Backstay Effect Due to Podium Structure Interaction

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Abstract - *Marvels of the modern world cannot be imagined without the involvement of enormous superstructures which form the very core of visual attraction for metropolitan cities. Modernization and urbanization have led to migration to a vast extend, causing scarcity of land. Economical and efficient use of land is the need of the hour as horizontal expansion of cities is a complicated task. So, to overcome this scenario the vertical expansion of cities in the form of Highrise structures is to be undertaken. To enhance the efficiency of a particular land, developers and architects have come forward to include below storey podium structure to Highrise buildings. These structures prove to be more efficient as they can be used for various commercial purpose. Focus of current work is to study the effects of these augmented portions of structure in the form of podiums, on the structural aspect of the entire structure. A 40 Storey RCC structure is been considered situated in the IVth seismic zone of India. Various effects of inclusion of podium are studied by comparing structures with and without the inclusion of below storey podium. Effect of the increased stiffness due to podium is studied by considering various structural parameters like Lateral Displacement, Storey Shear, Storey Drift, Time Period. Studies regarding Backstay Effect due to below storey podium structure are made and its effects are observed at the podium structure interaction level. Sensitivity analysis is been carried out as per IS 16700 to study effect of crack formation.*

Key Words: **Highrise buildings, Backstay Effect, Storey Shear, Storey Drift, Time Period, Sensitivity Analysis, Below Storey Podium, Podium Structure Interaction.**

1.INTRODUCTION

Increased job availability in major cities as a result of urbanisation has indirectly increased migration to these areas. The population of these cities grows as a result. The effects of population growth are directly related to the liveable area of a specific city. Population growth, urbanization, and the need for diverse infrastructure all contributed to the scarcity of adequate land for development. Because there is a lack of land, it is difficult to expand cities horizontally; therefore, tall buildings are constructed as a solution to this problem. Consequently, in order to gain leverage and satisfy the need for larger commercial space close to the road level, architects and developers have come up with a plan to provide a below storey podium to an existing structure.

At the base of medium-rise and tall structures, podiums are expanded floor surfaces. Metropolitan areas with low to moderate seismic activity prefer this type of construction since a structure with this configuration can support a variety of functionalities. (i.e., retail space in the podium's lower levels and housing or office space in the tower). Moment resistant frames and shear walls make up the lateral load-resisting system for such building constructions. Many tall structures have an arrangement in which the lower few storeys have a wider floor plan than the tower above. Any lower component of a tall structure with a wider floor plan and much higher seismic force resistance than the portion above it can be viewed as a podium structure. This sort of architecture is typical in multi-story buildings where the lower section of the storeys is commonly utilised for commercial spaces, retail stores, parking lots, etc.

1.1 Setback/Backstay Effect

In comparison to the above structure, the surface area of the below storey podium structure is significantly larger. This larger shift in stiffness occurs across the entire structure due to the podium structure's different dimensions. As a result, the podium structure's rigidity is substantially higher than that of the tower structure above. As a result, the podium structure helps in resisting lateral loads that act on the entire structure. At these levels, lateral load resistance within the podium level with a guaranteed load transfer path through the floor diaphragms, aids in the overall structure's ability to withstand lateral stresses. This aspect of the structure's resistance to lateral loads is known as the Backstay effect or shear reversal because shear forces in the structure tend to change direction at the podium structure interaction level. To equilibrate the lateral forces and moment of a tower projecting above a podium structure, a set of lateral forces are developed within the podium structure, which helps to resist the external lateral forces, this is termed as the backstay effect.

1.2 Sensitivity Analysis

When cracks are formed in a member the moment carrying capacity or stiffness of the member tends to reduce. Exact extend of these cracks cannot be determined. Once a crack is formed in a member, its stiffness reduces. Thus, different stiffness modifiers are applied to different structural elements in order to account the effect of cracking on stiffness of section and there by on the behaviour and analysis results of a building structure. Sensitivity Analysis is a procedure to assess the behaviour of a building under different scenarios by gradually changing the stiffness properties of its structural elements. According to IS 16700 two sets of sensitivity analysis should be carried out using upper bound and lower bound stiffness modifiers provided in table no. 7, clause 8.1.3.2.1 as a part of collapse prevention evaluation to study the effect of these modifiers on the behaviour of the structure. Upper bound and lower bound stiffness modifiers should be applied in the below storey podium structure along with crack section modifiers to be applied in the above tower.

2. METHODOLOGY

2.1 Problem Statement

To study the effect of podium structure interaction on the structural parameters of the building, multiple 40 storey RCC structures with and without a below storey podium and having a shear wall core are modelled and analysed. Considering them to be in IVth seismic zone and analysing it with response spectrum analysis for seismic analysis.

2.2 Objectives

- Analyse a 40-storey structure with and without a below storey podium structure by response spectrum analysis.
- Study the effect of podium structure interaction by comparing the results with a normal structure without the inclusion of a podium in it.
- Study effect of backstay on structural parameters of the structure like lateral displacement, base shear, time period and storey drift.
- Study the effect of upper bound stiffness modifiers and lower bound stiffness modifiers on the models.
- Study the effect of height of podium on the results by considering different height of podiums attached to the main structure.
- Study the effect of surface area of the below podium structure on the results by considering different surface area of podiums attached to the main structure.

3. MODELLING

3.1 Analysis

- In the presented study, Dynamic analysis is performed under the guidelines of IS 16700(2017), IS 1893: Part 1 (2016), IS 456 (2000), IS 13920 (2016), IS 875: Part 1 (2015), IS 875: Part 2 (1987) and IS 875: Part 3 (2015).
- 40 Storey SMRF RCC structures with height of 120m are modelled with and without below storey podium structures.
- Response spectrum analysis is use for seismic analysis
- Sensitivity analysis is carried out as per IS 16700 with the consideration of upper bound stiffness modifiers and lower bound stiffness modifiers.
- Rigid diaphragms are used for all floors.
- Dimensions of every structural member is kept the same throughout all the models for the comparative study.
- Slabs and Shear Walls are modelled as thin shells.
- Mass source consideration for loads is 1DL, 0.5LL and 1SIDL as live load to be considered is greater than 3KN/m^2.
- A total of 13 models are considered for analysis and comparative study.
- Results are displayed in terms of lateral displacement, base shear, time period, storey drift and shear reversed.
- Effect of backstay on various structural parameters is been studied due to the podium structure interaction.
- For sensitivity analysis upper bound and lower bound stiffness modifiers are applied as per IS 16700, clause 8.1.3.2.1 in the below storey podium structure and crack section modifiers are applied in the tower above.

3.2 Input Parameters

Table -1: Input Data

A	**Building Structure**	
1	Height of structure	120m
2	No. of Storeys	40
3	Plan Size	
a	Conventional Structure	42x35m^2 (6x5 bay structure of 7m c/c, height120m)
b	40 Storeys with 10 level podium	98x91m^2 (14x13 bay of 7m c/c, 6x5 bay structure above podium)
c	40 Soreys with 6 level podium	98x91m^2 (14x13 bay of 7m c/c, 6x5 bay structure above podium)
d	40 Storeys with 10 level podium	70x63m^2 (10x9 bay of 7m c/c, 6x5 bay structure above podium)

e	40 Storeys with 6 level podium	70x63m² (10x9 bay of 7m c/c, 6x5 bay structure above podium)
4	Slab Thickness (M50)	150mm
5	Beams (M40)	700x350mm
6	Columns(M50)	1st to 10th storey- 1100x1100mm 11th to 20th storey- 1000x1000mm 21st to 40th storey- 900x900mm
7	Shear Walls (M50)	300mm
B	**Loading**	
1	Live Load	4KN/m²
2	Floor Finishes	1.5KN/m²
3	Wall Load	Considering 230mm walls made up from engineering bricks. Thickness= 230mmig Weight Density of Brickwork =21.20KN/m³ Wall Load= (3-0.7) x 0.23 x 21.20 = 11.215 KN/m Parapet Load= 1.2 x 0.23 x 21.20 = 5.85 KN/m
C	**Seismic Loading (IS 1893 Part I)**	
1	Seismic Zone	IV (IS1893 Part I) 0.24
2	Soil Type	II (Medium)
3	Importance Factor	1
4	Response Reduction Factor	5 (SMRF Structure)
D	**Wind Load (IS 875 Part 3)**	
1	Wind Speed	50m/s
2	Terrain Category	2
E	**Material Properties**	
1	Grade Of Concrete	Slabs- M50 Columns- M50 Shear Walls- M50 Beams- M40
2	Grade Of Steel	Fe 415 Fe 500
3	Weight Density of Concrete	25KN/m³
4	Weight Density of Steel	77KN/m³

Table – 2: Stiffness Modifiers

Sr. No.	Structural Elements	Upper Bound Stiffness Modifiers	Lower Bound Stiffness Modifiers	Factored Load Modifiers
1	Slabs	0.5	0.15	0.25
2	Beams	0.5	0.15	0.35
3	Columns	-	-	0.7
4	Shear Walls	0.5	0.15	0.7

Table – 3: Model Configuration

Sr. No.	Model Name	Model Configuration
A	**Base Models**	
1	Conventional Structure (CS)	40 Storey structure without below storey Podium.
2	10SP	40 storey structure with podium(98x91m²) up to 10th storey.
3	6SP	40 storey structure with podium(98x91m²) up to 6th storey.
4	10SSP	40 storey structure with podium(70x63m²) up to 10th storey.
5	6SSP	40 storey structure with podium(70x63m²) up to 6th storey.
B	**Models with Upper Bound Stiffness Modifier**	
6	10SPUM	40 storey structure with podium(98x91m²) up to 10th storey with upper bound stiffness modifiers.
7	6SPUM	40 storey structure with podium(98x91m²) up to 6th storey with upper bound stiffness modifiers.
8	10SSPUM	40 storey structure with podium(70x63m²) up to 10th storey with upper bound stiffness modifiers.

9	6SSPUM	40 storey structure with podium(70x63m^2) up to 6th storey with upper bound stiffness modifiers.
C	**Models with Lower Bound Stiffness Modifier**	
10	10SPLM	40 storey structure with podium(98x91m^2) up to 10th storey with lower bound stiffness modifiers.
11	6SPLM	40 storey structure with podium(98x91m^2) up to 6th storey with lower bound stiffness modifiers.
12	10SSPLM	40 storey structure with podium(70x63m^2) up to 10th storey with lower bound stiffness modifiers.
13	6SSPLM	40 storey structure with podium(70x63m^2) up to 6th storey with lower bound stiffness modifiers.

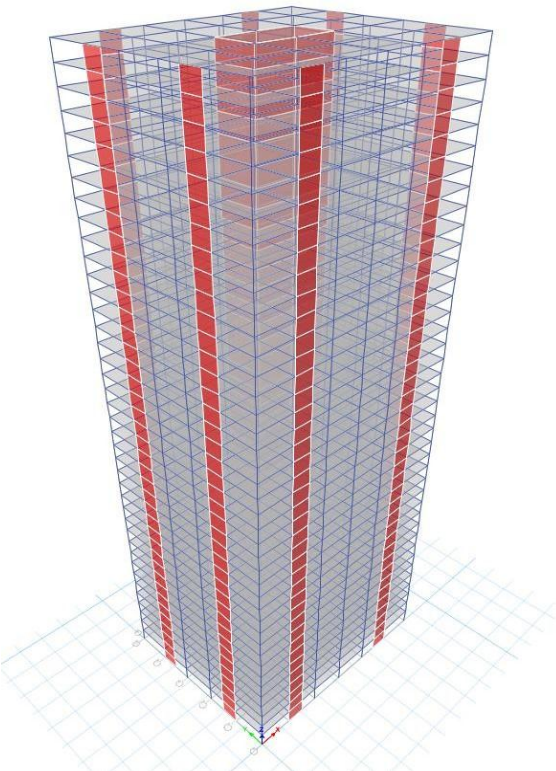

Fig – 1: 3D view of model CS.

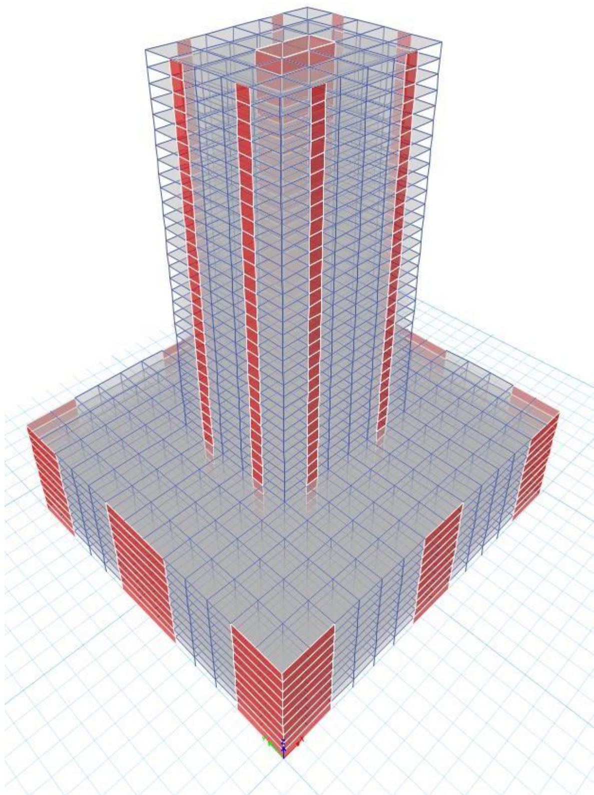

Fig – 2: 3D view of models 10SP, 10SPUM and 10SPLM.

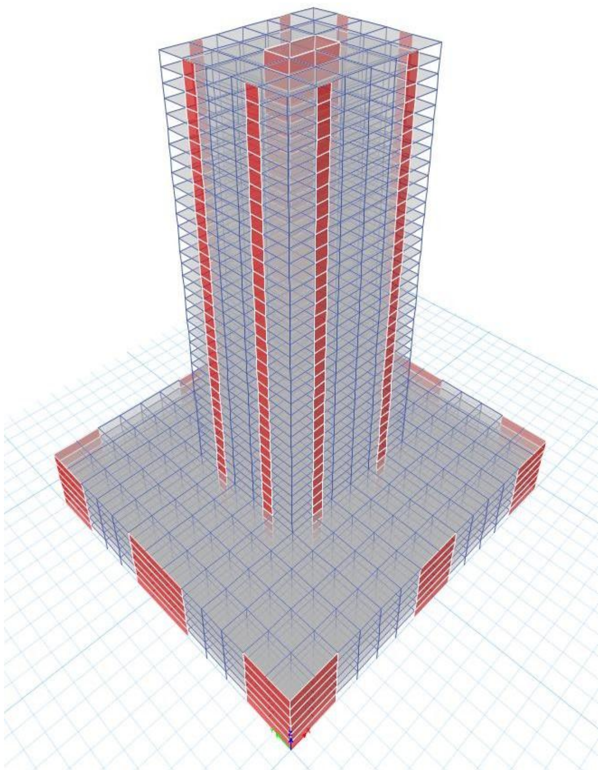

Fig – 3: 3D view of models 6SP, 6SPUM and 6SPLM.

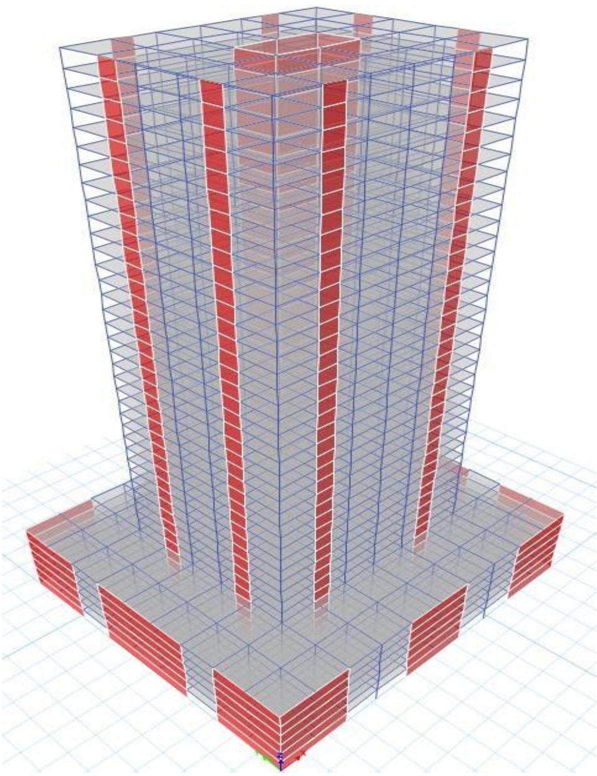

Fig – 4: 3D view of models 10SSP, 10SSPUM and 10SSPLM.

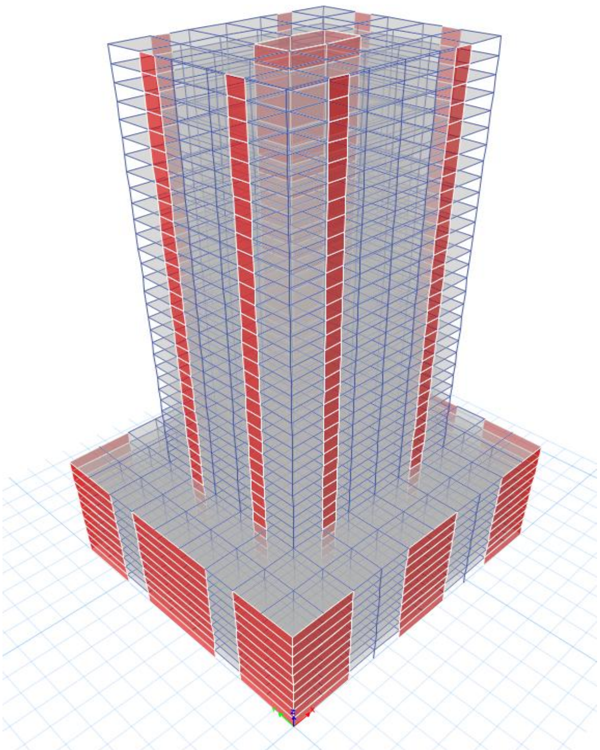

Fig – 5: 3D view of models 6SSP, 6SSPUM and 6SSPLM.

4. Results and Discussion

4.1 Lateral Displacement

Chart- 1, Chart- 2, Chart– 3, Chart– 4, Chart– 5 and Chart- 6 represent the values for lateral displacement in X and Y Direction for response spectrum analysis.

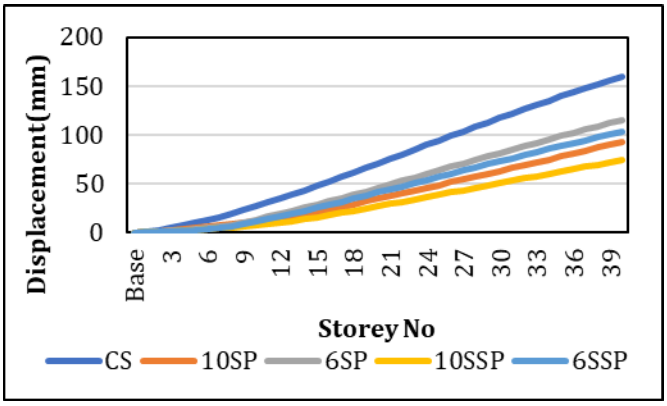

Chart -1: Lateral Displacement in X Direction for base models CS, 10SP, 6SP, 10SSP and 6SSP.

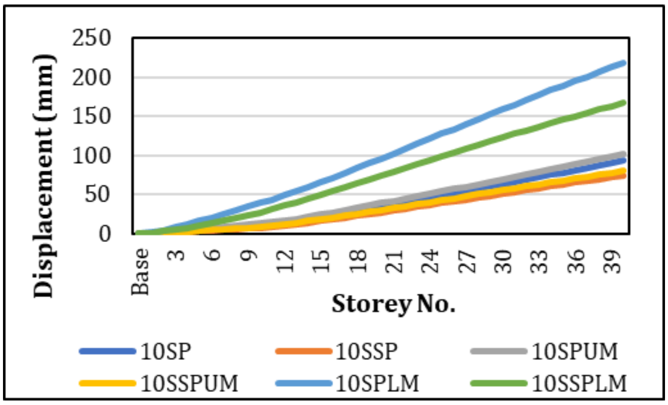

Chart -2: Lateral Displacement in X Direction for models 10SP, 10SSP, 10SPUM, 10SSPUM, 10SPLM and 10SSPLM.

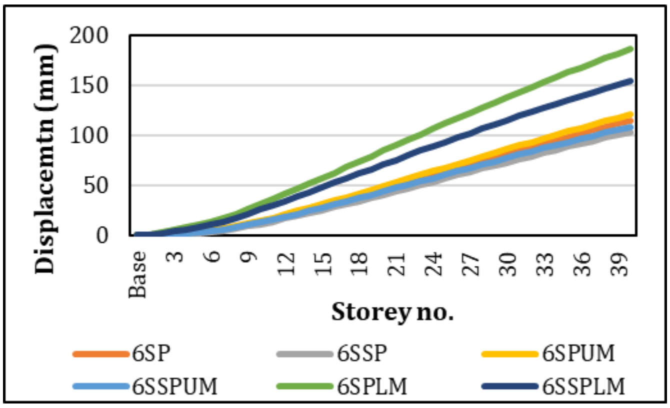

Chart -3: Lateral Displacement in X Direction for models 6SP, 6SSP, 6SPUM, 6SSPUM, 6SPLM and 6SSPLM.

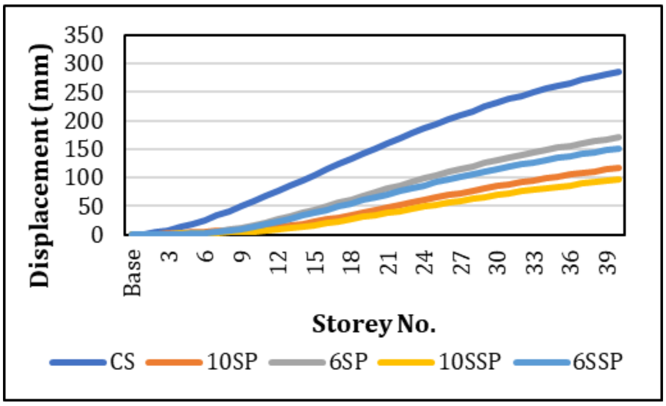

Chart -4: Lateral Displacement in Y Direction for base models CS, 10SP, 6SP, 10SSP and 6SSP.

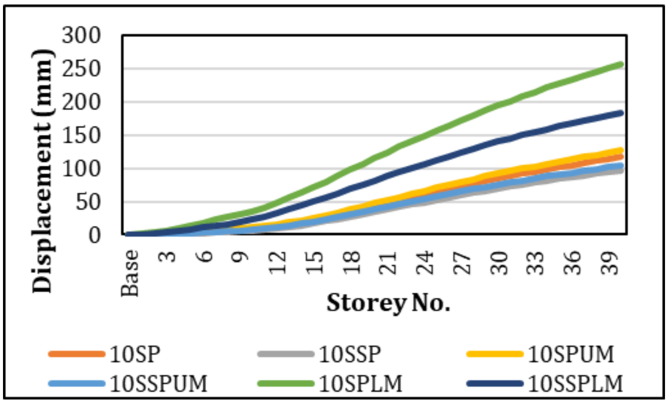

Chart -5: Lateral Displacement in Y Direction for models 10SP, 10SSP, 10SPUM, 10SSPUM, 10SPLM and 10SSPLM.

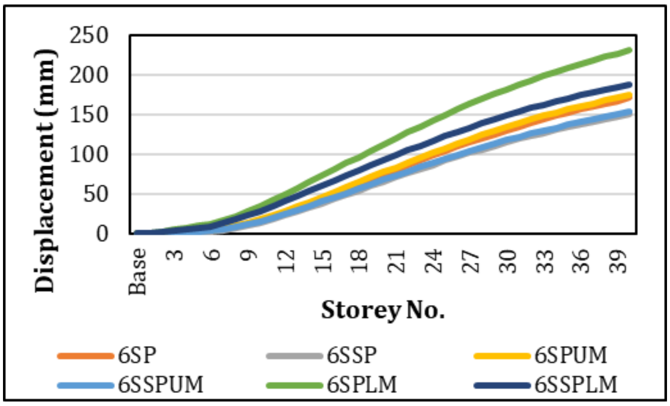

Chart -6: Lateral Displacement in Y Direction for models 6SP, 6SSP, 6SPUM, 6SSPUM, 6SPLM and 6SSPLM.

From chart-1 and chart-4, it is been observed that the values of lateral displacement for models with below storey podium are far lesser than basic conventional structure depicting an increase in general stiffness of these models as compared to basic structure.

The maximum values tend to decrease with the increase in the height of the Podium structure in the models. The maximum values for lateral displacement in X direction for 10SP and 6SP models are reduced to 58% and 72% respectively when compared with the basic conventional structure without below Storey Podium. In Y direction the same values are reduced to 41% and 59% respectively.

Models with reduce surface area of the podium structure were observed to be stiffer than other models with same podium heights as the values for lateral displacement were lesser as compared to other models. Maximum values for lateral displacement in X direction for 10SSP and 6SSP are reduced to 46% and 64% respectively when compared to the base model without below storey podium. Similarly in Y direction values are reduced to 33% and 52% respectively.

For sensitivity analysis, it can be observed from chart-2, chart-3, chart-5 and chart-6 that models with upper bound stiffness modifiers were a lot stiffer than models with lower bound stiffness modifiers, yet they were observed to be more flexible as compared to models with factored load property modifiers.

For 10SP model the value of 10SPUM is greater by 8% and for 10SPLM the maximum value goes up to approximately 134% in X Direction. While considering for Y direction the value of 10SPUM is greater by 7% and for 10SPLM the value is greater by 118%.

For 6SP model the maximum value for lateral displacement in X direction for 6SPUM is greater by 5% and for 6SPLM the values rise up approximately by 61%. In Y direction the maximum value is greater by 2% and for 6SPLM the value is greater by 35% as compared to 6SP.

For model 10SSP the maximum value for lateral displacement in X direction for 10SSPUM is greater by 7% and for 10SSPLM the value is greater by approximately 125%. When considered in Y direction the value for 10SSPUM is greater by 7% and for 10SSPLM the value goes up to 89% respectively as compared to the base model with factored load property modifiers.

For 6SSP model the maximum value for lateral displacement in X direction, for 6SSPUM is greater by 5% and for 6SSPLM the values are greater by 49%. In Y direction the value for 6SSPUM is greater by 1% and for 6SSPLM the value increases by approximately 25%.

4.2 Storey Shear

Chart -7, Chart -8, Chart -9, Chart -10, Chart -11, Chart -12 represent the values for storey shear in X and Y direction for response spectrum analysis.

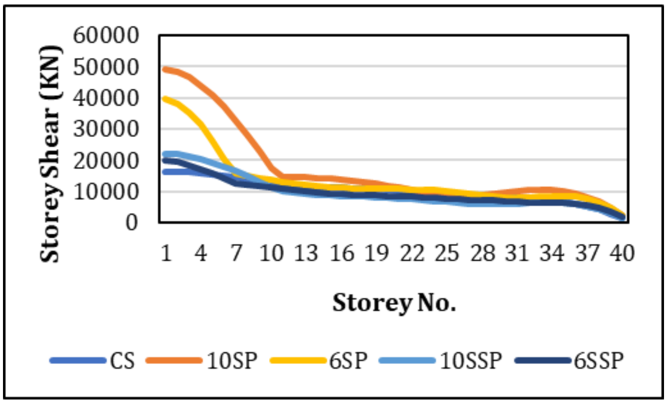

Chart -7: Storey Shear in X Direction for models CS, 10SP, 6SP, 10SSP and 6SSP.

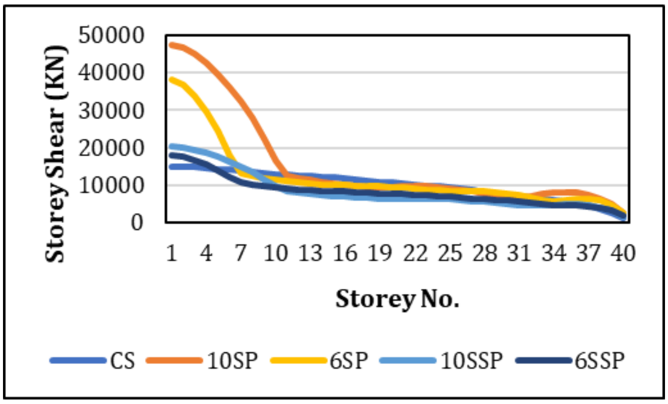

Chart -10: Storey Shear in Y Direction for models CS, 10SP, 6SP, 10SSP and 6SSP.

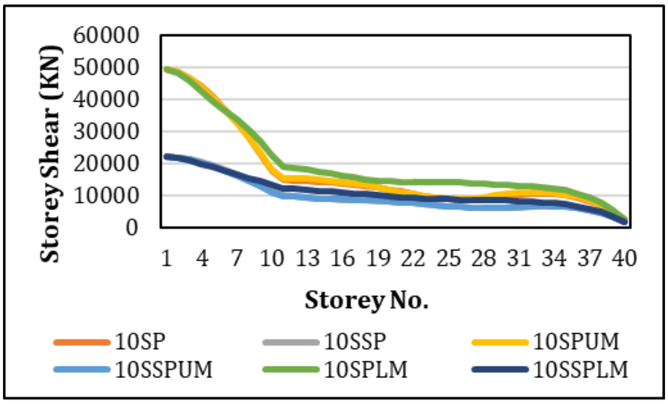

Chart -8: Storey Shear in X Direction for models 10SP, 10SSP, 10SPUM, 10SSPUM, 10SPLM and 10SSPLM.

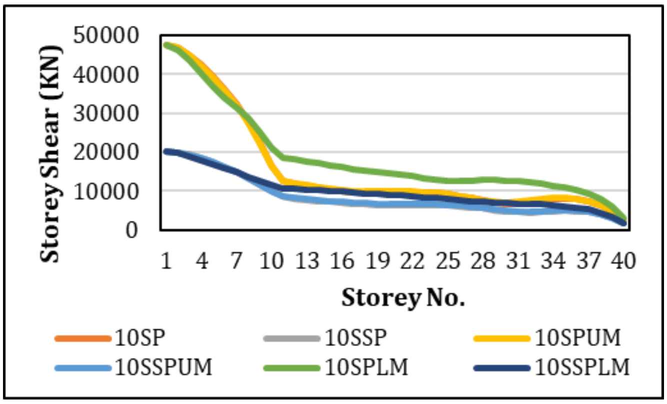

Chart -11: Storey Shear in Y Direction for models 10SP, 10SSP, 10SPUM, 10SSPUM, 10SPLM and 10SSPLM.

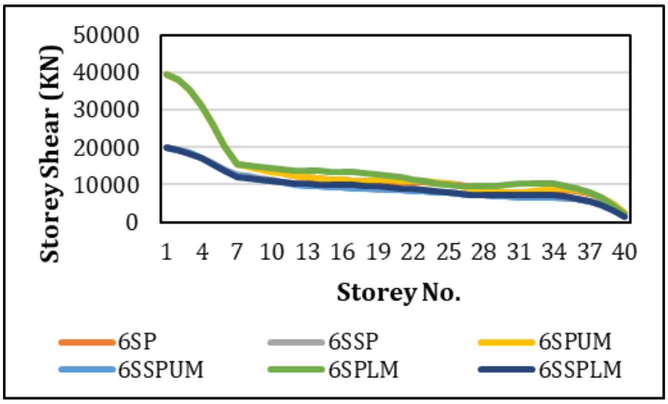

Chart -9: Storey Shear in X Direction for models 6SP, 6SSP, 6SPUM, 6SSPUM, 6SPLM and 6SSPLM.

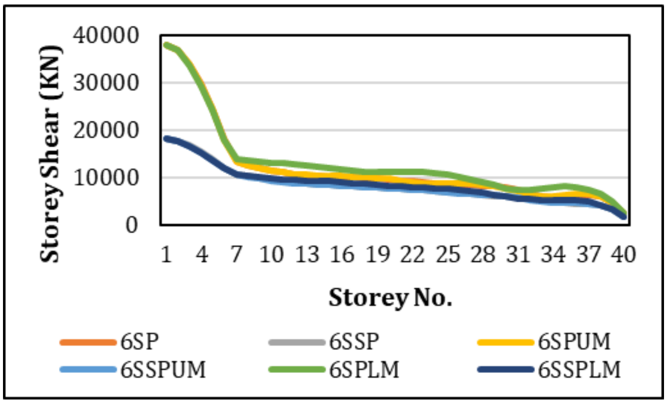

Chart -12: Storey Shear in Y Direction for models 6SP, 6SSP, 6SPUM, 6SSPUM, 6SPLM and 6SSPLM.

From above charts, it can be observed that structural models with the inclusion of below storey podium structure tend to have higher values of base shear as compared to the basic conventional model without below storey podium structure as they tend to have higher seismic weight due to increased structural elements in the podium. Among the presented structures, model 10SP has the highest value for base shear which is 49243KN in X direction and 47505KN in Y direction.

Maximum values for storey shear were observed at the base of every model. The values of base shear in X direction for the models 10SP and 6SP were observed to be greater by 202% and 142% when compared to the values of the basic conventional structure. For Y direction the values were greater by 219% and 156% for the respected models as compared to the base model.

Values for base shear decreases with the decrease in the surface area of the podium structure. Models with reduce surface area of the podium structure showcased lesser values when compared to other models with the same height of the podium with bigger surface area.

Maximum values of baseshear in X direction for 10SSP and 6SSP were observed to be greater by 36% and 21% when compared to the values of the base structure CS. For Y direction the values were greater by 36% and 21% for the respected models as compared to the base structural model CS.

Maximum values of base shear for the models with upper and lower bound stiffness modifiers were similar to their respective base models with same podium configuration with factored load property modifiers.

4.3 Storey Drift

Chart -13, Chart -14, Chart -15, Chart -16, Chart -17 and Chart -18 represent the values for Storey Drift in X and Y Direction for response spectrum analysis.

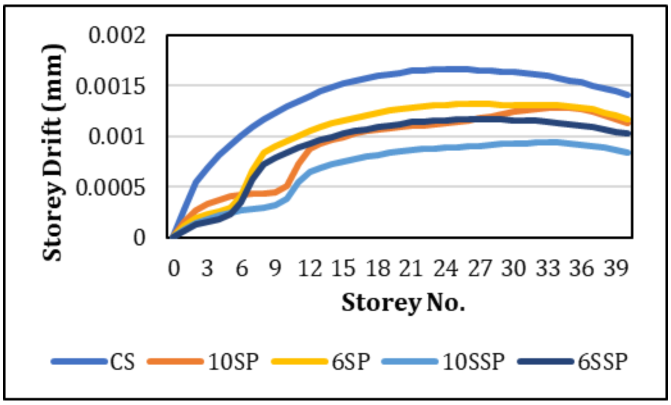

Chart -13: Storey Drift in X Direction for models CS, 10SP, 6SP, 10SSP, 6SSP.

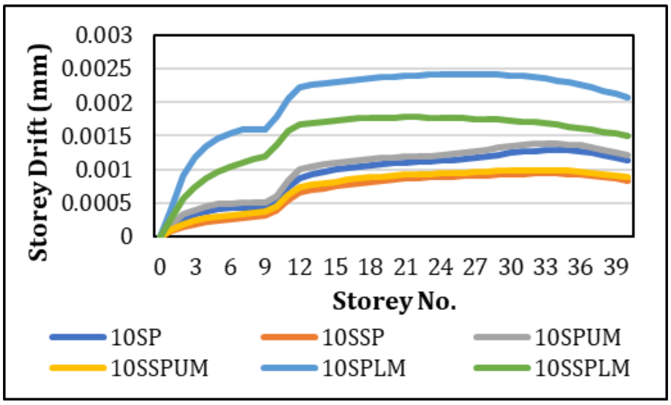

Chart -14: Storey Drift in X Direction for models 10SP, 10SSP, 10SPUM, 10SSPUM, 10SPLM and 10SSPLM.

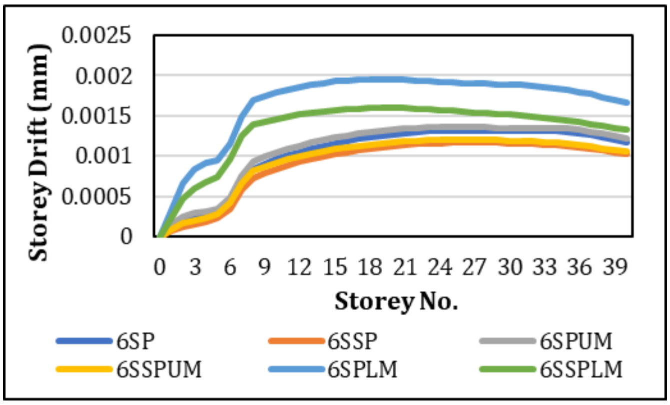

Chart -15: Storey Drift in X Direction for models 6SP, 6SSP, 6SPUM, 6SSPUM, 6SPLM and 6SSPLM.

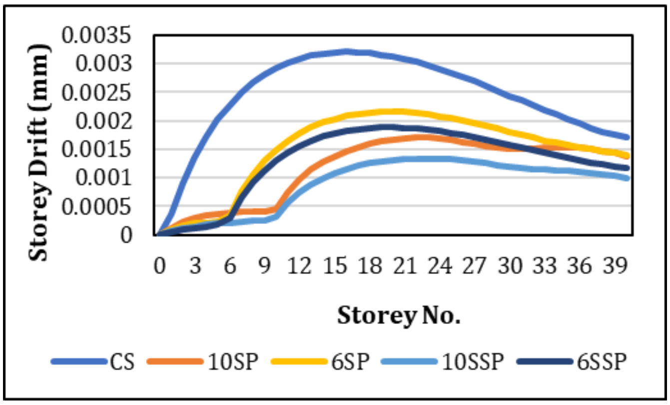

Chart -16: Storey Drift in Y Direction for models CS, 10SP, 6SP, 10SSP, 6SSP.

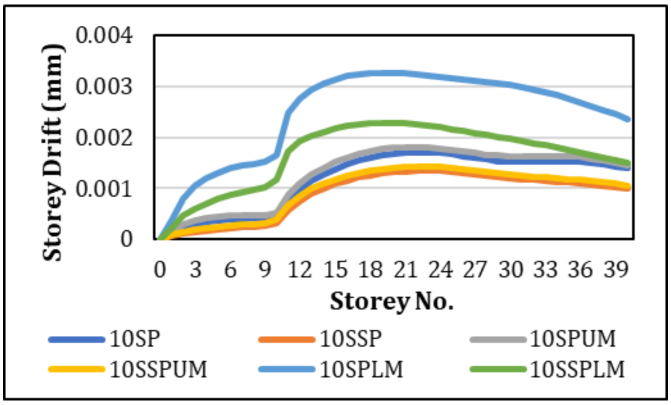

Chart -17: Storey Drift in Y Direction for models 10SP, 10SSP, 10SPUM, 10SSPUM, 10SPLM and 10SSPLM.

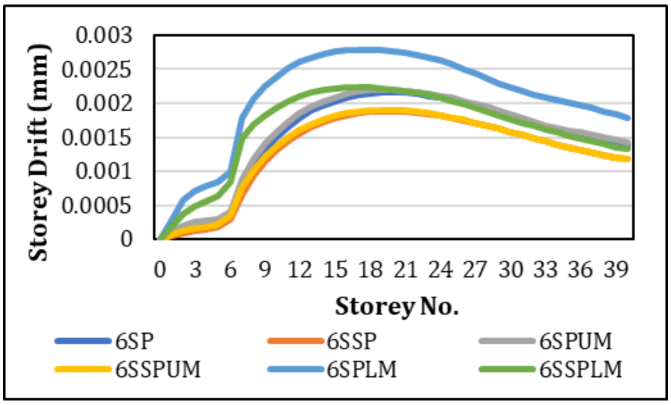

Chart -18: Storey Drift in Y Direction for models 6SP, 6SSP, 6SPUM, 6SSPUM, 6SPLM and 6SSPLM.

From chart-13 and chart-16 it can be observed that the values for maximum storey drift tend to decrease with the inclusion of the below storey podium structure indicating the increase in stiffness of the structure.

The values of storey drift tend to decrease with increase of height of below storey podium structure. The maximum values of storey drift for the Structures 10SP and 6SP in X direction are found to be reduced to 77% and 79% respectively of the values of the basic conventional model CS, without below storey podium. For Y direction the same values are reduced to 53% and 67% for the respective models when compared to the base model's values.

Maximum values for storey drift are observed to be reducing even more for structural models with reduce podium surface area. Models with reduced surface area of the podium structure showcased lesser values when compared to other models with same height of podium structure with bigger surface area.

Maximum values of storey drift for the structural models 10SSP and 6SSP in X direction are found to be reducing to 56% and 70% respectively of value of the base conventional structural model CS. Similarly for Y direction the values are reduced to 41% and 58% respectively of the values of base model.

For sensitivity analysis, it can be observed from chart-14, chart-15, chart-17 and chart-18 that models with upper bound stiffness modifier tend to show slightly higher values of storey drift when compared to models with crack section property modifiers but the values were far less as compared to models with lower bound stiffness modifiers. Maximum values for storey drift are observed in models with lower bound stiffness modifiers.

For 10SP model the value of 10SPUM is greater by 7% and for 10SPLM the maximum value goes up to approximately 88% in X Direction. While considering for Y direction the value of 10SPUM is greater by 5% and for 10SPLM the value isgreater by 91%.

For 6SP model the value of 6SPUM is greater by 3% and for 6SPLM the maximum value goes up to approximately 47% in X Direction. While considering for Y direction the value of 6SPUM is greater by 2% and for 6SPLM the value is greater by 29%.

For 10SSP model the value of 10SSPUM is greater by 5% and for 10SSPLM the maximum value goes up to approximately 89% in X Direction. While considering for Y direction the value of 10SSPUM is greater by 6% and for 10SSPLM the valueis greater by 70%.

For 6SSP model the value of 6SSPUM is greater by 3% and for 6SSPLM the maximum value goes up to approximately 36% in X Direction. While considering for Y direction the value of 6SSPUM is greater by 1% and for 6SSPLM the value isgreater by 18%.

4.4 Time Period

Table 4 represent the values for time period in both X and Y Direction for Response Spectrum Analysis.

Table -4: Time Period T(sec)

Sr. No.	Model Name	Time Period T_x(sec)	Time Period T_y(sec)
A	**Base Models**		
1	CS	5.472	6.199
2	10SP	3.96	4.598
3	6SP	4.7	5.387
4	10SSP	4.142	4.785
5	6SSP	4.706	5.395

B	Models with Upper Bound Stiffness Modifiers		
6	10SPUM	3.977	4.667
7	6SPUM	4.718	5.455
8	10SSPUM	4.165	4.876
9	6SSPUM	4.726	5.47
C	Models with Lower Bound Stiffness Modifiers		
10	10SPLM	4.756	5.229
11	6SPLM	5.107	5.873
12	10SSPLM	5.032	5.514
13	6SSPLM	5.162	5.921

From the above provided table it can be observed that time period reduces in the structures with the below storey podium structure as compared to the basic conventional structure without the inclusion of the podium structure. Thus, structural models with below storey podium structure tend to be stiffer than the model without podium.

With the increase in the podium height, it is observed that time period of the respective structure decrease indicating the increase in stiffness of the overall structure. Structural models with 10 storey podium showcased the least value for time period in both direction when compared to other models with reduced podium height.

Models with reduce surface area of podium structure are seen to be having approximately similar values for time period as that of models with increased podium surface area and having similar height of podiums respectively.

Models with upper bound stiffness modifiers have approximately similar time period as that of the models with factored stiffness modifiers but has lesser time period as compared to models with lower bound stiffness modifiers.

Models with Lower bound stiffness modifiers tend to have the highest time period ascompared to any other structure due to reduction in stiffness of the structure.

90% mass participation was observed within the provided modes for every model considered.

4.5 Backstay Effect

Chart -19, Chart -20, Chart -21, Chart -22, Chart -23 and Chart -24 represent the values in percentage of shear reversed at the podium structure interface level due to SPEC X and SPEC Y in the shear wall with spandrel id W3.

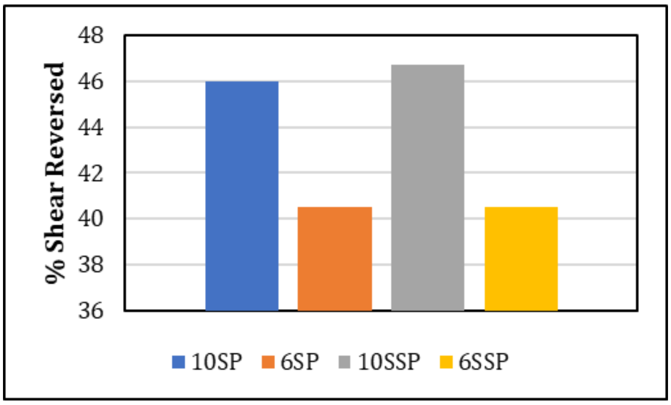

Chart -19: Percentage shear reversed due to SPEC X for models 10SP, 6SP, 10SSP and 6SSP.

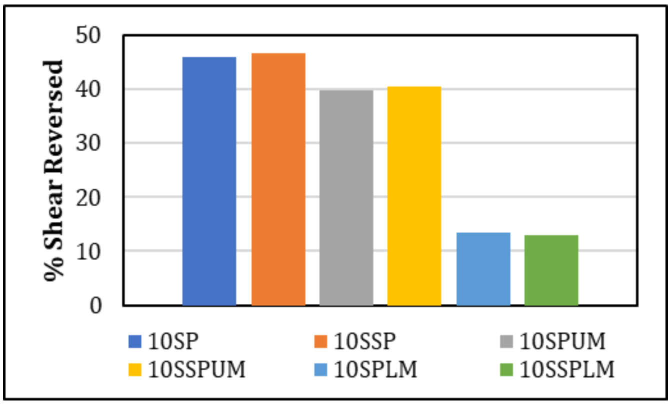

Chart -20: Percentage shear reversed due to Spec X for models 10SP, 10SSP, 10SPUM, 10SSPUM, 10SPLM and 10SSPM.

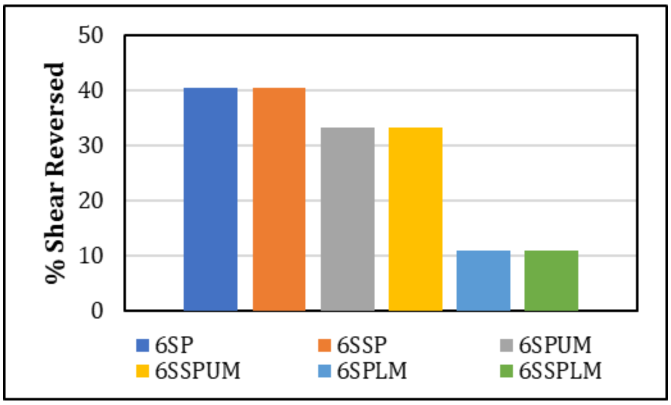

Chart -21: Percentage shear reversed due to SPEC X for models 6SP, 6SSP, 6SPUM, 6SSPUM, 6SPLM and 6SSPLM.

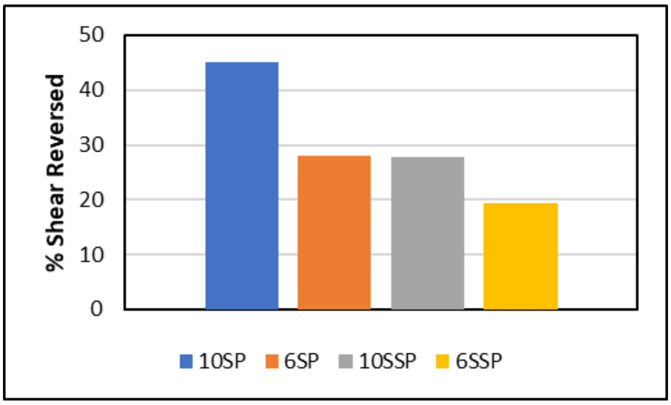

Chart -22: Percentage shear reversed due to SPEC Y for models 10SP, 6SP, 10SSP and 6SSP.

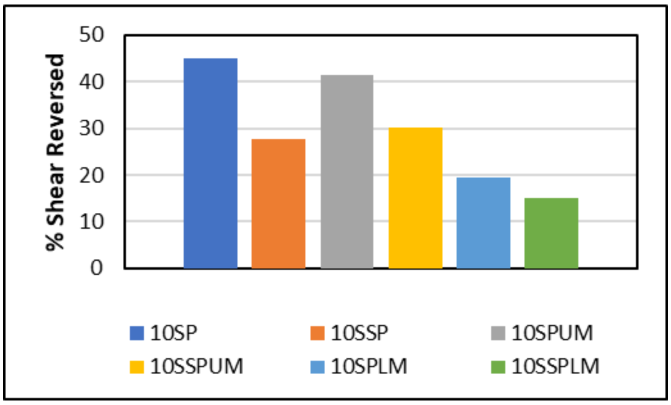

Chart -23: Percentage shear reversed due to Spec Y for models 10SP, 10SSP, 10SPUM, 10SSPUM, 10SPLM and 10SSPM.

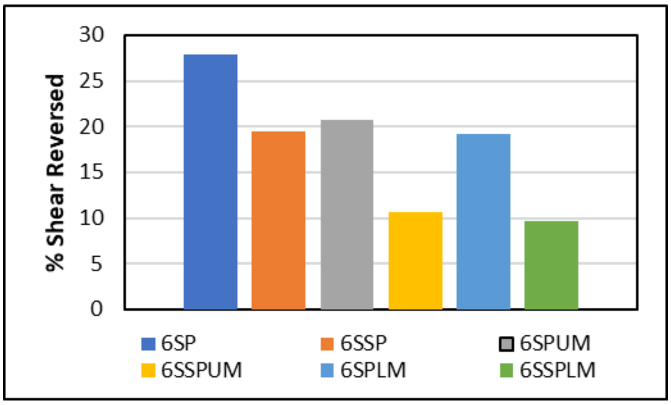

Chart -24: Percentage shear reversed due to SPEC Y for models 6SP, 6SSP, 6SPUM, 6SSPUM, 6SPLM and 6SSPLM.

According to the observed trend it is seen that the value of shear force for the structures with below storey podium reduces drastically at the podium structure interaction level due to increased stiffness of the structure owing to the inclusion of the below storey podium structure as compared to model without the below storey Podium structure.

The values of shear force due to SPECX at the podium structure interface level, for the models 10SP, 6SP, 10SSP 6SSP have reduced to 46%, 40%, 46%, 40% of the value of shear force of the storey right above the podium structure interface. For SPECY the values have reduced to approximately 45%, 27%, 27%, 19% of the value of shear force of the storey right above the podium structure interface level for the same respective models. While for CS the values are reduced by 5% at 10th storey and 10% at 6th storey for SPECX and 4% and 8% for SPECY at the respective floors.

Similar trend is been observed in models with upper bound stiffness modifiers. The values of shear force due to SPECX at the podium structure interface level, for the models 10SPUM, 6SPUM, 10SSPUM, 6SSPUM have reduced to approximately 39%, 33%, 40% and 33% of the value of shear force of the storey right above the podium structure interface. For SPECY the values at the interface level have reduced to approximately 41%, 20%, 30%, 10% of the value of shear force of the storey right above the podium structure interface for the same respective models.

For models with lower bound stiffness modifiers, the values of shear force due to SPECX at the interface level, for models 10SPLM, 6SPLM, 10SSPLM and 6SSPLM have reduced to approximately 13%, 10%, 13%, 10% of the value of shear force of the storey right above the podium structure interface. For SPECY the values at the interface level have reduced to approximately 19%, 19%, 15%, 9% of the value of shear force of the storey right above the podium structure interface for the same respective models.

The observed backstay effect is only seen at the podium structure interaction level.

5. CONCLUSIONS

The backstay effect due to podium structure interaction is been studied in this report. The effect of inclusion of below storey podium structure to the main tower is been studied and the results are expressed in terms of lateral displacement, storey shear, storey drift, time period and shear force reversed in shear wall W3. Varying structural configuration were considered of the podium structure by changing their height and surface area. Sensitivity analysis was carried out using upper bound and lower bound stiffness modifiers. From the above provided results following conclusions can be drawn.

- Backstay effect was observed mainly at the podium structure interaction level and tend to fade away as we move away along the height of the structure. shear force tends to change its direction at the podium structure interaction level.
- The below storey podium imposes restrain on the lower portion of tower, thus restricting its movement.

- It was observed that inclusion of the below storey podium structure tends to increase the general stiffness of the structures as the values of Lateral displacement, storey drift and time period tends to decrease for models with below storey podium structure.
- Models with increased number of podium levels, showcased decrease in values for lateral displacement, storey drift and time period.
- When models with reduced surface area of podium structure were observed, it was seen that the values of lateral displacement and storey drift were reducing when compared to models with bigger surface area and same respective height of below storey podium.
- For sensitivity analysis, models with lower bound stiffness modifiers showcase the maximum values for lateral displacement, storey drift and time period.
- Models with upper bound stiffness modifiers were observed to be a lot stiffer than models with lower bound stiffness modifiers.
- Base shear values for models with below storey podium structure was seen to be higher when compared to base model without podium because of the increased seismic weight of the structures owing to the inclusion of the podium structure.
- Models with increased height of podium showcased higher values of base shear than models with decrease height of podium attached to them.
- Values of base shear tend to decrease for models with smaller surface area of the podium structure as compared to models with bigger surface area and same respective height of the below storey podium structure.

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