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Assessment of Horizontally Connected High-Rise Buildings under Earthquake Loading

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***Abstract*— One of the key elements in the structural design of the structures is how they will react to lateral stresses brought on by earthquakes. For many reasons, designers are connecting the adjacent buildings horizontally. Such horizontal connections have the potential to change the structure's behaviour. This results in restrictions on the application of design guidelines. According to design-code criteria, this study evaluates the behaviour of connected high-rise structures under earthquake loads in detail. Also observed how the position of the sky-bridge affects the produced reactions. Different ground-motion data with various peak ground accelerations were used to excite the building configurations. The positioning of the sky bridge had a subtle but significant impact on certain of the building structures' expected dynamic load-induced reactions.**

Keywords*— *High-rise buildings, Sky bridge, Earthquake loadings, Time-history analysis

I. Introduction

Buildings are getting higher and taller as a result of technological advancements. Modern high-rise buildings require high-strength materials. This results in lighter, more flexible, and less heavily damped structures than their predecessors. As a result of the high value of land and space, the scarcity of property, and the need for centralized service, there is a propensity to develop buildings close to one another without maintaining an adequate separation gap in modern cities. These structures move vigorously during an earthquake event and could cause significant damage as a result of mutual pounding. In this study, two buildings of different heights are considered. Sky-bridge is placed at different locations and buildings were analysed for different ground motions. Buildings were studied for maximum story displacement, base shear, story drift, and time period. ETABS 2018 software is used for modelling and analysis.

30- to 60-story planar buildings with European standards were used to create the frames, which were taken from reference three-dimensional structures with an internal symmetric bracing core. To reduce inter-story drifts and second-order effects, outriggers were positioned every fifteen floors, and the core was made up of a concentrically braced frame structure. In order to account for probable buckling mechanisms in both the braces and the gusset plates, out-of-plane flaws were specifically included in the braces [1].

The main objective was to reduce the wind-induced displacement and acceleration responses of LB systems. A three-dimensional analytical model and a genetic algorithm were used to discover the ideal link position. It was discovered that situating the link between 0.7 and 1 (i.e., the top) of the buildings is optimum since increasing mass to the link tends to improve displacement responses while decreasing LB acceleration [2]

Carpinteri et al. [3] analysed two complex structures in a city of Italy. The efficacy of the strategy was assessed in the current study using a numerical example using the 39-story (166 m) Intesa Sanpaolo Tower. The displacements and rotations of the findings were compared to those displayed in the building's final project. The final step was the presentation of curves pertaining to the primary internal operations of a single bracing.

The structures of the shapes of H, an O, and a C of different sized with varying amounts of stories were taken into account. The response spectrum technique of seismic analysis was utilized. It was discovered that H-shaped buildings performed better than the others. Maximum B.M. and S.F. fluctuation was seen in O-shaped buildings. Maximum displacement was produced by L-shaped structures. It was determined that the shear pressures and bending moments rose from 1.17% to 1.84% [4].

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Chua et al. [5] modelled the load transmission behaviour of the vertical module connections, which was crucial for the structural behaviour of high-rise modular structures using translational spring models. For high-rise modular construction to be more productive and efficient, connecting the modules at the corners rather than coupling the adjacent beams or slabs was suggested.

Behaviour of high-rise structure with coupling were studied. High rise structures were connected via a sky bridge. The performance of the structure under static and dynamic loads was assessed using this when the sky bridge was erected at various points throughout the constructions [6].

Juraj and Juraj [7] offered a probabilistic analysis to examine how well symmetrical high-rise buildings resist the impacts of unsymmetrical forces. Based on the case of a single, biaxial, and L-symmetric high rise, this study was conducted erecting buildings. The effectiveness of the probabilistic analysis to the best design of high-rise structures was demonstrated using the example of the sensitivity analysis. According to the results summary, depending on how the structure is set up in a plane, the unequal distribution of the masses had a major impact on the structure's seismic resistance.

The impact of a building's basement was studied. Greater lateral displacements and longer vibration durations will occur as a result of the basement's added flexibility to the structure. By adopting a stiff diaphragm for either all or part of each basement floor, the matrix condensation technique was able to remove the majority of degrees of freedom in the basement. It was discovered that the basement-containing building's period was almost 10% longer than the buildings without a basement [8].

II. Proposed Study

Two high-rise buildings of different heights are taken into consideration for this study. One building is of G+24 and another building is of G+18. The base of both buildings is fixed. A sky bridge is used to connect two buildings. Depending upon the location of the connection of the sky bridge, buildings are categorized in four different cases.

Table: 1 Different cases considered for analysis.

Case	Connection at
Case 1	No connection
Case 2	6th floor
Case 3	12th floor
Case 4	18th floor

III. Modeling

Dead, live and seismic loads are taken into consideration. By considering applied seismic zone, all structural elements and components are designed. Importance factor is taken as 1. The various loads are applied to the building in combination with factors as indicated in the IS code. All reinforced concrete elements are designed by the ultimate strength method. Compressive strength fc' = 40 MPa. And Yield stress fy = 500 MPa for deformed main reinforcing bars, stirrups and column ties is used.

Table: 2 General specifications of buildings

Contents	
Structure	SMRF
Storey Height	3 m
Grade of Concrete	M 40
Grade of Steel	Fe500
Bay width in X Direction	5 m.
Bay width in Y Direction	4.5 m.
Slab thickness	0.18 m
Size of Column for building	0.45 m x0.45 m
Size of Column for Bridge	0.45 m x0.6 m
Size of Beam	0.3 m X 0.45 m
Floor finish	1kN/m²
Live load	3 kN/m²
Seismic Zone	IV
No. of stories	G+24 and G+18

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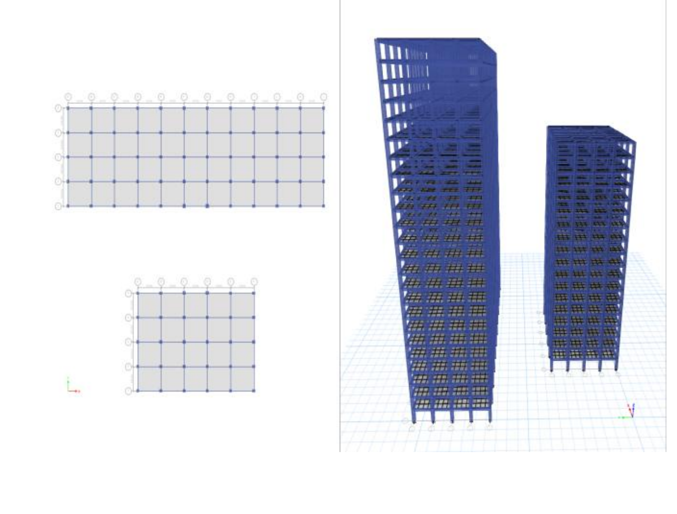	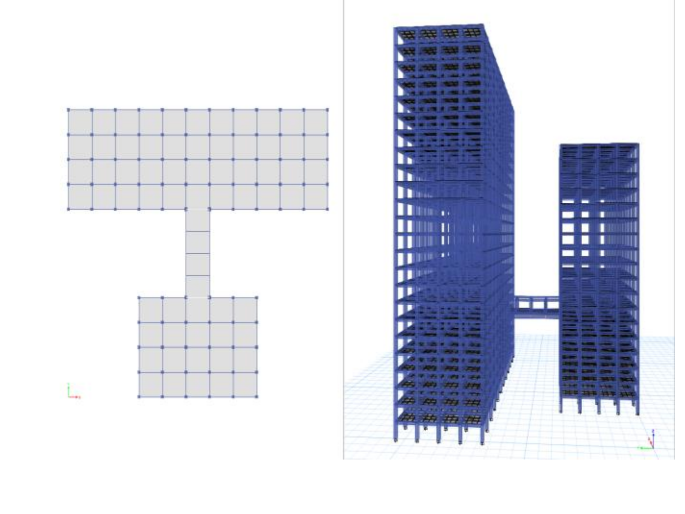
Case 1	Case 2

Fig:1 Plan and 3D modells of cases under consideration

Different cases are considered depending upon location of Sky Bridge as shown in above figure. Similarly, we can consider case 3 when Sky Bridge is provided at 12^{th} floor and case 4 when Sky Bridge is provided at 18^{th} floor.

Sky Bridge

It is the structural component used to connect the two buildings horizontally. In this study, a sky bridge of 16m span and 5m wide is used and it is resting on the columns of the buildings. Dimensions of the sky bridge is provided in below Fig: 2.

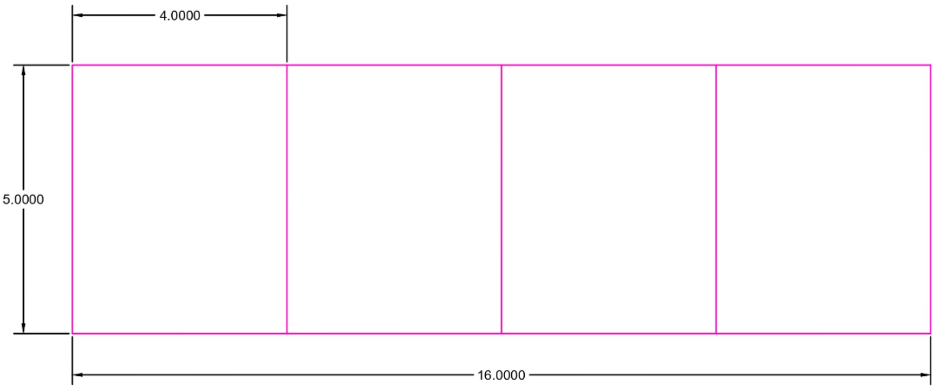

Fig: 2 Plan of sky bridge (meter)

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IV. Analysis Method

Time History Analysis which is a Non-linear dynamic analysis is used in this study. A structure's structural reaction to time-function loadings at different time steps is calculated using time-history analysis. In a nonlinear direct-integration time-history analysis, the material and geometric nonlinearities, including the P-delta and large-displacement effects, may be modelled. As an alternative, by using modal analysis, both linear and nonlinear equations of motion may be solved. It is important to note that connected objects in FNA applications capture nonlinear behaviour. The nonlinear time-history analysis used in the current work models a structure's behaviour during strong earthquakes better than other approaches.

Ground motion data

A sets of ground motion data is used to excite the buildings of different cases. It is shown in Fig: 3

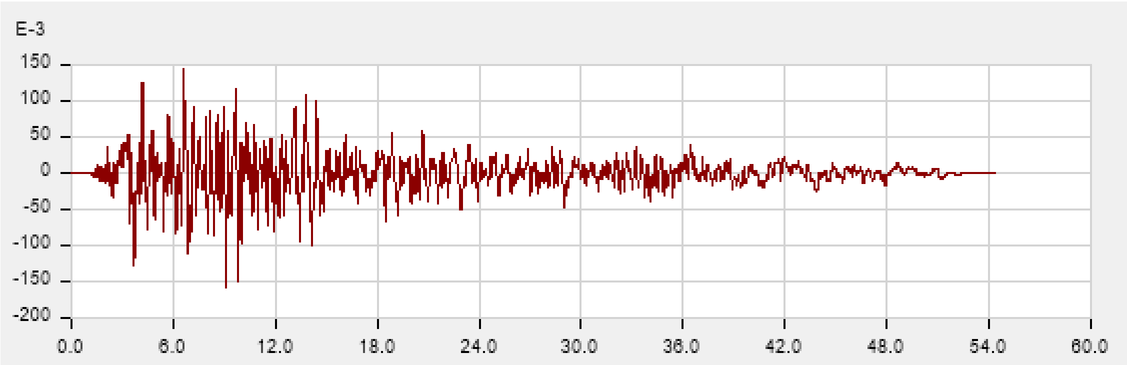

Fig: 3 Ground motion data recorded at Kern

V. Results

A. *Displacement*

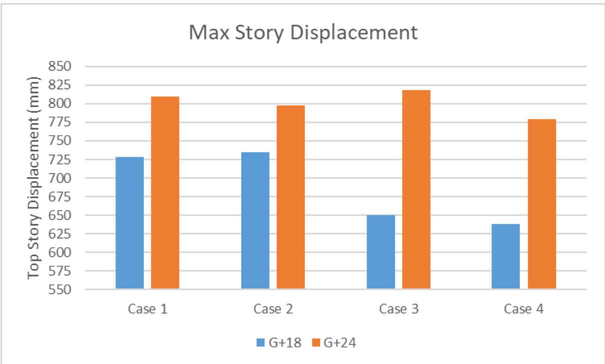

Fig: 4 shows the graph of top story displacement versus story number

It is seen that when there is no sky bridge, top story displacement of both the buildings is more. In case 2, top story displacement of G+24 building is reduced. In case 3, top story displacement of G+18 building is reduced. In case 4, top story displacement of both the building is reduced.

B. *Base Shear*

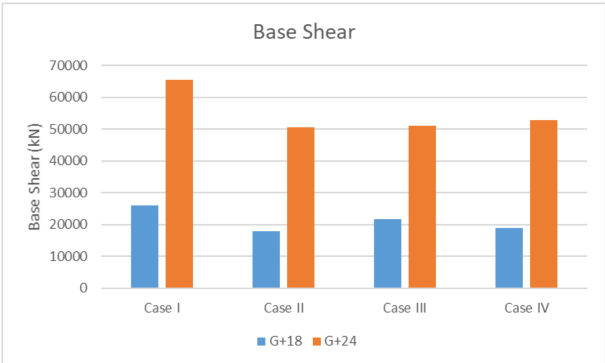

Fig: 5 shows the graph of base shear versus story number

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In case 1, base shear of G+24 building is maximum out of all cases. Minimum base shear can in obtained for the G+18 building of case 2.

C. Time Period

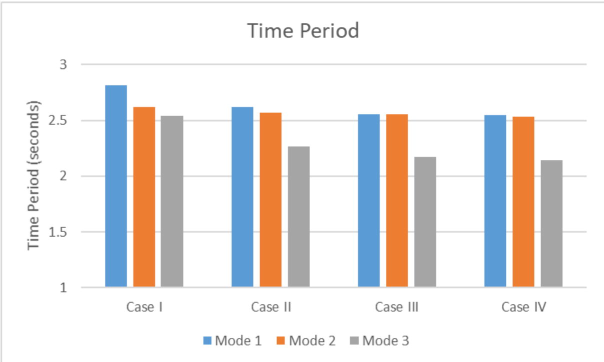

Fig: 6 shows the graph of time period of first three modes of each case

Time period of first three modes is maximum in case 1. As location of sky bridge moves from 6th floor to 18th floor, time period goes on decreasing for each case

D. Story Drift

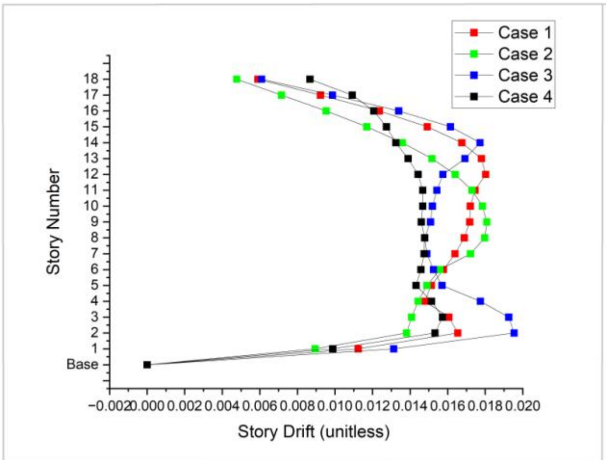

Fig: 6 shows the graph of story drift of each case

In case 3, maximum value of story drift is reached. Story drift is minimum in case 4. Story drift is at intermediate level in case 1 and case 2.

VI. Conclusion

This study investigated the dynamic responses of horizontally linked tall structures to several types of ground motion data. Investigation and longitudinal analysis were done on the impact of sky-bridge height on the generated dynamic responses of linked twin tall structures. The software programme ETABS, which simulates complex three-dimensional structures via a simple and effective technique, developed many configurations of the connected twin buildings. Over time, the structure's displacements, base shear, tale drift, and time period significantly changed. As soon as the connecting bridge was attached to the upper stories, these alterations in the generated reactions were considerably more obvious. From the study, the following findings might be made:

Peak displacements were less than in the other cases when the connecting bridge was positioned above the twin towers. Contrary to displacements, independent of loading direction and seismic motion, the basal shearing forces were much larger than at other sky-bridge site scenarios.

The PGA level of the earthquake motion affected the shear force that was produced at the base of the structure. In particular, the basal shear force increases as the PGA of the ground motion increases.

Under the whole collection of earthquake recordings, story moments along the building height were indifferent to sky-bridge height. The seconds generated at the bases, however, appeared to vary greatly depending on the sky-bridge location.

VII. References

[1] E. Brunesi, R. Nascimbene, and L. Casagrande, “Seismic analysis of high-rise mega-braced frame-core buildings,” Eng. Struct., vol. 115, pp. 1–17, 2016, doi: 10.1016/j.engstruct.2016.02.019.

[2] B. Kim, K. T. Tse, Z. Chen, and H. S. Park, “Multi-objective optimization of a structural link for a linked tall building system,” J. Build. Eng., vol. 31, no. September 2019, p. 101382, 2020, doi: 10.1016/j.jobe.2020.101382.

[3] A. Carpinteri, G. Lacidogna, and S. Cammarano, “Structural analysis of high-rise buildings under horizontal loads: A study on the Intesa Sanpaolo Tower in Turin,” Eng. Struct., vol. 56, pp. 1362–1371, 2013, doi: 10.1016/j.engstruct.2013.07.009.

[4] K. P. Chaudhary and A. Mahajan, “Response spectrum analysis of irregular shaped high rise buildings under combined effect of plan and vertical irregularity using csi etabs,” IOP Conf. Ser. Earth Environ. Sci., vol. 889, no. 1, 2021, doi: 10.1088/1755-1315/889/1/012055.

[5] Y. S. Chua, J. Y. R. Liew, and S. D. Pang, “Modelling of connections and lateral behavior of high-rise modular steel buildings,” J. Constr. Steel Res., vol. 166, p. 105901, 2020, doi: 10.1016/j.jcsr.2019.105901.

[6] I. Performance, O. F. Connected, S. Through, T. H. E. Use, and O. F. Skybridges, “Improving Performance of Connected High-Rise Structures Through the Use of Skybridges,” vol. 002701, no. Abstract ID, 2020.

[7] J. Králik and J. Králik, “Probability assessment of analysis of high-rise buildings seismic resistance,” Adv. Mater. Res., vol. 712–715, pp. 929–936, 2013, doi: 10.4028/www.scientific.net/AMR.712-715.929.

[8] D. Lee and H. S. Kim, “Efficient seismic analysis of high-rise buildings considering the basements,” Structure, no. 4, pp. 1–9, 2001.

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