Dynamic Analysis of Transmission Tower due to Sudden Snapping of Transmission Cables

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***Abstract*— Transmission line towers carry heavy electrical transmission conductors at a sufficient and safe height from ground. In addition to their self-weight they have to withstand all forces of nature like strong wind, earthquake and snow load. Therefore transmission line towers should be designed considering both structural and electrical requirements for a safe and economical design.**

This paper introduces different types of transmission tower and its configuration as per Indian Standard IS -802. A typical type of transmission line tower carrying 132kv double circuit conductors is modeled and analyzed using STAAD-pro considering forces like wind load, dead load of the structure and seismic load as per Indian Standard IS1893:2000(part 1). The transmission tower has height of 21m. which includes the ground clearance (h1) = 13.82 maximum sag =6.7347m of the lower most conductors wire(h2), = 4 vertical distance of earth wire from the uppermost conductor wire (h3) = 1m. The earth wire of ground wire is always located at top of the transmission tower. It has a square base width of 5.5m.

The type of transmission tower considered is a tangent tower having no deviation located on a plain landscape with minimal obstacles. It is located at the wind zone 6 with basic wind speed of 44m/s.

The transmission tower is situated in the most seismic sensitive region i.e. Zone V

The members are designed for maximum deflection and load for the most critical load combination as per code IS802. The members are also grouped for better fabrication. Steel optimization has been carried out to find the most suitable and economical section for the design.

Keywords- Transmission Tower Dynamic Analysis, STAAD PROV8i

INTRODUCTION

India has a large population residing all over country & the electricity supply need of this population creates requirement of a large transmission & distribution system. Transmission towers are necessary for purpose of supplying electricity to various regions of the nation. Aim is to provide optimum electric supply for required area to supply 220kv to 110kv, multi-voltage, multi-circuit. To various regions of the nation. Generally tower cost is 28% to 42% of total cost of transmission lines. Seismic design of transmission is important, against to protect against any kind of sudden shock or seismic attack/action. Transmission towers are classified based on their usage & based on the number of circuits. Towers are mainly designed for focus due to wind, ice & other loading conditions. Since, 40% of Indian sub-continent is prone to moderate to moderate to severe seismic shocks. It has become more vital to design life-line system (tower) for seismic safety. A very few countries are following guidelines for seismic load of towers. In addition to single tower, The behavior of transmission tower line system, which is 240m apart is considered in the present study to understand the response of these life line structures(tower) under seismic shock. Damage of tower was serious. It was reported that- Inclination & deformation of steel tower, Destruction & displacement of foundation of steel towers, caused by seismic shock. Generally, in design of a steel tower, a wind load is large than ordinary seismic load, so wind load controls the structural profile. The considerations on seismic load was not important except for design of well type foundation in India.

The average wind velocity in India is 44.5m/s. Generally, tensile strength of a cable is larger than that of a steel tower. Tensile load is transmitted to steel tower from cables in both sides-in the longitudinal direction. The height of steel tower is 21m The distance between the legs at the foot is 5.5m According to seismic action, each side was shaken hard. It is considered that- Damage of steel tower was possibly caused by strong vibration (due to cable cut).

I. METHODOLOGY

This paper introduces different types of transmission tower and its configuration as per Indian Standard IS -802. A typical type of transmission line tower carrying 132kv double circuit conductors is modeled and analyzed using STAAD-pro considering forces like wind load, dead load of the structure and seismic load as per Indian Standard IS1893:2000(part 1). The transmission tower has height of 21m. It has a square base width of 5.5m.

II. LOADS ON TRANSMISSION TOWERS

The transmission line towers may be designed as per IS : 802 (Part I) 'code of practice for use structural steel in Over head transmission the towers to establish a minimum acceptable level of safety.

The vertical loads acting on towers are the dead load and live load. The vertical loads on the power transmission line towers include the self-weight of the towers, the self-weight of insulators and fitting, the self-weight of ice coatings, if any, and weight of lineman with tools. The vertical loads on towers supporting water tanks include the self-weight of towers, self –weight of tank and water, weight of ladder, and weight of the platform. The self-weight of tower is found on the basis of provisional estimate of the cross section of the

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members. The self weight of towers may be found by comparison with similar existing structures. The self weight of towers may also be determined from existing available Ryle's empirical formulae.

The weight of conductors and ground wires on a tower depends on the appropriate weight span. The horizontal distance between the lower points of the conductors in the two adjacent spans in known as weight span. The weight of lineman with tools to be included in the design is taken as 150Kg.

The transmission line towers are exposed to open atmospheric conditions. These towers are subjected to severe temperature variations. The minimum and maximum values of temperatures noted from appendices C and D of IS: 800-1962. These values are increased by 17 C to permit the radiation due to sun and effects of heat to current in the conductors.

When the symmetry exists in the arrangement of legs of the towers (columns). then the vertical loads are assumed to be distributed equally between them. It is assumed that the struts and diagonals are not stressed by such vertical loads.

The towers are also subjected to wind load. Wind loads are the transverse loads, which are caused by the wind pressure on wires and the structures, and the transverse component of the line tension at angles.

Transverse load due to line angle
Where a line changes direction, the total transverse load on the structure is the sum of the transverse wind load and the transverse component of the wire tension (which may of significant magnitude, specially for large angle structures)
In order to calculate the total transverse load, a wind direction should be used which will give the maximum resultant load considering the effects of on the wires and structures.

Longitudinal loads
may occur on the structure due to accidental events (such as broken conductors, broken insulators, or collapse of an adjacent structure in the line due to an environmental events), such as a to rnade .

Unbalanced Wire condition

The unbalanced wire pull due to broken conductor is adopted as 60 percent of the maximum working tension in the cable in case of supports with suspension cables, when the ground wire is broken then the unbalanced wire pull is taken as 100 percent, or such percent of ground wire tension for which the ground wire clamp is designed. The unbalanced wire pull depend Dynamic analysis is conducted to obtain either a linear (elastic) or a nonlinear (inelastic) structural response. When elastic analysis is conducted, an empirical assessment of in-elastic response is made, since the design philosophy is based on nonlinear behavior of buildings under strong earthquakes. This does not, however, deter engineers from preferring elastic dynamic analysis because of its simplicity and direct correspondence to the design response spectra provided in building codes. The first step in dynamic analysis is to devise a mathematical model of the building, through which estimates of strength, stiffness, mass, and inelastic member properties (if applicable) are assigned. Detailed discussion of mathematical modeling is presented later in the paper in the section titled Mathematical modeling. on the number of cables broken and type of tower.

III. PARAMETRIC STUDY –

Topmost conductor broken condition –

Node	Nodal displacement			Resultant	Load Comb.
	X	Y	Z		
	(MM)	(MM)	(MM)	(MM)	
57	30.866 -30.881	-3.77E+00 3.399	-6.524 6.593	31.771 31.759	9 10
60	30.585 - 30.881	2.692 3.399	6.227 6.593	31.329 31.759	9 10
75	35.837 -35.874	9.802 -11.943	25.712 -27.355	41.792 46.033	9 10
76	21.655	13.743	25.209	35.963	9
	-21.712	-13.237	-26.845	36.1977	10

Mode Shapes :-

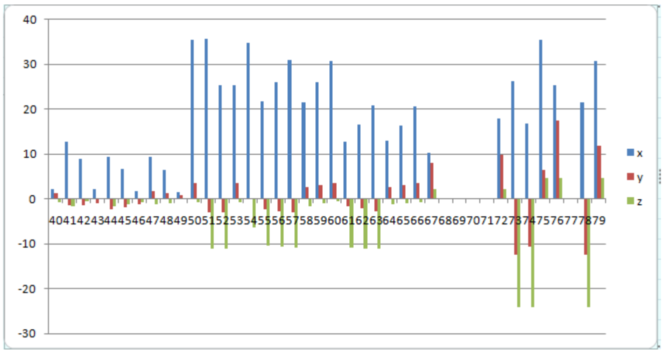
Node	Mode	X	Y	Z
75	1	0.013	0.682	1.000
	2	-0.006	-0.497	-0.700
	3	-0.007	-0.019	-0.026
	4	0.868	0.360	-0.000
	5	-0.370	1.000	0.016
	6	-0.446	-0.991	0.000

IV. PARAMETRIC STUDY –

Ground wire Broken condition-

Node	Nodal displacement			Resultant	Load Comb.
	X	Y	Z		
	(MM)	(MM)	(MM)	(MM)	
57	30.436 -30.572	-4.23E+00 3.87	-2.449 2.553	30.825 30.862	9 10
60	30.079 -30.165	1.254 -1.673	10.242 10.121	31.8 31.862	9 10
75	34.604 -34.707	6.698 -8.743	30.296 -31.838	46.477 47.902	9 10

Node Displacement –
Under Load Combination Case- WL+DL



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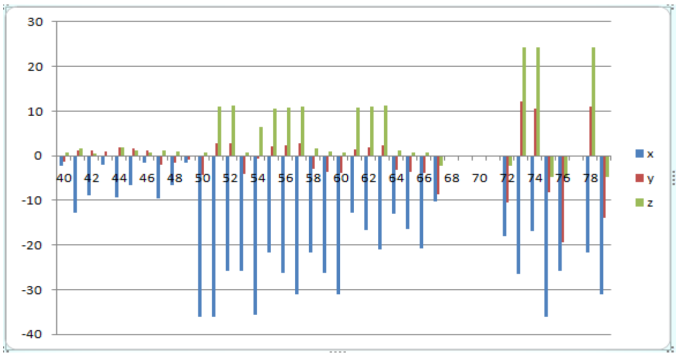
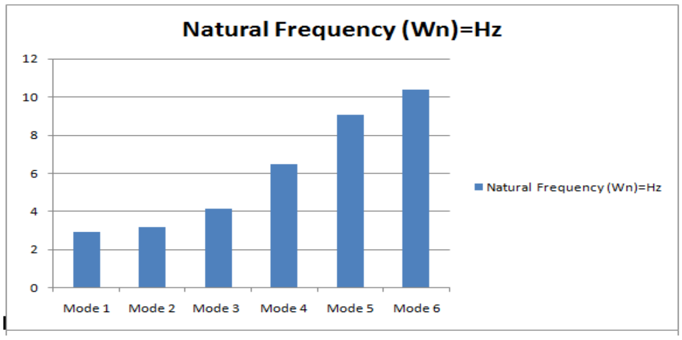
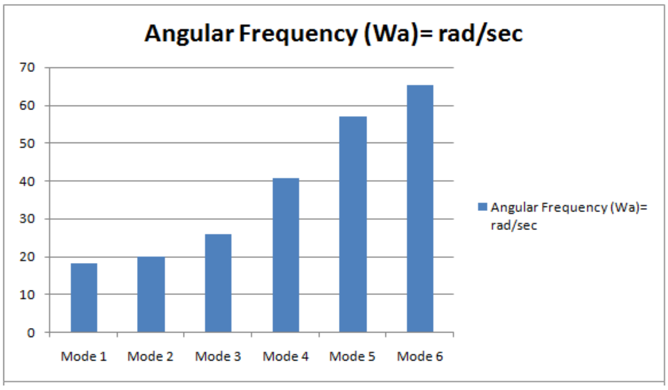
Under Load Combination Case- WL+DL



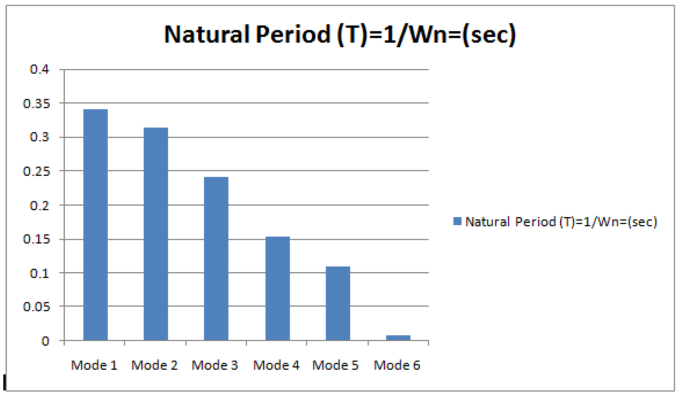
Natural Frequency – (Wn)



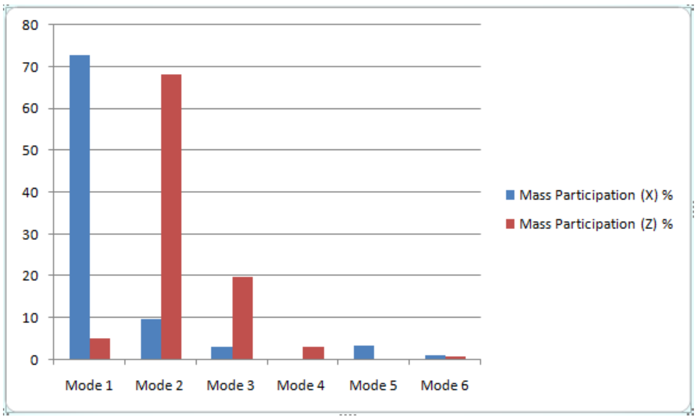
Angular Frequency - (Wa)



Natural Period – (T)



Mass Participation –



In dynamic study, we analysis 6 different natural & angular frequencies of possibilities of different tower failure. Time history include 6 natural periods gives vibration of time (seconds) of each mode. Mass deformations of each tower members are displaced in X,Y,Z %.

Mode Shapes :-

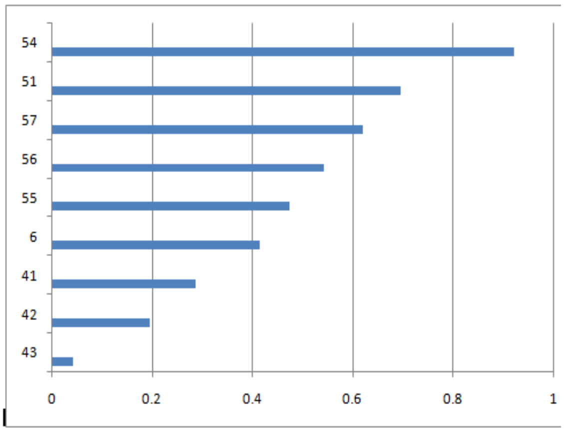
Node	Mode	X	Y	Z
75	1	- 0.005	- 0.054	-0.085
	2	0.000	0.701	1.000
	3	0.000	-0.108	- 0.129
	4	-0.850	-0.927	-0.116
	5	0.152	-0.581	-0.066
	6	0.328	0.732	0.040

When we plot this X,Y,Z co-ordinates, of all the 79 nodes, then we get the mode shapes of tower failures. And hence therefore, we consider the critical nodes & critical mode shape for designing the tower.

V. ANALYSIS & RESULTS –

3 Conductors broken + groundwire broken condition –

Mode Shapes :- 1)Bending Mode -



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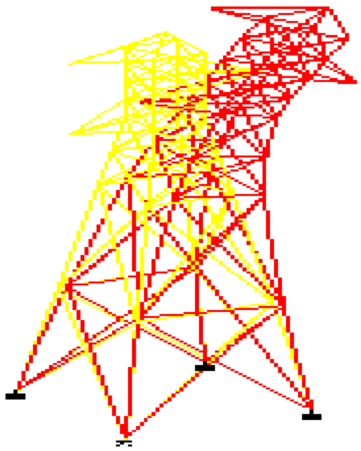
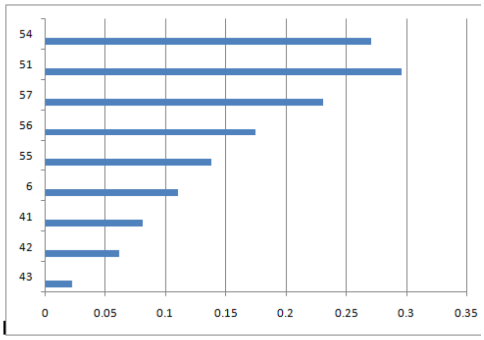
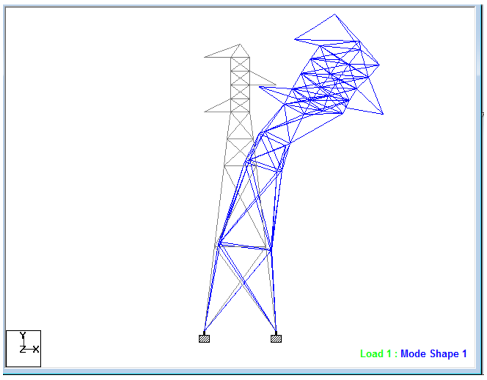
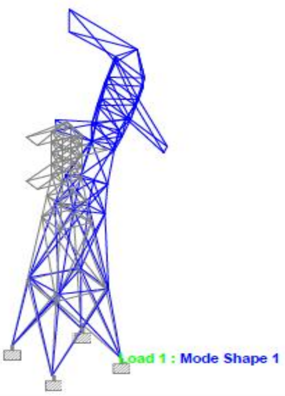


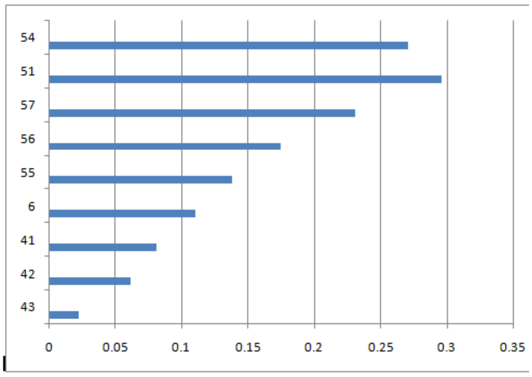
Mode Shape 2) Thickness Stretch Mode –



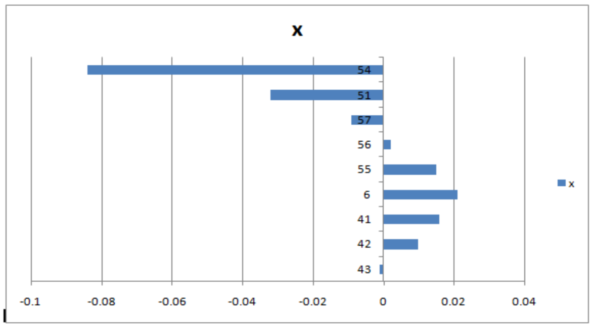


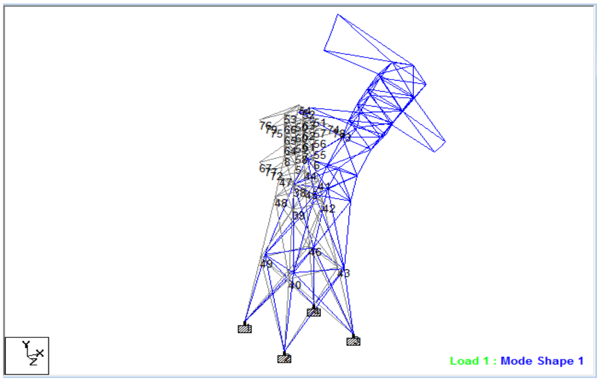
Mode Shape 3) Shear Mode –



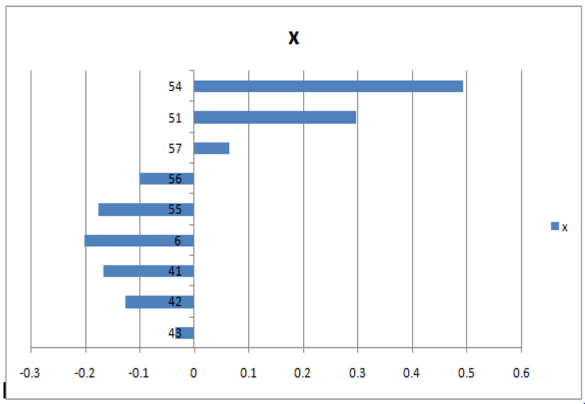


Mode Shape 4)Thickness Twist Mode (-X) -





Mode Shape 5)Thickness Twist Mode (+ X)



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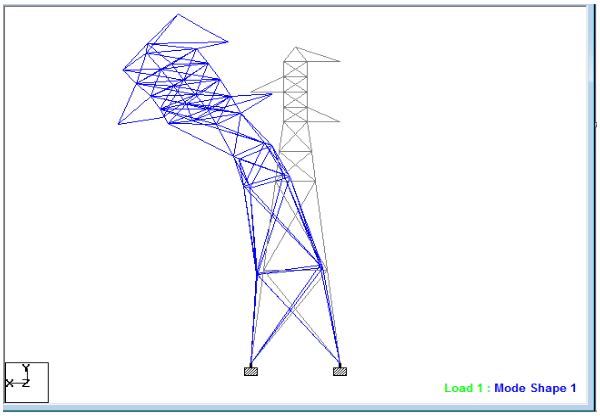
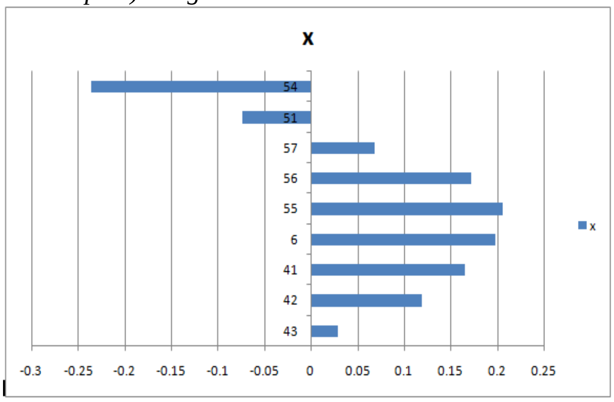
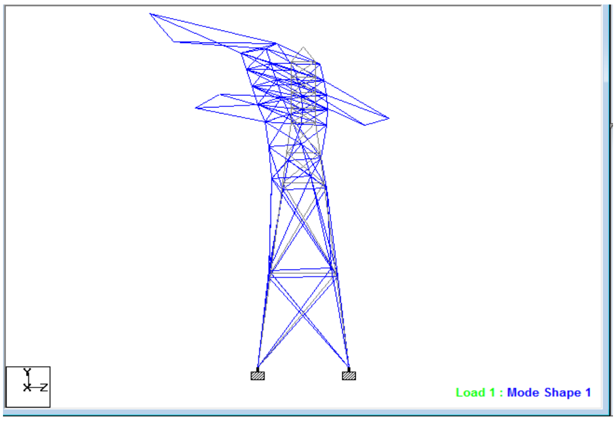


Mode Shape 6) Longitudinal Twist Mode –





Calculated Modal Frequencies & Mass Participations

Mode	Frq. (Hz)	Period (sec)	Parti. X (%)	Parti. Y (%)	Parti.Z (%)	Type
1	1.103	0.907	0.004	0.000	6.902	Elastic
2	1.171	0.854	0.048	0.000	13.265	Elastic
3	1.279	0.782	0.011	0.000	6.573	Elastic
4	2.895	0.345	70.037	0.000	10.342	Elastic
5	3.660	0.273	15.274	0.000	56.323	Elastic
6	6.169	0.162	0.287	0.000	0.160	Elastic

VI.CONCLUSIONS

1. A transmission tower is used to support overhead transmission EHV, UHV, AC440KV power lines railway traction 3 phase ,110KV power lines .

2. When sudden breaking of (snapping) of cables ,a seismic shock is attacked to steel tower to cross arms of tower 17.918KN is considered at cross arms & 25.40 KN is axial tension considered .

3. Hence, tower model is accurately study the dynamic behavior of steel tower (during seismicity).

Find -1.Nodal & Beam displacements.
2. Nodal & Beam Deformations.
3. Natural & Angular frequencies.
4. Natural Periods
5. Mode Shapes .
6. Eigen Vector

4. In present parametric study , the present work is analysed all above dynamic behavior of tower in considering 5 cases -
I. Normal working of tower .
II. Topmost conductor broken.
III. Ground wire broken.
IV. Topmost conductor broken +groundwire broken
V. 3Conductors + groundwire broken condition –

5. In this above cases,

In parametric study, we observe –
Case –IV (Critical Case)

Node	Load comb.	Nodal displacements			Resultant
		X (MM)	Y (MM)	Z (MM)	(MM)
75	9	33.93	13.93	43.82	59.792
	10	34.18	-15.22	-43.72	59.033

6. Observed that – Transmission tower is analyzed at critical Case V - 3Conductor broken + ground wire broken found Maximum resultant Nodal Displacement 59.792 MM.
Hence , To understand complete behavior , tower should be designed for static & dynamic analysis for critical case (V) to withstand seismic shocks.

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