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Research on the Effect of Horizontal Walkway Location Connecting Two High-Rise Buildings (G+20) Under Seismic Loading

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Abstract - This study investigates the influence of the location of a horizontal walkaway connecting to 4th floor, 8th ,12th and 16th floors of G+20 high rise building under seismic loading conditions. The horizontally connected structures are subjected to various seismic loading Conditions to evaluate how the walkways position influences the overall Dynamic behaviour and stability of the buildings. Using finite element Analysis (FEA), multiple scenarios with the walkway located at different Heights are modelled and analysed. Key performance indicators Such as story drift, base shear, and overall displacement are compared across Different configurations. The findings reveals that the walkway's location Significantly affects the seismic performance of the connected buildings, with optimal placement reducing structural stresses and enhancing safety. This research provides valuable insights for architects and engineers in Designing more resilient horizontally connected high rise structures in Seismically active regions. This research focuses on the structural performance and dynamic behaviour of the buildings. When subjected to earthquake forces considering different locations of horizontal walk connected forces and height of the structures. In this connected building, The effect of sky bridge structural responses is examined as well. The building is analysed for the Max displacement, max reaction, max BM and max base shear. This analysis and modelling is done by using Staad pro software.

***Key Words*: Staad pro, horizontally connected building (sky bridge), max displacement, support reaction, max bending moment and maximum base shear**

1.INTRODUCTION

High-rise buildings are subjected to lateral forces such as wind and seismic forces. Structural engineers focus on understanding the behavior of these structures when subjected to horizontal forces. For high-rise buildings, maximum displacement and maximum base shear are critical parameters to withstand horizontal forces caused by winds and earthquakes. This study investigates the effects of different locations of a horizontally connected twin high-rise building using a bridge. It examines the structural response when exposed to an earthquake and assesses the seismic load response of the linked high-rise buildings. The influence of the bridge's location is also analyzed. The buildings are evaluated for maximum displacement, maximum reactions, maximum bending moment (BM) results, and maximum base shear. The primary objective is to study the impact of the location of a horizontal walkway connecting two high-rise buildings (G+20) under seismic loading. Dead load, live load, seismic load, and wind load are applied, and the design for beams and columns is obtained using STAAD.Pro. The study concludes that STAAD.Pro is a highly efficient and accurate tool for designing multistoried buildings, significantly saving time and ensuring precise designs.

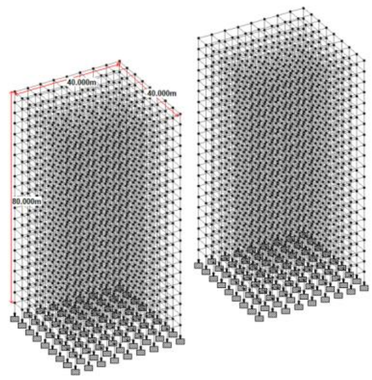


Fig -1: Without Connected Building

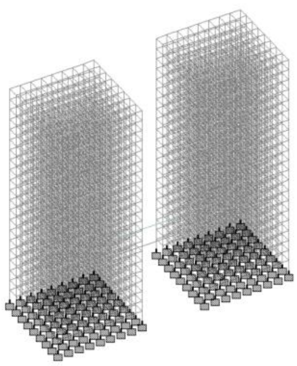


Fig -2: 4rth Floor Connected Building

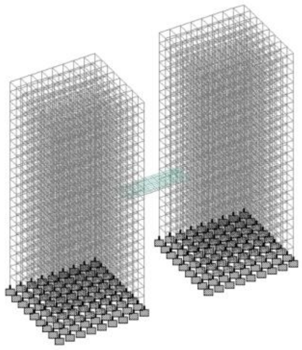


Fig -3: 8th Floor Connected Building

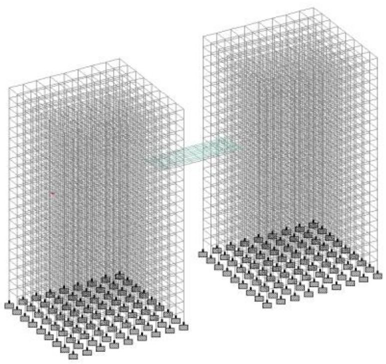


Fig -4: 12th Floor Connected Building

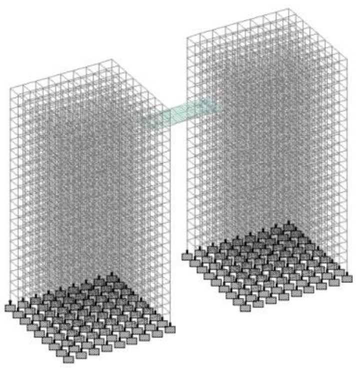


Fig -5: 16th Floor Connected Building

Fig -6: Horizontal Walk Connected Building

2. OBJECTIVE OF RESEARCH WORK

- The main objective of this project is to investigate seismic analysis of high rise building with horizontal walk and without horizontal walk as per code IS 1893-2016 part I criteria.
- The present work is to investigate the performance of G+20 RCC base shear of building with 4-meter height of each story.
- Comparisons of the max. displacement, max reaction, max BM, max base shear value of connected building and without connected building.
- Compare acceleration of building with and without horizontal walk.
- To study the result of various parameters such as displacement, reaction, BM and base shear.

Design of the structural elements of a high rise building with horizontal walk including beams, columns.

3. OBJECTIVE OF RESEARCH WORK

3.1 General

The seismic performance of high rise building with horizontal connection 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. The required horizontal connections 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 G+20 twin building connected with horizontal skybridge model using stadd pro connector. Without connected twin tower , 4th floor , 8th floor, 12th and 16th floor models are created.

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

e) Seismic performance of building with varying connected horizontal walk and sky bridge height are compared based on the parameters such as maximum displacement , maximum reaction, maximum BM and maximum base shear.

3.2 Software Used

Staad pro is an engineering software that are used for multi-story building , high rise building and twin tower connected building analysis and design.

Basic or advanced systems under static conditions or dynamic conditions can be examined and checked by using Staad pro software.

Staad pro allows for detailed 3D modeling of complex high-rise buildings including horizontal connections like sky bridges and connected structure.

In a staad pro:

i) static analysis to check the overall load distribution of building.

ii) response spectrum analysis to understand the maximum expected response of the building.

iii) the software provides modal analysis to determine the natural frequencies and mode shapes of the structure.

4. MODELLING AND ANALYSIS PROCESS

4.1. General:

The horizontal walk connected by two high rise building for modelling and analysis, The connected and without connected twin tower building height and properties were adopted from the validation journal. After remodeling a sky bridge is drawn connecting both the structure at respective stories require for modelling. The distance of 30m is provided between both the structure, A total of 20 floor is provide. 5 models are created with 5 cases. These cases are based on at which the sky bridge is provided. The sky bridges are provided at 4th floor, 8th, 12th and 16th floor. The static analysis method and response spectrum analysis is done on each model and the behaviour of structure is compared and discussed.

4.2 Static Analysis

static analysis methods are essential in the structural engineering of horizontally connected high rise building, often known as structure or building with skybridges. These methods help engineers ensure that the structure can safety support both vertical and lateral loads. Load combinations analyzing various combinations of loads including dead load, live loads, wind and seismic loads, and other environmental forces.

4.3 Response Spectrum Analysis

Response spectrum analysis is a crucial method in structural engineering for assessing the seismic response of buildings, particularly high-rise structures. When dealing with horizontally connected high-rise buildings, the analysis must account for the interaction between the structures due to the coupling effects during seismic events.

4.4 Model Specification:

The sky bridges are provided at 4th floor, 8th , 12th, and 16th floor. The distance of 30 m is provided between both the structures.
Various type of structural model consider for this study:

Model 1: - RCC G+20 story without walks
Model 2: - RCC G+20 story with walk at 4thfloor
Model 3: - RCC G+20 story with walk at 8th floor
Model 4: - RCC G+20 story with walk at 12th floor
Model 5: - RCC G+20 story with walk at 16th floor

5. STRUCTURE MODELING

This research having four floor are connected. The RCC framed structure are designed and analyzed according to IS-456-2000 and IS 1893:2016 by using STADD Pro software.

The structural model descriptions are listed in below tables

Table -1: structural model descriptions

Type of Structure	Horizontally connected (Twin tower) building
Plan Area (Top View)	110m x 40m
No. Of Storey	G+20 With 4th,8th,12th And 16th Floor Connected
Area Of Tower A	40m x 40m
Area Of Tower B	40m x 40m
Distance Between Tower A And B	30m
Story Height	4m

Table -2: structural model descriptions

No. Of Bays In X- Direction	5
No.Of Bays In Z Direction	5
Height Of Building	84 m
Size Of Beam	1000mmx1000mm
Size Of Column	1000mmx1000mm
Concrete And Steel Grade	M40 AND FE500(AS PER DESIGN)
Earthquake Parameters	Z= 0.24 (ZONE IV) WITH RF 5 AND 5% damping ratio= 0.05, I= 1.2

Dead Load For Floor	1 KN/m^2
Dead Load	3.75 KN/m^2
Live Load	4 KN/m^2
Wall Thickness	230 mm
Wall Load	16.1 KN/M

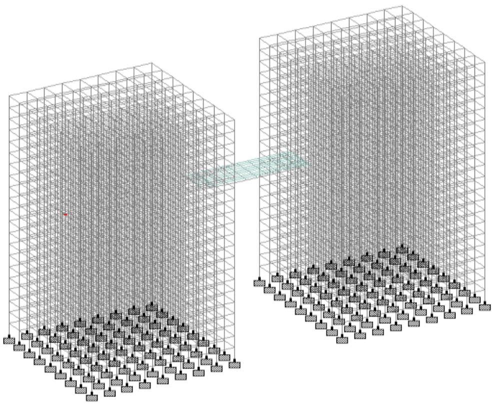


Fig -7: 12th floor connected

5.1 GRAVITY LOAD

Table -3: Gravity load

SR.NO	Type of Loading	Load to be Applied
1	Live load on floor	4 KN/m^2
2	Live load on roof	1.5 KN/m^2
3	Floor finish	1 KN/m^2
4	Roof finish	1 KN/m^2
5	Water proofing	1 KN/m^2
6	Dead load of wall	16.1 KN/m^2
7	Dead load of slab	3.75 KN/m^2

6. RESULT

The analysis of a G+20 high-rise building, both with and without horizontal connections at various floor levels (4th, 8th, 12th, and 16th floors), using both static and response spectrum methods, reveals significant variations in structural behavior. The percentage changes across different seismic performance parameters such as displacement, support reaction, bending moment, and base shear offer insights into the impact of connecting walkways at different heights.

6.1 Static Method:

6.1.1 Displacement:

Table-4: Maximum Displacement In X Direction(mm)

BUILDING	MAX DISP.
WITHOUT CONNECTED	52.352 mm
4TH FLOOR CONNECTED	52.907 mm
8TH FLOOR CONNECTED	54.608 mm
12TH FLOOR CONNECTED	58.352 mm
16TH FLOOR CONNECTED	60.408 mm

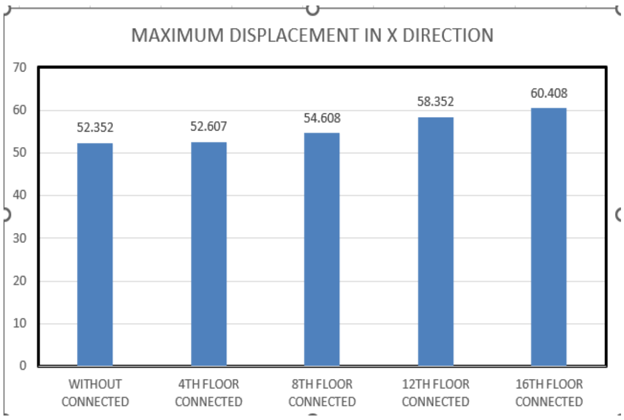
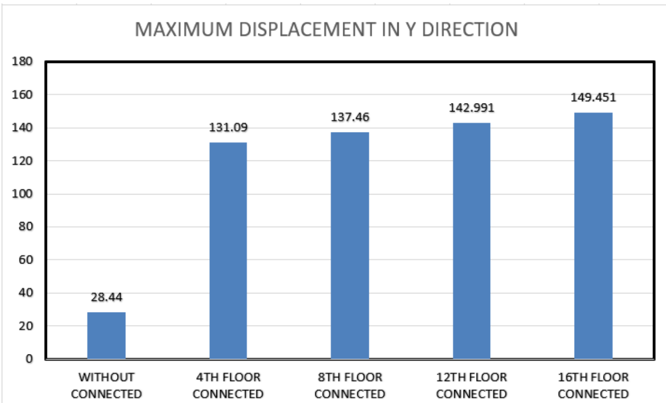


Table-4: Maximum Displacement In Y Direction(mm)

BUILDING	MAX DISP.
WITHOUT CONNECTED	28.44
4TH FLOOR CONNECTED	131.09
8TH FLOOR CONNECTED	137.46
12TH FLOOR CONNECTED	142.991
16TH FLOOR CONNECTED	149.451



The maximum displacement increases slightly when connections are added at any floor, with increases of about 1.20% to 1.25% in the X direction and significantly more in the Y direction, up to 425.49% at the 16th floor. This indicates a considerable increase in lateral movement with higher connections.

6.1.2 Support Reaction:

Table-5: Maximum Support Reaction In X Direction(KN)

BUILDING	MAX SUPP.
WITHOUT CONNECTED	327.847
4TH FLOOR CONNECTED	329.871
8TH FLOOR CONNECTED	332.053
12TH FLOOR CONNECTED	332.803
16TH FLOOR CONNECTED	333.19

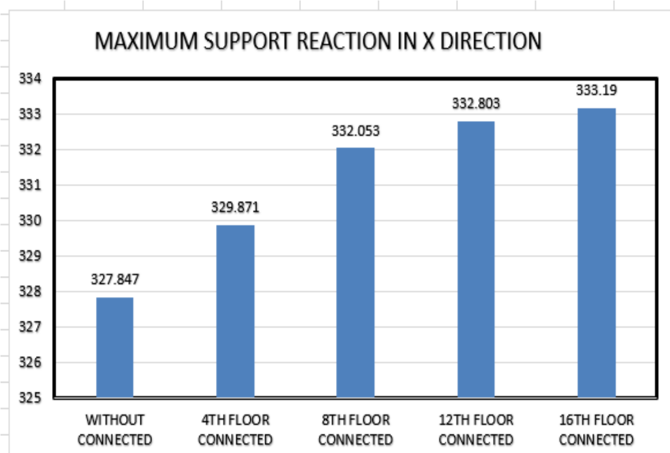
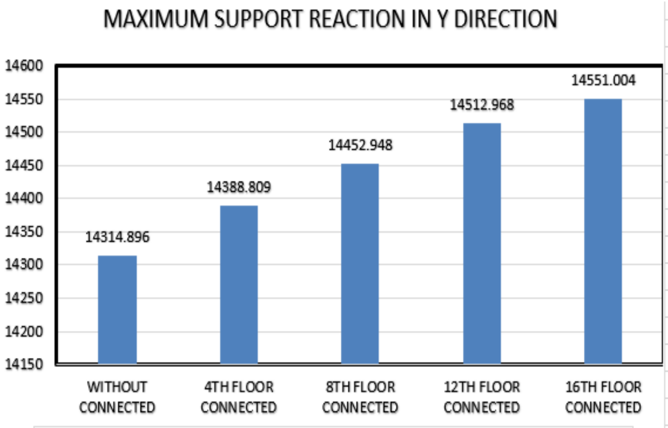


Table-6: Maximum Support Reaction in Y Direction(KN)

BUILDING	MAX SUPP.
WITHOUT CONNECTED	14314.896
4TH FLOOR CONNECTED	14388.809
8TH FLOOR CONNECTED	14452.948
12TH FLOOR CONNECTED	14512.968
16TH FLOOR CONNECTED	14551.004



The increase in maximum support reactions is moderate across all connected floors, ranging from 1.15% to 1.76%. This suggests a slight increase in the load-bearing demand on the building's support structure due to additional horizontal connections.

6.1.3 Bending Moment:

Table-7: Maximum Bending Moment in X Direction(KN.M)

BUILDING	MAX BM.
WITHOUT CONNECTED	14314.896
4TH FLOOR CONNECTED	14388.809
8TH FLOOR CONNECTED	14452.948
12TH FLOOR CONNECTED	14512.968
16TH FLOOR CONNECTED	14551.004

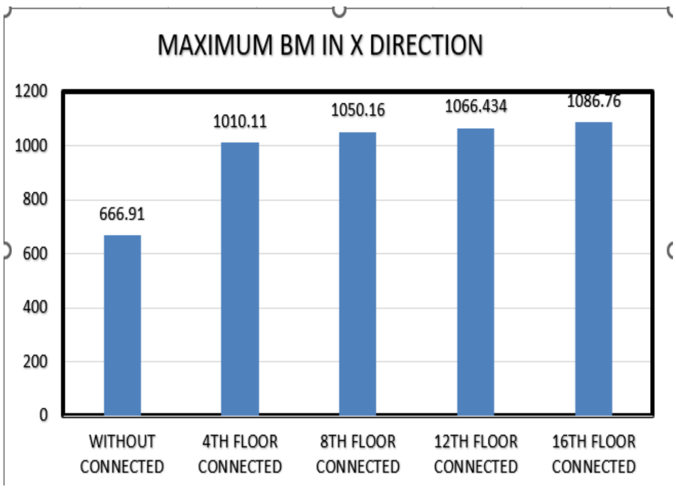
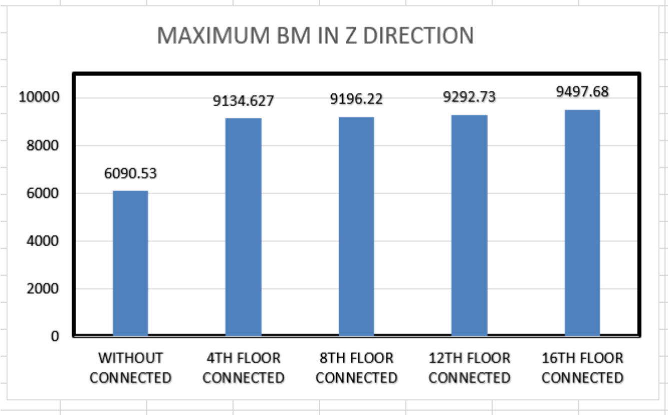


Table-8: Maximum Bending Moment in Z Direction(KN.M)

BUILDING	MAX BM.
WITHOUT CONNECTED	6090.53
4TH FLOOR CONNECTED	9134.627
8TH FLOOR CONNECTED	9196.22
12TH FLOOR CONNECTED	9292.73
16TH FLOOR CONNECTED	6090.53



There's an extraordinary increase in bending moments, especially in the X direction, with values escalating over 1.25% on connected floors. This dramatic rise indicates a much higher moment resistance required due to the additional stiffness and mass provided by the connections.

6.2 Static Wind:

6.2.1 Displacement:

When connections are added at any floor, the maximum displacement shows a slight increase, ranging from approximately 0.49% to 0.53% in the X direction. In contrast, the Y direction experiences a much more substantial increase, reaching up to 261.66% at the 16th floor. This suggests a significant rise in lateral movement as more connections are added at higher levels.

Table-9: Maximum Displacement in X Direction(mm)

BUILDING	MAX DIS.
WITHOUT CONNECTED	52.352
4TH FLOOR CONNECTED	52.607
8TH FLOOR CONNECTED	54.608
12TH FLOOR CONNECTED	58.352
16TH FLOOR CONNECTED	60.408

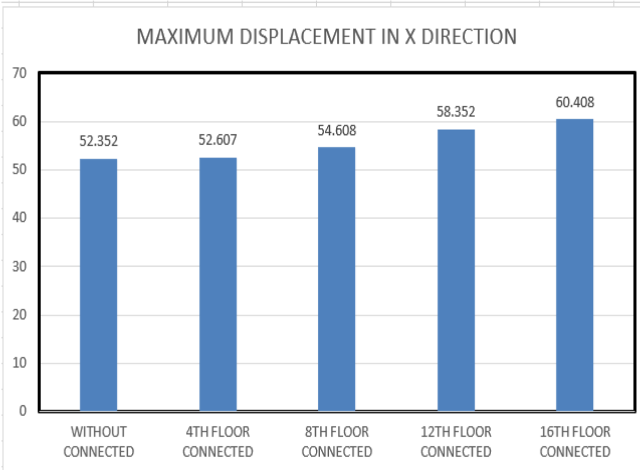
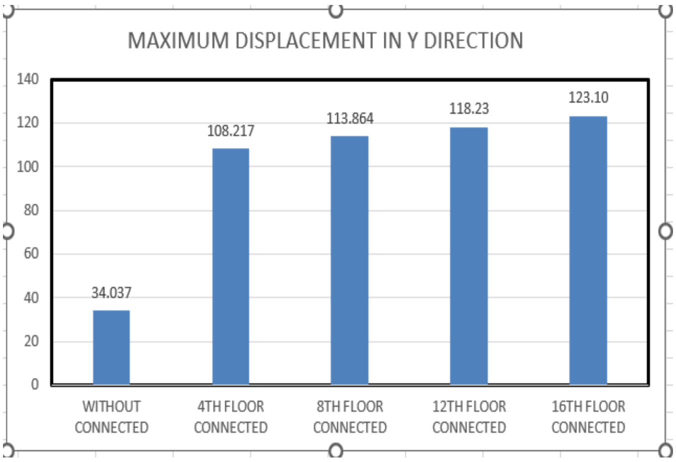


Table-10: Maximum Displacement in Y Direction(mm)

BUILDING	MAX DIS.
WITHOUT CONNECTED	34.037
4TH FLOOR CONNECTED	108.217
8TH FLOOR CONNECTED	113.864
12TH FLOOR CONNECTED	118.23
16TH FLOOR CONNECTED	123.10



6.2.2 Bending Moment:

There is a notable increase in bending moments, especially in the X direction, where values can exceed 213.29% on connected floors. This substantial rise highlights the need for higher moment resistance due to the added stiffness and mass provided by the connections.

Table-11: Maximum Bending Moment in X Direction(KN.M)

BUILDING	MAX BM.
WITHOUT CONNECTED	331.456
4TH FLOOR CONNECTED	665.578
8TH FLOOR CONNECTED	695.291
12TH FLOOR CONNECTED	991.631
16TH FLOOR CONNECTED	1038.421

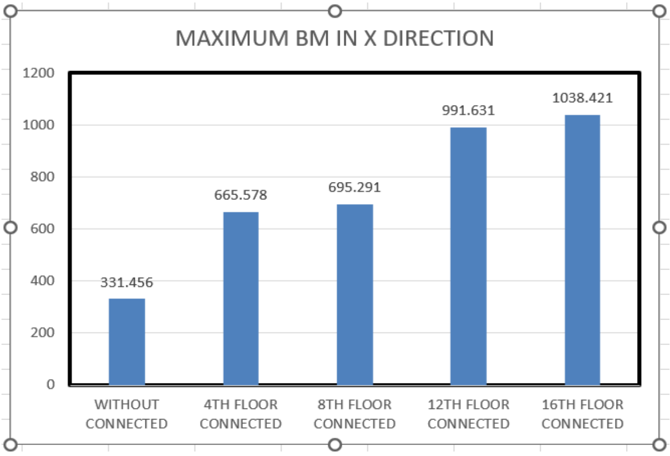
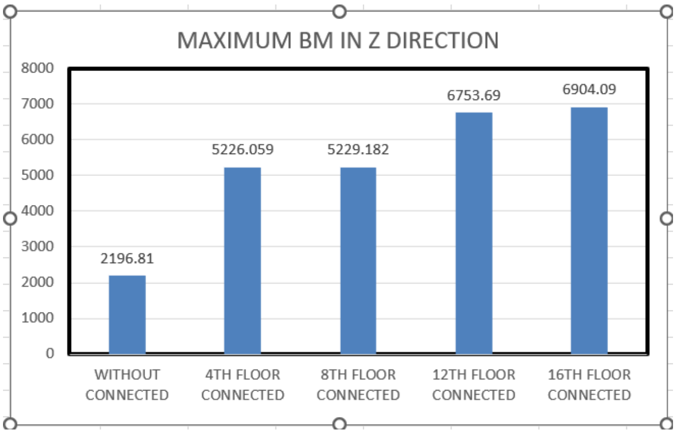


Table-12: Maximum Bending Moment in Z Direction(KN.M)

BUILDING	MAX BM.
WITHOUT CONNECTED	2196.81
4TH FLOOR CONNECTED	5226.059
8TH FLOOR CONNECTED	5229.182
12TH FLOOR CONNECTED	6753.69
16TH FLOOR CONNECTED	6904.09



6.3 Response Spectrum Method:

6.3.1 Displacement:

Table-13: Maximum Displacement In X Direction(mm)

BUILDING	MAX DISP.
WITHOUT CONNECTED	45.384
4TH FLOOR CONNECTED	45.553
8TH FLOOR CONNECTED	46.013
12TH FLOOR CONNECTED	46.049
16TH FLOOR CONNECTED	46.089

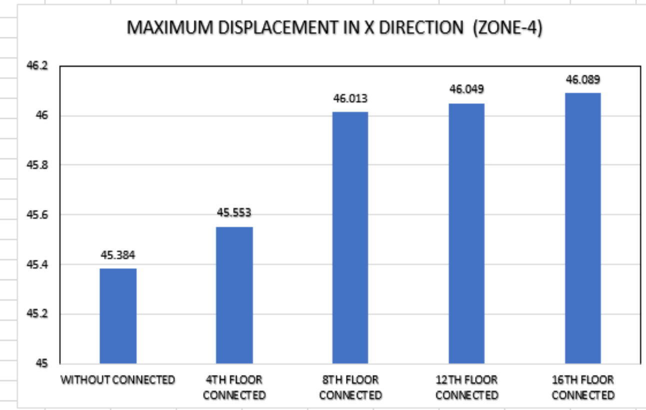
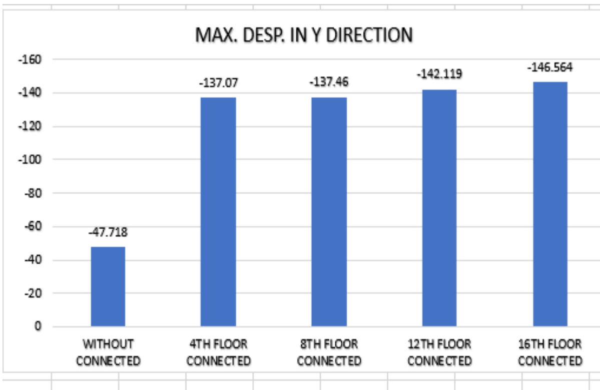


Table-14: Maximum Displacement In Y Direction(mm)

BUILDING	MAX DISP.
WITHOUT CONNECTED	-47.718
4TH FLOOR CONNECTED	-137.07
8TH FLOOR CONNECTED	-137.46
12TH FLOOR CONNECTED	-142.119
16TH FLOOR CONNECTED	-146.564



Displacement variations are less uniform. While most floors show minimal changes in the X direction, the Y direction exhibits extreme increases or reductions, notably a decrease in Y displacement by 1.55% to - 207.14% for the connected floors, indicating a drastically different dynamic response under seismic loading due to changes in structural stiffness and mass distribution.

6.3.2 Support Reaction:

Table-15: Maximum Support Reaction In X Direction(KN)

BUILDING	MAX SUPP.
WITHOUT CONNECTED	327.805
4TH FLOOR CONNECTED	337.289
8TH FLOOR CONNECTED	338.009
12TH FLOOR CONNECTED	339.757
16TH FLOOR CONNECTED	340.184

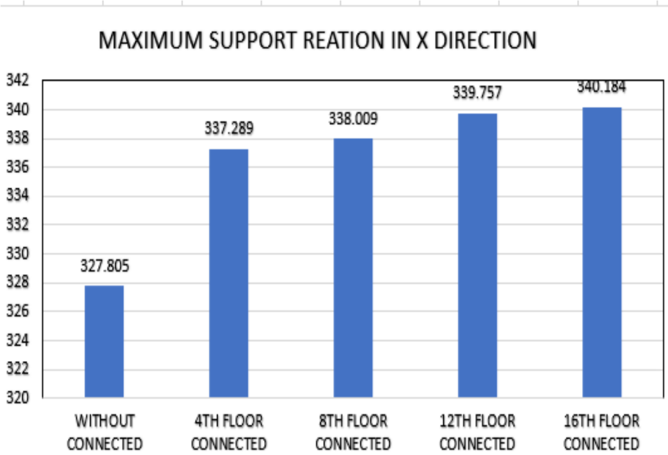
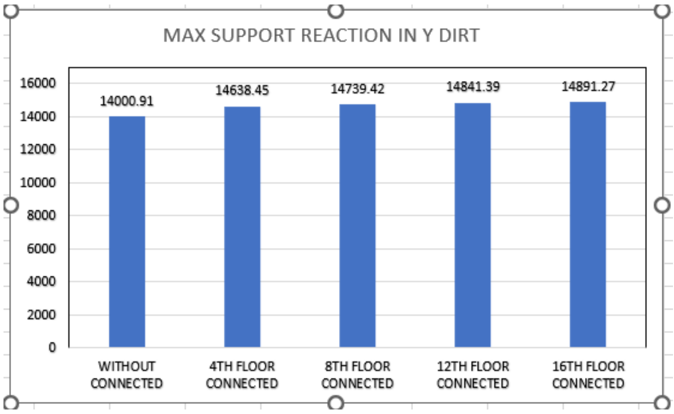


Table-16: Maximum Support Reaction In Y Direction(KN)

BUILDING	MAX SUPP.
WITHOUT CONNECTED	14000.91
4TH FLOOR CONNECTED	14638.45
8TH FLOOR CONNECTED	14739.42
12TH FLOOR CONNECTED	14841.39
16TH FLOOR CONNECTED	14891.27



Similar to the static method, there's a slight increase in support reactions, except for a significant decrease of 3.77% in the Y direction at the 16th floor, pointing towards a potential redistribution of forces under dynamic conditions.

6.3.3 Bending Moment:

Table-17: Maximum Bending Moment in X Direction(KN.M)

BUILDING	MAX BM.
WITHOUT CONNECTED	666.73
4TH FLOOR CONNECTED	1066.05
8TH FLOOR CONNECTED	1066.626
12TH FLOOR CONNECTED	1067.612
16TH FLOOR CONNECTED	1067.911

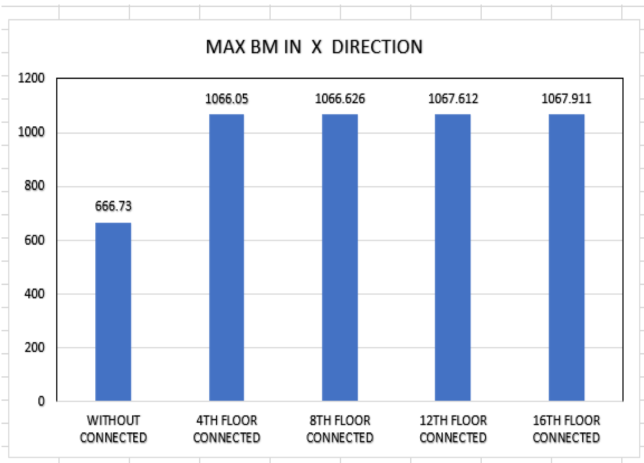
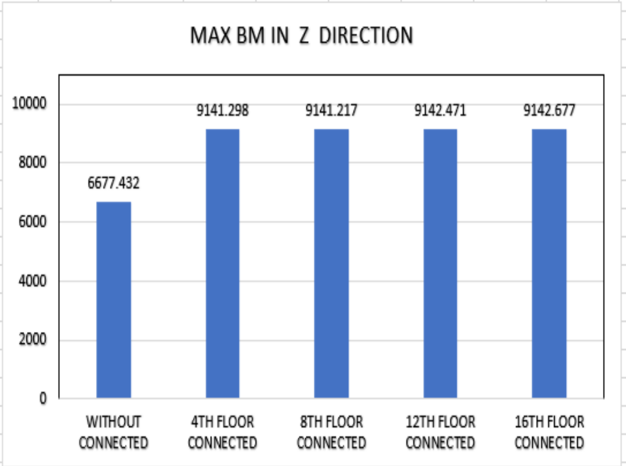


Table-18: Maximum Bending Moment in Z Direction(KN.M)

BUILDING	MAX BM.
WITHOUT CONNECTED	6677.432
4TH FLOOR CONNECTED	9141.298
8TH FLOOR CONNECTED	9141.217
12TH FLOOR CONNECTED	9142.471
16TH FLOOR CONNECTED	9142.677



The increases are similarly high as in the static method, underscoring the need for robust design considerations to manage these enhanced moments in seismic conditions.

6.3.4 Base Shear:

Table-19: Maximum Base Shear in X Direction(KN)

BUILDING	BASE SHEAR.
WITHOUT CONNECTED	49231.51
4TH FLOOR CONNECTED	49364.45
8TH FLOOR CONNECTED	49356.5
12TH FLOOR CONNECTED	49352.25
16TH FLOOR CONNECTED	49347.12

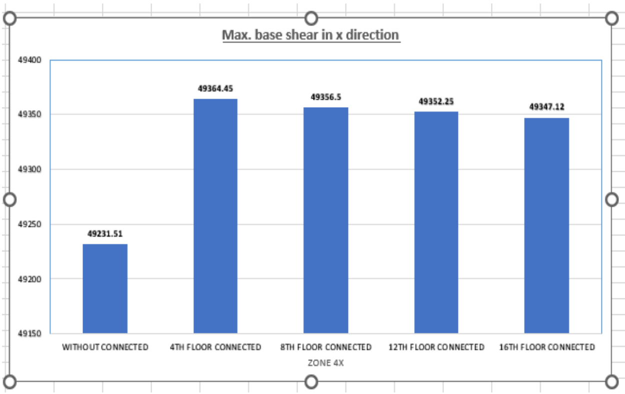
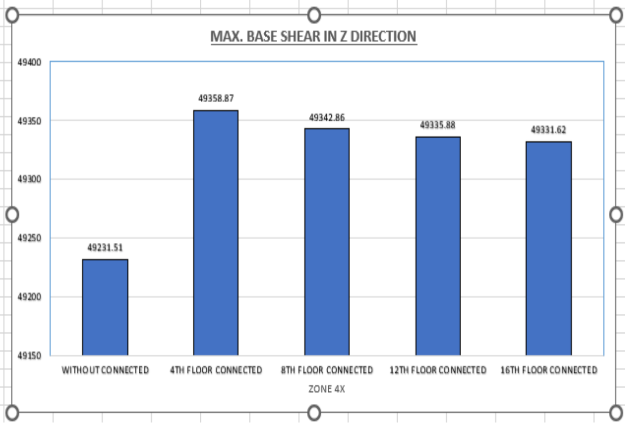


Table-20: Maximum Base Shear in Z Direction(KN)

BUILDING	BASE SHEAR.
WITHOUT CONNECTED	49231.51
4TH FLOOR CONNECTED	49358.87
8TH FLOOR CONNECTED	49342.86
12TH FLOOR CONNECTED	49335.88
16TH FLOOR CONNECTED	49331.62



The changes in base shear are minimal, generally under 0.30%, suggesting that the overall shear force acting at the base of the building due to lateral seismic forces remains relatively stable despite the floor connections.

6.4 Response Spectrum Method Wind:

6.4.1 Displacement:

The variations in displacement are less consistent. Most floors exhibit minimal changes in the X direction, while the Y direction shows extreme increases, with up to 16.57% for the connected floors. This indicates a significantly different dynamic response to wind loading, influenced by changes in structural stiffness and mass distribution.

Table-21: Maximum Displacement In X Direction(mm)

BUILDING	MAX DISP.
WITHOUT CONNECTED	0.629
4TH FLOOR CONNECTED	0.694
8TH FLOOR CONNECTED	0.799
12TH FLOOR CONNECTED	0.835
16TH FLOOR CONNECTED	0.865

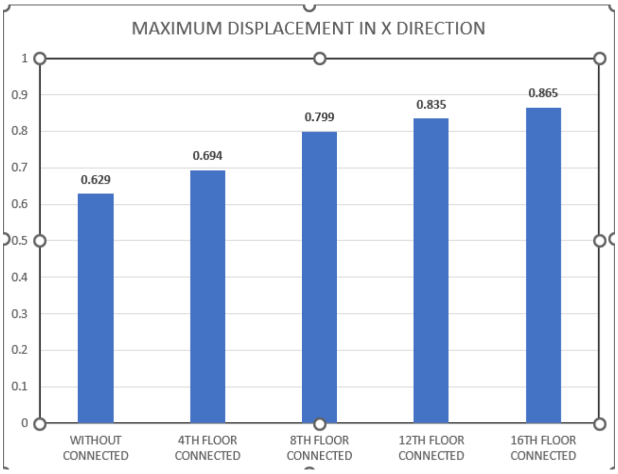
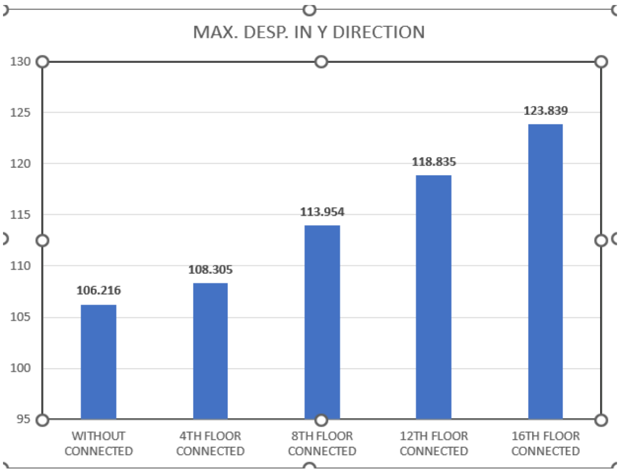


Table-22: Maximum Displacement in Y Direction(mm)

BUILDING	MAX DISP.
WITHOUT CONNECTED	106.216
4TH FLOOR CONNECTED	108.305
8TH FLOOR CONNECTED	113.954
12TH FLOOR CONNECTED	118.835
16TH FLOOR CONNECTED	123.839



6.4.2 Bending Moment:

The increases in bending moments are similarly high as in the static method, with values escalating over 1.20% on connected floors. This underscores the necessity for robust design considerations to manage these enhanced moments under wind conditions.

Table-23: Maximum Bending Moment in X Direction (KN.M)

BUILDING	MAX BM.
WITHOUT CONNECTED	665.117
4TH FLOOR CONNECTED	666.177
8TH FLOOR CONNECTED	667.117
12TH FLOOR CONNECTED	667.91
16TH FLOOR CONNECTED	669.873

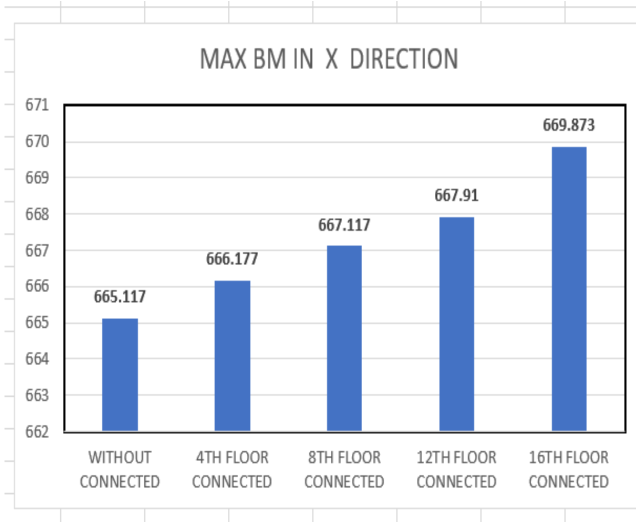
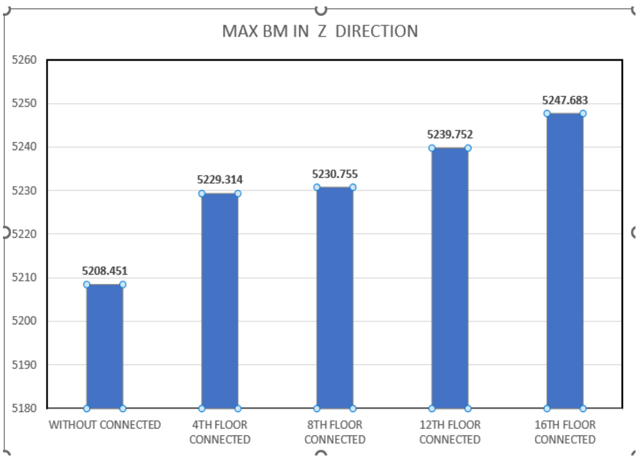


Table-24: Maximum Bending Moment in Z Direction(KN.M)

BUILDING	MAX BM.
WITHOUT CONNECTED	5208.451
4TH FLOOR CONNECTED	5229.314
8TH FLOOR CONNECTED	5230.755
12TH FLOOR CONNECTED	5239.752
16TH FLOOR CONNECTED	5247.683



7. CONCLUSION

Adding horizontal connections at various floors of a high-rise building significantly alters its response to earthquakes. While these connections slightly increase the overall movement and forces at the building's base, they greatly increase the bending forces, highlighting the need for stronger, more resilient building designs.

This analysis underlines the importance of carefully planning and reinforcing buildings with such features to ensure safety

and stability in earthquake-prone areas. The findings stress the necessity for engineers to consider these additional forces in their designs to prevent structural failures during seismic events.

The horizontally connected sky bridge plays a major role in the seismic performance of structure.

The maximum displacement increases slightly when connections are added at any floor, with increases of about 1.20% to 1.25% in the X direction and significantly more in the Y direction, up to 425.49% at the 16th floor. This indicates a considerable increase in lateral movement with higher connections.

The increase in maximum support reactions is moderate across all connected floors, ranging from 1.15% to 1.76%. This suggests a slight increase in the load-bearing demand on the building's support structure due to additional horizontal connections.

The horizontal connected building at different height under earthquake and seismic loads, the most unfavorable location of sky bridge is the top (12^{th} and 16^{th} floor) of building and most favorable location at sky bridge is 4^{th} and 8^{th} floor connected twin tower building and the induced dynamic response demands of the twin tower building

8. FUTURE SCOPE

1. **Enhanced Simulation Techniques:** Explore advanced modeling tools to better predict and analyze the seismic behavior of buildings with different types of horizontal connections.

2. **Policy and Code Improvements:** Use research findings to contribute to the development of updated building codes and safety regulations, particularly for earthquake-sensitive areas.

3. **Design guidelines developments**: develop comprehensive design guidelines and standards for the Construction of horizontal walkways in seismic regions.

4. **Retrofit strategies** : investigate retrofit strategies for existing buildings that may benefit from the addition of A horizontal connection. This include assessing the feasibility and impact of retrofitting in Different seismic zones.

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