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SEISMIC ANALYSIS OF HORIZONTALLY CONNECTED HIGH-RISE BUILDING BY DIFFERENT CONFIGURATION OF SHEAR WALL AND THE HORIZONTAL SKY BRIDGE

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Abstract - *Shear walls provide strength and stiffness to buildings, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Now a days, adjacent tall buildings are being horizontally connected for different purposes. Structural Engineers are concerned with finding out the behavior of a structure when subjected to horizontal forces and adequate stiffness is required for the buildings which are high-rise in order to confront horizontal forces caused by winds and earthquakes. This project aims to study the usage of Shear walls at different locations in a horizontally connected twin high-rise building (G+30) interconnected using skybridge and to study the nature of the structure exposed to earthquake and also comprehensively assesses the response of linked high-rise buildings under earthquake loads, following design-code requirements. The effect of sky-bridge location on the induced structural responses is examined as well. The building is analyzed for, base shear, maximum allowable displacement and stiffness. The analysis and modeling for the whole structure is done by using Etabs.*

Key Words: **Shear wall, Sky Bridges, Stiffness, seismic forces, lateral load, high-rise building, storey drift, base shear, maximum allowable displacement, torsional irregularities**

1.INTRODUCTION

Modern tall and super-tall buildings are lightweight, more flexible, and more lightly damped. Shear walls are generally used in high-rise buildings which are subject to lateral forces such as wind and seismic forces. Structural Engineers focus finding out the behavior of a structure when subjected to horizontal forces and adequate stiffness is required for the buildings which are high-rise in order to confront horizontal forces caused by winds and earthquakes. To tackle the horizontal forces which are developed by earthquakes and to give stiffness to the structure we use Shear walls, which are added to the interior of the structure. This project aims to study the usage of Shear walls at different locations in a horizontally connected twin high-rise building interconnected using skybridge and to study the nature of the structure exposed to earthquake and also assesses the response of linked high-rise buildings under earthquake loads, following design-code requirements. The effect of sky-bridge location on the induced structural responses is examined as well. The building is analyzed for, base shear, maximum allowable displacement and stiffness.

1.1. Shear Walls

In structural engineering, a shear wall is a vertical element of a seismic load resisting system that is designed to resist in-plane lateral forces, such as wind and seismic loads. A shear wall withstand loads parallel to the plane of the wall. Collectors, also known as drag members, transfer the d shear to diaphragm hear walls and other vertical elements of the seismic force resisting system.

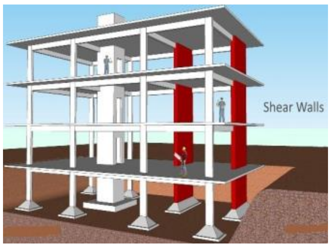

Fig -1: Shear Walls

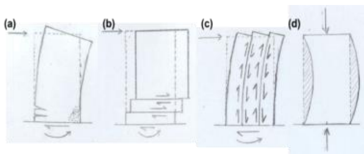

Fig -2: Critical Failure Mechanisms

1.2. Sky Bridge

Fig -3: Sky Bridge

A skyway is an elevated type of pedestrian way connecting two or more buildings in an urban area, or connecting elevated points within mountainous recreational zones. They sometimes take the form of covered footbridges that protect pedestrians from the weather. Open-top modern skyways in mountains may have glass bottoms. Enclosed skywalks are made totally from glass, including ceilings, walls and floors. Also, some skyways functions as linear parks designed for walking. They usually connect the first few floors above the ground floors, though they are sometimes much higher, as in Petronas Tower.

2. METHODOLOGY

2.1 General

The seismic performance of high rise building with horizontal connection and shear wall is investigated. The first stage of this project is the study of various recent journals and preparation of a literature review of the same. Which is followed by performing the validation of the software in order to check the performance and accuracy of the software and results obtained. After validation, building models with plan eccentricity and elevation eccentricity are developed. The required horizontal connections are provided and shear walls are provided according to the requirement.

The methodology is described in the following.

a) Literature review: The data for defining the problem is collected from the literature review.

b) Validation of software is done for 20 storeys building as in the main journal and the obtained result is compared with the values in the journal.

c) A 30-storey twin building interconnected with horizontal skybridge model with plan and elevation eccentricity is developed using ETABS 2018. Total of 12 models are created.

d) The seismic performance analysis of each case is studied on the software.

e) Seismic performance of building with varying shear wall configuration and sky bridge height are compared based on the parameters such as maximum storey displacement and maximum stiffness and maximum base shear.

2.2. Software Used

ETABS is an engineering software that are used for multi-story building analysis and design. Basic or advanced systems under static conditions or dynamic conditions can be examined and checked using ETABS. Intuitive and integrated features make it easy to apply any complexity practical to implement. ETABS is a coordinated and effective tool for designs ranging from simple 2D frames to modern high-rises. ETABS automatically generates and assigns code-based loading conditions for gravity, seismic, wind, and thermal forces after modelling. Users can provide with an unlimited number of load cases and combinations.

3. MODELLING AND ANALYSIS OF BUILDINGS

3.1. General

Buildings with plan and elevation eccentricities are developed for modelling and analysis. The basic building plan and properties were adopted from the validation journal, and a mirror copy of the same is created to provide a twin tower. After remodeling a sky bridge is drawn connecting both the structure at respective stories require for modelling. The distance of 10 m is provided between both the structure. A total of 30 floor is provide. 12 models are created with 4 cases. These cases are based on the height at which the sky bridge is provided and each cases include 3 model each based on configuration of shear walls. The sky bridges are provided at 24th, 18th, 12th, and 6th floors. Response spectrum analysis is done on each model and the behavior of structure is compared and the best configuration is discussed.

3.2. Response Spectrum Analysis

Response spectrum analysis estimates the response to short, nondeterministic series of events. It can estimate the peak response of a structure to a particular base motion. The method is only approximate, but it is often a useful, inexpensive method for preliminary design studies Due to the short length of the event, it cannot be considered as an stochastic process, so a random response approach is not applicable either. The response spectrum method is in the basis of a special type of mode superposition.

3.3 Model Specifications

- Number of storeys: 30
- Size of beams (other than sky bridge): 300 mm x 500 mm
- Size of beams (sky bridge): 600mm x 700mm
- Size of column: 500mm x 600mm
- Thickness of slab 125mm
- Thickness of sky bridge slab 300mm
- Wall load on beams 12.0 KN/m

The modelling is done on Etabs 2018 software. Response spectrum analysis is carried out with damping of 5% and the response reduction factor is adopted as 5 as in the case of special RC moment resisting frame the response reduction factor is taken as 5 as mentioned in IS 1893 (part 1): 2002 (table 7). Beam, column and slab are provided as per reference with the base journals. Support condition is fixed and the importance factor provided is 1.

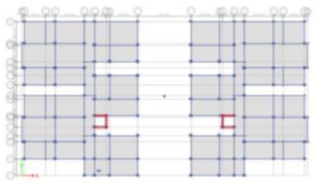

Fig 5: Plan (Till 24th Floor)

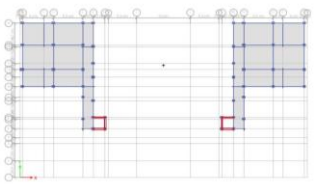

Fig 6: Plan (25th to 30th Floor)

3.4 Case 1: Twin Tower with Sky Bridge at Top Height (24th Floor)

Here shear walls are provided at the 24th floor and three models are analyzed based on the configuration of shear walls.

3.4.1. Model 1: Structure without Shear Wall

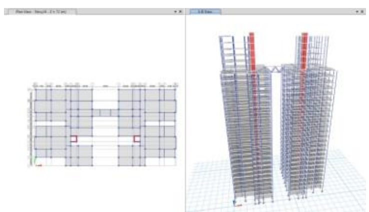

Fig -7: Case 1: Model 1

3.4.2 Model 2: Structure with Shear Wall on One Side Each of Twin Building

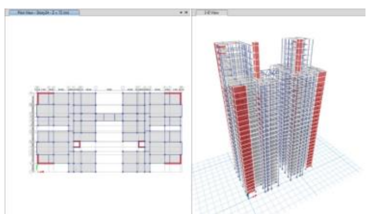

Fig 8: Case 1: Model 2

3.4.3 Model 3: Structure with Shear Wall on Two Side Each of Twin Building

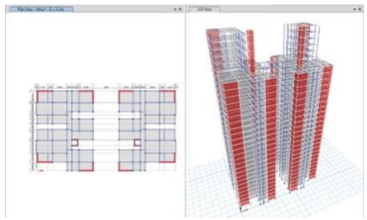

Fig 9: Case 1: Model 3

3.5 Case 2: Twin Tower with Sky Bridge at Three Fourth Height (18th Floor)

Here the interconnecting sky bridge is provided at the 18th floor of the structure

3.5.1 Model 1: Structure Without Shear Wall

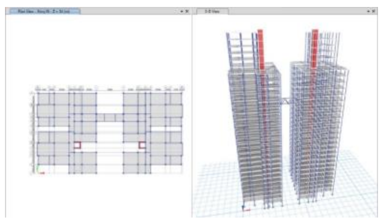

Fig 10: Case 2: Model 1

3.5.2 Model 2: Structure with Shear Wall on One Side Each of Twin Building

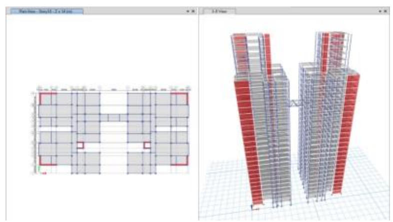

Fig-11: Case 2: Model 2

3.5.3 Model 3: Structure with Shear Wall on Two Side Each of Twin Building

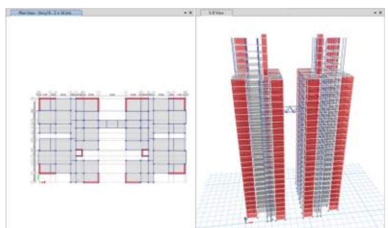

Fig-12: Case 2: Model 3

3.6 CASE 3: TWIN TOWER WITH SKY BRIDGE AT HALF THE HEIGHT (12TH FLOOR)

3.6.1 Model 1: Structure Without Shear Wall

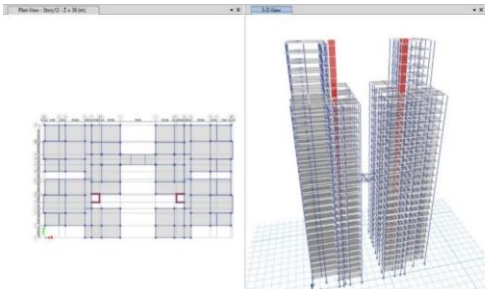

Fig 13: Case 3: Model 1

3.6.2 Model 2: Structure with Shear Wall on One Side Each of Twin Building

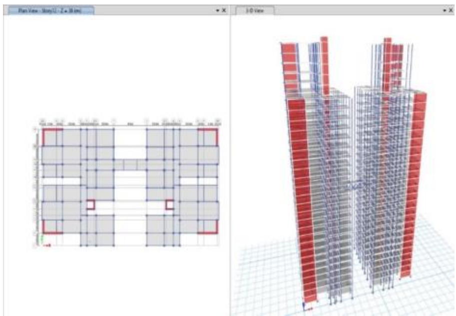

Fig 14: Case 3: Model 2

3.6.3 Model 3: Structure with Shear Wall on Two Side Each of Twin Building

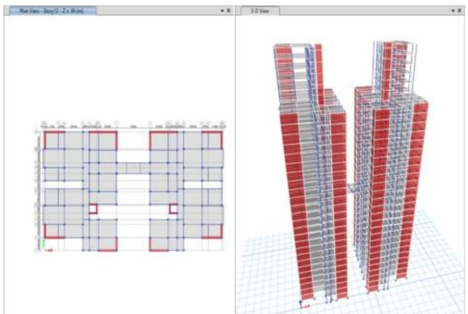

Fig-15: Case 3: Model 3

The connecting sky bridge is provided at half the height of the structure.

3.7 CASE 4: TWIN TOWER WITH SKY BRIDGE AT ONE HALF THE HEIGHT (6TH FLOOR)

The horizontal connecting sky bridge is provided at 6th floor of the structure and the model is analyzed for displacement, base shear and stiffness.

3.7.1 Model 1: Structure Without Shear Wall

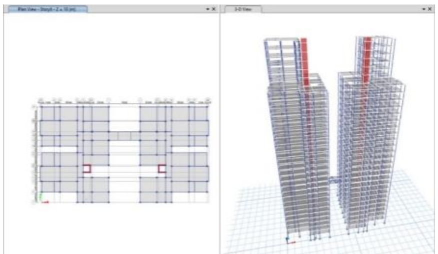

Fig 16: Case 4: Model 1

3.7.2 Model 2: Structure with Shear Wall on One Side Each of Twin Building

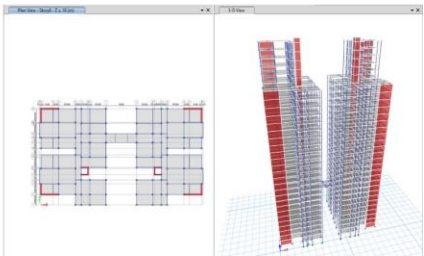

Fig 17: Case 4: Model 2

3.7.3 Model 3: Structure with Shear Wall on Two Side Each of Twin Building

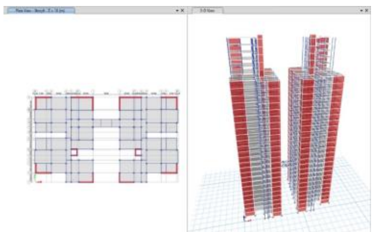

Fig 18: Case 4: Model 3

4 RESULTS AND DISCUSSIONS

This chapter deals with the results obtained from the seismic analysis of different types of building with different configuration of shear walls and height of sky bridge provided. Comparison was done on the basis of maximum storey displacement, maximum base shear and maximum stiffness.

4.1 Comparison Based on The Configuration of Shear walls For Each Cases

4.1.1: Sky Bridge at the Top

Here comparison is done based on the changes in property due to shear wall locations

4.1.1.1: Case 1: Model 1: Structure Without Shear Wall

Table -1: Result Case 1: Model 1

	X Direction	Y Direction
Displacement (mm)	82.20	91.44
Base Shear (KN)	3456.69	3667.47
Storey Stiffness (KN/m)	2.996×10^6	2.705×10^6

4.1.1.2: Case 1: Model 2: Structure with Shear Wall on One Side Each of Twin Building

Table -2: Result Case 1: Model 2

	X Direction	Y Direction
Displacement (mm)	50.40	69.70
Base Shear (KN)	4692.25	4237.50
Storey Stiffness (KN/m)	15.721×10^6	9.161×10^6

4.1.1.3: Case 1: Model 3: Structure with Shear Wall on Both Side Each of Twin Building

Table -3: Result Case 1: Model 3

	X Direction	Y Direction
Displacement (mm)	38.65	56.37
Base Shear (KN)	5370.88	4765.49
Storey Stiffness (KN/m)	24.206×10^6	14.683×10^6

4.1.2: Sky Bridge at Three Fourth Height

4.1.2.1: Case 2: Model 1: Structure Without Shear Wall

Table -4: Result Case2: Model 1

	X Direction	Y Direction
Displacement (mm)	80.20	91.18
Base Shear (KN)	3491.82	3676.26
Storey Stiffness (KN/m)	3.045×10^6	2.705×10^6

4.1.2.2: Case 2: Model 2: Structure with Shear Wall on One Side Each of Twin Building

Table -5: Result Case2: Model 2

	X Direction	Y Direction
Displacement (mm)	49.86	69.47
Base Shear (KN)	4680.64	4238.61
Storey Stiffness (KN/m)	15.739×10^6	9.171×10^6

4.1.2.3: Case 2: Model 3: Structure with Shear Wall on One Side Each of Twin Building

Table -6: Result Case 2: Model 3

	X Direction	Y Direction
Displacement (mm)	35.60	54.38
Base Shear (KN)	5816.39	4844.42
Storey Stiffness (KN/m)	29.699×10^6	15.082×10^6

4.1.3: Sky Bridge at Halt the Height

4.1.3.1: Case 3: Model 1: Structure Without Shear Wall

Table -7: Result Case3: Model 1

	X Direction	Y Direction
Displacement (mm)	80.53	93.43
Base Shear (KN)	3600.01	3777.30
Storey Stiffness (KN/m)	3.079×10^6	2.710×10^6

4.1.3.2: Case 3: Model 2: Structure with Shear Wall on One Side Each of Twin Building

Table -8: Result Case3: Model 2

	X Direction	Y Direction
Displacement (mm)	51.30	71.14
Base Shear (KN)	4788.62	4326.05
Storey Stiffness (KN/m)	15.748×10^6	9.173×10^6

4.1.3.3: Case 3: Model 3: Structure with Shear Wall on Both Side Each of Twin Building

Table -9: Result Case 3: Model 3

	X Direction	Y Direction
Displacement (mm)	36.26	55.83
Base Shear (KN)	5962.21	4948.42
Storey Stiffness (KN/m)	29.830 $\times 10^6$	15.086$\times 10^6$

4.1.4: Sky Bridge at One Fourth Height

4.1.4.1: Case 4: Model 1: Structure Without Shear Wall

Table -10: Result Case 4: Model 1

	X Direction	Y Direction
Displacement (mm)	78.75	94.58
Base Shear (KN)	3639.91	3634.10
Storey Stiffness (KN/m)	3.219 $\times 10^6$	2.802 $\times 10^6$

4.1.4.2: Case 3: Model 2: Structure with Shear Wall on One Side Each of Twin Building

Table -11: Result Case 4: Model 2

	X Direction	Y Direction
Displacement (mm)	51.67	68.96
Base Shear (KN)	4805.01	4222.90
Storey Stiffness (KN/m)	15.876 $\times 10^6$	9.271 $\times 10^6$

4.1.4.3: Case 4: Sky Bridge at One Fourth Height: Model 3: Structure with Shear Wall on Both Side Each of Twin Building

Table -12: Result Case 4: Model 3

	X Direction	Y Direction
Displacement (mm)	36.55	55.05
Base Shear (KN)	5965.71	4875.67
Storey Stiffness (KN/m)	29.866 $\times 10^6$	15.209 $\times 10^6$

4.2 Comparison Based on The Height Of Sky Bridge

4.3 Model 1: Without Shear Wall

Table -13: Result Model 1 Comparison

CASE	DISPLACEMENT (mm)		BASE SHEAR (KN)		STIFFNESS (KN/m)	
	x	y	x	y	x	y
Case 1	82.20	91.44	3456.69	3667.47	2.996	2.705
Case 2	80.20	91.18	3491.82	3676.26	3.045	2.705
Case 3	80.53	93.43	3600.01	3777.30	3.079	2.710
Case 4	78.75	94.58	3639.91	3634.10	3.219	2.802

4.4 Model 2: With Shear Wall on One Side Each of Twin Building

Table -14: Result Model 2 Comparison

CASE	DISPLACEMENT (mm)		BASE SHEAR (KN)		STIFFNESS (KN/m)	
	x	y	x	y	x	y
Case 1	50.40	69.70	4692.25	4237.50	15.721	9.161
Case 2	49.86	69.47	4680.64	4238.61	15.739	9.171
Case 3	51.30	71.14	4788.62	4326.05	15.748	19.173
Case 4	51.67	68.96	4805.01	4222.90	15.876	9.271

4.5 Model 3: With Shear Wall on One Side Each of Twin Building

Table -4: Result Model 3 Comparison

CASE	DISPLACEMENT (mm)		BASE SHEAR (KN)		STIFFNESS (KN/m)	
	x	y	x	y	x	y
Case 1	38.65	56.37	5370.88	4765.49	24.206	14.683
Case 2	35.6	54.38	5816.39	4844.42	29.699	15.082
Case 3	36.26	55.83	5962.21	4948.42	29.830	15.086
Case 4	36.55	55.05	5965.71	4875.67	29.866	15.209

5. CONCLUSIONS

In structural engineering the major stress is given to withstand the effect of various forces acting on the structure like seismic forces etc. and to maintain its structural stability. In this study, investigation on seismic performance of buildings with plan and elevation eccentricities are developed for analysis. And here the impact of shear walls on a twin building interconnected by a horizontal sky bridge is studied. It is seen that along with the shear wall, the horizontally connected sky bridge plays a major role in the seismic performance of the structure. The following conclusions are quoted from the overall analysis.

1) The maximum displacement decreases on addition on shear walls. On addition of shear wall on one side displacement is reduced both in X and Y direction and further on giving shear walls on both the side each, maximum displacement is further decreased.

2) In the case of comparing the maximum base shear on the basis of configuration of shear walls, in each case it is seen that the base shear increases on addition of shear walls.

3) The stiffness is an important factor determining the strength of the structure and it is seen that on increasing the shear walls the maximum stiffness also increases.

4) While moving on to the comparison based on the location of sky bridge, it is expected that on providing skybridge at the one fourth height or at least height will give the best performance. But on combined effect of shear wall and sky bridge height there has been seen some variation to the expectation.

5) Model with shear wall on both the side each of the twin building and sky bridge at one fourth height give the maximum stiffness among all the model as expected.

6) In the case of base shear also, model with shear wall on both side each of the twin building and sky bridge at one fourth height give the maximum value in x direction.

7) In the case of displacement along X and Y direction, model with shear wall on both sides each of the twin building and sky bridge at three fourth height gives the least displacement.

8) In case of sky bridge locations, even though there are slight deviation in the expected tendency of structure, the model with shear wall on both side of the twin building and sky bridge at one fourth height (6^{th} floor) gives the maximum stiffness.

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