COMPARATIVE STUDY OF MULTI-STORIED BUILDING WITH AND WITHOUT TRANSFER FLOOR

Seismic Strength Evaluation of a Live Project using Response Spectrum Analysis

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Abstract: High-rise buildings are very popular in places where land availability is an issue also in densely populated areas as it requires less space and accommodates a large number of People. Satisfying both residential and commercial needs in one building is a common solution in developing cities, such buildings consist of bottom stories which are used as Podiums for Malls & parking, etc. and top stories are used for residential purposes. Vertical irregularity is a common problem in such buildings because of discontinuity in load transferring mechanism. This problem can be solved by introducing the transfer floor which acts as a load transferring medium at the level of discontinuity. This paper primarily focuses on the effect of the transfer floor on the behavior of the building in the event of an earthquake by comparing the response of building with and without transfer floor.

***Index Terms* - Multistoried building, Podium, Transfer floor, Structural Irregularity, Response spectrum analysis**

1 INTRODUCTION

Multi-storied buildings have become an indispensable form for the construction of new housing in urban areas [1]. A Multi-storied building with a transfer floor system consisting of a structure located below the transfer floor, which serves as functional areas of an atrium with a large elevator, a shopping center, commercial markets, parking lots, multi-purpose rooms, etc., while the structure above the transfer slab is a residential unit. Residential units use shorter column spacing for cheaper design, for these results, the structure below transfer floor uses long spaced columns, while the upper phase includes short space columns [2]. It's been a common solution to use transfer slab as a medium to transfer load between upper and lower part of building.

Most of the buildings are constructed with these vertical irregularities, i.e. structural walls and columns, with transferring mechanism between different column arrangements at floor level. A transfer floor is a floor that supports a system that is resistant to vertical and lateral loads. There are two different types of transfer floor systems namely transfer slab and transfer beam. Depending on the load distribution on the transport structure, the type of transfer floor system is selected [3].

It is necessary to ensure safety and serviceability of the structures with vertical irregularities before it is permanently resided in. Lack of proper planning and ill-engineered construction are the main causes which increases the risk of natural hazards [4]. Analysis of and design of irregular buildings have become possible due to powerful structural analysis tools available today. Discontinuity in vertical elements i.e. shear walls and column are no longer considered as a design mistake in high-rise buildings [3]. A major disadvantage of the transfer floor is that the lateral stiffness of the building changes rapidly around that level. The direct result of such irregularities is the ductility reduction of elements near the transfer floor which is greatly affected by the formation of the soft story mechanism under moderate to heavy earthquakes and lateral wind loads [5]. Therefore, to prevent these sources of damage during strong earthquake shaking the vertical irregularity should be given due consideration in the early design stage.

Research says that in buildings with transfer floors, base shear will increase significantly when located about 10% of the total height of the building [6].

Also, the vertical location of transfer floor greatly affects the performance of the building with respect to the total height of the building and it is advisable to locate transfer floor on the lower part of structure approximately 20% to 30% of total building height from the foundation [6].

2 PROPOSED WORK

2.1 Methodology

The study is focused on the analysis and design of 16 story building with podium and transfer slab. In this work, an attempt is made to check the design and safety requirement of Live project of a 16-floor building with transfer slab located in Mumbai. The building lies in zone 3 with an overall dimension of building as 18.85m width 51.55m Length and 61.2m height. The building has unique features and has vertical irregularities which make it susceptible in the event of an earthquake. In this study comparative analysis was performed to predict buildings behavior and response so that any harm or loss to the life and property can be minimized. Basically, two types of model are prepared to capture the behavior, the first model consists of a building having transfer floor arrangements and the Second model has built without transfer floor arrangement. Basic structural and dynamic properties of the building have been found out manually as well as by model and comparison with different parameters have been presented in this paper.

2.2 Building data

The building has three basements Podium parking with sixteen floors and swimming pool above terrace out of which fourteen floors are habitable and two floors namely seven and fourteen serves as a refugee in case of emergency. The building is provided with transfer floor of thickness 1250mm for satisfying both residential and parking needs as parking is a big problem in mega cities. Two separate models are prepared for analysis namely with and without transfer floor is shown below in Figure 1.

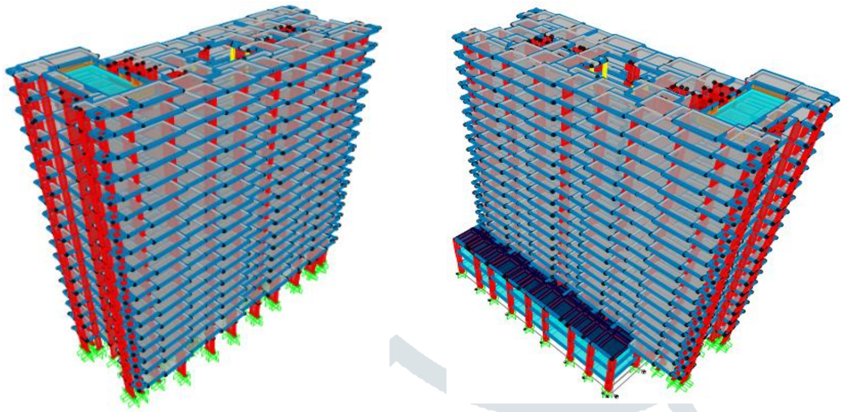

Figure 1 3D view of the building

Table 1 Building data

Sr. No.	Item	Dimension (mm)	Description
1	Basement height	2950	Podium Parking
2	Floor height	2900	Habitable floor
3	Podium Slab	200	M25, Fe500, Fe415
4	Transfer slab	1250	M30, Fe500,Fe415
5	Floor slabs	125	M25, Fe500, Fe415
6	Podium column	500x1000	M30, Fe500,Fe415
7	Shear wall	230	M30, Fe500,Fe415
8	Beam	230x700, 230x450	M25, Fe500, Fe415

3 ANALYSIS AND DESIGN OF BUILDING

3.1 Loading on the structure

The dead and live load has been considered as per function and purpose of the floor for which it is intended to be used Table 2 [11, 12}. Wind and earthquake load has been considered with reference to codal provision Table 3 [9, 13].

Table 2 Loading on Floors

Sr. No.	Type	Podium Suits	Floor Suits	Terrance	Swimming pool
1	DL	5kN/m^2	3.75kN/m^2	3.75kN/m^2	3.75kN/m^2
2	LL	5kN/m^2	2kN/m^2	1.5kN/m^2	2kN/m^2
3	FF	1.5kN/m^2	1.5kN/m^2	1.5kN/m^2	1.5kN/m^2
4	WF	-	-	1.5kN/m^2	1.5kN/m^2
5	WT	-	-	-	12kN/m^2

Table 3 Wind and Earthquake data

Sr. No.	Seismic Load	Wind load	
1	Seismic zone = 3	V_b = 44 m/s	
2	IF= 1.2	k_1 =1, k_2 =1.12, k_3 =1, k_4 =1	
3	Soil type = 2	Terrain category =3	
4	Response reduction factor = 5	X-direction $C_{pe,w}$ = 0.7, $C_{pe,l}$ = 0.7 C_{pi} = +/- 0.2	Y-direction $C_{pe,w}$= 0.8, $C_{pe,l}$ = 0.5 C_{pi} = +/- 0.2

3.2 Transfer slab details

Unlike normal slabs, it has a higher thickness that satisfies punching shear requirement also with double mesh connected by vertical links as shown in Figure 2.

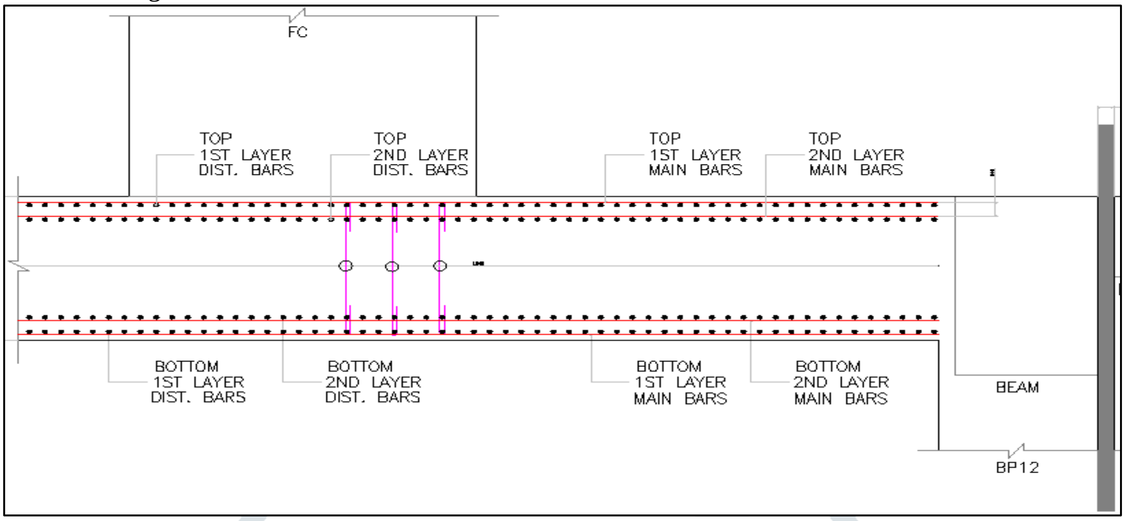

Figure 2 Transfer slab Section details

3.3 Evaluation of Seismic Parameters

Important seismic parameters have been calculated manually which are the base of further calculations, which includes calculation of time period of the structure, seismic weight of the structure, limiting values of maximum story displacement, inter-story drift, and Storey shear, etc. [7-8].

3.3.1 Seismic weight of the structure

Seismic weight of floor is full dead load plus the appropriate amount of live load with the proportionate weight of column and walls above and below the floor.

$$\left.\begin{array}{l}\text{DL+25\%LL+wt. of walls and columns}\\ \text{DL+50\%LL+wt. of walls and columns}\end{array}\right\} \quad \text{(Cl.7.3.2. IS 1893-1, 2016)}$$

Time period in direction of acceleration

$$\mathrm{Ta} = \frac{0.075\mathrm{h}^{0.75}}{\sqrt{\mathrm{Aw}}} \geq \frac{0.09h}{\sqrt{d}} \qquad \text{Eq. 1}$$

$$Aw = \sum_{i=1}^{Nw}\left[Awi\left\{0.2 + \left(\frac{lwi}{h}\right)^2\right\}\right] \qquad \text{Eq. 2}$$

Where,

$A_{w,}$ is the total effective area (m^2) of walls in the first story of the building.

h is the height of building in m. (Cl.7.6.2. (a) IS 1893-1, 2016)

A_{wi} is the effective cross-sectional area of a wall i in the first story of building in m^2.

L_{wi} is the length of a structural wall i in the first story of building in considered direction of lateral force in m.

d is the base dimension of the building at the plinth level along the considered direction of earthquake shaking in m.

N_w is the number of walls in the considered direction of earthquake shaking.

Table 4 Summary of calculated seismic parameters

With Transfer floor		Without Transfer floor	
Total Seismic wt	4,43,850 kN	Total Seismic wt	2,35,768 kN
Seismic wt/m^2	2.89 T/m^2	Seismic wt/m^2	1.5 T/m^2
Time period in Y-direction	By Calculation 1.28sec	Time period in Y-direction	By Calculation 1.04sec
	By model 1.73sec		By model 1.49sec
	By Calculation 1.01 sec		By Calculation 0.87 sec

Time period in X-direction	By model 1.22 sec	Time period in X-direction	By model 2.1 sec

4 RESULTS

Response spectrum analysis has been performed on both types of models viz. with and without transfer floor. Basic parameters are chosen and results are compared to determine the behavior of the building. To know the influence of the presence of the transfer floor whether it is allowable in terms of safety and serviceability of the building or not is also assured.

Figure 3 compares the absolute top story displacements of the floor and shows that building with transfer floor has about 25% more displacement in X-direction by building without transfer floor.

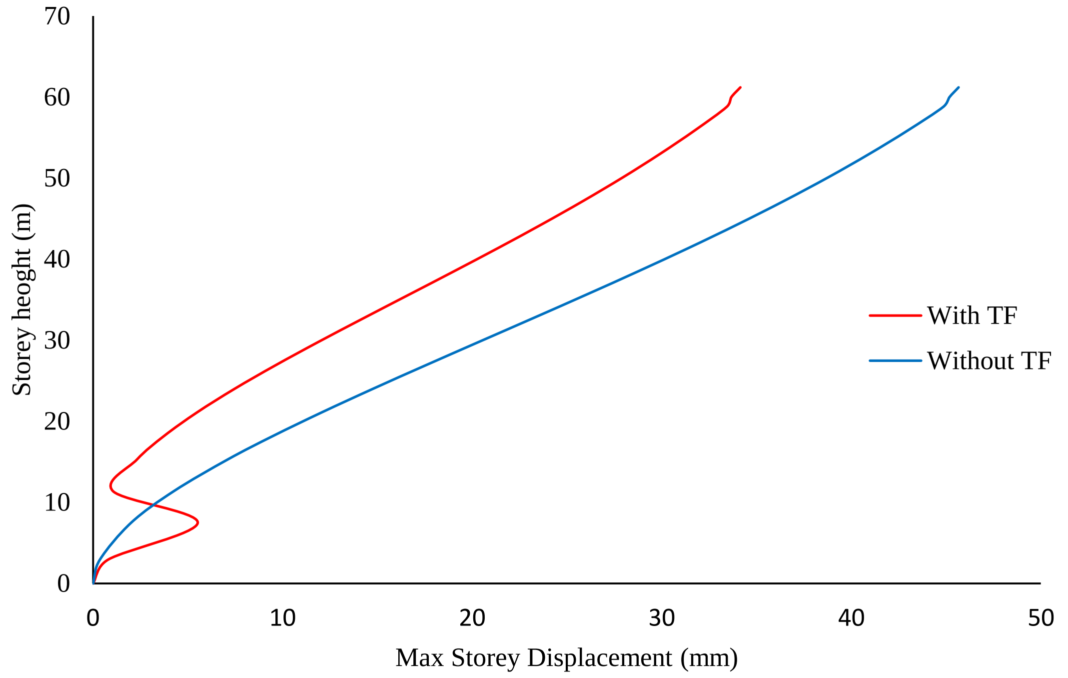

Figure 3 Top story displacement in X-direction

Figure 4 compares the absolute top story displacements of the floor and shows that building with transfer floor has about 45% less displacement in Y-direction by building without transfer floor.

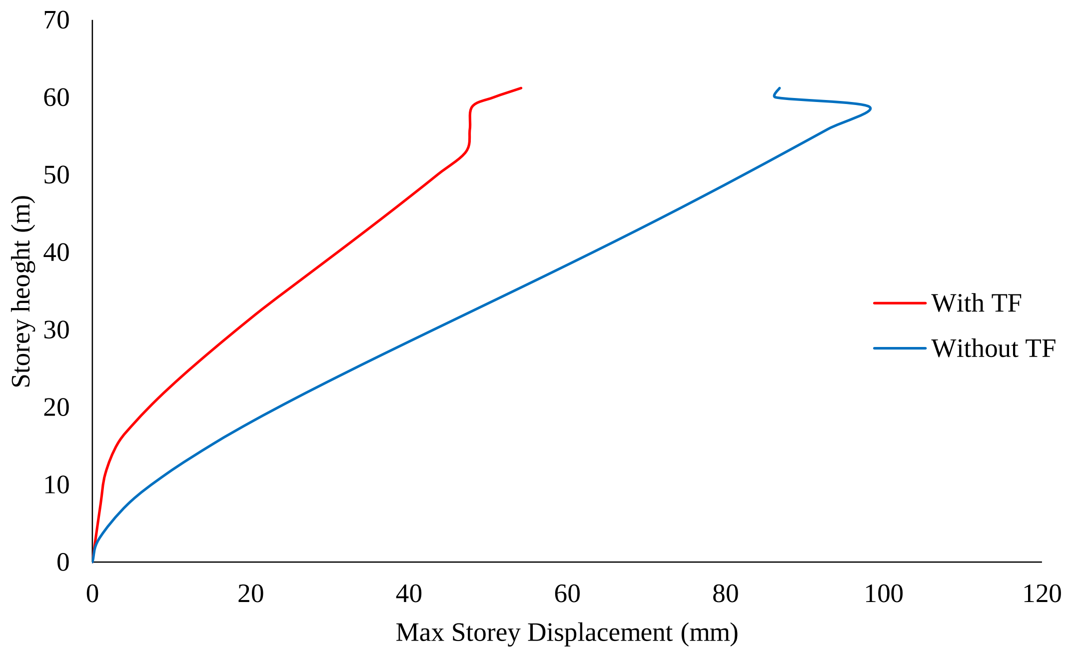

Figure 4 Top story displacement in Y-direction

Figure 5 compares the inter-story drift of the floors and shows that building with transfer floor has peak drift at the level of transfer floor in X-direction and about 48% higher than building without transfer floor.

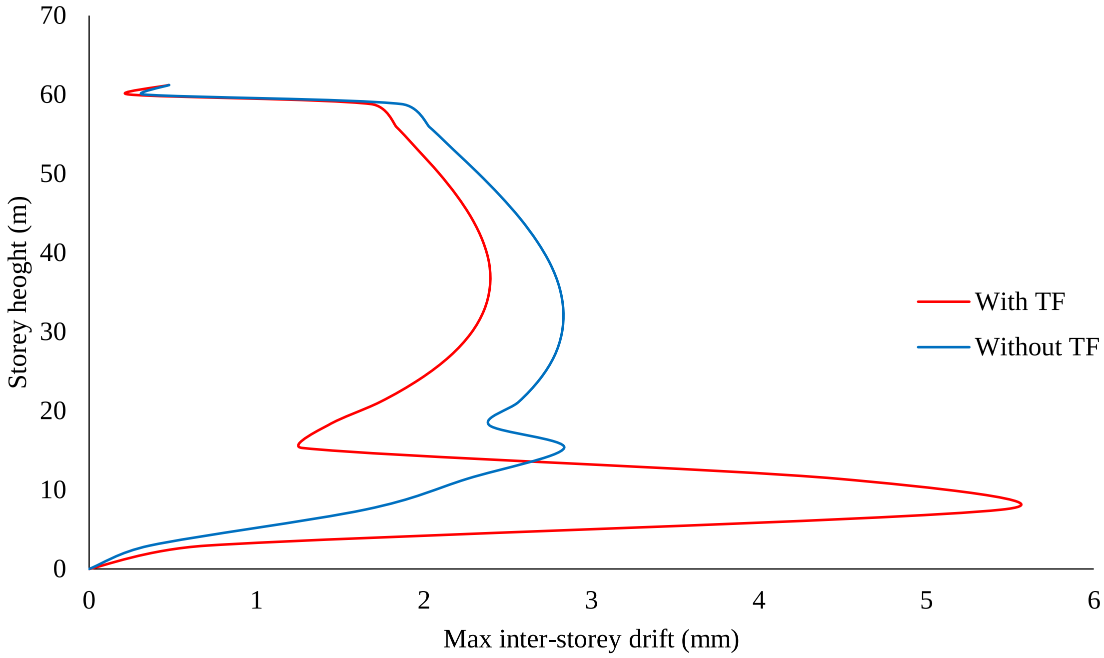

Figure 5 Inter-storey drift in X-direction

Figure 6 compares the inter-story drift of the floors and shows that building with transfer floor has about 50 % less drift in Y-direction than building without transfer floor.

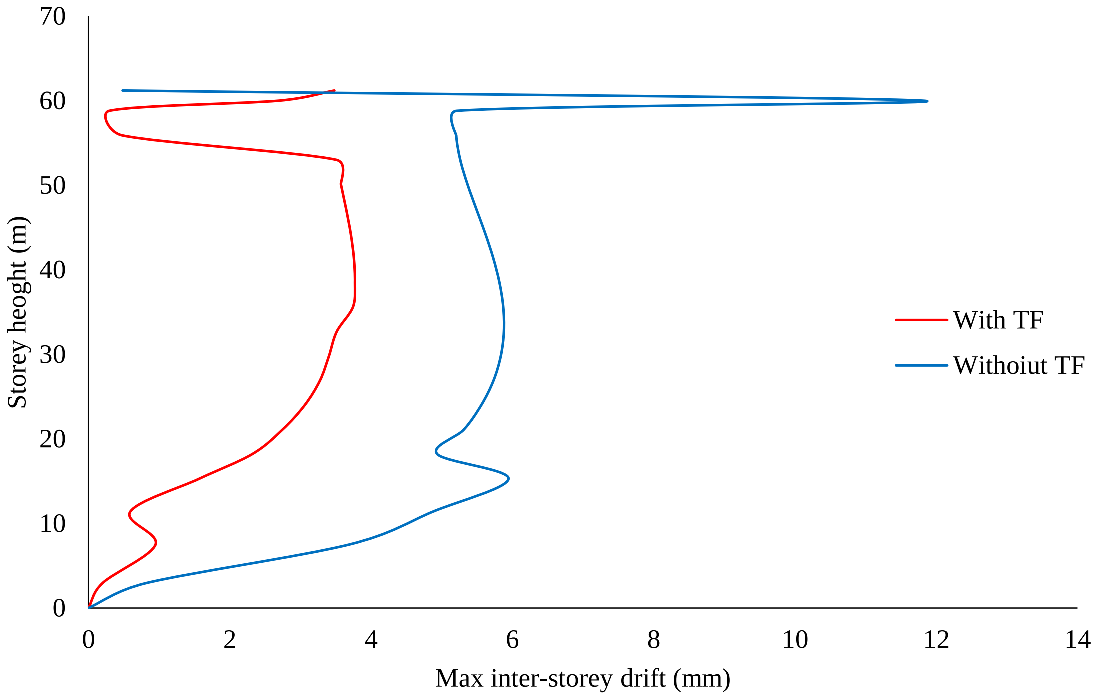

Figure 6 Inter-storey drift in Y-direction

Figure 7 compares the base shear of the floors and shows that building with transfer floor has max base shear at the level of transfer floor which is about 38 % more in X-direction than building without transfer floor.

Figure 8 compares the base shear of the floors and shows that building with transfer floor has max base shear at the level of transfer floor which is about 35 % more in Y-direction than building without transfer floor.

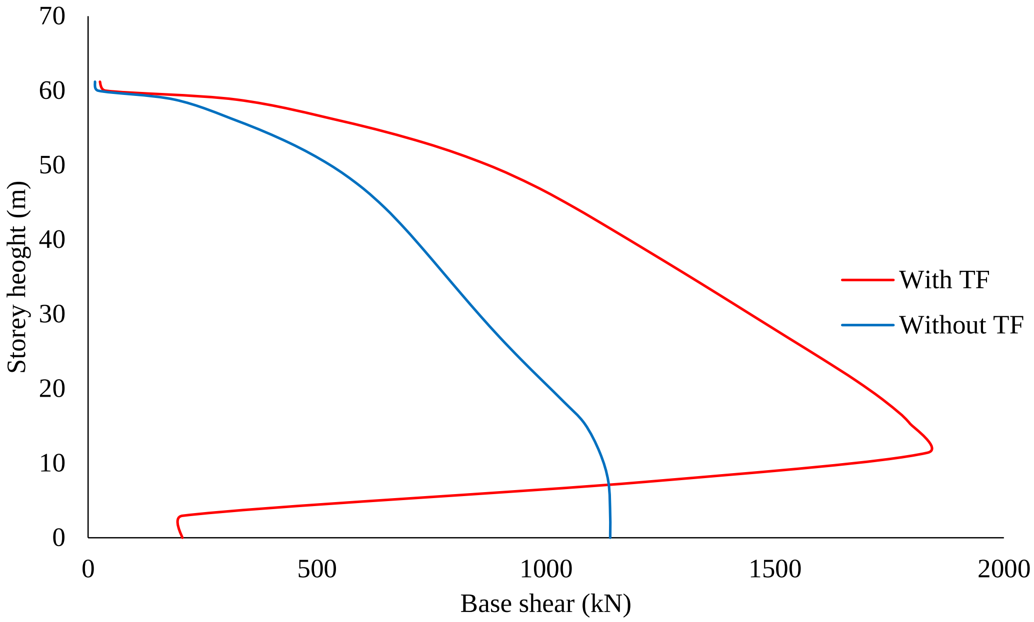

Figure 7 Base Shear in X-direction

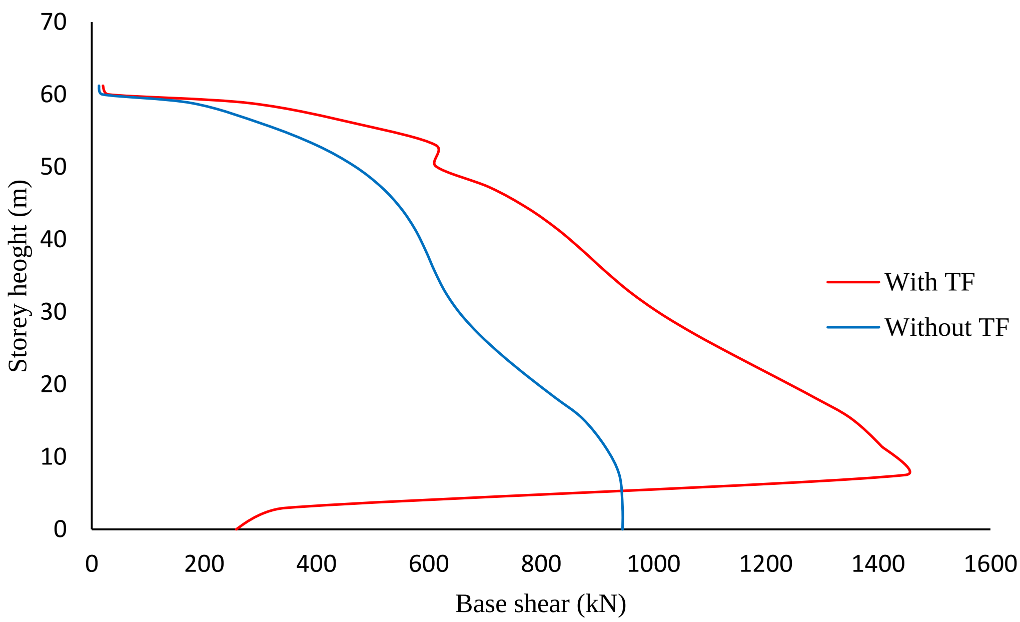

Figure 8 Base Shear in Y-direction

5 CONCLUSIONS

The present study is based on response spectrum analysis performed on two types of models namely with and without transfer floor. The building with transfer floor is having more stiffness, damping and less time period as compared with the building without transfer floor given by the model. The transfer floor has a large thickness which might be the reason for high seismic weight about 50% more than building without transfer floor but it also helps in reducing the response of the structure. The top story displacement is less in longer direction while in a shorter direction it is more in building without transfer floor. There is a sudden change in buildings inter-story drift in a longer direction near the transfer floor level and inter-story drift in shorter direction is more in a building without transfer floor. The max base shear occurred at the level of transfer floor unlike at the base the reason might be the presence of weight at transfer floor level.

It can be inferred from the above discussion that selected parameters are more affected in the longer direction of the building with transfer floor than the shorter direction. The opposite case can be seen in building without transfer floor that the selected parameters are more affected in longer direction than its shorter direction. After verifying the results obtained from the model with the limiting values described by the code the selected parameters are found under the zone of safety however detailed analysis is required to know the complete behavior of the building to comment upon its safety and serviceability.

6 ACKNOWLEDGMENT

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