

# Analysis of a Multi-Tower Frame Structure connected at different levels using ETABS

RISHABH SISODIA<sup>1</sup>, N. Tej Kiran<sup>2</sup>, K. Sai Sekhar Reddy<sup>3</sup>

<sup>1</sup>Student, Dept. of Structural and Geotechnical Engineering, Vellore Institute of Technology, Vellore, India

<sup>2</sup>Student, Dept. of Structural and Geotechnical Engineering, Vellore Institute of Technology, Vellore, India

<sup>3</sup> Student, Dept. of Structural and Geotechnical Engineering, Vellore Institute of Technology, Vellore, India

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**Abstract** - A Multi-Tower is a pair of tall structures which are connected to each other by a means of bridge. When there is decrease in the area of construction in horizontal dimension it is preferred to go for tall structures. At high vertical dimensions there is always an issue due to cantilever action, wind loads and seismic loads. To make the structure resistant to all these types of forces the concept of "MULT-TOWER" came into picture where the structure is more rigid, damp and stable for the wind and seismic loads. Here in this analysis considering a G+30 symmetric structure which is an office building being connected with one Steel Bridge at different levels to find out the action of seismic loads on the Structure using E-tabs.

**Key Words** Multi-tower, Bridge, Seismic Load, ETABS.

## 1.INTRODUCTION

A Multi-Tower (G+30) is a high raised structure which is constructed when the buildings are high raised and there are many lateral forces are acting on the Structure, to make the structure stiffer we connect the two high raised structures such they are stiff and the deflections at the higher levels due to Wind loads is relatively less.

It is outstanding that tall structures go about as imperative jobs in present day urban areas.

Most importantly, tall structures can be viably used to meet the necessities of present-day society and

tackle the issue of constraint of building site assets. Then again, they are the signs of financial properties and human progress.

These days tall structures ascend ever more elevated, with increasingly mind boggling and singular arrangement and height, for example, multi-tower structures.

The nonlinear time-history analysis and structural model tests are seldom presented in document. Some perfect software, such as ADINA, SAP, SUPER-SAP, ANSYS, TBSA, SAP84, TAT and SATWE etc. are widely used by designers and researches in this field.

## LITERATURE REVIEW

S Wensheng LU and Xilin LU performed analysis of Seismic Model Test and Analysis of Multi-Tower High-Rise Building and he found that distribution of floor mass and lateral stiffness changes sharply at different levels.

Ernesto F. Cruz, Anil K. Chopra performed analysis on Elastic Earthquake Response of Building Frames and found that the errors in the results of response spectrum analysis depend on the response quantity they are all below 15% for building frames with fundamental vibration period less than the end of the medium period region of the spectrum.

Roberto Villaverde performed analysis on Simplified Response-Spectrum Seismic Analysis of Nonlinear Structures and found that. The method maintains the simplicity and convenience of the conventional response-spectrum technique and appears to give an accuracy that is consistent with the accuracy attained in the analysis of linear systems.

S Abhishek, Manoj S K, Roopa B D, Bhagyashree M S, Guruprasad.C.H.M performed Analysis And Design On A High Raised Residential Building using ETABS and found that The flexible connections between towers can significantly reduce the drift of multi-tower high-rise buildings, and they will be destroyed

and act as energy dissipation members during a



moderate earthquake.

**Figure 1:** Plan of the Multi-Tower

• **LOADS:**

The loads acting on the structure are pre-defined in the software. Self-weight of the beam members, slabs are also to be considered and applied at each level of the structure. The following are the loads that are applied on the framed structure:

1. Dead load – Self-weight of the members
  2. Live load on the slabs and roof
  3. Floor finish – On floors
  4. Seismic Forces – Along X & Y directions
  5. Wind Forces
- ✓ All the dead loads and super-dead loads (floor finish) are assigned with a multiplier **1**. Live loads, Seismic, Wind, Response spectrum and Time history are given with a self-weight multiplier **0**.
  - ✓ The above loads are defined with the corresponding self-weight multiplier in the “**Load Cases**” option.

• **LOAD COMBINATIONS:**

Load combinations for the analysis of the Multi-Tower structure are auto generated in the load combinations menu, after all the required loads for analysis and design are defined.

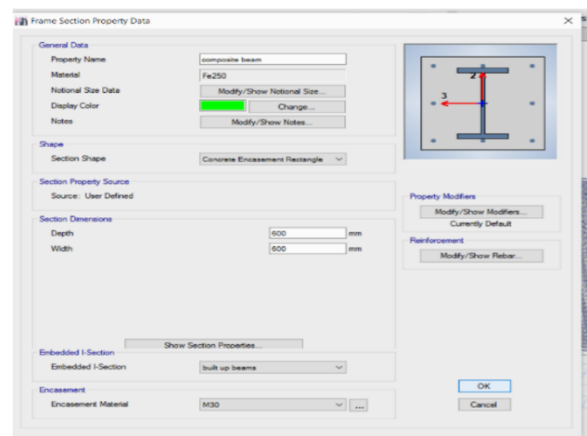
Below are some of the load combination factors that is program determined in the software.

- Dead and Live loads = 1.5
- Dead + Live + Seismic/Wind = 1.2

- Dead + Response spectrum = 1.5
- SECTIONS ADOPTED FOR BEAMS AND COLUMNS:

Since Trial and Error method was adopted for the assigning of beams and columns. Heavy beam sections also failed, which leads to assigning of built up sections for both columns and beams.

- ✓ Composite beams of 400mm x 400mm are defined for the longitudinal, transverse and cross beam members.
- ✓ ISMB350 sections are used in the rectangular concrete encasement.
- ✓ The flange thickness of ISMB350 is increased from 25mm to 30mm. The web thickness is increased from 13mm to 20mm.



**Figure 2:** Built Up Beam Section

- ✓ Composite columns of 450mm x 500mm are defined.
- ✓ ISWB550 sections are used in the rectangular concrete encasement.
- ✓ The flange thickness of ISWB550 is increased from 25mm to 50mm. The web thickness is increased from 13mm to 26mm.

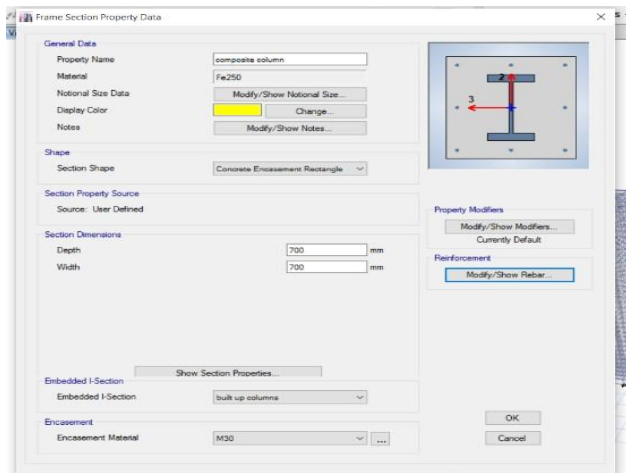


Figure 3: Built Up Column Section

### STATIC ANALYSIS OF THE TOWER

A **G+30** story framed structure is modelled in ETABS and primarily analyzed for the vertical loads acting on all the floors (like dead and live loads). The deflections, maximum shear forces and bending moments are observed to check the stability of the framed structure for the acted vertical loads and sufficiency of the member sizes. The dynamic forces are then acted on the structure when the frame passes the design checks after static analysis.

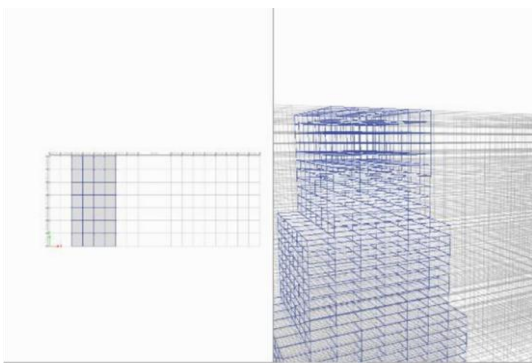
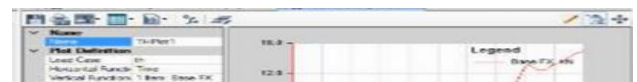


Figure 4: Plan and 3-D View of the Tower

- The defined static loads are acted on the members and run analysis with the load combinations.
- Design check is done after the analysis. Once the structure passes the static analysis, dynamic forces are acted on the frames.

- The response spectrum function is defined for a selected seismic zone, Hyderabad (**Zone - II**) and soil type (**Soil type - II**).
- The time-history functions are also defined along both X & Y directions as the ground motion databases obtained from [peer.berkeley.edu](http://peer.berkeley.edu).
- The response spectrum curve and the time-history curve are matched on the frequency domain for both X & Y directions.
- Seismic, Wind and the matched response spectrum & time history forces are added in the load case tree and the structure is analyzed.

Figure 5: Response spectrum plot of a single tower



The results obtained from the analysis are as follows:

Maximum deflection of all the beam elements =

a) Maximum shear force =

b) Maximum bending moment =

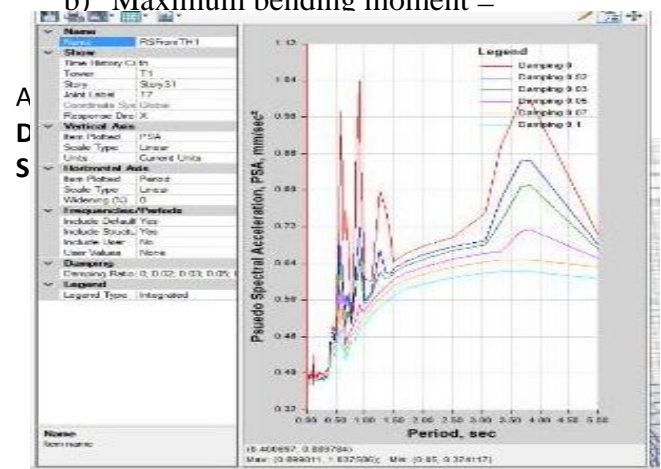
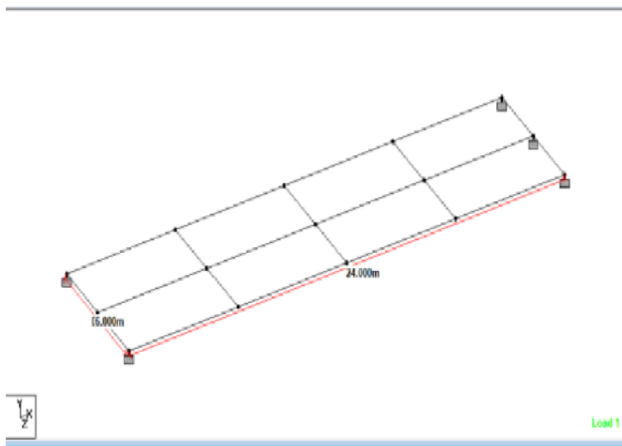


Figure 6: Time history plot of a single tower

- The maximum Pseudo Spectral Acceleration (from response spectrum plot) is ....
- The maximum base shear (from time history plot) is.

### DESIGN OF THE CONNETING BRIDGE



**Figure 7:** The Connection Bridge

The steel section selected for the design of the bridge is ISHB500. The displacement for the bridge for the loads assigned is 5.78mm. The Bending Moment and Shear Force are 281.267kNm and 63kN respectively.

### COMBINED TOWER PARAMETERS

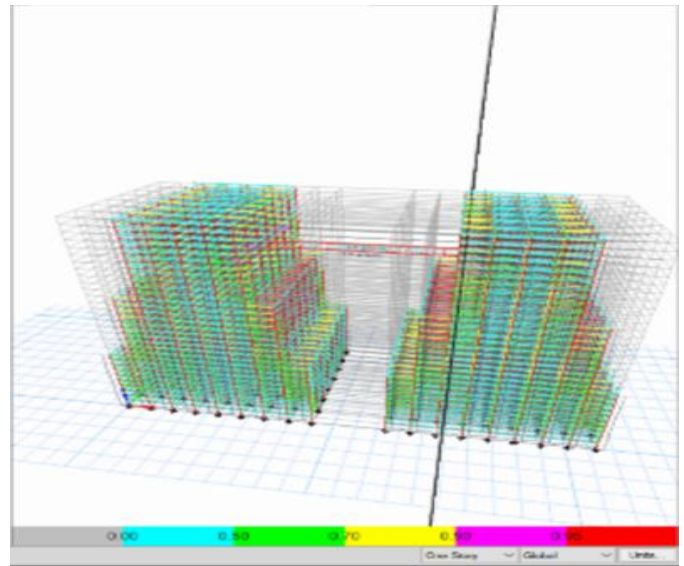
The two towers are connected by means of the above designed bridge at three different levels. The connection between the bridge and the towers is maintained at the floor level for each of the stories.

The bridge is connected at 10<sup>th</sup>, 15<sup>th</sup> and 25<sup>th</sup> storey and the optimum level of connection is verified for the multi-tower structure to be stable. The members are designed and checked whether all the members are passing the check.

- CONNECTION AT 25<sup>th</sup> STOREY:

The first connection made is at 25<sup>th</sup> storey, as the height of the structure increases, the effect of lateral forces (wind and seismic) will increase and might cause failure of frames.

Firstly, the members adopted were of ISMB350 for beams and ISHB450-1 for columns. The loads are acted and analysis is performed. After the design check, the outer beams and most of the columns failed due to higher column-beam capacity ratio.



**Figure 8:** Failure Frames for the Combined Towers

Therefore, composite beams and columns are adopted of above mentioned specifications and again design check is performed. All the members passed the design check. Plots of maximum storey drifts, story displacements, story shears, response spectrum and time history are obtained.

The similar procedure is adopted for the connections at 15<sup>th</sup> and 10<sup>th</sup> storey of the multi-tower.

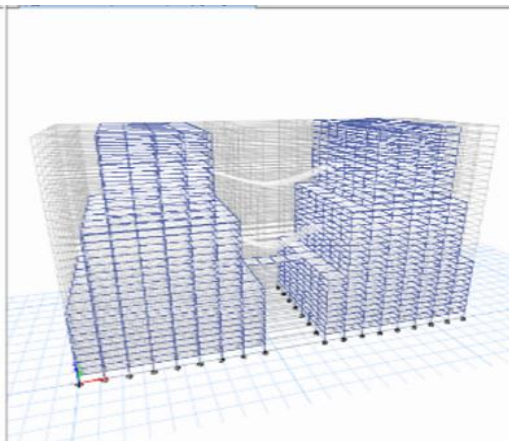
- CONNECTION AT 15<sup>th</sup> STOREY:

The bridge connection is made of bolts of diameter 32mm and 4 number of bolts for each connection. Analysis is run after application of loads. Like the connection at 25<sup>th</sup> storey, plots of all the desired parameters are obtained.

- CONNECTION AT 10<sup>th</sup> STOREY:

Similar analysis and design checks are performed for the connection at 10<sup>th</sup> storey as done for 25<sup>th</sup> and 15<sup>th</sup> stories. Deformed shape of the multi-tower when connected at 10<sup>th</sup> storey is shown as an example figure below.





**Figure 9:** Deformed Shape of the frames & bridge for connection at 10<sup>th</sup> storey

COMPARISON OF DEFLECTIONS, SF AND BM OF THE LOWER BEAM FOR ALL CONNECTED LEVELS:

**Table 1:** Deflection, Shear force and Bending moments of the lower beam of the structure

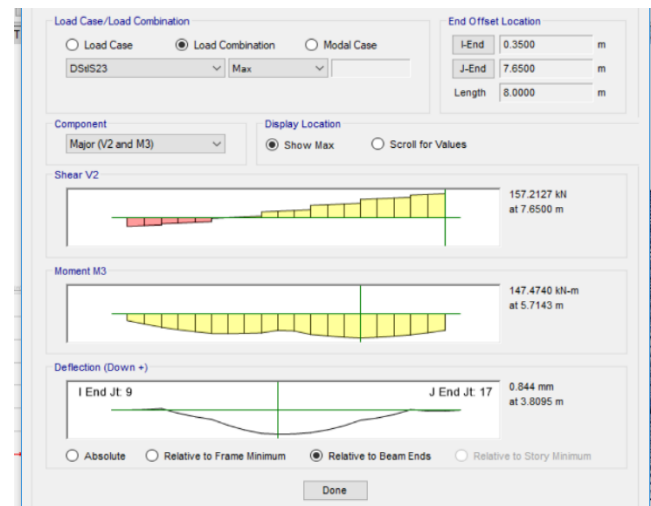
The increase of deflection in the lower beam of a single tower is due to the weights of upper floors acting on the bottom floors. When a bridge is connected, the stiffness is increased between the two towers and some part of the loads from the above floors is taken by the bridge-tower connection. Therefore, the deflections in the lower beams of a connected structure are less as compared to the single tower structure.

From the above observations, the connection of the

| Connection \ Parameter | Single Tower | 10 <sup>th</sup> Storey | 15 <sup>th</sup> Storey | 25 <sup>th</sup> Storey |
|------------------------|--------------|-------------------------|-------------------------|-------------------------|
| Deflection (mm)        | 1.56         | 1.249                   | 0.84                    | 1.18                    |
| Shear Force (kN)       | 122.42       | 113.36                  | 157.2                   | 116.4                   |
| Bending Moment (kN-m)  | 234.11       | 270.67                  | 147.4                   | 113.1                   |

bridge at 15<sup>th</sup> storey is expected to be safe and economical as the deflections, shear forces and bending moments are less.

The observations are more for the connection at 10<sup>th</sup> storey as the weights from the above floors is maximum as compared to the connection at 15<sup>th</sup> storey.



**Figure 10:** Example of deflection, SFD and BMD of the lower beam (when frames are connected at 15<sup>th</sup> storey)

• COMPARISON OF STOREY DRIFTS, STOREY SHEARS AND STOREY DISPLACEMENTS:

When the seismic, wind, response spectrum and time history load cases are acted on the structure, the frames not only displace along the vertical direction (due to the gravity loads), but also displace along the horizontal direction. Tilt of the structure occur and even the frame may collapse because of this lateral displacements called "STOREY DRIFTS". Therefore, storey drifts and storey displacements are to be evaluated for the stability of the structure.

Storey shears are required to assess the member capacities (especially columns) for the applied lateral forces.

| Connection \ Parameter  | Max Storey Displacements (mm) | Max Storey Shears (kN) |
|-------------------------|-------------------------------|------------------------|
| Single tower            | 5.6                           | 0.79                   |
| 10 <sup>th</sup> storey | 4.21                          | 0.56                   |
| 15 <sup>th</sup> storey | 3.48                          | 0.48                   |
| 25 <sup>th</sup> storey | 2.9                           | 0.41                   |

**Table 2:** Storey displacements and Storey shears

- ✓ The storey displacements and storey shears decreased as the connection level is made higher, as the stiffness between the frames is increased and greater stability is provided to the multi-tower structure.
- ✓ Considering the vertical loads also, as the connection at 15<sup>th</sup> storey is giving better results in terms of shear and bending of lower beams, an example of maximum storey displacements (mm) is represented as in the figures below:

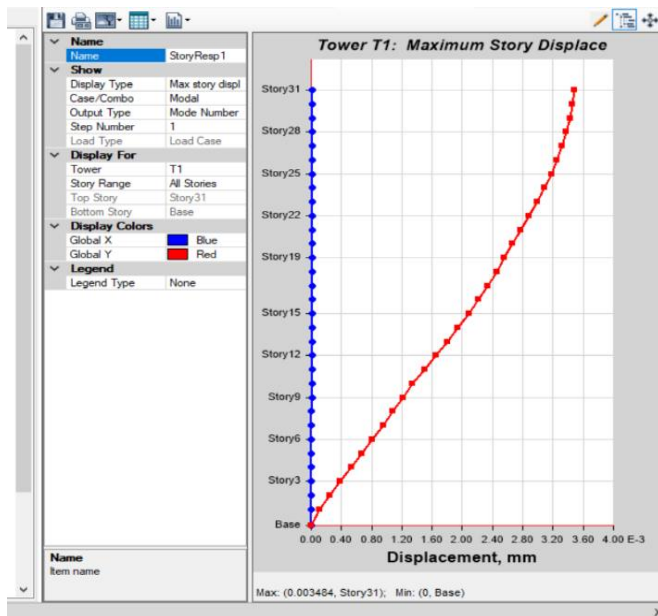


Figure 11: Storey displacement plot when bridge and frames are connected at 15<sup>th</sup> storey

DESCRIPTION OF CONNECTIONS MADE:

Bolted connections are chosen for all the bridge-frame links. The bolted connections are only possible to be given when built up sections were used as beams and columns (before adopting the composite sections). This explains that the complete steel frame was safe even when heavier I-sections are provided as the members, but the columns failed because of the high column-beam capacity ratio. Bolts of diameter 32mm and 4 number of bolts per each link are adopted. These connections are checked for bearing capacity, moment and shear. All the connections are observed to pass the check as shown in the below figure:

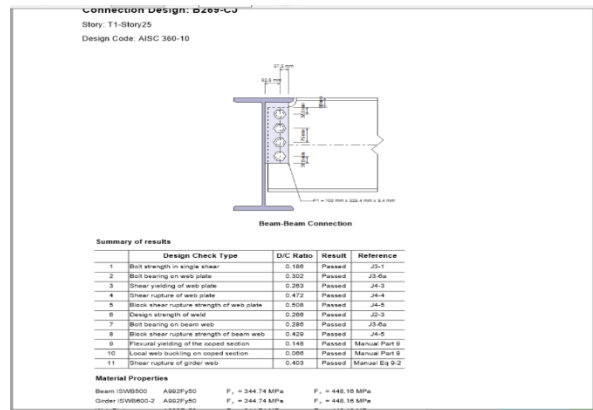


Figure 12: Check for bolted connections

COMPARISON OF RESPONSE SPECTRUM AND TIME HISTORY PLOTS:

Matched response spectrum and time history plots (pre-defined) along X & Y directions are studied and the maximum Pseudo Spectral Acceleration (mm/sec<sup>2</sup>) and Base forces (kN) are analyzed to evaluate the actual performance of the modelled multi-tower frame structure. The accelerations and displacements obtained from the graphs are the modal values which vary based on the maximum number of modes and cycles given by the user.

| Parameter / Connection  | Pseudo Spectral Acceleration (mm/sec <sup>2</sup> ) | Base Shear (kN) |
|-------------------------|---|-----------------|
| Single Tower            | 1.03  | 16.53           |
| 10 <sup>th</sup> storey | 0.99  | 24.12           |
| 15 <sup>th</sup> storey | 0.993   | 29.77           |
| 25 <sup>th</sup> storey | 0.989   | 30.23           |

Table 3: Response Spectrum and Time-History plot observations

The accelerations of the stories due to lateral force combinations decreased as the level of connection is higher. This is because of increase in stiffness of the frames and making the multi-tower rigid.

By making the frames rigid enough, the columns are meant to take more shear forces as the height of the building and connection level increases. Therefore, there is increase in the base shear values.

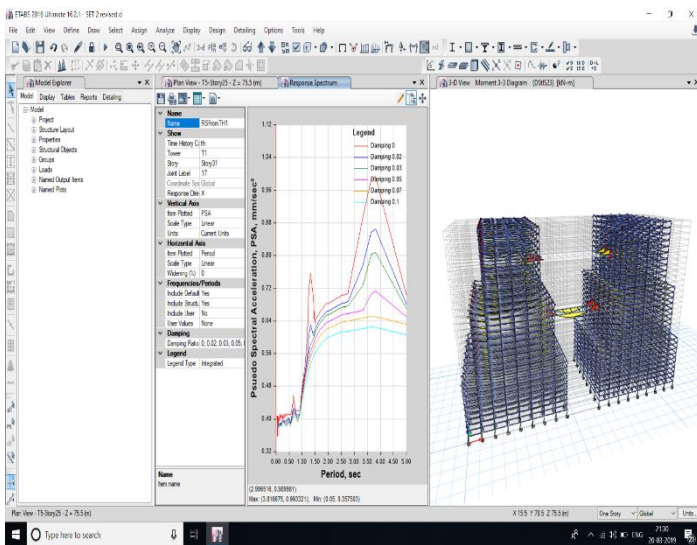


Figure 13: Example of response spectrum plot (when bridge is connecting the 2 frames at 15<sup>th</sup> storey)

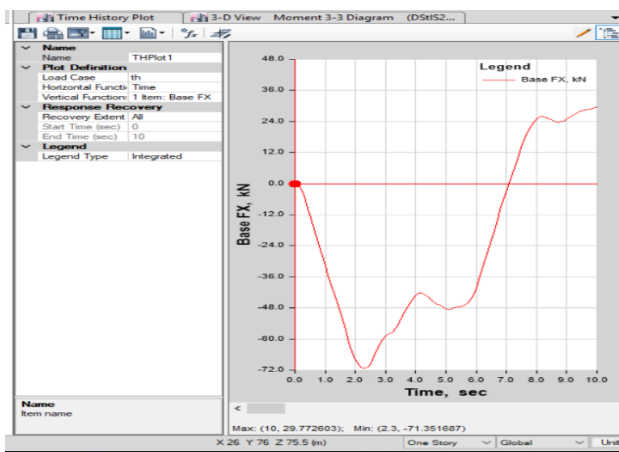


Figure 14: Example of a Time-History plot (15<sup>th</sup> storey)

### CONCLUSION

1. The most optimum connection was found to be at 15<sup>th</sup> floor where this connection can compensate between the vertical loads and the lateral forces.
2. The connection should not be made above the 20<sup>th</sup> floor due to the action of wind loads and the cantilever action of the Multi-Tower.
3. When the seismic forces and the Wind forces act on the tower these connections serves as the “Stiffener” for both the towers.
4. It reduces the Storey Displacements of the towers imparting better durability and long life of the Multi-Tower.

5. Composite sections are used with rectangular concrete encasement for beams and columns as the number of stories is very high.

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