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Comparative Study of Seismic Behaviour of Open Ground Storey Buildings, After Replacing Rectangular Columns With Circular Columns

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Abstract:** The earthquake resistant design of structures requires that structures should sustain, safely, any ground motions of an intensity that might occur during their construction or in their normal use. However ground motions are unique in the effects they have on structural responses. The most accurate analysis procedure for structures subjected to strong ground motions is the Push over analysis. Pushover analysis is based on the assumption that structures oscillate predominantly in the first mode or in the lower modes of vibration during a seismic event. This leads to a reduction of the multi-degree-of-freedom, MDOF system, to an equivalent single-degree-of- freedom, ESDOF system, with properties predicted by a nonlinear static analysis of the MDOF system. The ESDOF system is then subsequently subjected to a nonlinear time history analysis or to a response spectrum analysis with constant-ductility spectra, or damped spectra. The seismic demands calculated for the ESDOF system are transformed through modal relationships to the seismic demands of the MDOF system. In this study the seismic behaviour of a frame building has been analysed by using push over analysis. The seismic performance evaluation of the building has been carried out by changing the sizes of the columns and also by replacing the rectangular columns with the circular columns. Static type of pushover analysis is to be used in this research work where the loads consist of permanent gravity loads and incremental horizontal forces at each storey level. Capacity curves (base shear versus story total drift) obtained from static pushover analysis using commercially available software called Etabs (Etabs 2015) are used for the calculation of some seismic demand parameters. The dimensions of the buildings have been kept constant and only the column sizes have been changed. Three different combinations of the rectangular column dimensions are taken and the non linear response of each is evaluated by using the pushover analysis. The rectangular columns are then replaced with the circular columns of suitable dimension. The buildings are designed for the gravity and seismic loadings as per IS 456: 2000 and IS 1893: 2002.

***Keywords:** Non-Linear Static Procedure; Reinforced Concrete Frame; Pushover Analysis; Target Displacement; Yield Strength; Pushover Curve.*

LITERATURE REVIEW

M C Griffith and A V Pinto [6] have investigated the specific details of a 4-story, 3-bayreinforced concrete frame test structure with unreinforced brick masonry (URM) infill walls with attention to their weaknesses with regards to seismic loading. The concrete frame was shown to be a "weak-column strong-beam frame" which is likely to exhibit poor post yield hysteretic behaviour. The building was expected to have maximum lateral deformation capacities corresponding to about 2% lateral drift. The unreinforced masonry infill walls were likely to begin cracking at much smaller lateral drifts, of the order of 0.3%, and completely lost their load carrying ability by drifts of between 1% and 2%

Shunsuke Otani [15] studied the development of earthquake resistant design of RCC Buildings (Past and Future). The measurement of ground acceleration started in 1930's, and the response calculation was made possible in 1940's. Design response spectra were formulated in the late1950's to 1960's. The non-linear response was introduced in seismic design in 1960's and the capacity design concept was introduced in 1970's for collapse safety. The damage statistics of RCC buildings in 1995 Kobe disaster demonstrated the improvement of building performance with the development of design methodology. Buildings designed and constructed using outdated methodology should be upgraded. Performance basis engineering should be emphasized, especially for the protection of building functions following frequent earthquakes.

SUMMARY OF REVIEW

Pushover analysis yields insight into the elastic and inelastic response of structures under earthquakes provided that adequate modeling of structure, careful selection of lateral load pattern and careful interpretation of results are performed. However, pushover analysis is more appropriate for low to mid-rise buildings with dominant fundamental mode response. For special and high-rise buildings, pushover analysis should be complemented with other evaluation procedures since higher modes could certainly affect the response.

Object:

i) To assess the seismic behavior of Open ground Story with rectangular columns

ii) To assess the seismic behavior of Open Ground Story Building with circular columns.

iii) Compare the Results which types of columns are most suitable in seismic condition for Open Ground Story Building.

In this study, the seismic behaviour of a frame building has been analysed by using pushover analysis. The seismic performance evaluation of the building has been carried out by changing the sizes of the columns and also by replacing the rectangular columns with the circular columns keeping in mind that the area of the rectangular column is equal to the perimeter of the circular column. Static type of pushover analysis has been used in this research work where the loads consist of permanent gravity loads and incremental horizontal forces at each storey level. Capacity curves (base shear versus story total drift) obtained from static pushover analysis using commercially available software called Etabs (Etabs 2015) are used for the calculation of some seismic demand parameters.

The dimensions of the buildings have been kept constant and only the column sizes have been changed. Three different combinations of the rectangular column dimensions are taken and the nonlinear response of each is evaluated by using the pushover analysis. The rectangular columns are then replaced with the circular columns of keeping in mind that the area acquired by them is same. The buildings are designed for the gravity and seismic loadings as per are 456: 2000 and IS 1893: 2002.

Preliminary assumed data for G+9 RCC framed building

Table 1 shows the summary of the elements and their respective sizes used while analysing the building

S.NO	CONTENT	DESCRIPTION
1	Type Of Structure	Multi-story High Raised Frame (Moment Resisting Frame)
2	Seismic Zone	5
3	Zone Factor	0.36
4	Number of Storey	G+9
5	Floor Height	3.00m
6	Base Floor Height	3.3m
7	Wall Thickness	External-230mm Internal- 115mm

8	Materials		Concrete (M25for beams) and (M30for columns) reinforcement Fe415
9	Size of Column		
	Rectangular	Set 1	450*600mm
		Set 2	500*600mm
		Set 3	550*600mm
	Circular	Set 1	Radius = 250mm
		Set 2	Radius = 300mm
		Set 3	Radius = 350mm
10	Size of the Beam in all Floors and Roof		450*600
11	Depth of Slab		125mm
12	Specific Weight of RCC		25KN/m3
13	Type of Soil		Medium

METHODOLOGY

Pushover analysis procedure

The utilization of the nonlinear static analysis pushover analysis came into practice in 1970's but the perspective of pushover analysis has been identified for last 10 to 15 years. This procedure is mainly used to estimate the strength and drift capacity of existing structure and the seismic demand for this structure subjected to selected earthquake this procedure can be used for checking the fairness of new structural design as well pushover analysis is explained as an analysis wearing a mathematical model directly incorporating the normal load-deformation characteristics of individual components and elements of the building shall be subjected to monotonically interesting lateral loads representing inertia forces in an earthquake until a target displacement is excised accident exceeded target displacement is the maximum displacement elastic plus in asterisk inelastic of the building address expected under selected earthquake ground motion pushover analysis assesses the structural performance by estimating the force and deformation capacity and seismic demand using a nonlinear static analysis algorithm the seas meet demand parameters are global displacement at roof or any other reference point story dressed story forces component deformation and component forces the analysis accounts for geometrical nonlinearity, material inelasticity and the redistribution of internal forces.

Pushover analysis can be performed as either force control or displacement controlled depending on the physical nature of the Lateral load and behaviour expected from the structure force. The controlled procedure is useful when the load is known such as gravity loading and the structure is expected to be able to support the load. The displacement controlled procedure should be used when a specified source such as in seismic loading where the magnitude of the applied load is not known in advance or when the structure can be anticipated to lose the strength or become unsteady. The nonlinear pushover analysis of a structure is an iterative procedure. It depends on the final displacement as the effective damping depends on the hysteretic energy loss due to inelastic deformation which in turn depends on the final displacement. This makes the analysis procedure iterative. Difficulty in the solution is faced near the ultimate load as the stiffness Matrix at this point becomes negative, definite due to the instability of the structure becoming a mechanism.

RESULTS

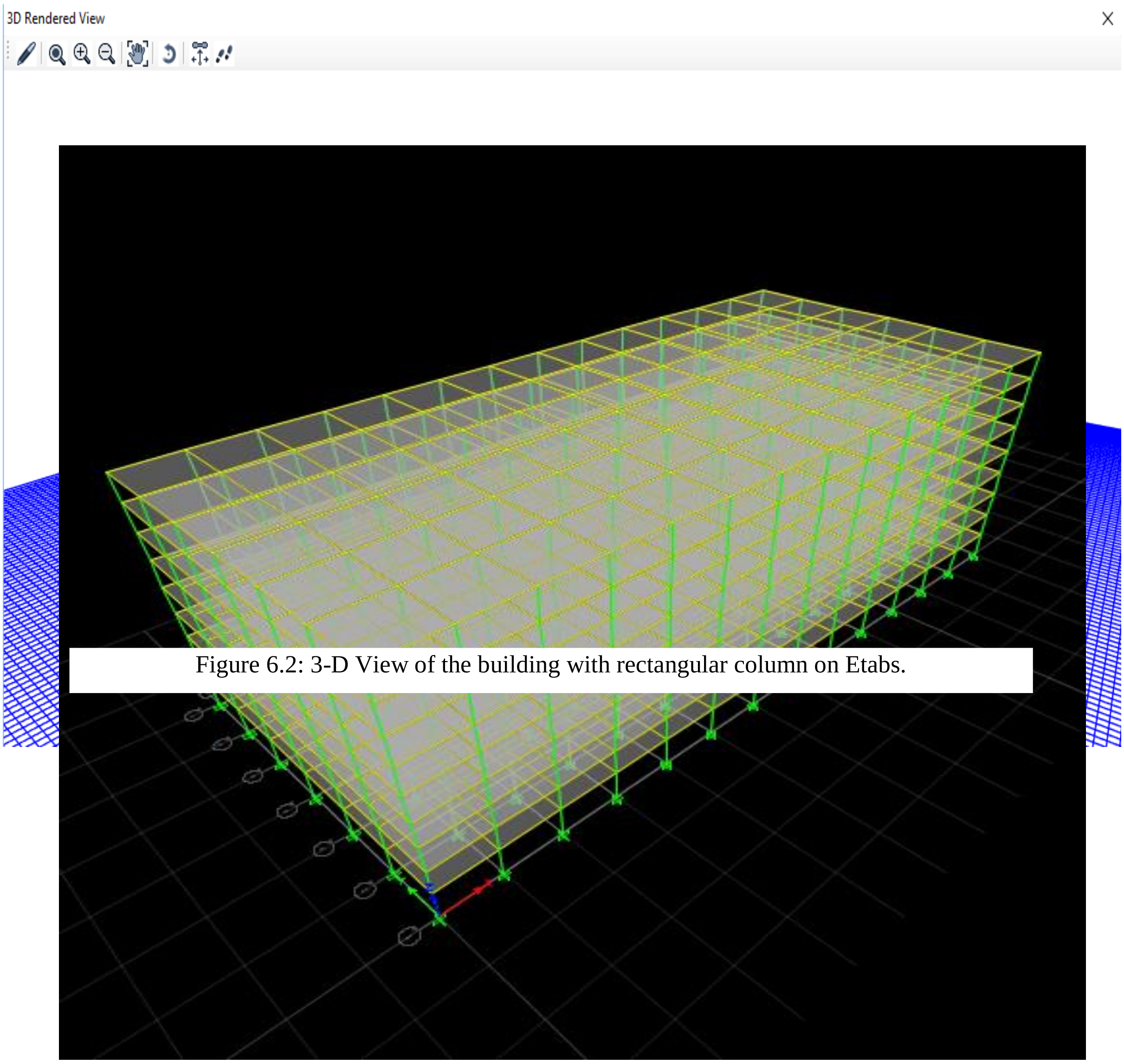


Figure 6.2: 3-D View of the building with rectangular column on Etabs.

Figure 3-D View of the building with rectangular column on Etabs.

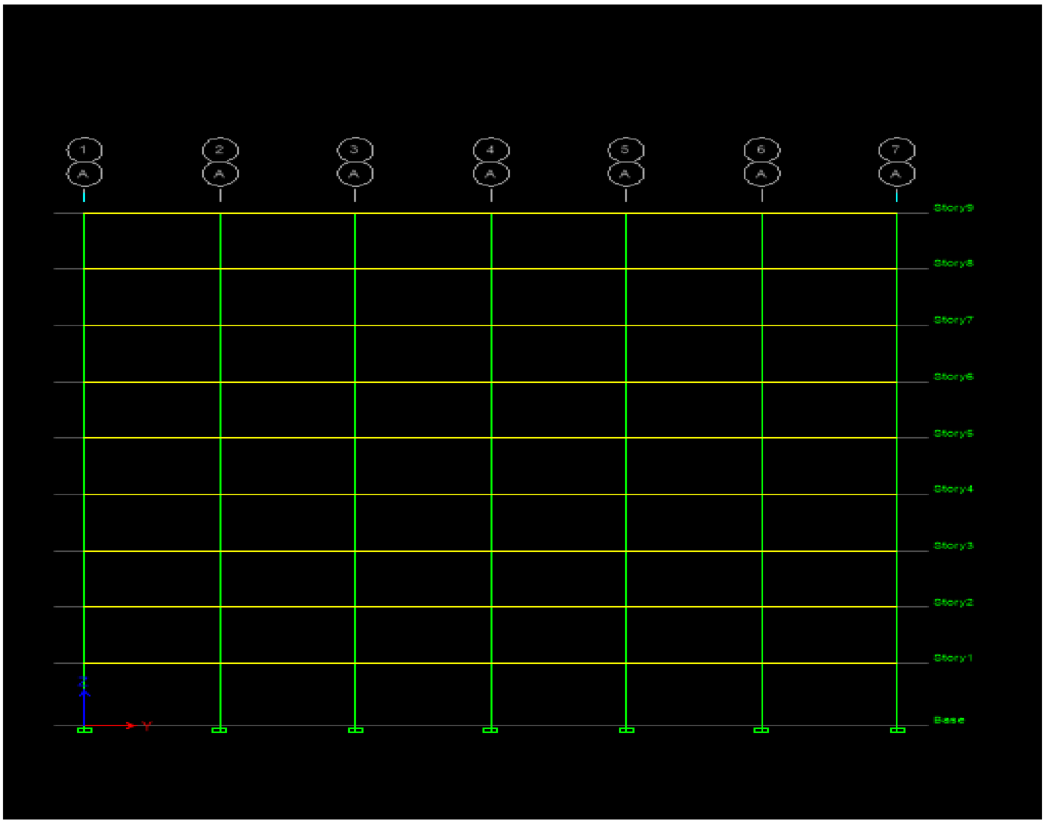


Figure Elevation of the building on Etabs.

The results shown below are the results evaluated after performing the pushover analysis on the building provided with rectangular columns of size 450mm X 600mm.

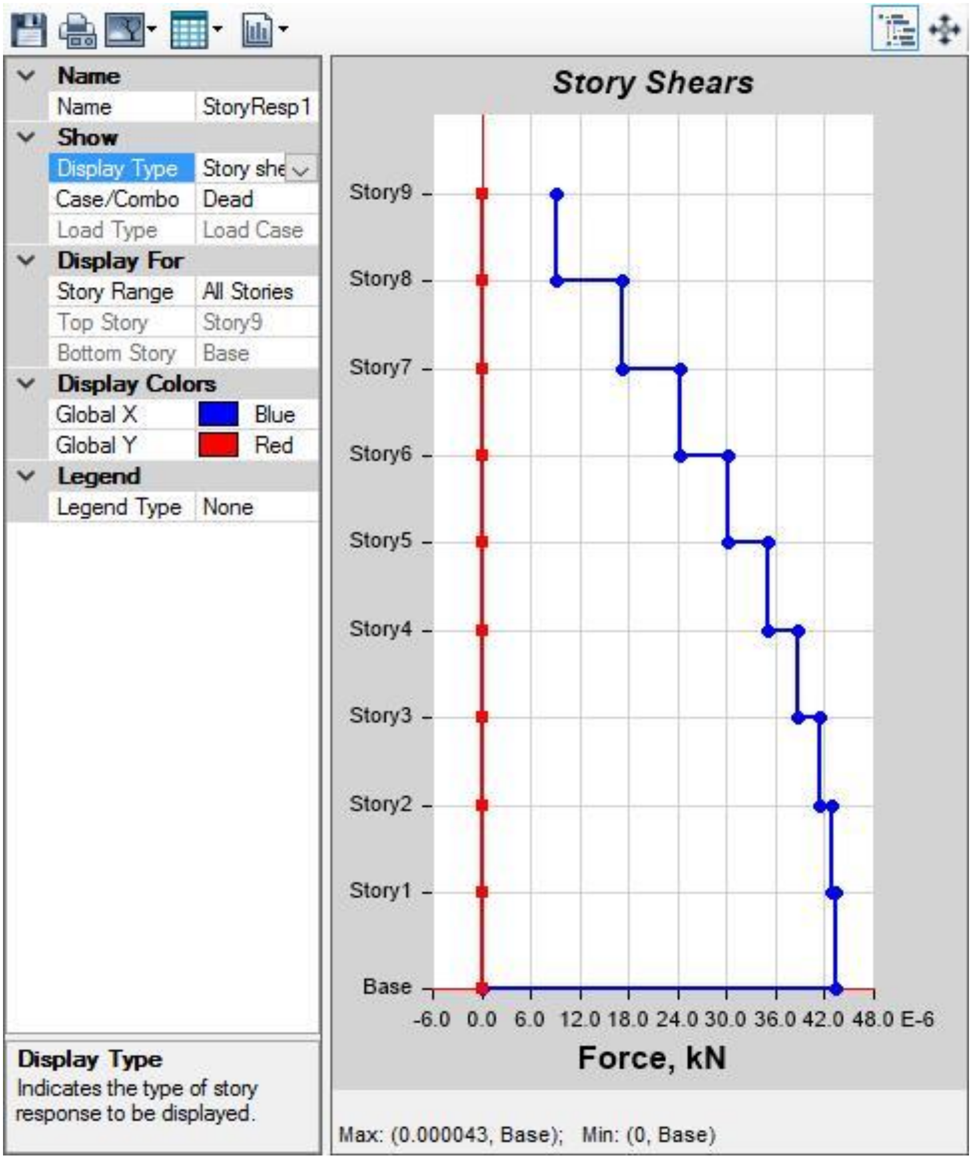
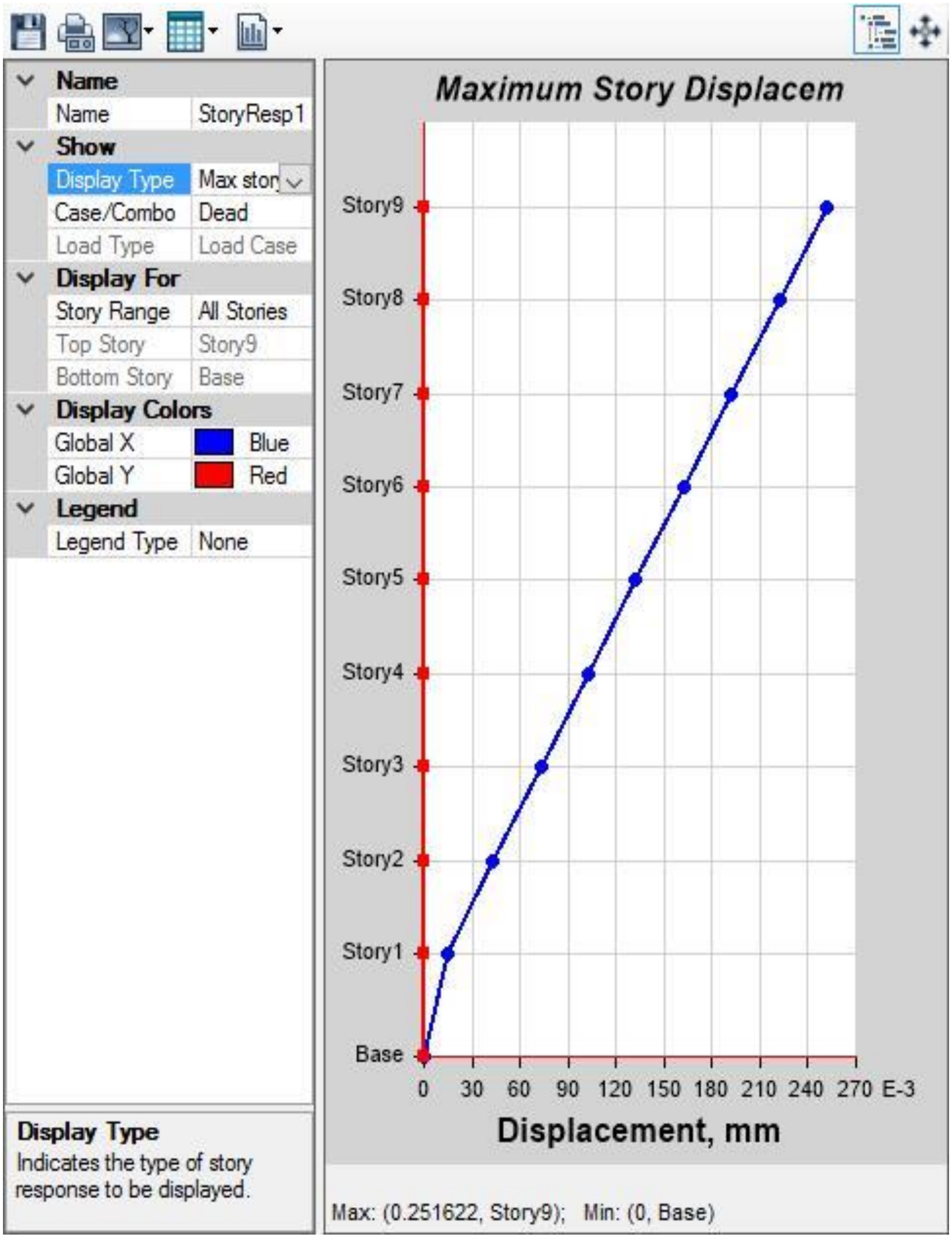


Figure Plot of story shear Vs story on Etabs.


Name
Name StoryResp1
Show
Display Type Max story
Case/Combo Dead
Load Type Load Case
Display For
Story Range All Stories
Top Story Story9
Bottom Story Base
Display Colors
Global X Blue
Global Y Red
Legend
Legend Type None
Display Type
Indicates the type of story response to be displayed.
Maximum Story Displacem
Story9
Story8
Story7
Story6
Story5
Story4
Story3
Story2
Story1
Base
0 30 60 90 120 150 180 210 240 270 E-3
Displacement, mm
Max: (0.251622, Story9); Min: (0, Base)

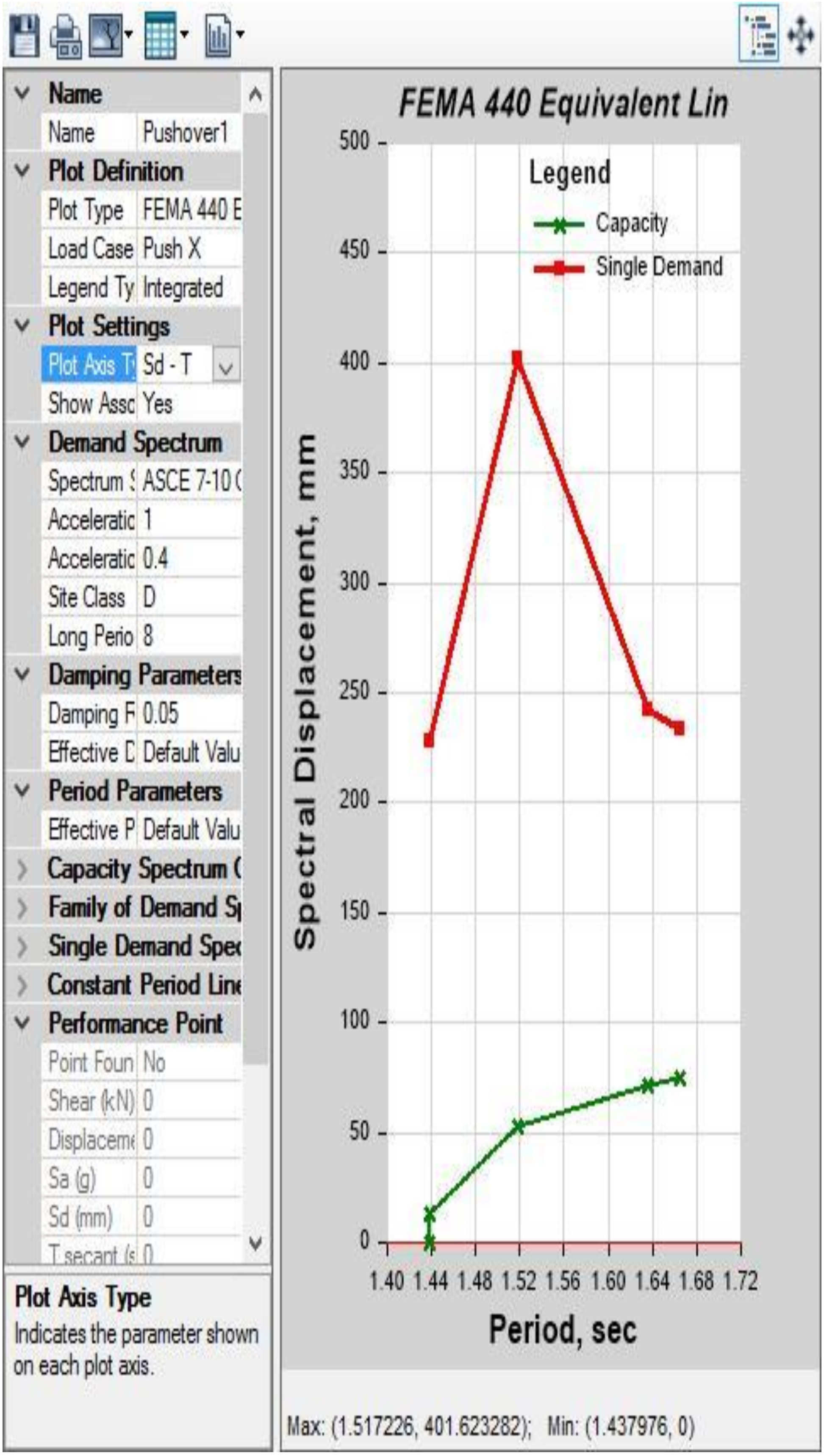


Figure: Plot of spectral displacement Vs time period in seconds on Etabs.

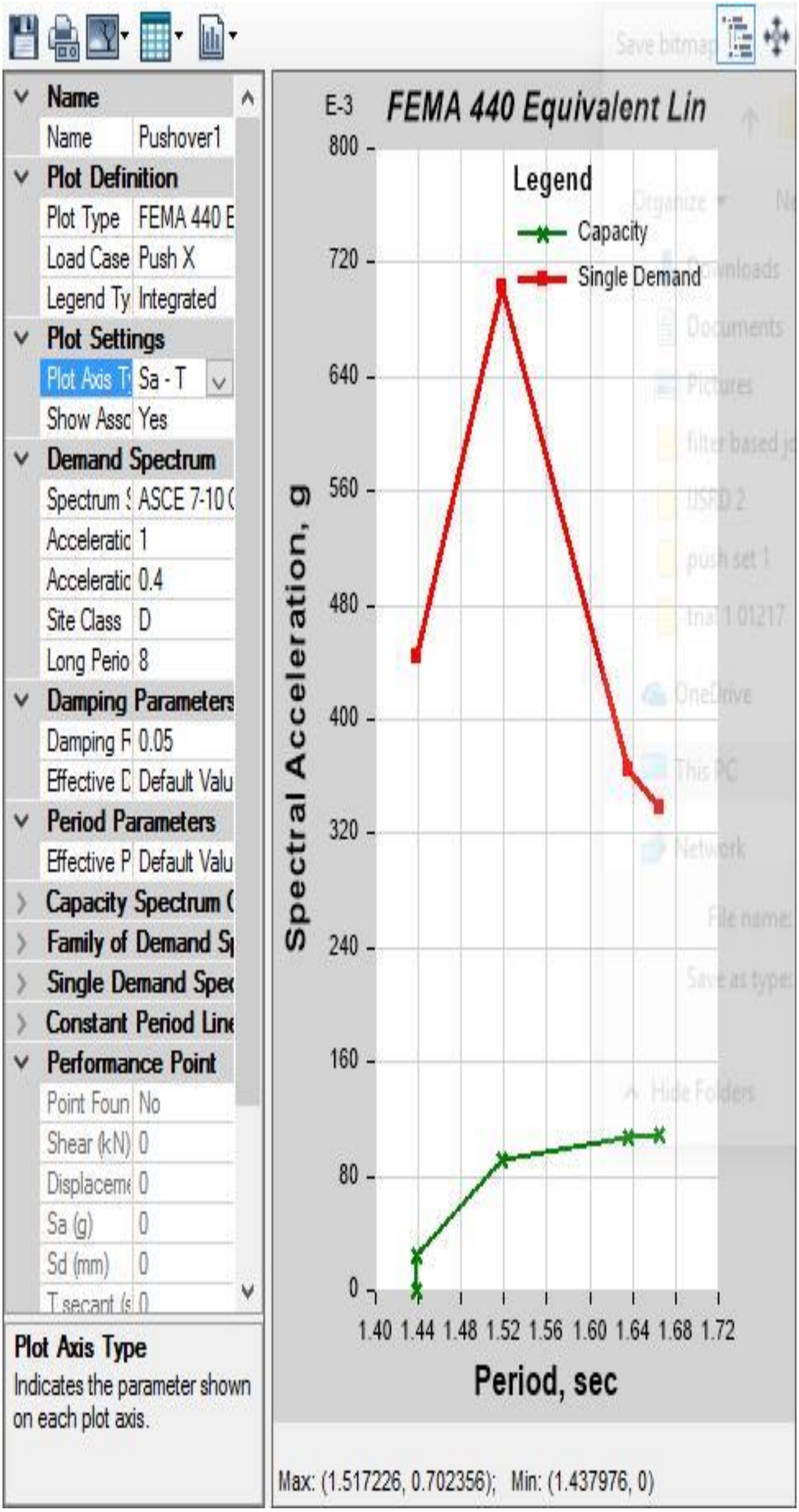


Figure: Plot of spectral acceleration Vs time in seconds on Etabs.

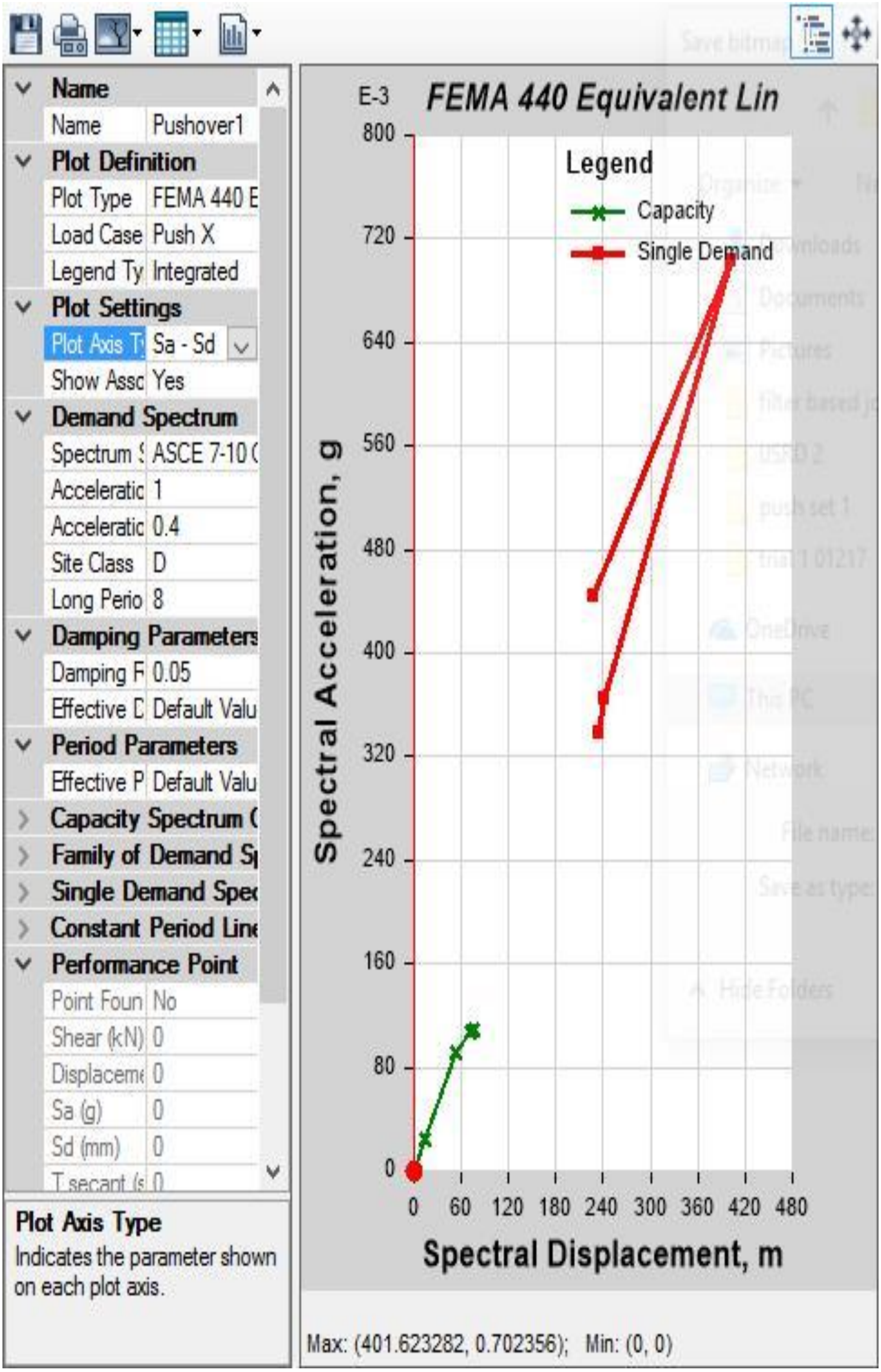


Figure Plot of spectral acceleration spectral displacement on Etabs.

The results shown below are the results evaluated after performing the pushover analysis on the building provided with rectangular columns of size 500*600mm.

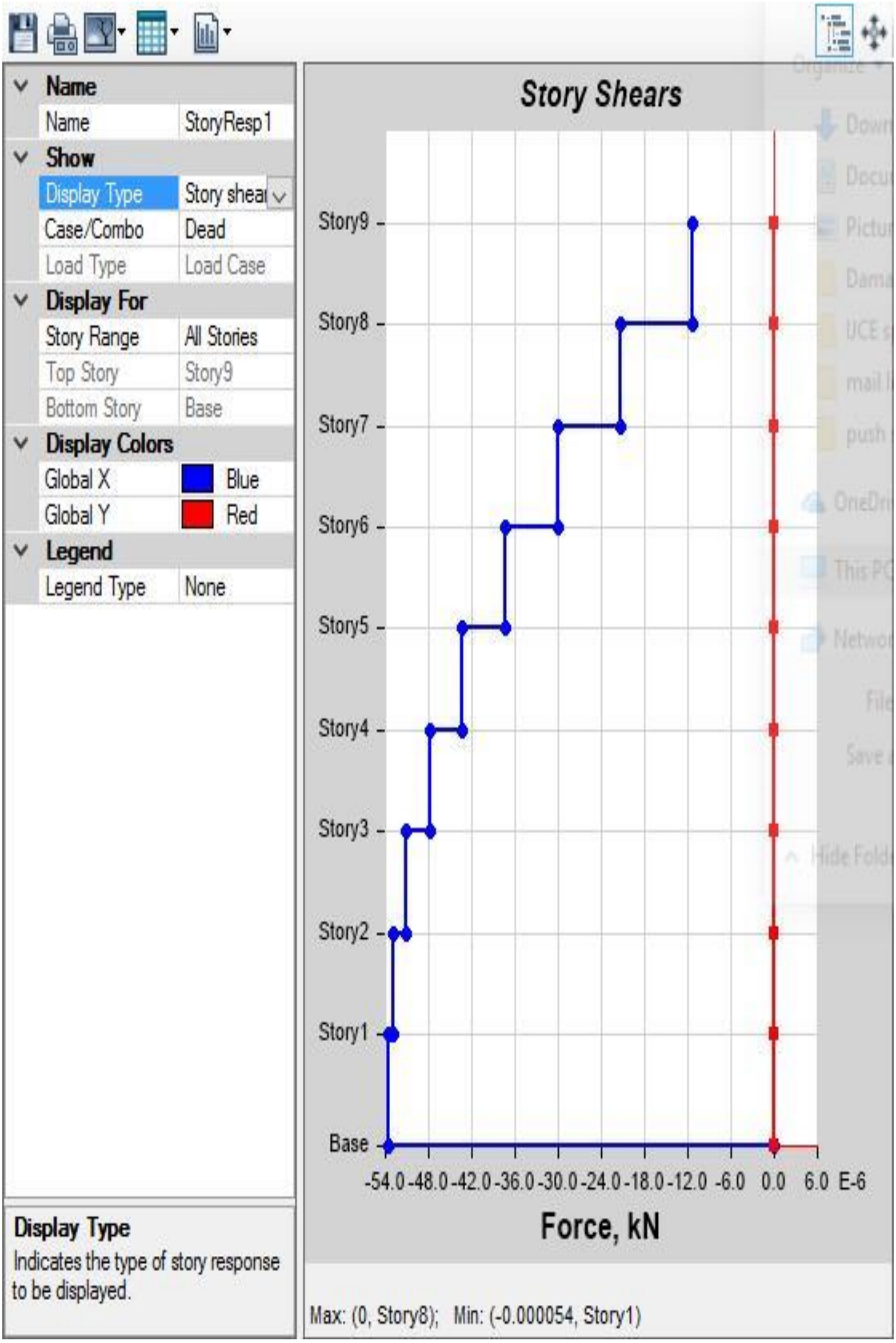


Figure: Plot of story shear Vs story on Etabs.

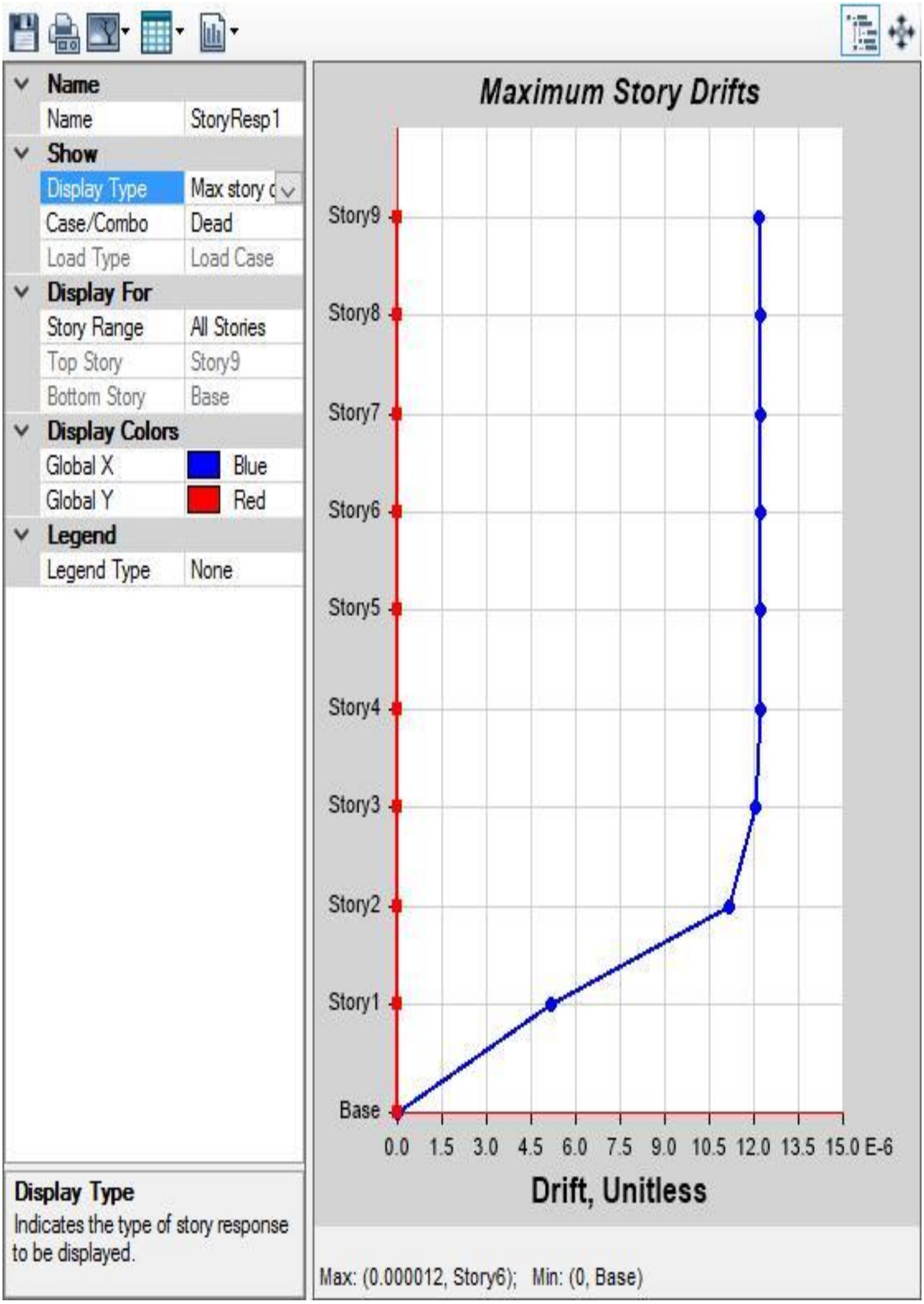


Figure: Plot of story Vs story drift on Etabs.

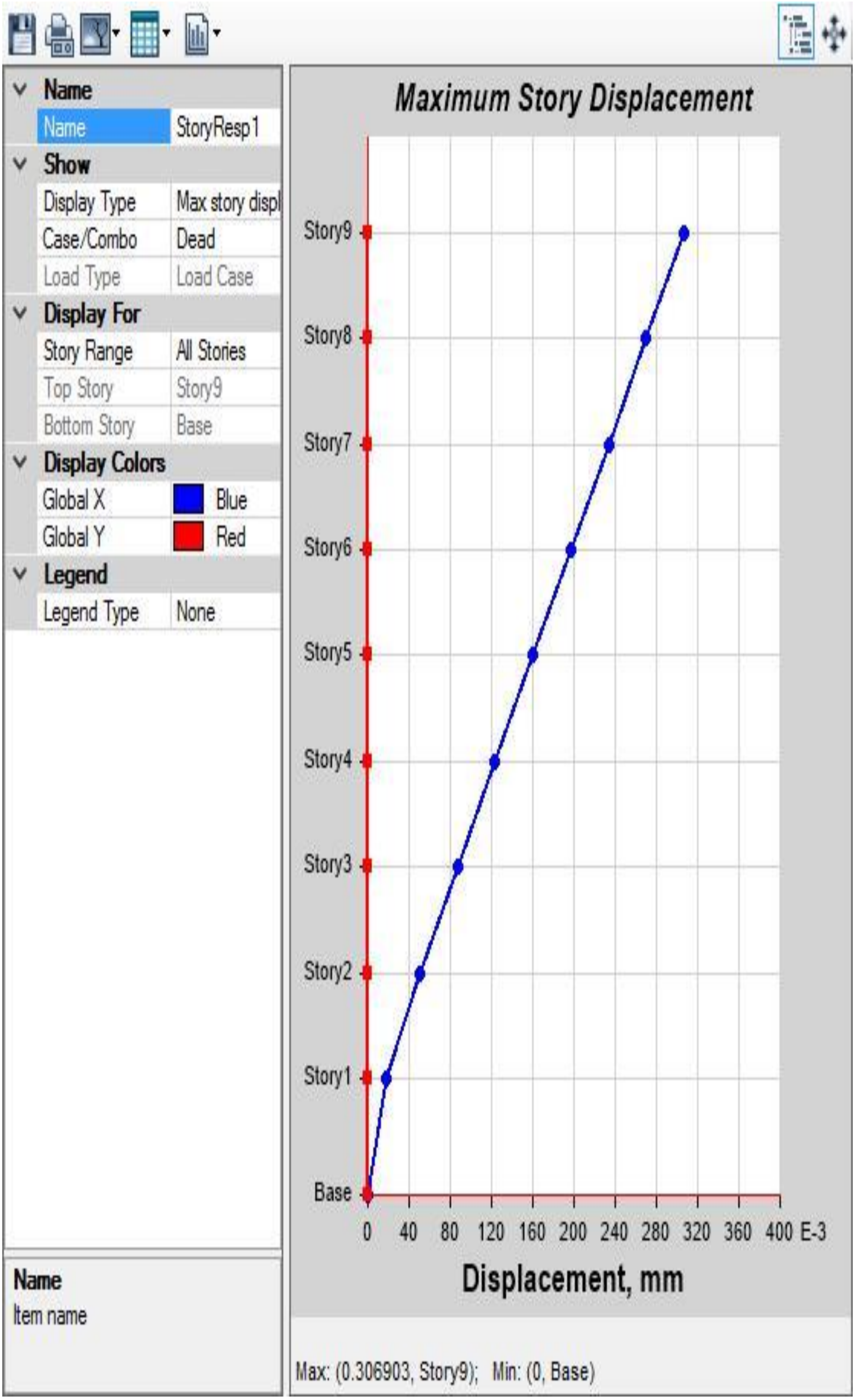


Figure: Plot of story Vs story displacement on Etabs.

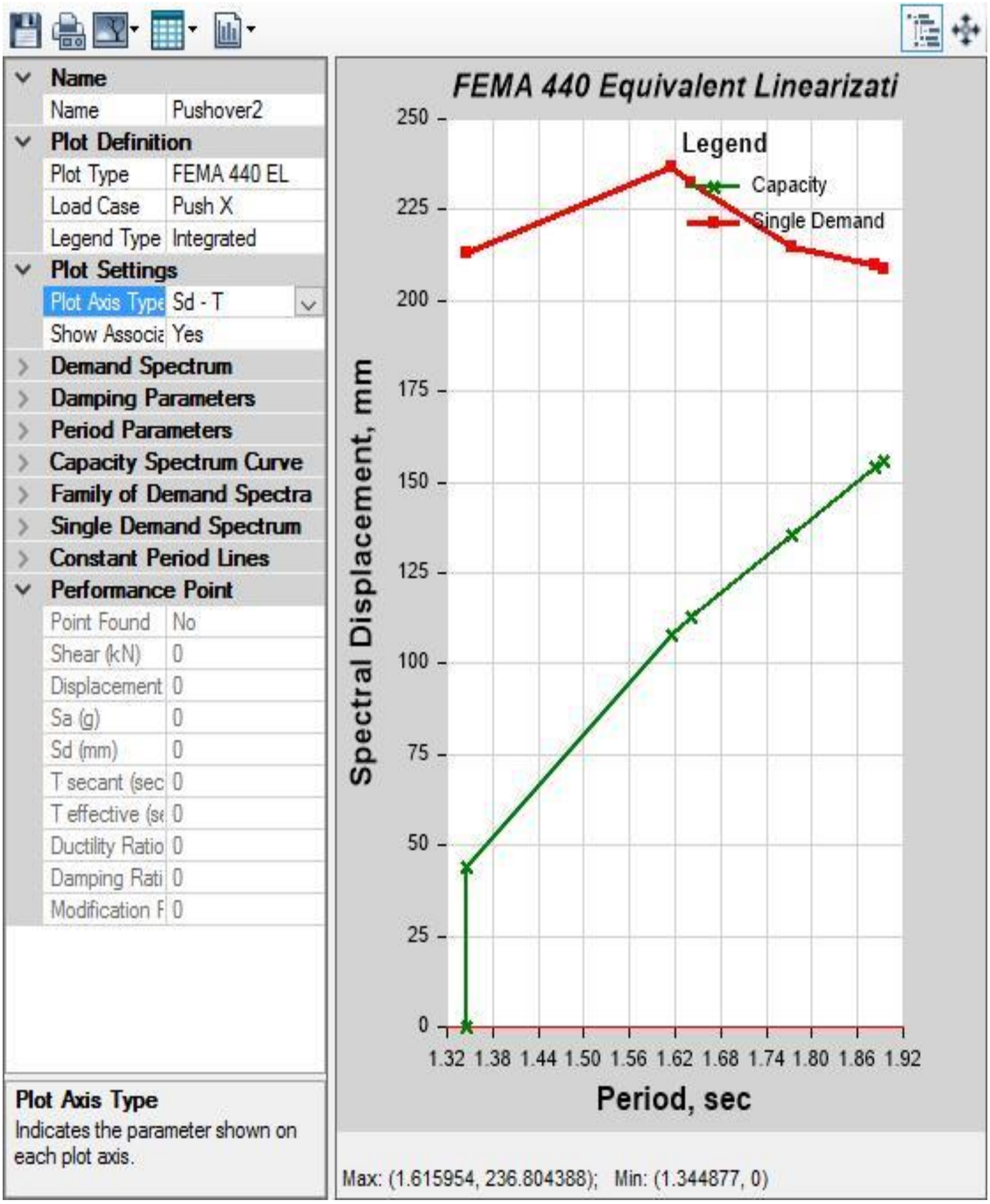


Figure: Plot of spectral displacement Vs time period in seconds on Etabs.

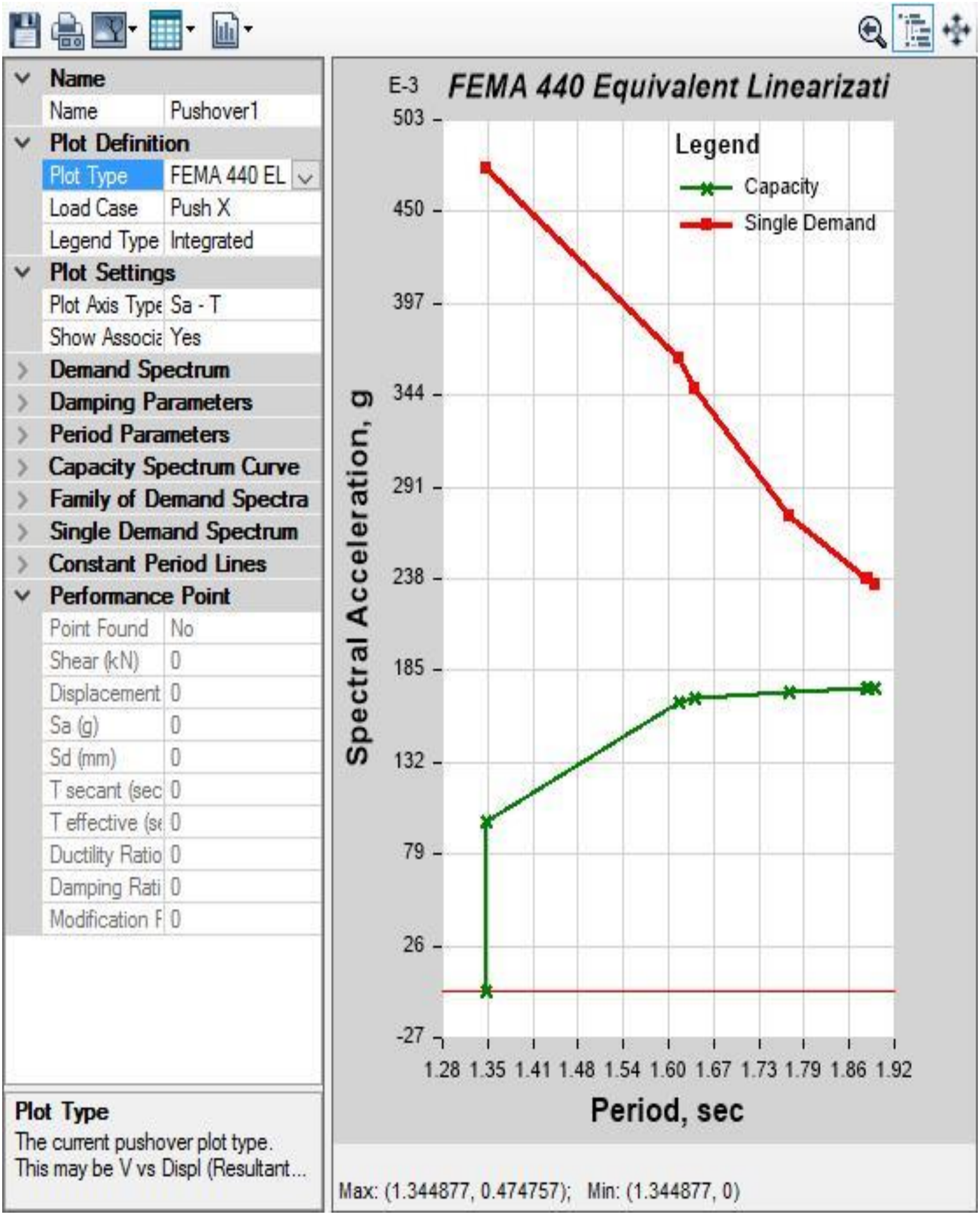


Figure: Plot of spectral acceleration Vs time period in seconds on Etabs.

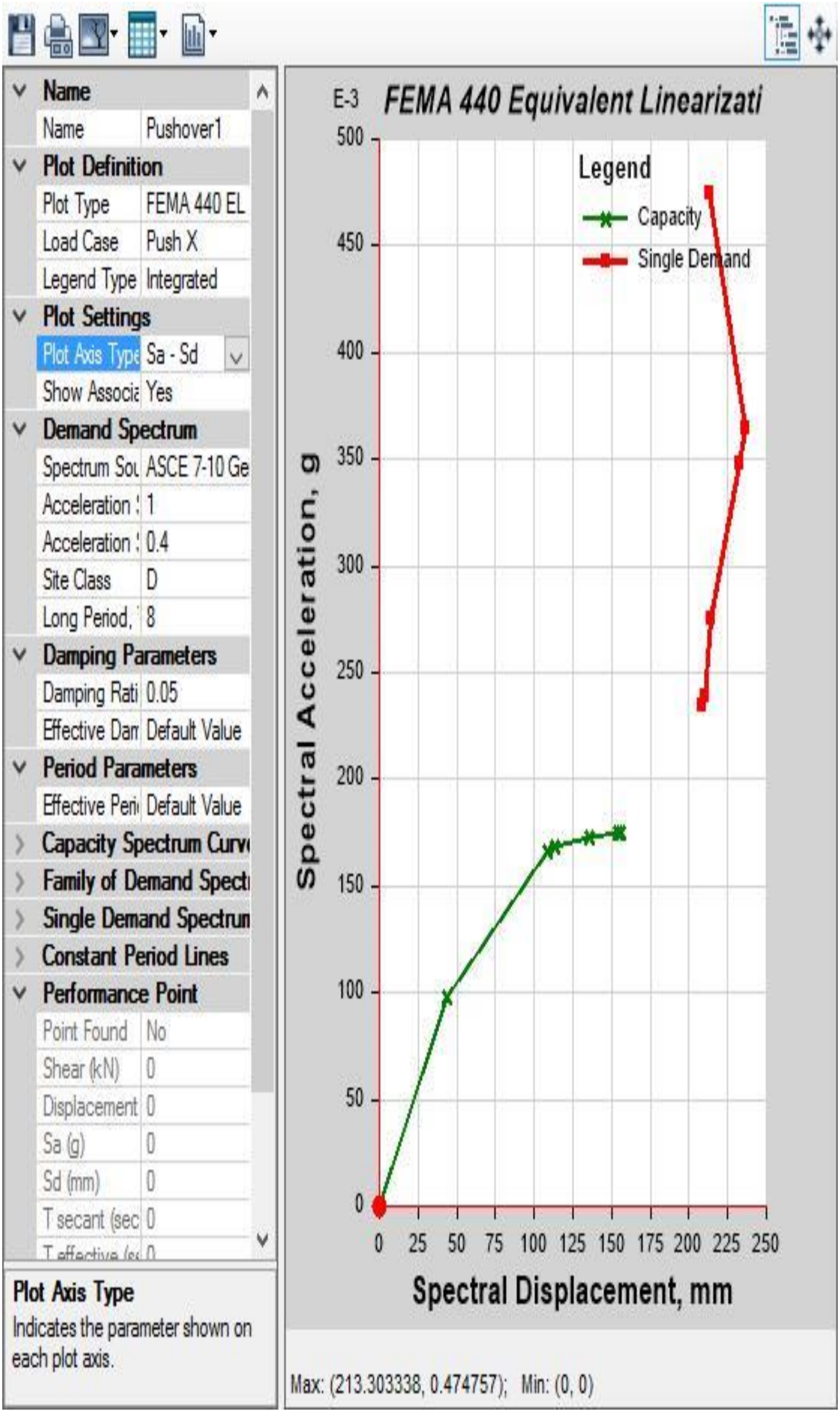


Figure: Plot of spectral acceleration Vs spectral displacement on Etabs.

The results shown below are the results evaluated after performing the pushover analysis on the building provided with rectangular columns of size 550*600mm .

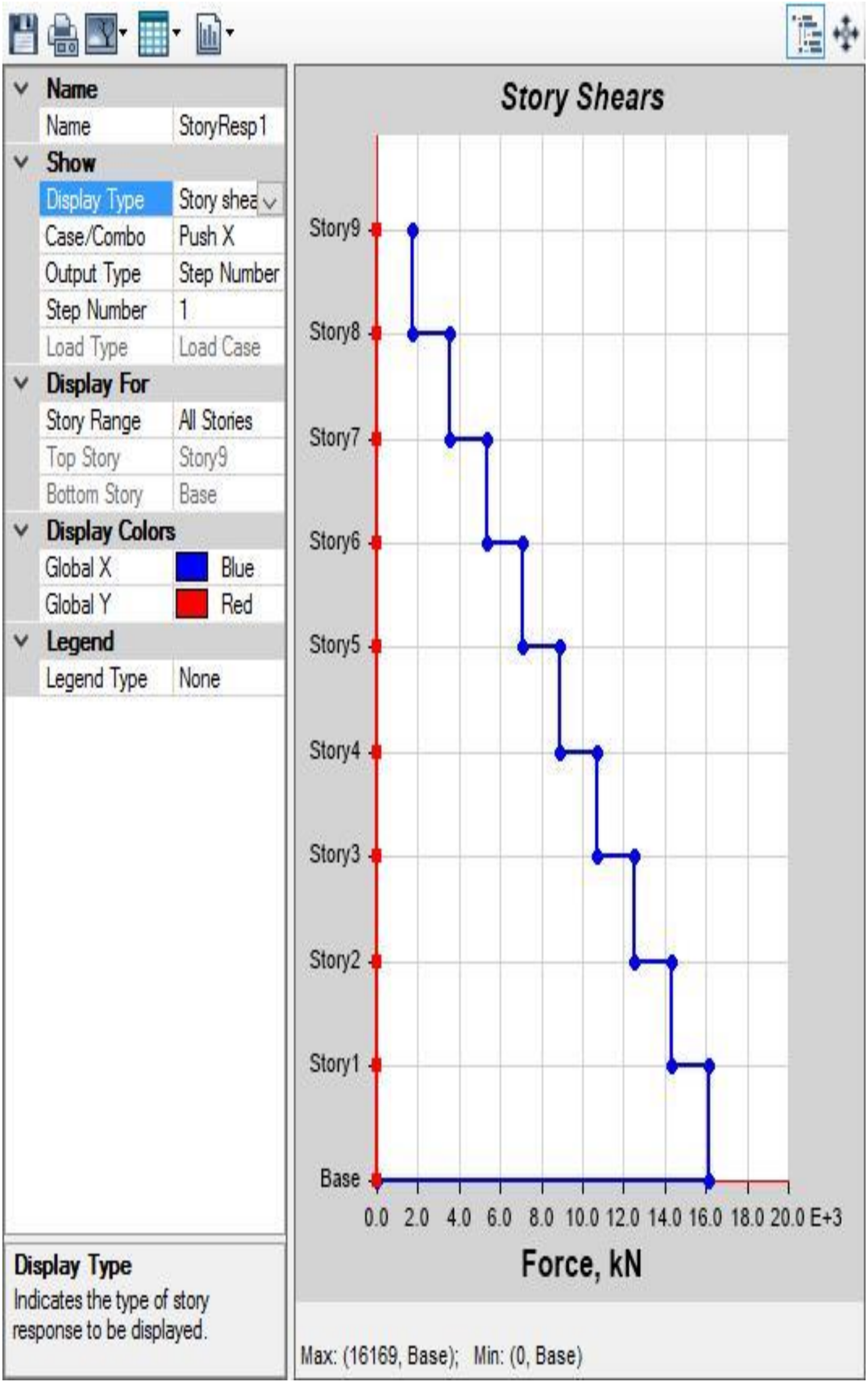
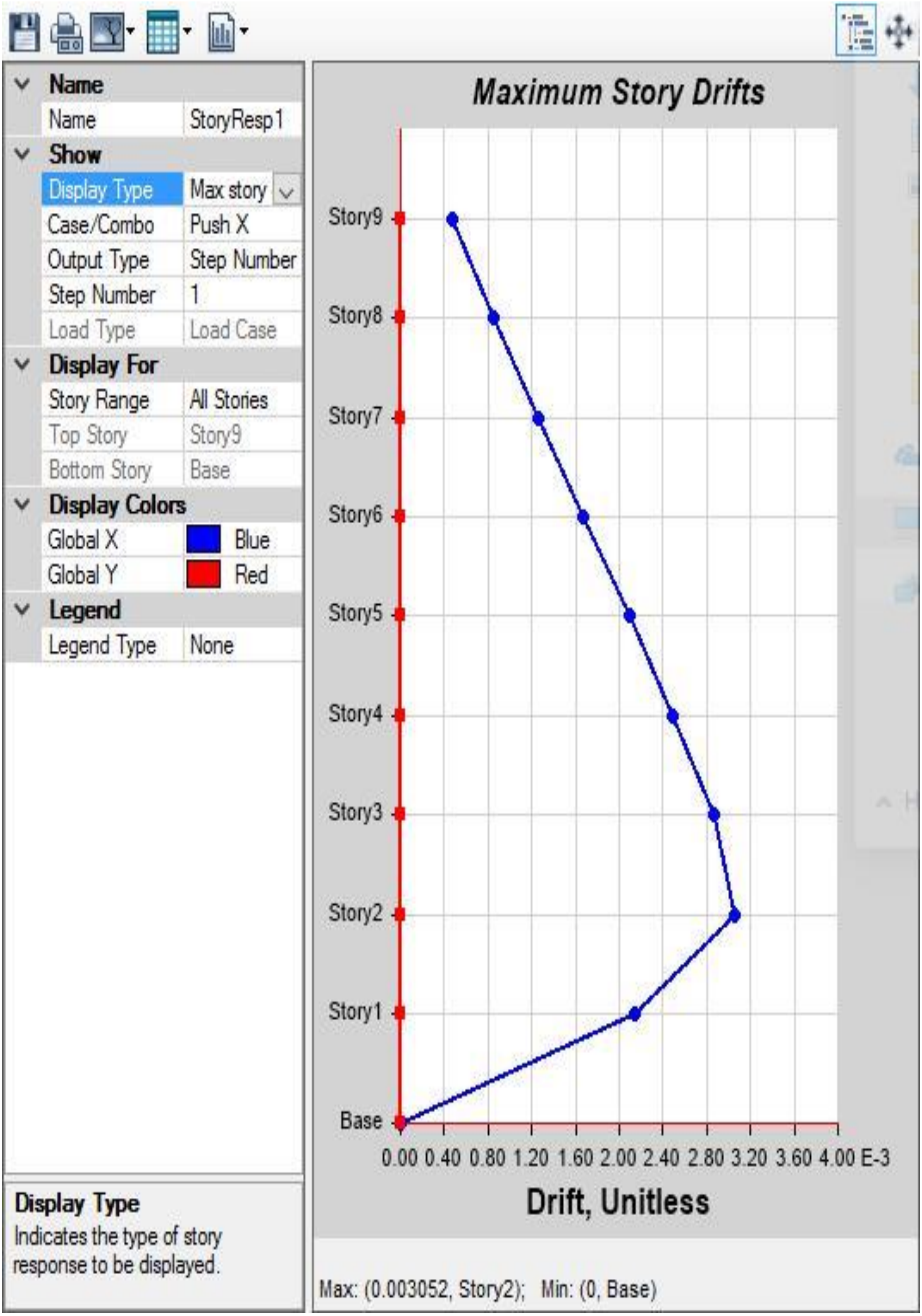


Figure: Plot of story shear Vs story on Etabs.



Name
Name StoryResp1
Show
Display Type Max story
Case/Combo Push X
Output Type Step Number
Step Number 1
Load Type Load Case
Display For
Story Range All Stories
Top Story Story9
Bottom Story Base
Display Colors
Global X Blue
Global Y Red
Legend
Legend Type None
Display Type
Indicates the type of story response to be displayed.
Maximum Story Drifts
Story9
Story8
Story7
Story6
Story5
Story4
Story3
Story2
Story1
Base
0.00 0.40 0.80 1.20 1.60 2.00 2.40 2.80 3.20 3.60 4.00 E-3
Drift, Unitless
Max: (0.003052, Story2); Min: (0, Base)

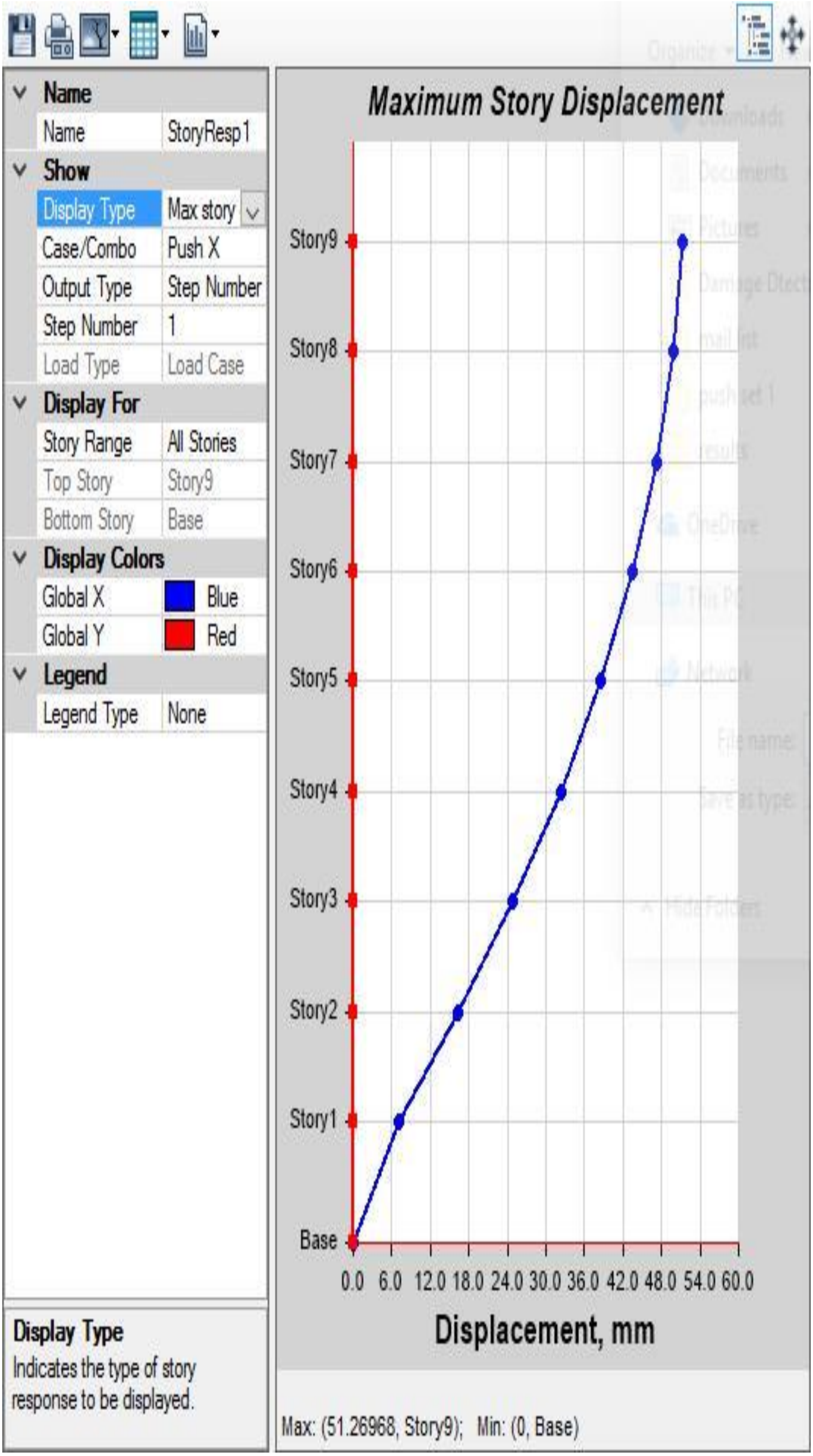


Figure: Plot of story Vs story displacement on Etabs.

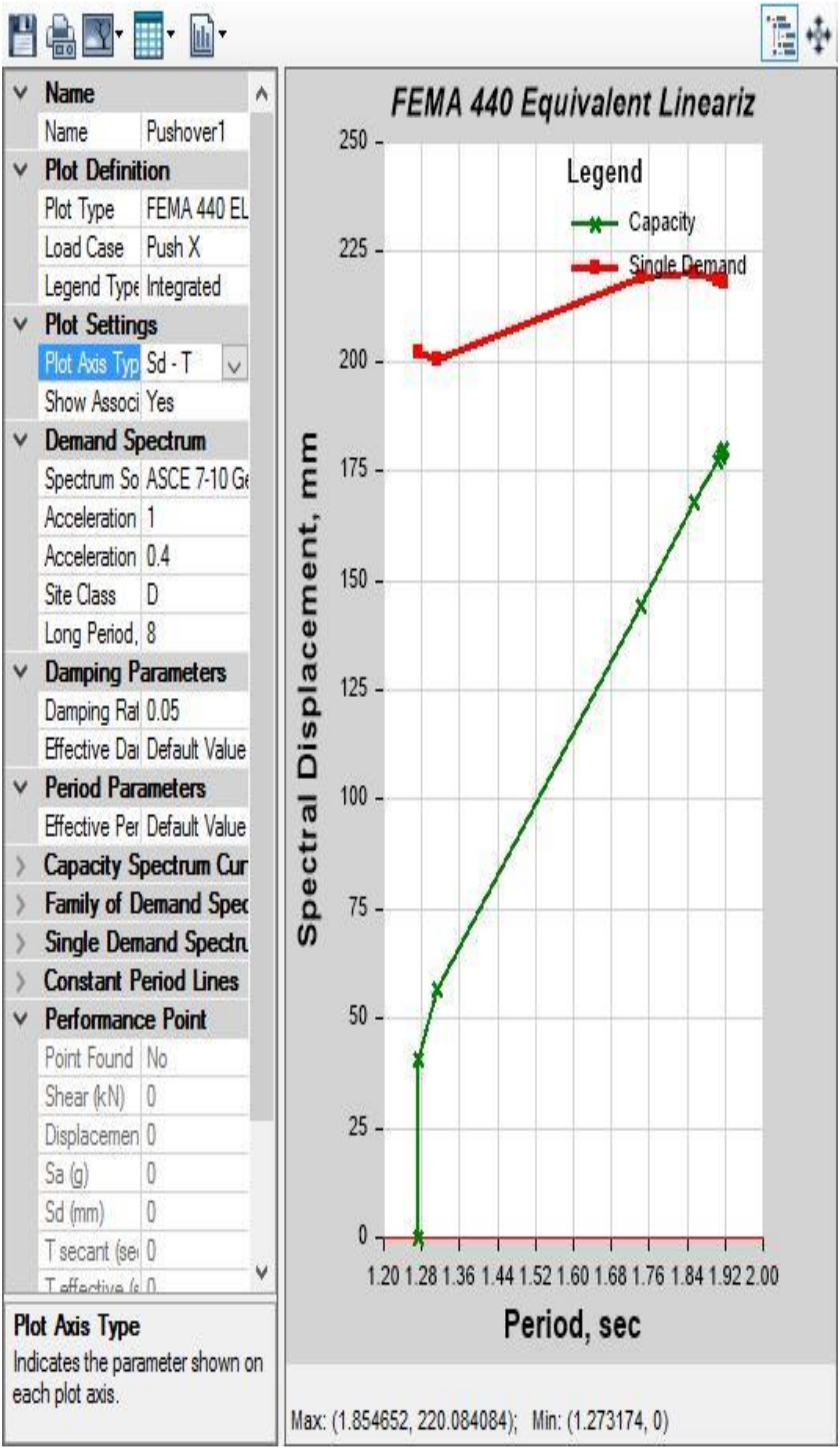


Figure: Plot of spectral displacement Vs time period in seconds on Etabs.

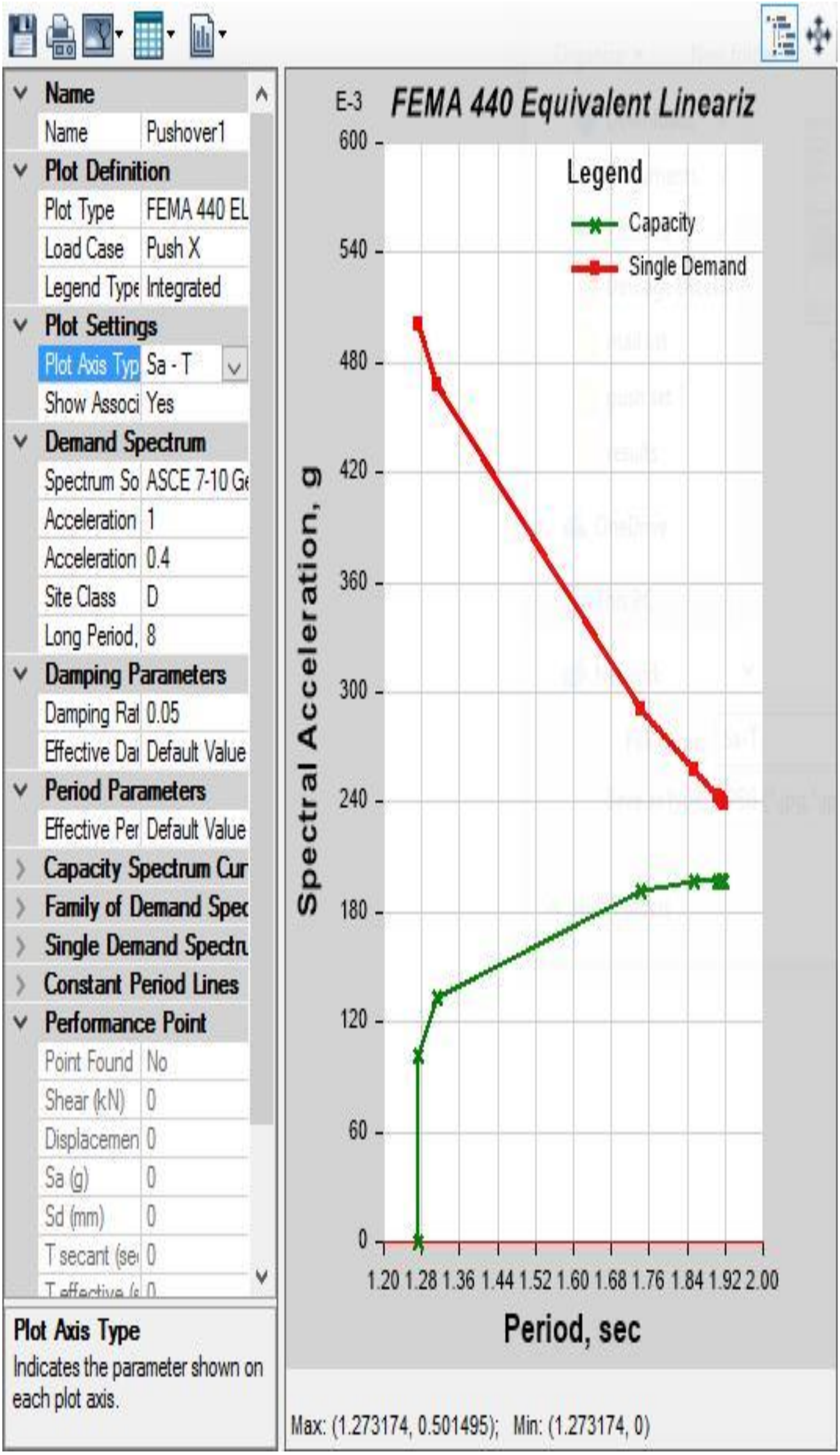


Figure: Plot of spectral acceleration Vs time period in seconds on Etabs.

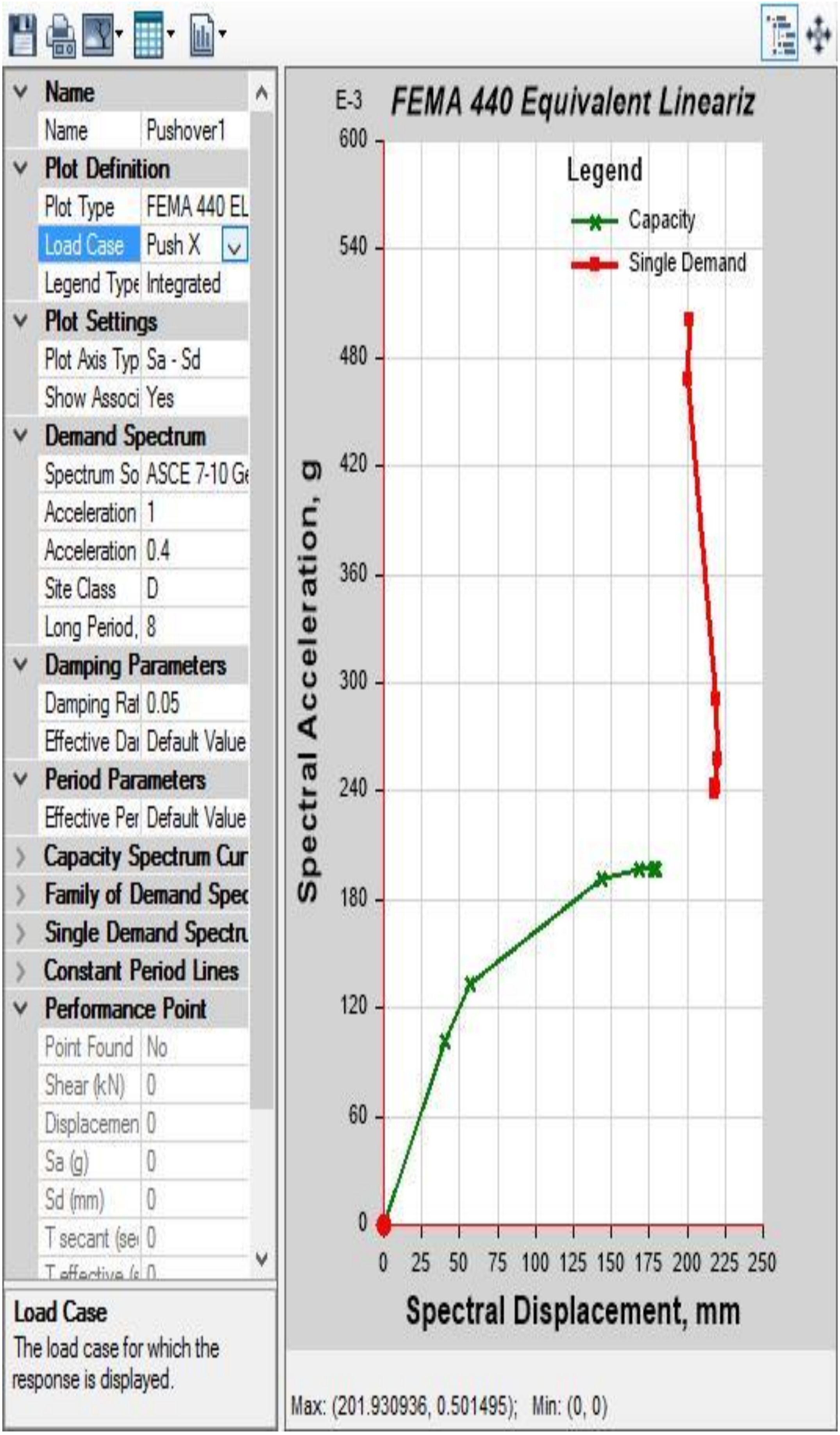


Figure: Plot of spectral acceleration Vs spectral displacement on Etabs.

The results shown below are the results evaluated after performing the pushover analysis on the building provided with circular columns of size Radius = 250mm.

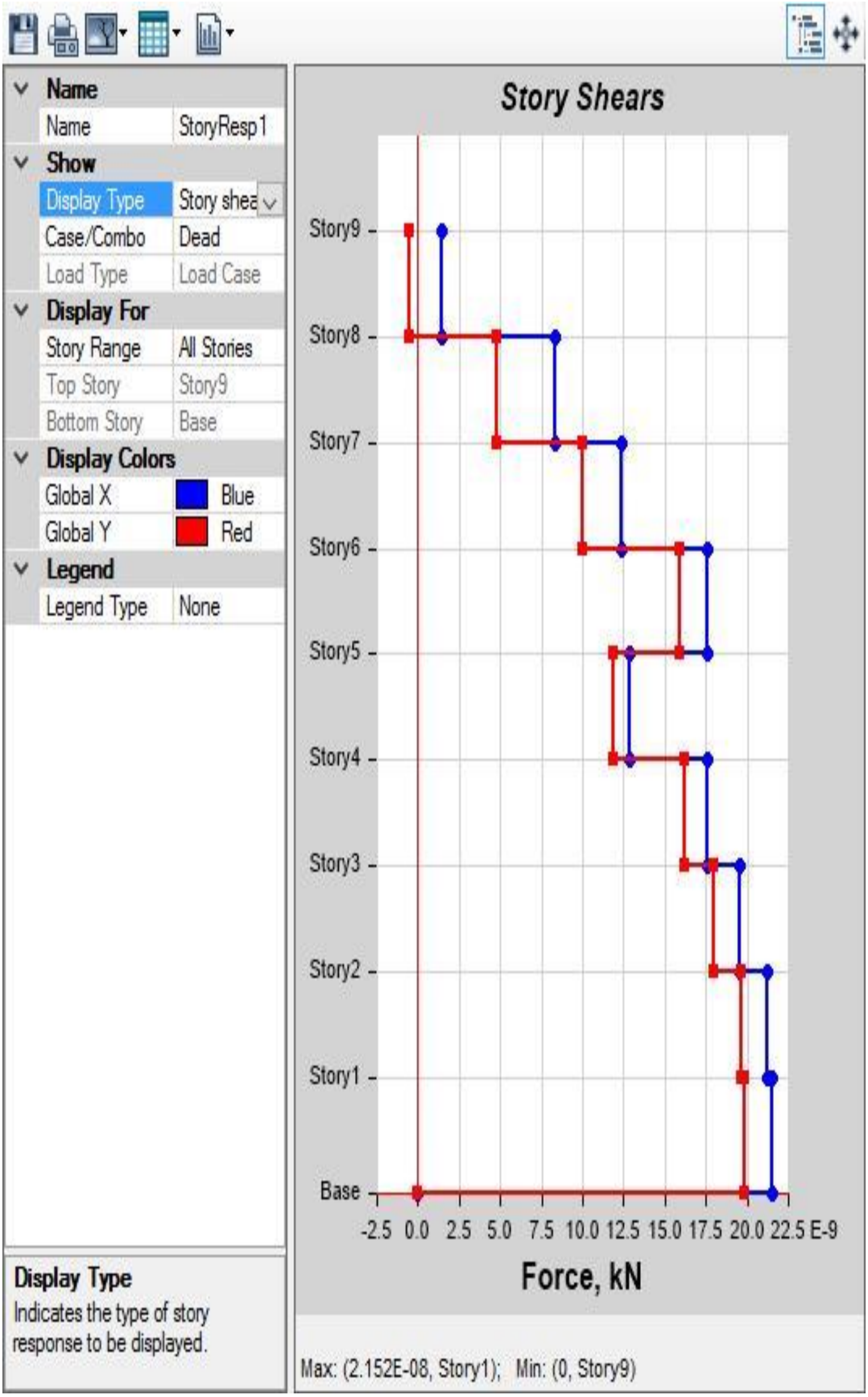


Figure: Plot of story shear Vs story on Etabs.

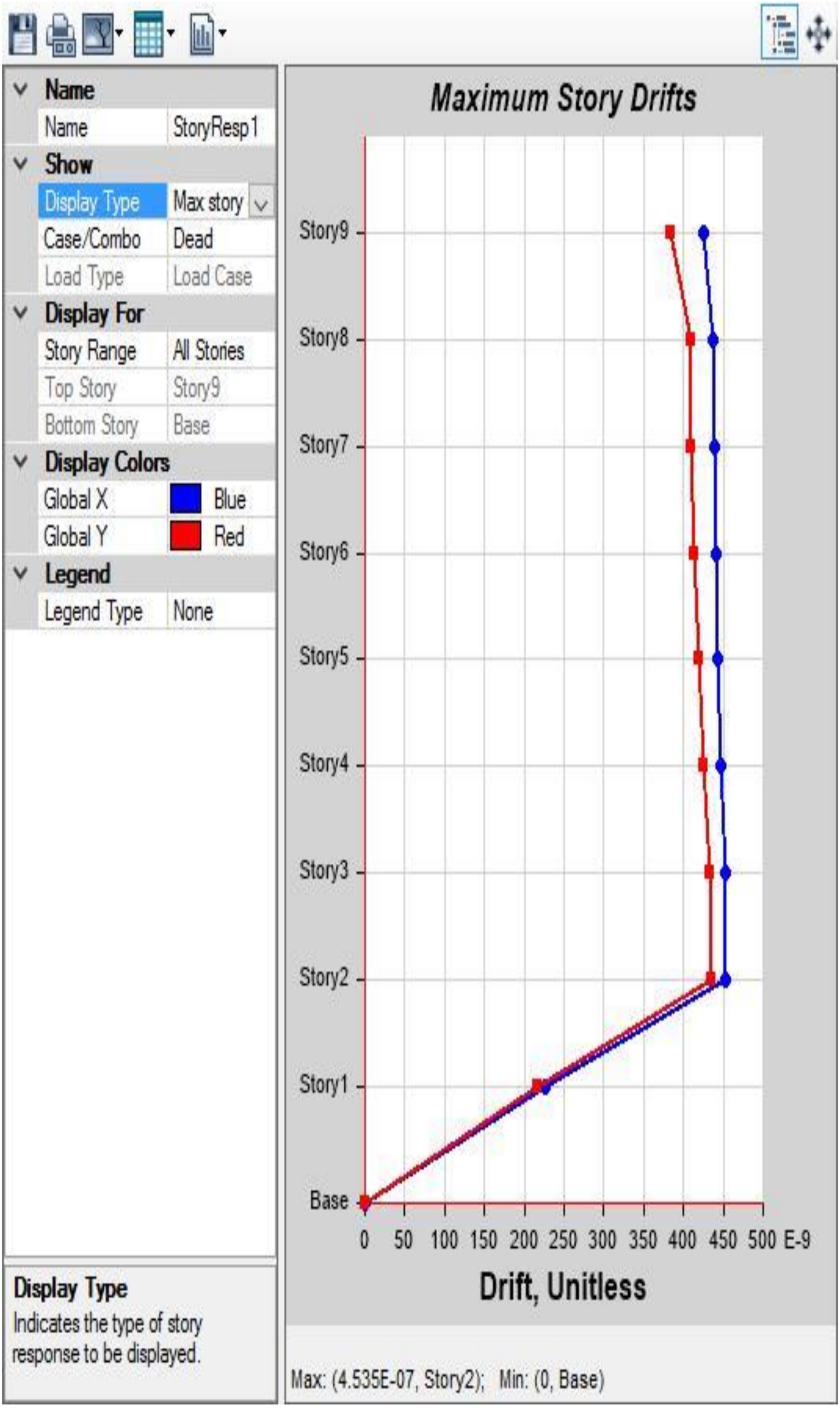


Figure: Plot of story Vs story drift on Etabs.

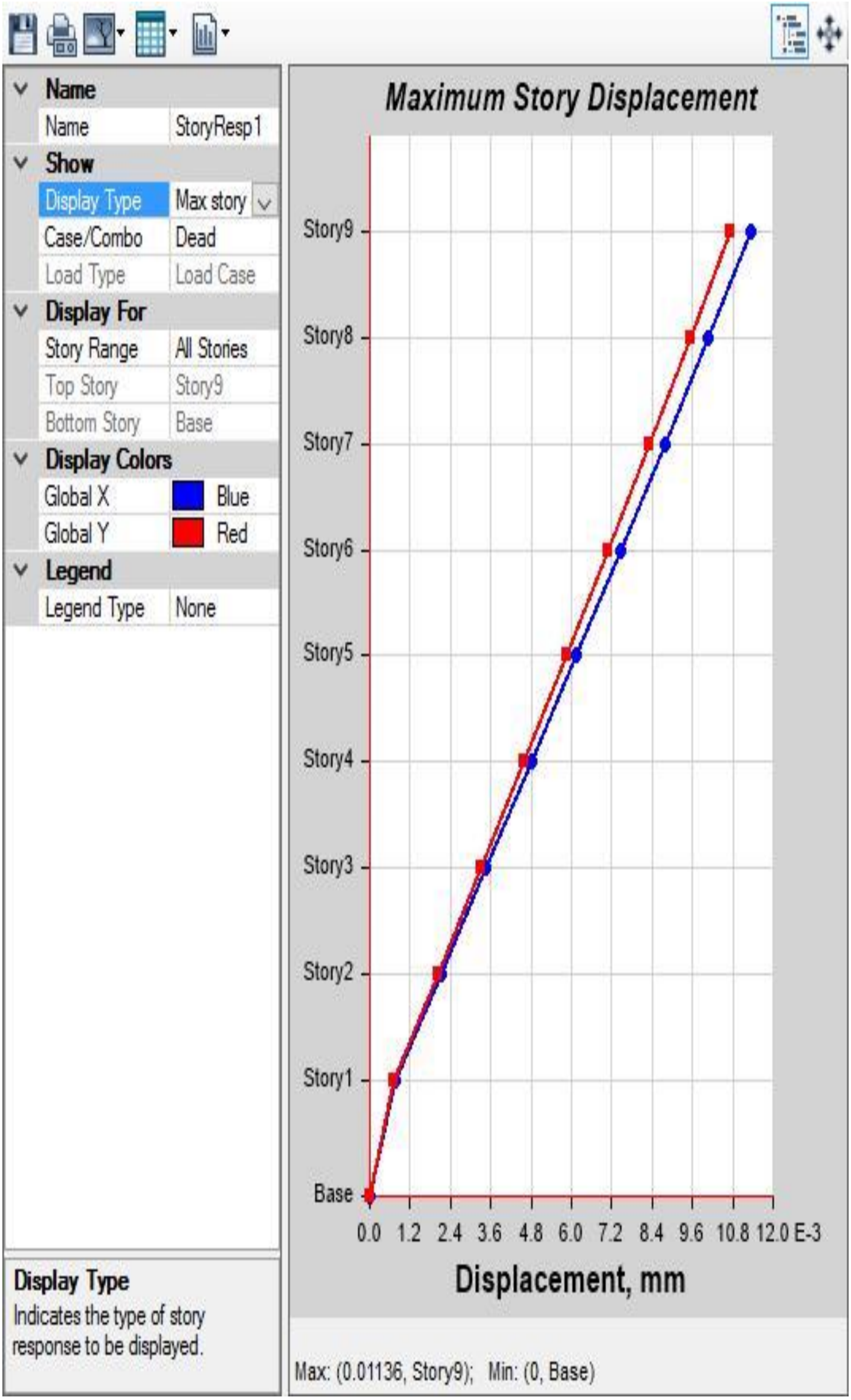


Figure: Plot of story Vs story displacement on Etabs.

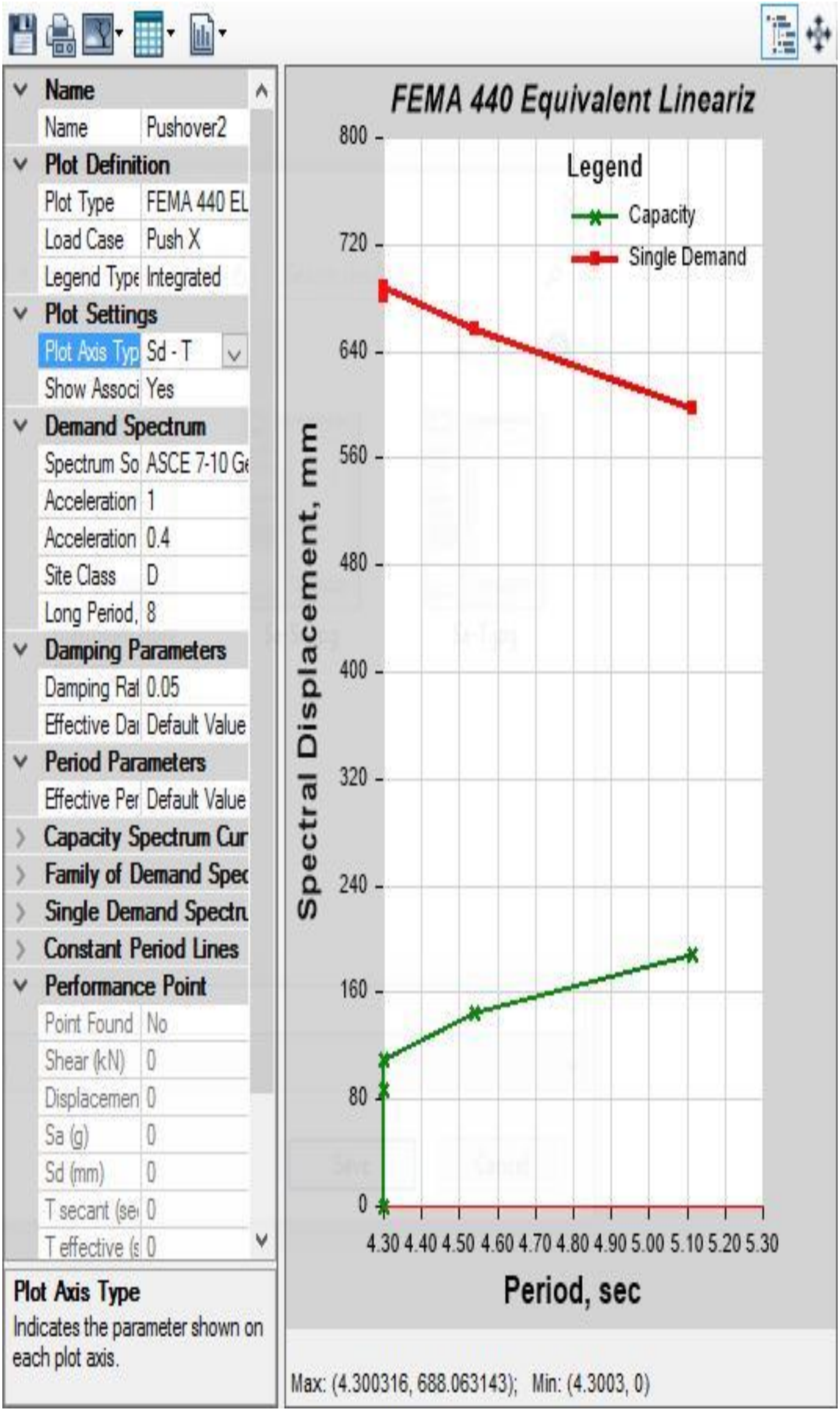


Figure: Plot of spectral displacement Vs time period in seconds on Etabs.

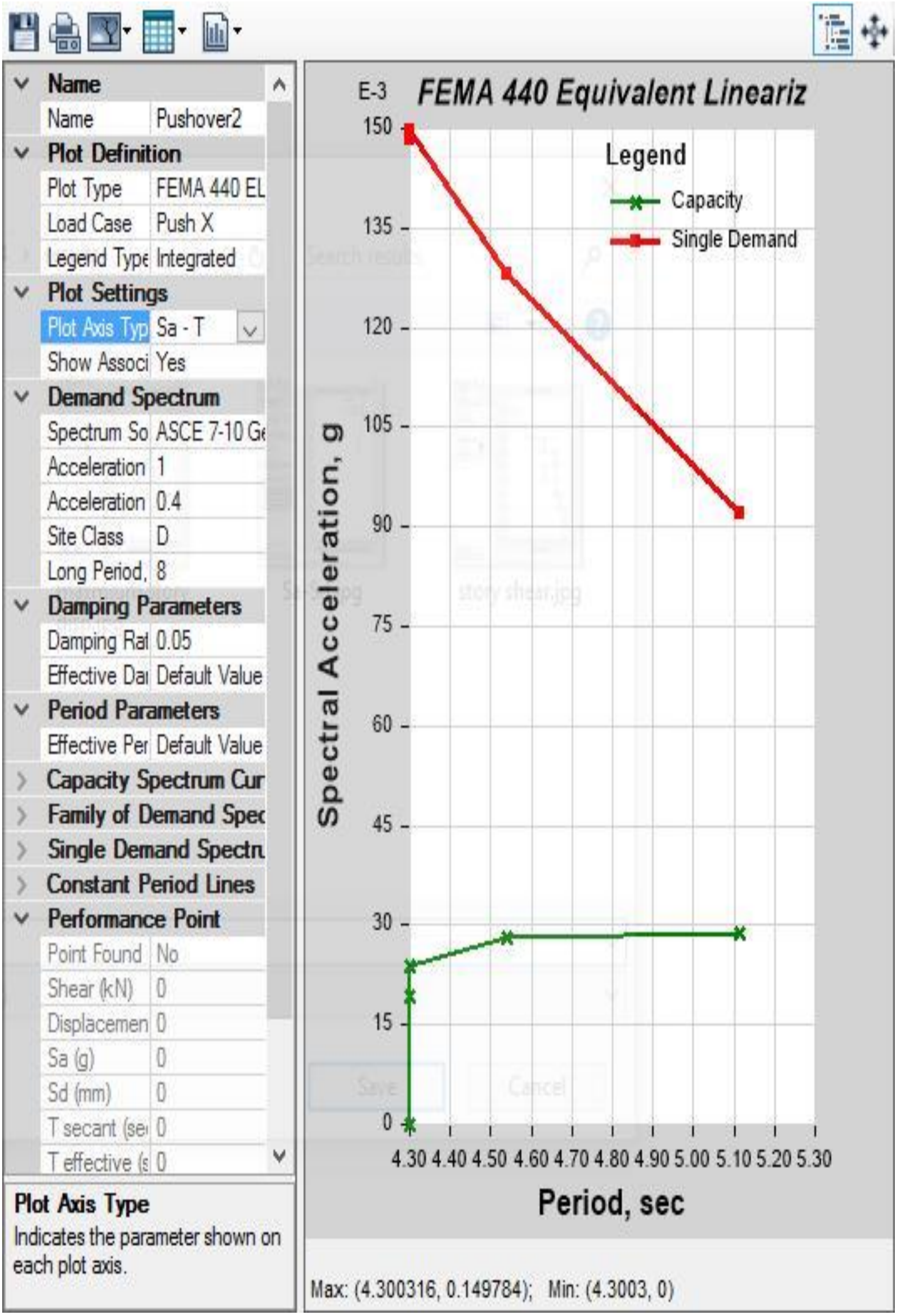


Figure: Plot of spectral displacement Vs time period in seconds on Etabs.

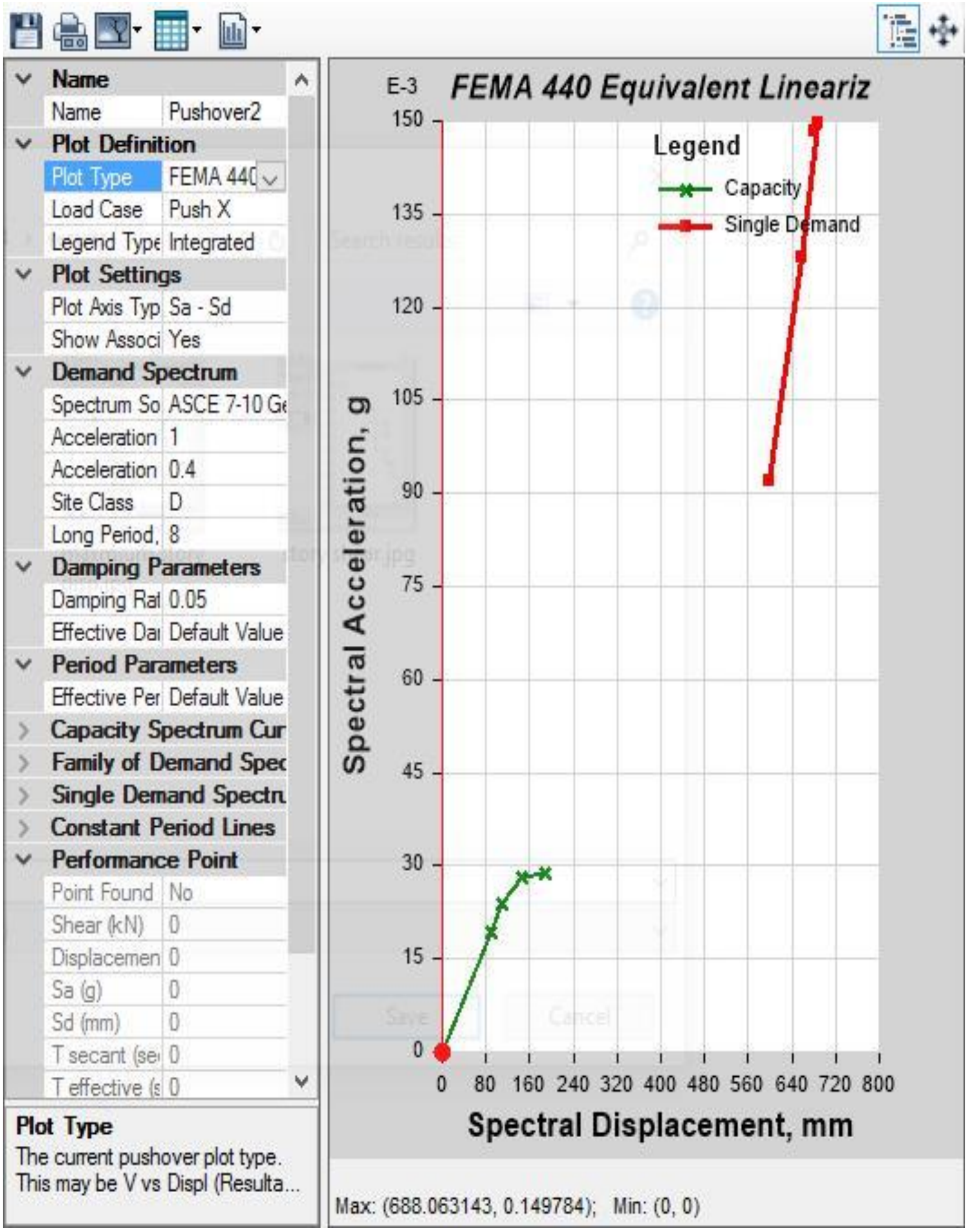


Figure: Plot of spectral acceleration Vs spectral displacement on Etabs.

The results shown below are the results evaluated after performing the pushover analysis on the building provided with circular columns of size Radius = 300mm.

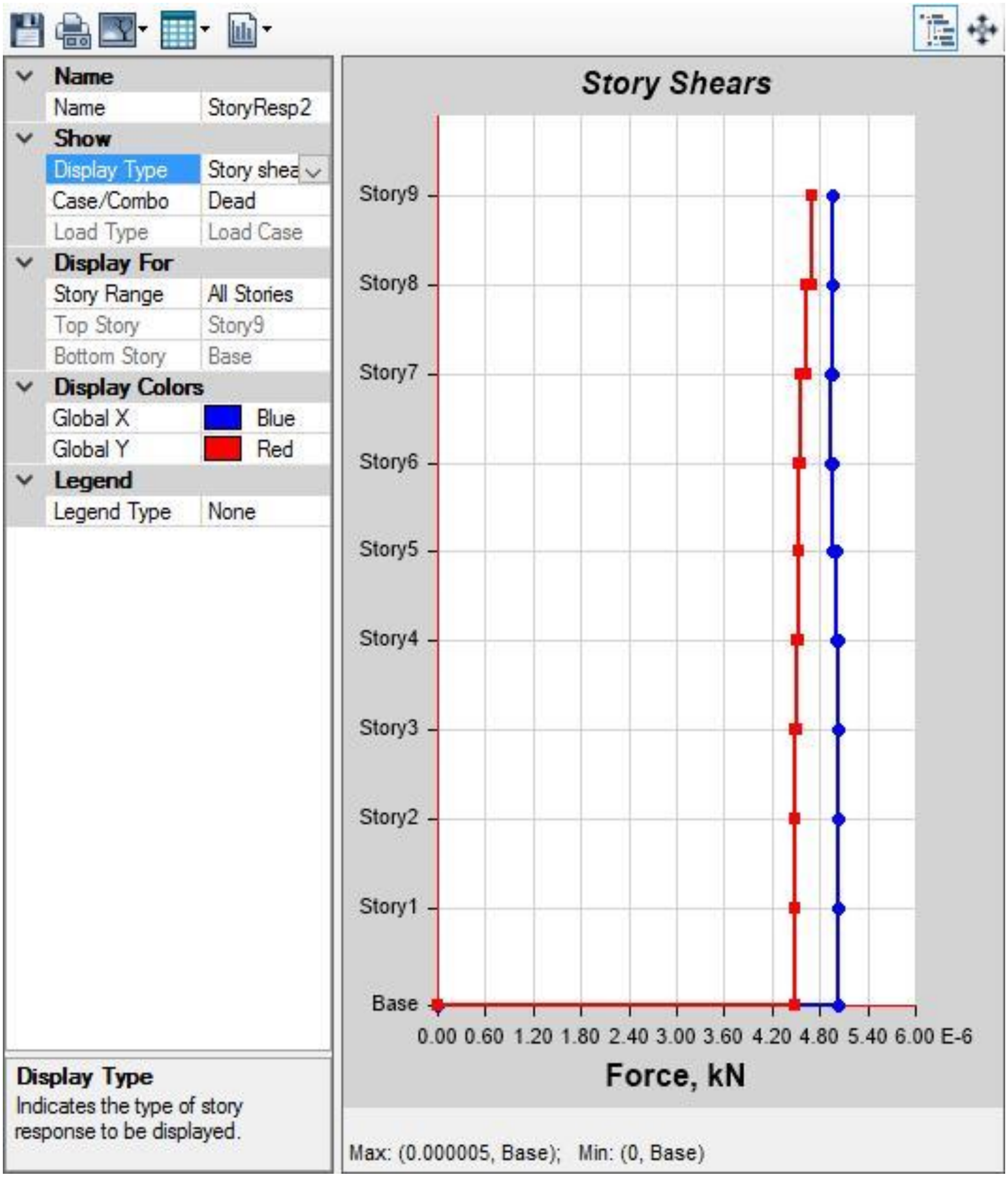


Figure: Plot of story shear Vs story on Etabs.

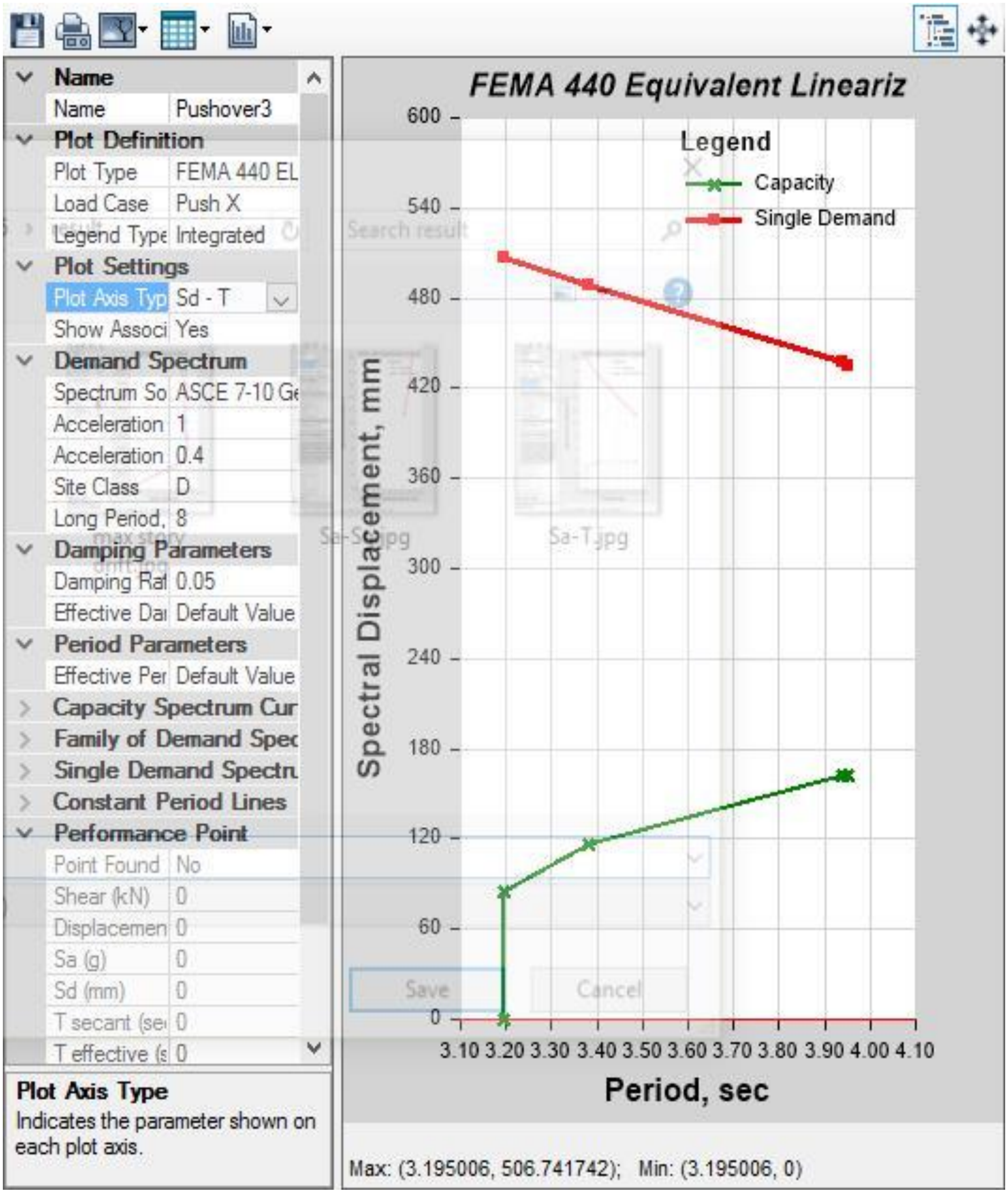


Figure: Plot of spectral displacement Vs time period in seconds on Etabs.

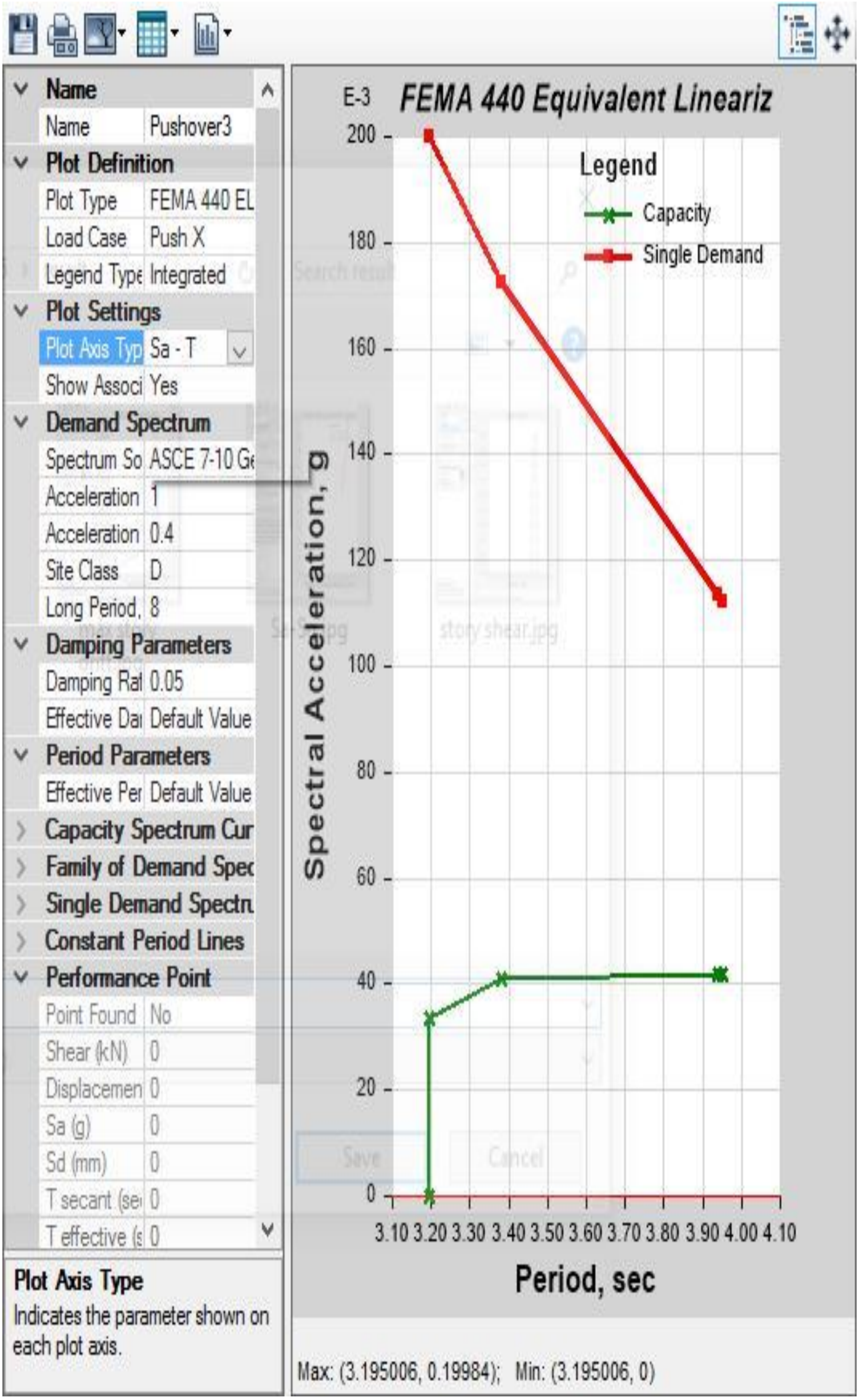


Figure: Plot of spectral acceleration Vs time period in seconds on Etabs.

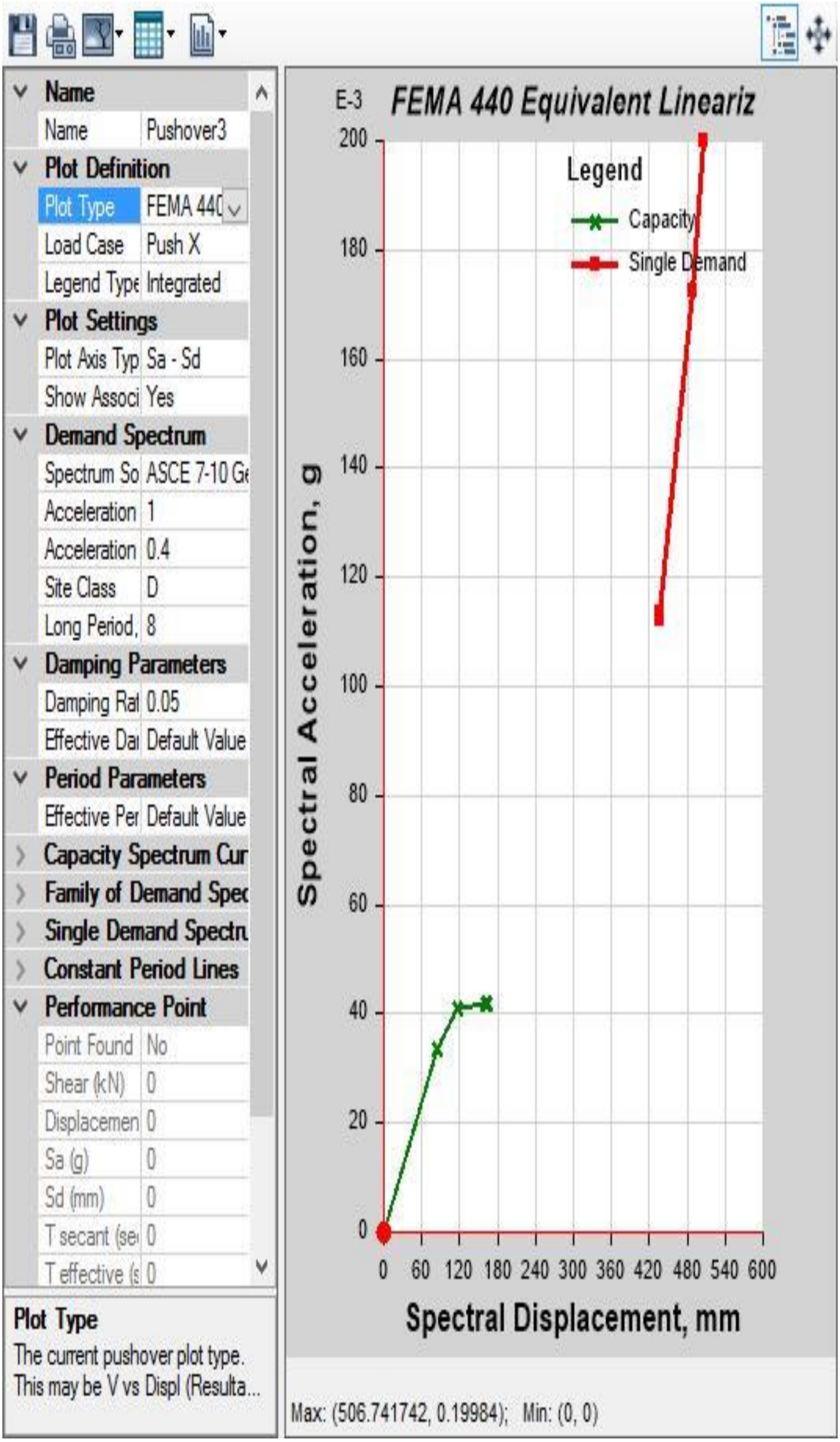


Figure: Plot of spectral acceleration Vs spectral displacement on Etabs.

The results shown below are the results evaluated after performing the pushover analysis on the building provided with circular columns of size Radius = 350mm.

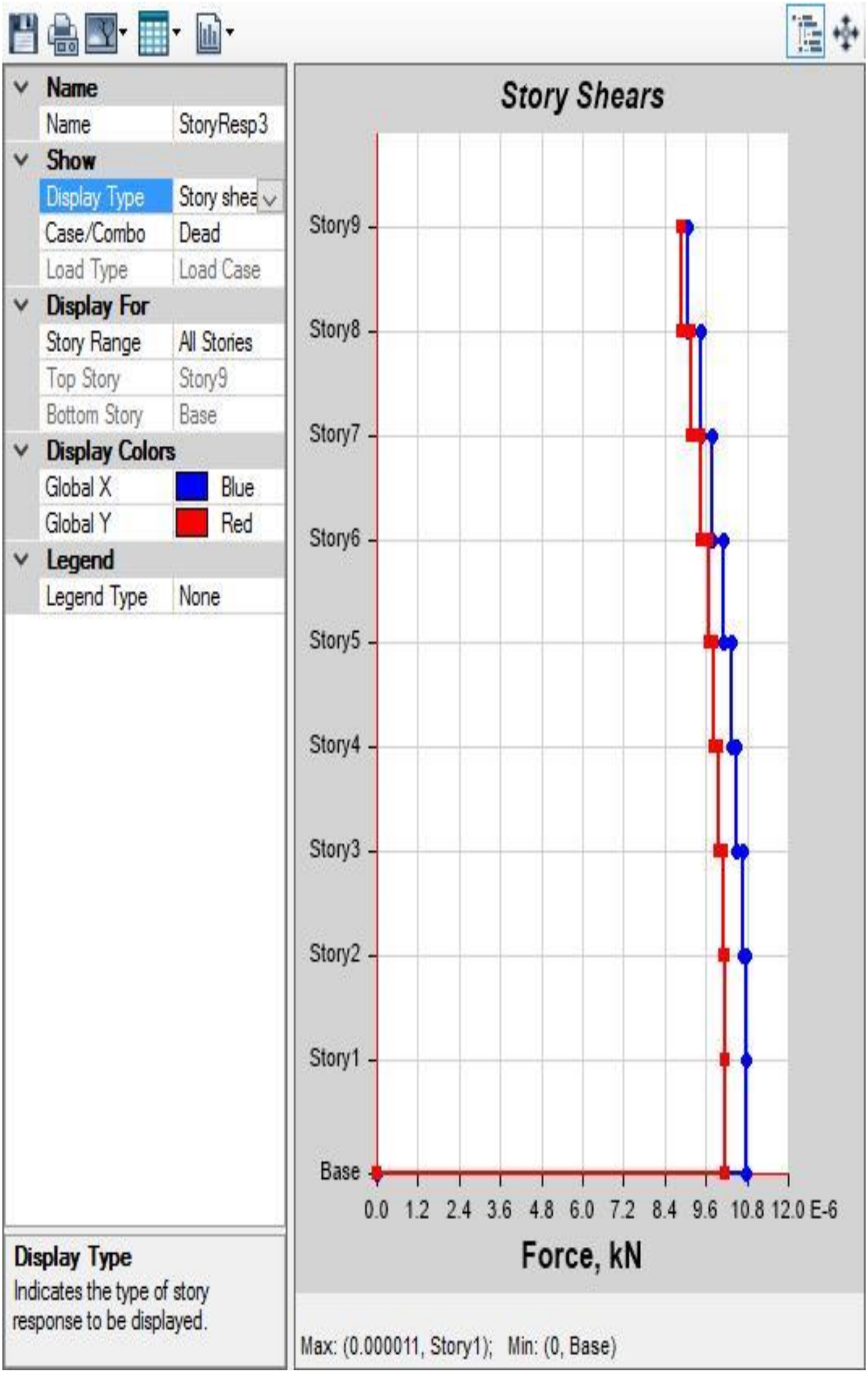


Figure: Plot of story shear Vs story on Etabs.

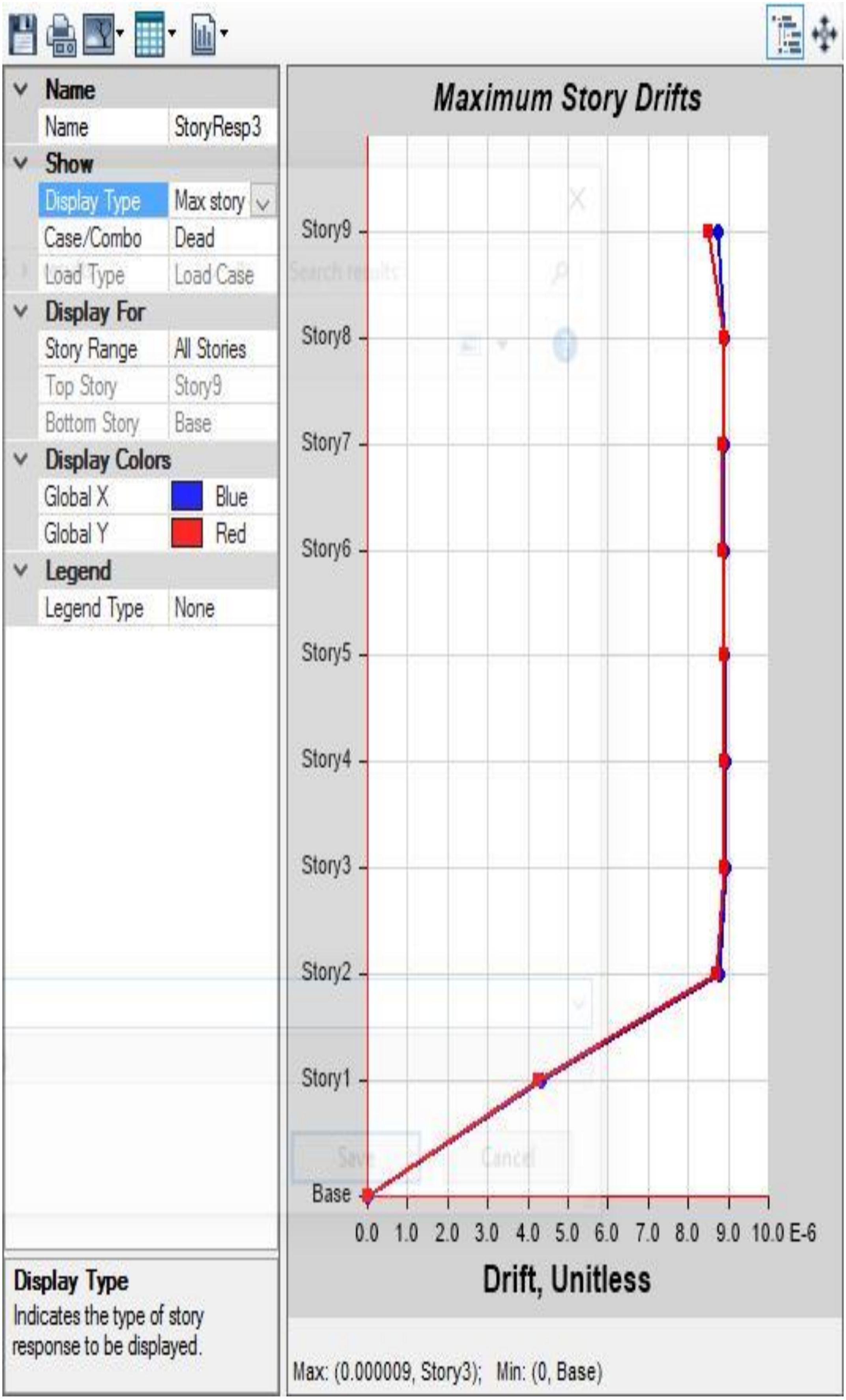


Figure: Plot of story Vs story drift on Etabs.

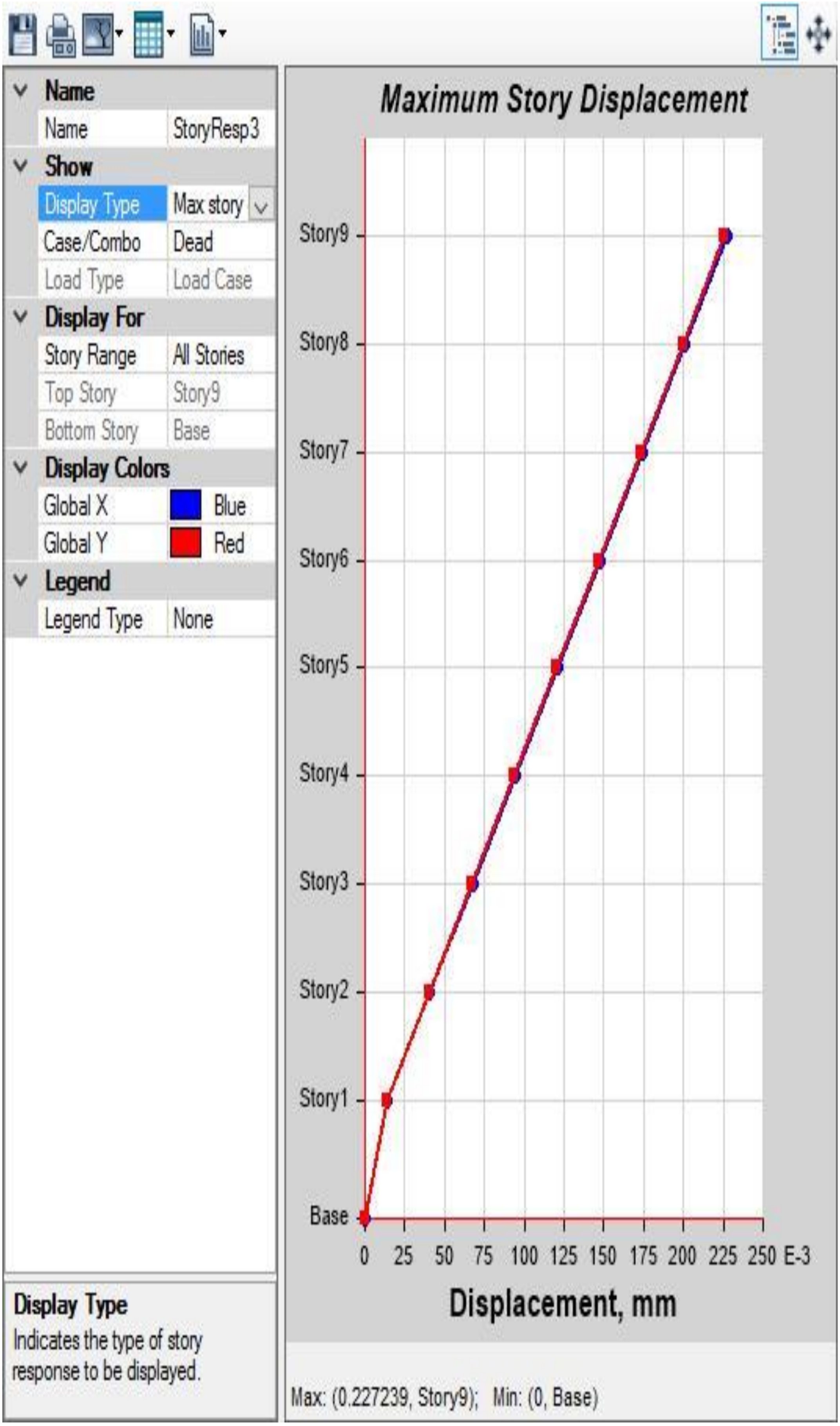


Figure: Plot of story Vs story displacement on Etabs.

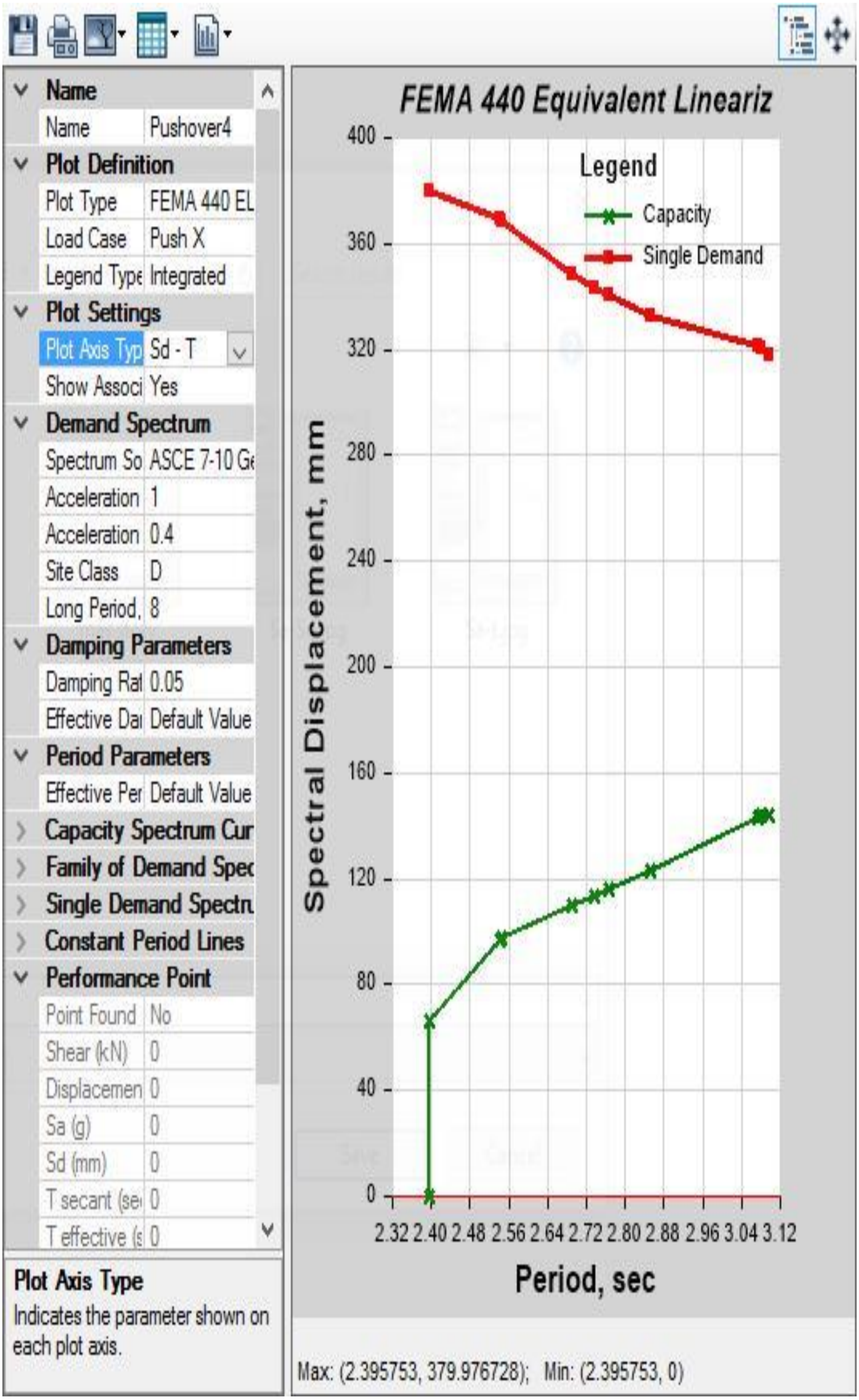
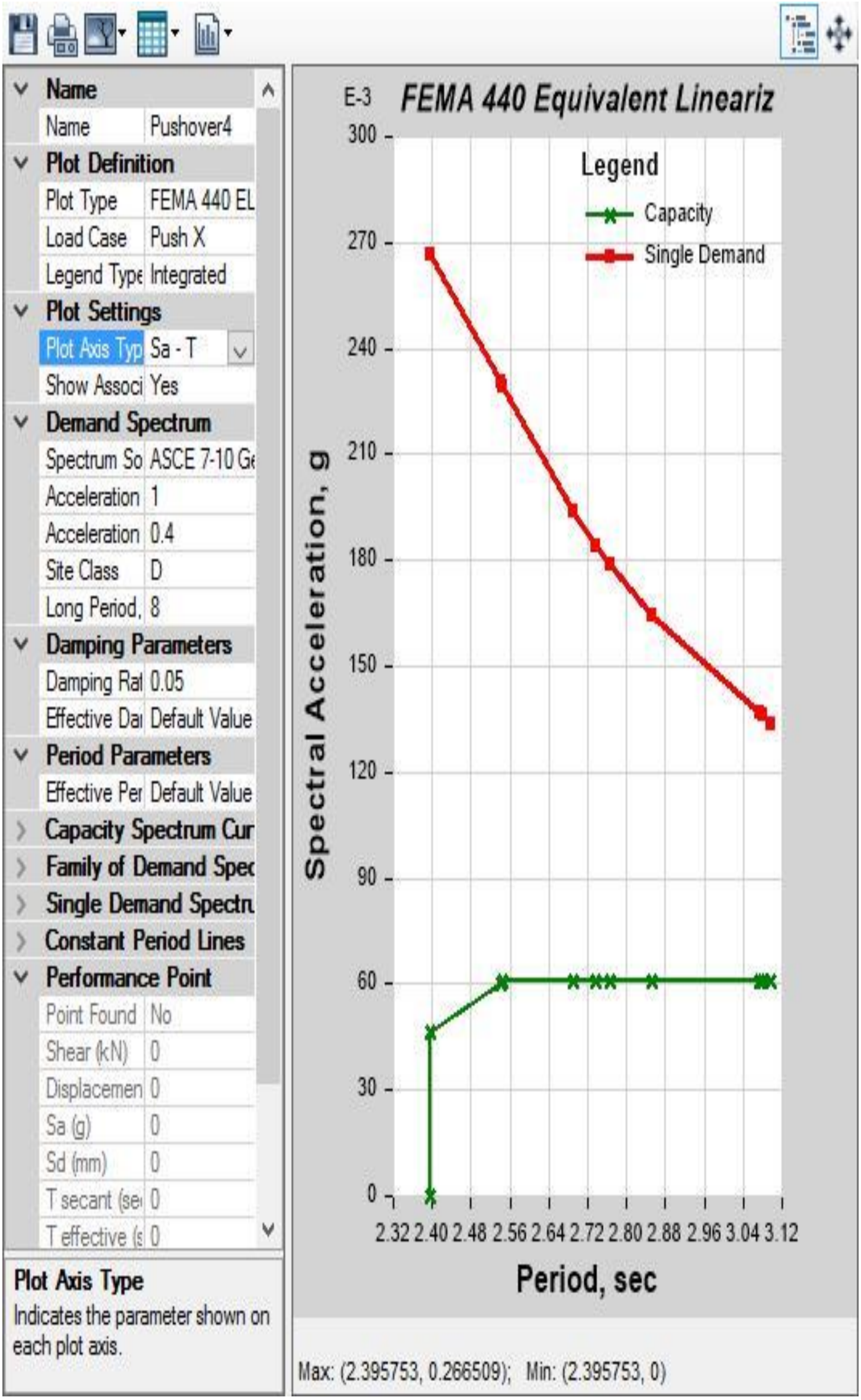


Figure: Plot of spectral displacement Vs time period in seconds on Etabs.


Name
Name | Pushover4
Plot Definition
Plot Type | FEMA 440 EL
Load Case | Push X
Legend Type | Integrated
Plot Settings
Plot Axis Typ | Sa - T
Show Associ | Yes
Demand Spectrum
Spectrum So | ASCE 7-10 Ge
Acceleration | 1
Acceleration | 0.4
Site Class | D
Long Period, | 8
Damping Parameters
Damping Rat | 0.05
Effective Dai | Default Value
Period Parameters
Effective Per | Default Value
Capacity Spectrum Cur
Family of Demand Spec
Single Demand Spectru
Constant Period Lines
Performance Point
Point Found | No
Shear (kN) | 0
Displacemen | 0
Sa (g) | 0
Sd (mm) | 0
T secant (sec | 0
T effective (s | 0
Plot Axis Type
Indicates the parameter shown on each plot axis.
FEMA 440 Equivalent Lineariz
E-3
Legend
Capacity
Single Demand
Spectral Acceleration, g
Period, sec
300
270
240
210
180
150
120
90
60
30
0
2.32 2.40 2.48 2.56 2.64 2.72 2.80 2.88 2.96 3.04 3.12
Max: (2.395753, 0.266509); Min: (2.395753, 0)

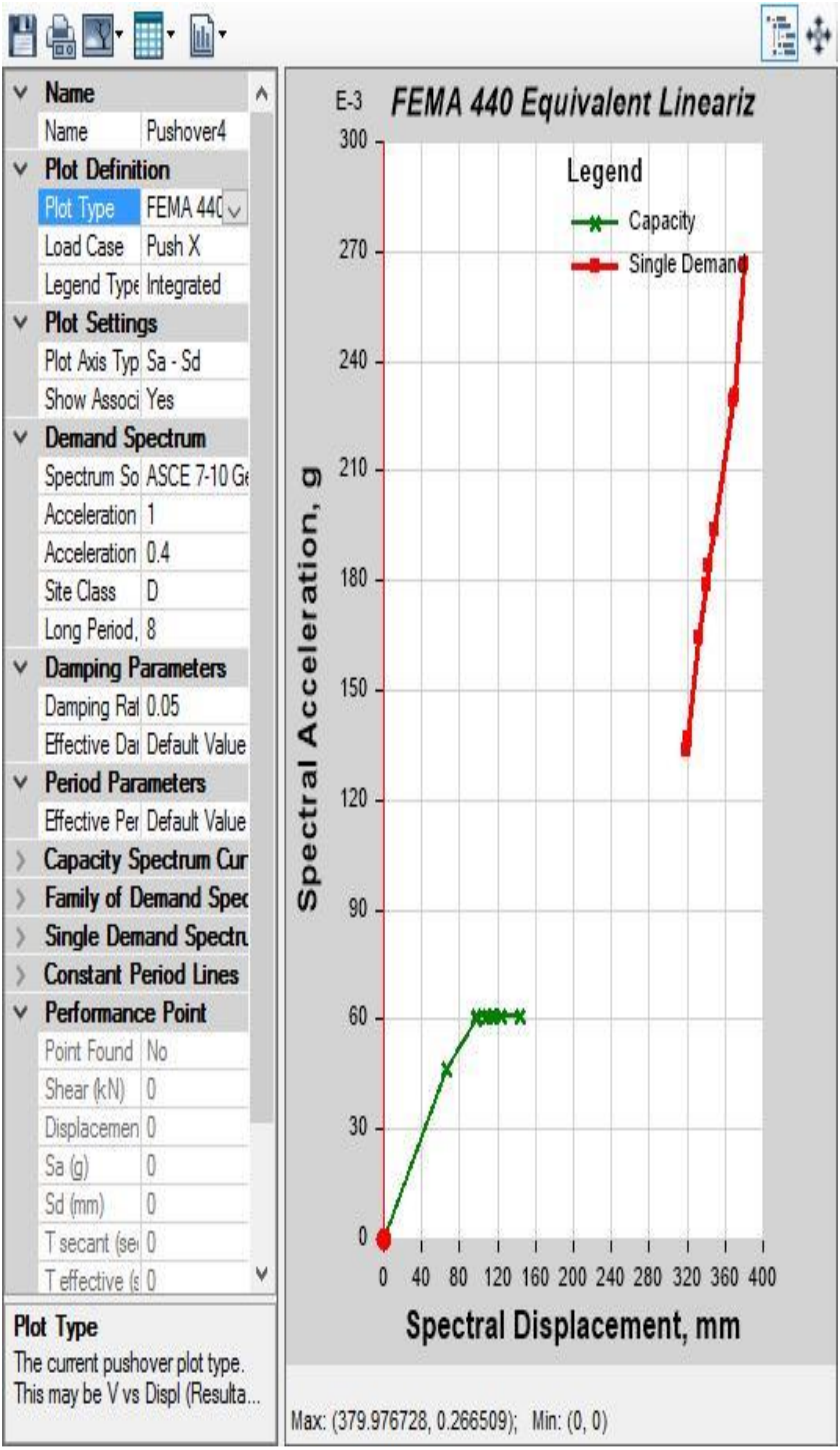
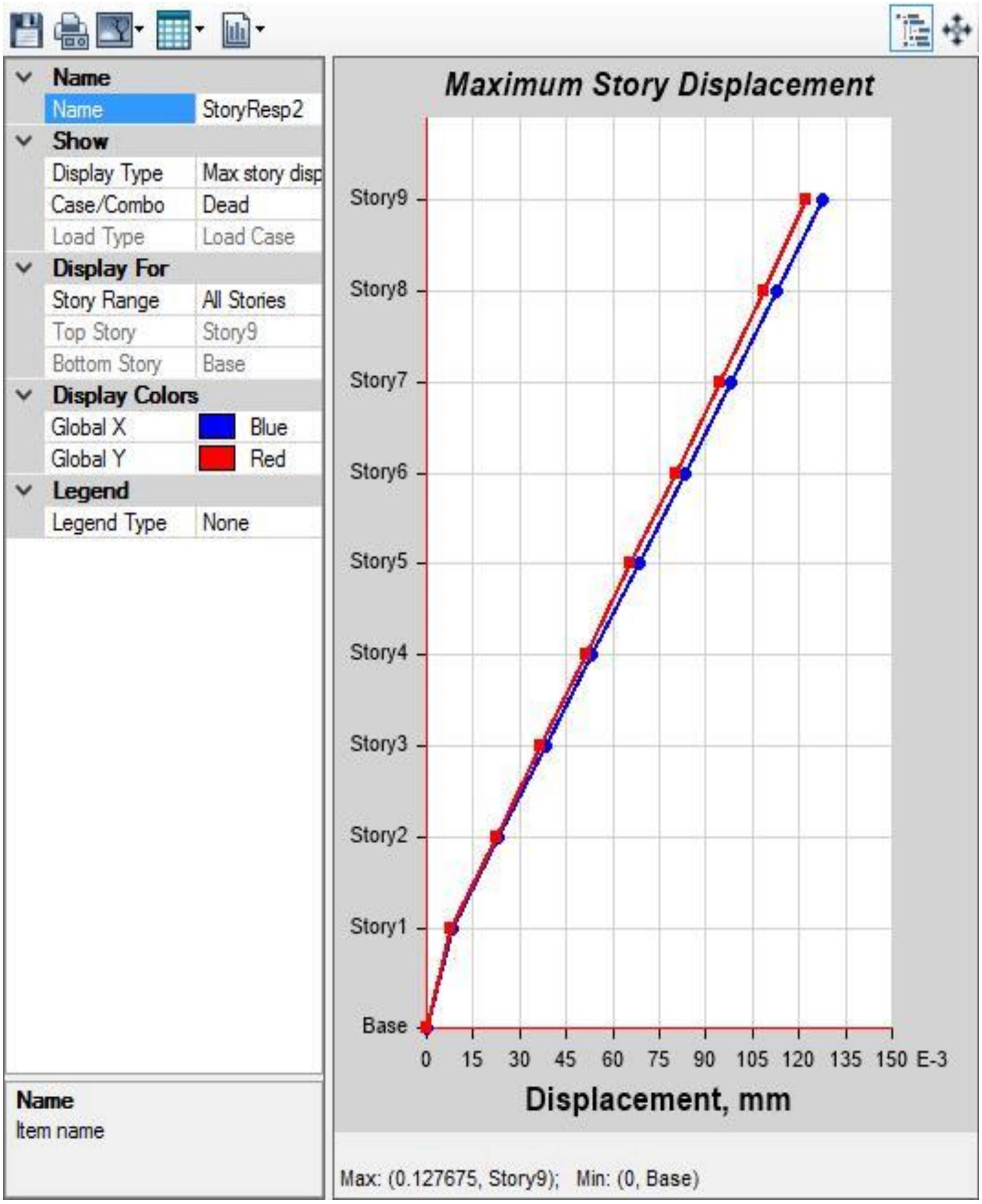
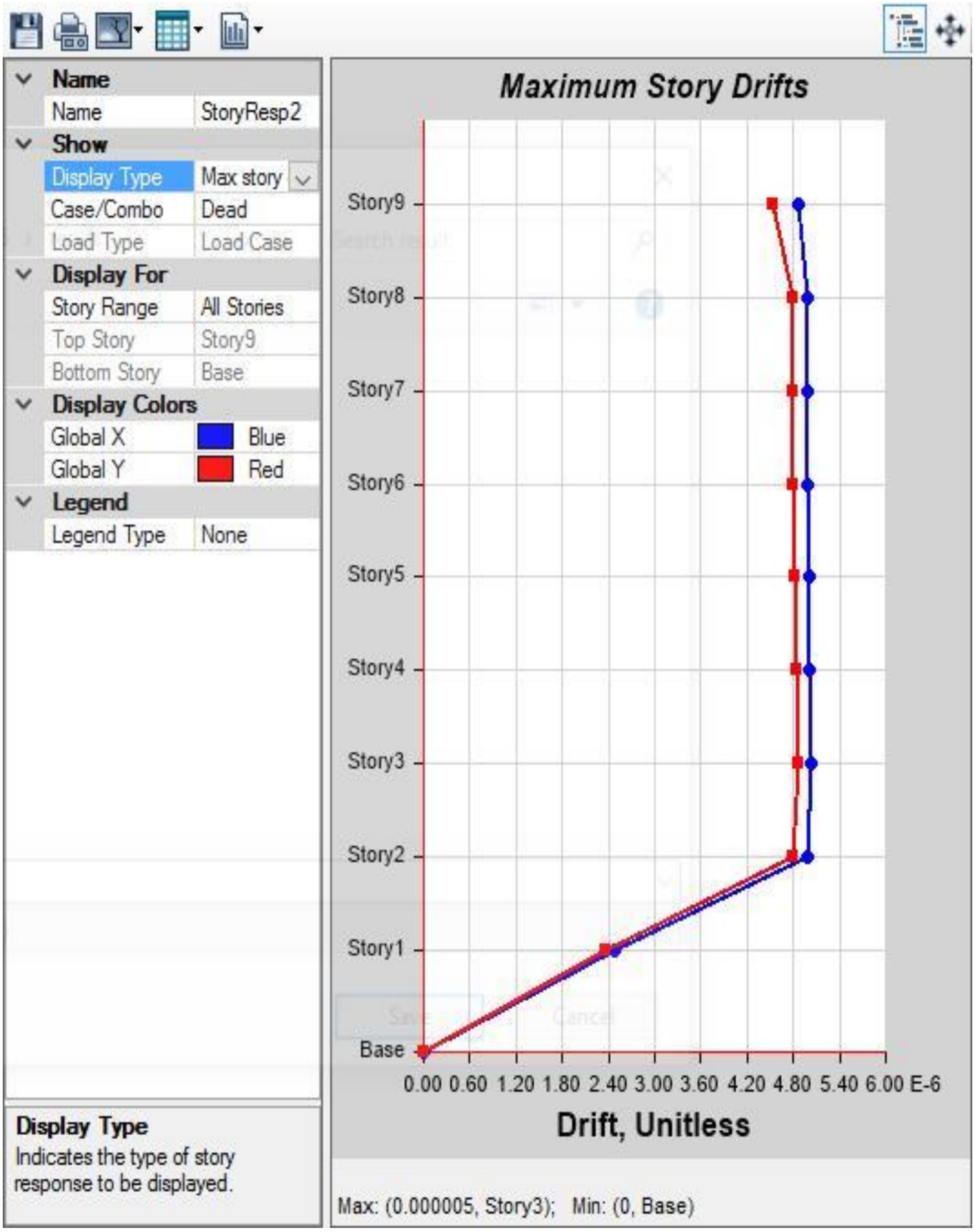


Figure: Plot of spectral acceleration Vs spectral displacement on Etabs.


Name
Name
StoryResp2
Show
Display Type
Max story disp
Case/Combo
Dead
Load Type
Load Case
Display For
Story Range
All Stories
Top Story
Story9
Bottom Story
Base
Display Colors
Global X
Blue
Global Y
Red
Legend
Legend Type
None
Name
Item name
Maximum Story Displacement
Story9
Story8
Story7
Story6
Story5
Story4
Story3
Story2
Story1
Base
0 15 30 45 60 75 90 105 120 135 150 E-3
Displacement, mm
Max: (0.127675, Story9); Min: (0, Base)



DISCUSSION

The earthquake resistant design of structures needs that structures should support, safely, any ground motions of an intensity that might occur during their construction or in their normal use. However, ground motions are unique in the effects they have on structural responses. The most accurate analysis procedure for structures subjected to strong ground motions is the Push over analysis. Pushover analysis is based on the assumption that structures oscillate predominantly in the first mode or in the lower modes of vibration during a seismic event. This leads to a depletion of the multi-degree-of-freedom, MDOF system, to an equivalent single-degree-of- freedom, ESDOF system, with properties predicted by a nonlinear static analysis of the MDOF system. The ESDOF system is then subsequently subjected to a nonlinear time history analysis or to a response spectrum analysis with constant-ductility spectra, or damped spectra. The seismic demands calculated for the ESDOF system are transformed through modal relationships to the seismic demands of the MDOF system.

In this study, the seismic behaviour of a frame building has been analysed by using push over analysis. The seismic performance evaluation of the building has been carried out by changing the sizes of the columns and also by replacing the rectangular columns with the circular columns. Static type of pushover analysis is to be used in this research work where the loads consist of permanent gravity loads and incremental horizontal forces at each storey level. Capacity curves (base shear versus story total drift) extracted from static pushover analysis using commercially available software called Etabs (Etabs 2015) are used for the calculation of some seismic demand parameters.

The dimensions of the buildings have been kept constant and only the column sizes have been changed. Three different combinations of the rectangular column dimensions are taken and the nonlinear response of each is evaluated by using the pushover analysis. The rectangular columns are then replaced with the circular columns of suitable dimension. The buildings are designed for the gravity and seismic loadings as per are 456: 2000 and IS 1893: 2002. Table 1 shows the summary of the elements and their respective sizes used while analysing the building.

The pushover curves prove that the roof displacement is maximum for a rectangular column when compared to circular columns. For the same loading, the displacement is found to be more in the square for all the similar loading patterns.

The performance points of the capacity curves show that circular columns perform better than rectangular columns with regards to the values given.

The storey displacement curves indicate that the story displacements are a just a bit more for rectangular columns. Not much significant variation was found.

CONCLUSION

1. The effect of the column shape on the stability of the structure is studied. The efficiency of circular and rectangular columns can be compared since the cross-sectional area of the two columns is kept constant. The % reinforcement is also to be maintained in both columns.
3. Story drift is found to be more in the rectangular columns than the frames having circular columns.
4. The behaviour of circular column is a little better than rectangular column when the comparison is in terms of storey drift, base shear and roof displacement.
5. The performance of circular column RC frame is also found to be better than the rectangular column RC frame.
6. The pushover curves prove that the roof displacement is maximum for a rectangular column when compared to circular columns. For the same loading, the displacement is found to be more in the square for all the similar loading patterns.
7. The performance points of the capacity curves show that circular columns perform better than rectangular columns with regards to the values given.
8. The story displacement curves indicate that the story displacements are a just a bit more for rectangular columns. Not much significant variation was found.

FUTURE SCOPE OF STUDY

- An inclusion of shear failure limits in the performance criteria may lead to a better and more comprehensive understanding of the building's behaviour.

- Nonlinsear time history analysis can be used for the structure to have a more accurate assessment of the structure's capacity and understanding a more realistic demand scenario.

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