floor has minimised the shear force on upper-level walls.

5. Conclusions

This study investigated storey shear force concentration in shear walls located immediately above transfer floors in rectangular tall buildings, with a focus on seismic conditions in Sri Lanka. Five parametric 3D building models were analysed using both Response Spectrum Analysis (RSA) and Time History Analysis (THA) to assess how transfer floor depth and elevation influence the seismic performance.
The analyses reveal that THA consistently predicts higher shear forces than RSA, particularly when transfer floors are located at lower levels. This highlights that dynamic effects, such as in-plane slab deformation, push-pull interactions, and modal coupling, significantly influence shear force distribution, which may be underestimated if relying solely on RSA. For high-rise buildings with vertical irregularities or transfer floors, THA is recommended to accurately capture critical forces.
The transfer floor depth critically affects structural response. A depth of 1.5 m provides a balance between stiffness and flexibility, limiting shear force concentration in upper-level walls. Shallower floors permit excessive deformation, whereas deeper floors increase the rigidity-induced force transfer.
The elevation of the transfer floors also significantly affects seismic performance. Lower transfer floors exhibit greater shear forces in upper stories due to larger overlying mass and complex modal interactions. Whereas higher transfer floors reduce shear concentration, resulting in a more uniform seismic response. The study also highlights the critical role of core walls beneath transfer floors, which attract the majority of shear due to their continuity and high stiffness at the podium level over supporting columns. Supporting columns contribute less to the shear resistance of the discontinuity above the transfer level. This insight informs design prioritisation: adequately designing the core wall beneath transfer floors is imperative, while column sizing may be optimised for serviceability rather than maximum shear.
Overall, the findings provide practical guidance for the seismic design of tall buildings with transfer floors. The geometry of the transfer floor, including its depth and vertical location, should be carefully selected to control shear concentration in shear walls immediately above the transfer floor. Additionally, core walls below the transfer floor should serve as the

primary lateral load-resisting elements at the podium level due to their stiffness and continuity. In structures with vertical irregularities, Time History Analysis (THA) is recommended to capture dynamic effects accurately and avoid underestimating critical seismic forces.

Future work may extend this study in several directions to enhance seismic design strategies for tall buildings with transfer structures. These include investigating bidirectional seismic loading, exploring different wall configurations below the transfer floor to minimise shear concentration, and assessing the phenomenon in high-rise buildings (30-40 storeys). The effects of varying seismic intensities, including very low seismicity (e.g. 0.1 g), should also be examined to generalise the findings across diverse seismic conditions. Additionally, studies could consider irregular plan shapes, material nonlinearities, and soil-structure interaction to further refine the understanding of transfer floor behaviour and provide more robust guidance for practical design.

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