

# Progressive Collapse Analysis of 132kv And 220kv Transmission Tower In Different Wind Zones

Mr. Jangapalle Yogesh Vithalrao<sup>1</sup>, Prof. Dr. V. S. Rajamanya<sup>2</sup>

<sup>1</sup>Dept of Civil Engineering

<sup>2</sup>Professor & HOD, Dept of Civil Engineering

<sup>1,2</sup>M.B.E.S. College of Engineering, Ambajogai– 431517

**Abstract-** Power stations provide a connection between Sources of electricity and User agencies. Tower, Electrical wires, Insulators, and Neutral conductor make up the Transmission System System. High-stress rate loadings, such as explosion or impact, cause the progressive failure of a structure in a short amount of time, with the failure being triggered by the loss of crucial structural components. The purpose of this study is to determine the behaviour of a 132kV double-circuit transmission system in changes in wind zones considering progressive failure scenarios. There will be research done on ten distinct progressive collapse conditions. Alteration in displacement in the X and Z dimensions must be observed. The impact of loading condition on the structure should be investigated in more depth. Need to Evaluate A 132kV Power Lattice Communication Structure's Vulnerability to Various Progressive Collapse Conditions.

**Keywords-** Transmission line tower, Progressive collapse, Local failure, Bracings, Load combination.

## I. INTRODUCTION

Transmission lines serve as connecting link between the sources of Power and User agencies. The Transmission Line System consists of Towers, Conductors, Insulators and Ground wire. The basic function of a transmission tower is to keep the conductors at necessary distance from each other and from the earth. The conductors are hung from the towers with the help of Insulators. Generally, these towers are made up of hot rolled steel angle sections and are assembled in situ.

Power is a primary prerequisite for improving the standard of living of the people. "The growth of India's electricity sector, since the first plan in terms of size and magnitude has been extraordinary by any standards. The total installed capacity of the country which was about 1300 MW in 1947 has now increased to a level of 76,600 MW by the end of March 1994. This represents an increase of over 55 times. The total transmission lines of all categories constructed till April 1994 is around 4 Million Circuit Km as compared to about 29,000 circuit Km in 1950".

Another important development in the field of Transmission towers in India has been the modifications effected in 1995 to the I.S. 802 "code for use of structural steel in overhead Transmission Line Towers". The earlier version of the code used deterministic data for the external loads and took the ever present probability of these being exceeded into account by stipulating permissible stresses and safety factors in design. The deterministic approach in general is based on criteria believed to be conservative enough to attain the required design goal and cannot assess quantitatively the line reliability level. The design criteria in this approach are mostly derived from past experience and simplified analytical and model studies.

### Transmission line tower

- Towers are often subjected to severe conditions, such as wild weather, earthquakes, and even explosions.
- As a result of such extreme external loads, towers could suffer loss of some of their critical structural members and consequent collapse may occur.
- The reasons causing the tower progressive collapse can be due to:

1. Unexpected events
2. Degradation of structural performance due to corrosion of steel members.
3. Improper design or faulty construction methods

### Progressive collapse of structure

- Progressive collapse occurs, when any one of the major structural load carrying members is removed suddenly from a structure due to any unfavorable situation. Such as
- Heavy object impact
- Elevated temperature
- Design or construction errors
- Explosion
- Inadequate connection

### 1.1. Transmission Tower

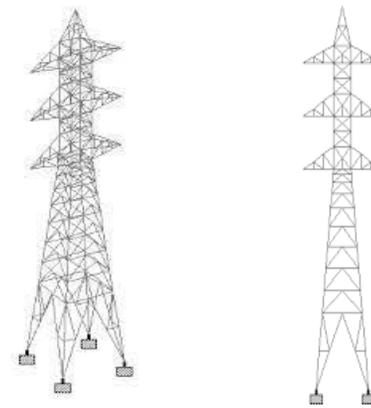
Towers are tall structures having height much more compared to their lateral dimensions. The main purpose of transmission line tower is to support conductors and earth wires. They are space frames or truss made up of steel having foundation under each leg. Transmission line towers constitute about 28 to 42 percent of the cost of the transmission line. The increasing demand for electrical energy can be met more economically by developing different light weight configurations of transmission line towers that is optimization of transmission tower. The selection of an optimum outline together with right type of bracing system, height, cross arm type, configuration and other parameters contributes to a large extent in developing an economical design of transmission line tower. As a goal of every designer are to design the best (optimum) systems. As transmission towers are tall structures, they are more susceptible to wind load compared to earthquake load. Generally, four legged lattice towers are most commonly used as a transmission line towers and three legged towers only used as telecommunication, microwaves, radio and guyed towers but not used in power sectors as a transmission line towers.

A transmission tower (also known as a power transmission tower, power tower, or electricity pylon) is a tall structure (usually a steel lattice tower) used to support an overhead power line. In electrical grids, they are used to carry high voltage transmission lines that transport bulk electric power from generating stations to electrical substations; utility poles are used to support lower-voltage sub-transmission and distribution lines that transport power from substations to electric customers.

A power transmission tower is a key part of a power transmission system. A power transmission tower consists of the following parts:

1. The peak of the transmission tower
2. The cross arm of the transmission tower
3. The boom of transmission tower
4. Cage of transmission tower
5. Transmission Tower Body
6. Leg of transmission tower
7. Stub/Anchor Bolt and Baseplate assembly of the transmission tower.

These parts have been described below. Note that the construction of these towers is not a simple task, and there is a tower erection methodology behind building these high voltage transmission towers.



**Fig 1.2 Transmission Tower**

### 1.2. Progressive Collapse Analysis

Progressive collapse initiated by the loss of critical structural components occurs over a short period of time due to high strain rate loadings such as blast or impact. Since the collapse of Ronan Point apartment building in 1968, progressive collapse has been an important issue in structural design and a significant amount of research has been conducted on progressive collapse response of building structures subjected to extreme loading scenarios. Apart from building structures, the dynamic behavior of the tower structures subject to extreme loading scenarios (e.g. blast loadings) and critical member loss are currently of high interest to structural engineers and researchers. Towers are often subjected to severe conditions, such as wild weather, earthquakes, and even explosions.

As a result of such extreme external loads, towers could suffer loss of some of their critical structural members and consequent collapse may occur. A progressive collapse is typically triggered by a sudden loss of one or more critical structural components. The disproportionate failures are the small initial local failures i.e. if a member is damaged and loses its functional property, the load of this member is redistributed to the remaining adjacent members. If the remaining members could not withstand the load severity, the tower will fail. Thus, the possible mechanisms of collapse are different compared to the buildings. The reasons causing the tower progressive collapse can be due to:

- i. Unexpected events such as collision with earthquake.
- ii. Degradation of structural performance due to corrosion of steel members.
- iii. Improper design or faulty construction methods.

### 1.3. Wind Zones

Wind speed and direction are inputs for calculation of evapotranspiration. Wind speeds are controlled by local pressure anomalies which in turn are influenced by temperature and local topographic features. Wind speed exhibits a wide variation not only from place to place but also during the day. The wind direction may influence evaporation if the surrounding environment has different humidity in different directions. Wind speed and wind direction are measured using anemometer and wind vane, respectively. Observations are made daily or twice daily at standard times at 08:30 and 17:30 hrs. Wind speed measurement may be instantaneous or, if wind run over a time interval is observed, then it is accumulative. Wind direction may influence measured evaporation totals if the surrounding environment in terms of wetness differs in different directions.

#### 1.4. Wind Load Model

The wind flow speeds and the direction changes with time and space. As a dynamical action, the wind load is a key design load for structures, especially for high-rise and super high-rise transmission tower structures. Generally, design wind loads are determined by wind tunnel tests, field measurements, or numerical simulations. Currently, numerical simulation wind is used widely and trusted in civil engineering. Stochastic wind simulation is often divided into two parts, including stationary and nonstationary wind simulation. Both the classical linear filtration method and harmonic superposition method all belong to stationary stochastic simulation method. The nonstationary stochastic wind simulation also can be realized by autoregressive method (AR), empirical mode decomposition method (EMD), spectral representation method (SR), Spline-interpolation-based FFT approach (SFFT), and so on. Considering transmission tower structural geometric nonlinearities, explicit finite element dynamics analysis, and simplification wind load, the turbulent wind is assumed zero-mean stationary stochastic process in this paper. Furthermore, the Kaimal fluctuating wind power spectrum and harmonic superposition method are employed by MATLAB.

1. Wind General Conditions
2. Harmony Superposition Method
3. Cross-Power Spectrum

#### 1.5. Scope of the study

1. Study was conducted for three different bracings of transmission tower [K-bracing, X- bracing, (K-X) bracing].
2. Study was conducted for six progressive collapse conditions.

3. Three different types of bracings are considered for the study. They are K-bracing, X-bracing and (K-X)-bracing.

#### 1.6. Objectives

Following are the objectives of future work:

- Main Objective of This Study Is to Know the Behaviour of 132kv Double Circuit Transmission Tower in Different Wind Zones Under Progressive Collapse Conditions.
- Study Will Be Conducted for 10 Different Progressive Collapse Condition.
- To Evaluate the Progressive Collapse Vulnerability of a Lattice Tower in A 132kv Power Transmission Line.
- Displacement Variation in X as Well as in Z Direction Should Be Need to Observe.
- Effect of Wind Load On the Tower Should Be Studied in More Details.
- Need to Evaluate Susceptibility of A 132kv Power Lattice Transmission Structure to Different Progressive Collapse Conditions.

## II. LITERATURE REVIEW

### ARASH NAJI ET.AL. “PROGRESSIVE COLLAPSE ANALYSIS OF STEEL BRACED FRAMES” (2019)

This paper studies the behavior of concentrically braced frames (CBFs) and eccentrically braced frames (EBFs) under a progressive collapse scenario, by using the alternate load path method, recommended in progressive collapse guidelines. The model structure is a 10-story steel moment frame with five bays in each direction. The present study has investigated the CBF with two types of failure scenarios, each of which examines the effects of reducing the brace's sections, and the EBF, including three types of failure scenarios, each of which investigates the effects of link beam length on structural capacity. Failure scenarios include the sudden removal of a column with one or more adjacent braces on the ground floor, which, for simplicity, is examined in a two-dimensional form in a perimeter bay of the building. The ability of the structure to absorb and withstand extra load after the sudden removal of the members in each of the states is examined, and their capacity and ductility are compared. According to the results, both EBF and CBF systems can withstand the progressive collapse. Moreover, in the CBF system, while the cross sections of braces decrease, the ductility of the CBF structure increases.

### CHIRANJIT BHOWMIK ET.AL. “ANALYTICAL AND EXPERIMENTAL MODAL ANALYSIS OF ELECTRICAL TRANSMISSION TOWER TO STUDY

## **THE DYNAMIC CHARACTERISTICS AND BEHAVIORS” (2020)**

Experimental modal analysis of electrical transmission tower has been a challenging task for transmission tower researchers and design engineers in industry all over the world. Requirement of large numbers of sensors and accelerometers have been major constrain. In this study an innovative approach has been developed to investigate the dynamic characteristics and behavior of tower structure through analytical and experimental modal analysis. Firstly, a scale down (1:15) prototype model of transmission tower structure has been constructed with mild steel straps, joint together by welding, for modal testing. Modal hammer test has been conducted on the prototype tower model for extracting modal parameters; modal frequency, modal damping and modes, of the tower model which representing the actual tower structure. Secondly, the transmission tower structure has been modeled in standard finite element tools and analyzed analytically for natural frequencies. The first six natural frequencies and corresponding mode shapes have been determined analytically and first six natural frequencies have also been determined experimentally and compared with each other. The first six natural frequencies are determined analytically; the frequency range of 2–9 Hz has been found. The analytical and experimental modal analysis of transmission tower structure has been found to be in correlation with some differences. The maximum natural frequencies percentage difference 11.1% has been found; between the scale down model and the stand software model. Additionally, the tower structure has been modified and optimized to improve the stiffness of the diaphragm as per specification and practical limitations. The first order natural frequency of the modified tower has been reduced to 2.171 Hz from the 2.1773 Hz

## **SUYASH MALVIYA ET.AL. “DETERMINATION OF OPTIMUM LOCATION OF ROOFTOP TELECOMMUNICATION TOWER OVER MULTISTORY BUILDING UNDER SEISMIC LOADING” (2019)**

In the last ten years, the growing trend of telecommunication towers has seen a demanding growth. There have been many competitors among operators that have to enhance network reliability and coverage area. The location of tower is very important because it uses latitudes and longitudes with the specified height of mounted antenna which focus towards the practical necessities of the network. In urban areas, it seems that there is scarcity of land and there is no substitute but to implement roof top towers which satisfies ideal installation conditions with respect to its position and

height so that spectrum covers the large area. In this work, the results are obtained in terms of the multistoried building situated in seismic Zone-IV. Staad Pro program is used on the structure which is experiencing seismic forces with telecommunication tower positioned at 5 different placing with respect to square base of tower and optimum location of tower over roof.

## **KAPADIA FATEMA ET.AL. “OPTIMIZATION OF POWER TRANSMISSION TOWER” – A CRITICAL REVIEW” (2015)**

In this paper, an attempt has been made to study the possibilities to make the transmission line more cost effective by changing the bracings, configuration and type of transmission line structure for optimizing the weight of transmission tower. Due to the increasing demand of electrical energy, the tower should be made economical by developing different light weight structures. The present literature study has been carried out for optimizing the geometry for different sections; type of bracings, different configurations and for different supply of voltage and necessary conclusions for optimizing the geometry has been drawn out.

## **SANDEEP T D “PARAMETRIC STUDIES ON TRANSMISSION LINE TOWER DUE TO DYNAMIC LOADING” (2017)**

India has a large population residing all over the country and the electricity need of this population creates requirements of large transmission and distribution system. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one system for each category of support structure. Structural system of transmission line represents a significant portion of the cost of the line and they play an important role in the reliable power transmission. This thesis is concerned with the performance of three types of transmission line towers with varying heights under seismic and wind induced dynamic loads. Wind loads are considered as per IS 802(part1/sec1):1995, IS 875(part3):1987 and seismic load as per IS 1893(part1):2002. The finite element analyses of transmission line tower involve modal analysis, equivalent static, response spectrum, time history and wind analysis with gust factor. The results obtained from the analyses are compared and the conclusions are drawn.

## **SHAIK ESUB SALAAM ET.AL. “FAILURE ANALYSIS OF TRANSMISSION LINE TOWER SUBJECTED TO COMBINED WIND AND DUST LOADS” (2021)**

Towers play a vital role in the transmission line (TL) system. The main objective of the present study is to analyses

the failure of towers subjected to dust storms. This study, analyses the failure of a 765 kV single circuit delta-type horizontal configuration tower in the river delta region near Agra. TL towers are designed based on IS 802 Part 1/Sec 1 and 2 standards. Dust particles of soil may be lighter individually, but have definite density. The wind carrying dust particles may increase the wind pressure on the tower line system. The increased wind pressure significantly affects the sag and tension of ground wire and conductor and results in additional loads on the tower, thus causing failure. It also increases wind load on the tower body and insulator string. There is literature related to numerical and wind tunnel studies on the combined effect of wind and rain loads, but no information is available on the wind and dust loads at present. The density variation method is used in the present study for calculation of additional wind pressure due to dust particles during storms. A relation between density of air mix, volume fraction of dust and density of dust particles is considered. Using FEM software, the tower is analyzed for existing design loads and verified for its strength adequacy. The tower stability is studied by analyzing for additional loads considering the presence of dust particles in the wind for three different volume fractions of 0.01%/m<sup>3</sup>, 0.02%/m<sup>3</sup> and 0.03%/m<sup>3</sup>. The wind pressure increases by about 10% for an increase of every 0.01% of dust particles in the wind. The tension in the conductor and ground wire increases by 8%. The existing tower design is inadequate to withstand the additional forces from wind storms associated even with a small fraction of dust particles and may be the reason for the failure of towers in northern India during a particular period of the year.

### III. METHODOLOGY

This chapter deals with the model specifications, element loss scenarios, modelling of the cable transmission line tower, nonlinear static how they were performed. The loads acting on the structure are calculated in three directions: vertical, transverse, and longitudinal. The transverse loads are perpendicular to the line, caused due to component force of tension in wire due to angle of deviation of tower line and the longitudinal loads act parallel to the line which generally occurs when a wire breaks. The towers are modelled in Staad. Pro. The towers are separated into panels consisting of various members and trial sections for analysis are assigned.

#### 3.1 Loading Considered for the 132KV Transmission line tower

Apart from the dead load of the conductors are considered based on IS 802part –I, part-II. Apart from the wind load of the conductors are considered based on IS 875 part-III

Transmission towers of 132kV shall be of the self-supporting type in single or double circuit configuration as specified in Tables (1) and (2) (MOE, 2006), depending on the deviation angle of the conductor. The common types are 1S2 or 2S2 tower with suspension insulator sets normally used subject to the sum of adjacent span limitation

#### 3.2 Geometrical Configuration of the Transmission Line Tower

Following are the geometrical parameters of transmission line tower. The 200Kv Transmission line tower geometric details are manually calculated and wind analysis is done in both Staad-Pro & Etabs comparison of defection values by both Staad- pro is done.

##### a. General service authority (gsa-2003)

- General Service authority (gsa-2003) again revised in 2013.
- “Progressive collapse analysis and design guidelines for new federal office buildings and major modernization projects”
- Alternate path method the alternate path method is used to satisfy the progressive collapse requirements of this document for the removal of specific vertical load-bearing elements that are prescribed in gsa guidelines.

##### b. Analysis in staad pro v8 software

- Transmission tower structure will have been modelled, designed as per is 802:1995 and is 5613 part 2 and cpib manual “268”.
- To study the progressive collapse conditions i will model a tower structure using staad programme.
- Analysis will be done on the modelled tower structure.
- To compare the results of various parameters of analysis.
- To evaluate the vulnerability of structure in different progressive collapse conditions.

#### Type of Load

The loads acting on a transmission tower are (ASCE 10-97(2000):

- a. Dead load of tower (self-weight).
- b. Dead load from conductors and other equipment.
- c. Load from ice, rime or wet snow on conductors and equipment.
- d. Ice load on the tower itself.
- e. Erection and maintenance loads.

- f. Wind load on the tower.
- g. Wind load on conductors and equipment.
- h. Loads from conductor tensile forces.
- i. Damage forces.
- j. Earthquake forces.

**3.3 Earthquake Tower Design**

Earthquakes are natural phenomena which cause the ground to shake violently; thereby triggering landslides, creating floods, causing the ground to heave and crack and causing large-scale destruction to life and property. In particular, the effect of earthquakes on structures and the design of structures to withstand earthquakes with no or minimum damage form the subject of earthquake resistant structural design. The important factors which influence earthquake resistant design are: the geographical location of the structure, the site’s soil and foundation conditions, the importance of the structure as well as the dynamic characteristics of the structure such as the natural periods and the properties of the structure, like: strength, stiffness, ductility and energy dissipation capacity.

**3.4 Seismic Coefficient Method**

This is the simplest of the available methods and is applicable to structures which are simple, symmetric and regular. In this method, the seismic load is idealized as a system of equivalent static loads, which is applied to the structure, and an elastic analysis is performed to ensure that the stresses are within allowable limits. The sum of the equivalent static loads is proportional to the total weight of the structure and the constant of proportionality, known as the seismic coefficient, is taken as the product of various factors which influence the design and are specified in the codes.

**IV. MODELING AND ANALYSIS**

Configuration of the tower.

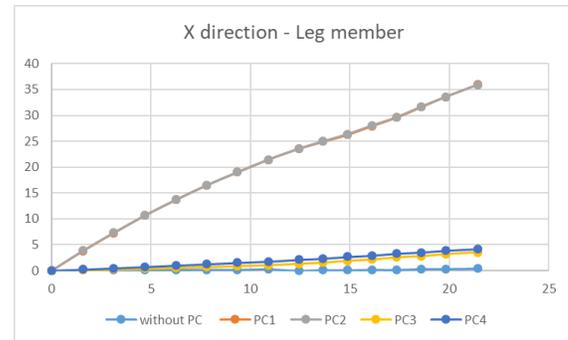
The towers lie in wind zones III, IV and V

I)Material Data			
Material		Still	
Height		30m	
Panel	Height	Tower	Membrane
1-4	Up to 12m	Leg Membrane	ISA150X150X15
		Horizontal Membrane	ISA100X100X12
		Bracing Membrane	ISA80X80X10

5-8	12m–21m	Leg Membrane	ISA120X120X12
		Horizontal Membrane	ISA90X90X12
		Bracing Membrane	ISA70X70X10

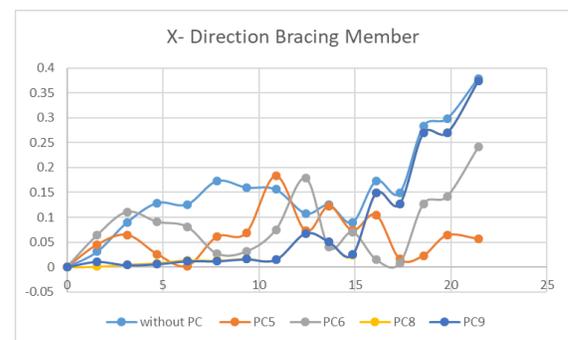
**V. RESULTS AND DISCUSSION**

**1. Progressive Collapse Zone 2 Condition (X- Direction)**



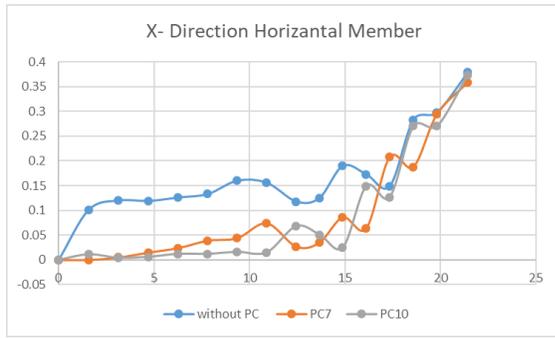
**Graph.1 X- Direction Leg Member**

Above graph shows displacement in x direction for leg member in zone 2. different conditions of leg member are considered. Progressive collapse condition 2 has the higher displacement than the other leg conditions.



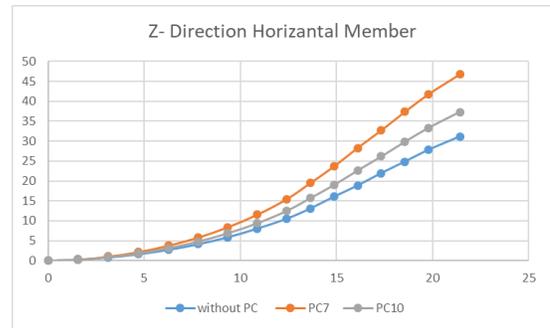
**Graph.2 X- Direction Bracing Member**

Above graph shows displacement in x direction for Bracing member in zone 2. different conditions of Bracing member are considered. Progressive collapse condition 9 has the higher displacement than the other Bracing conditions.



**Graph.3 X- Direction Horizontal Member**

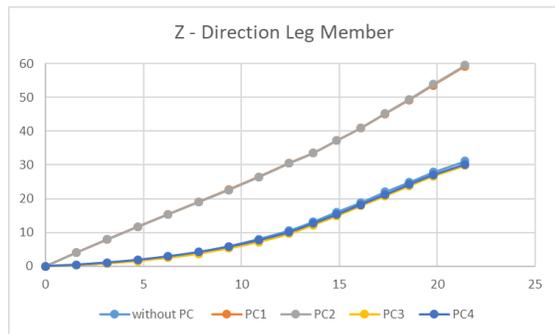
Above graph shows displacement in x direction for Horizontal member in zone 2. different conditions of Horizontal member are considered. Progressive collapse condition 10 has the higher displacement than the other Horizontal conditions.



**Graph.6 Z- Direction Horizontal Member**

Above graph shows displacement in z direction for Horizontal member in zone 2. different conditions of Horizontal member are considered. Progressive collapse condition 10 has the higher displacement than the other Horizontal conditions.

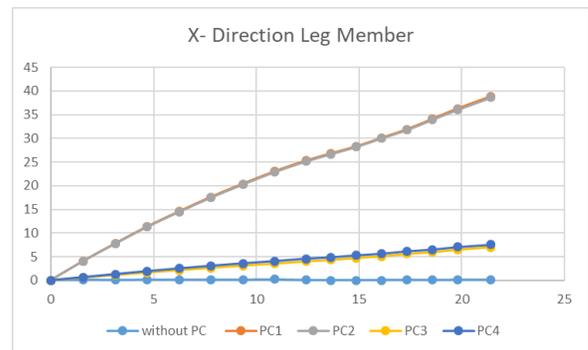
**2. Progressive Collapse Zone 2 Condition (Z- Direction)**



**Graph.4Z- Direction Leg Member**

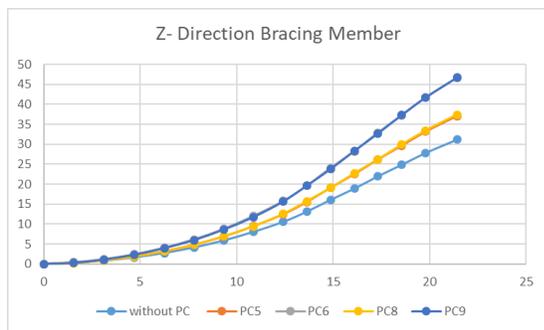
Above graph shows displacement in z direction for leg member in zone 2. different conditions of leg member are considered. Progressive collapse condition 2 has the higher displacement than the other leg conditions.

**3. Progressive Collapse Zone 3 Condition (X- Direction)**



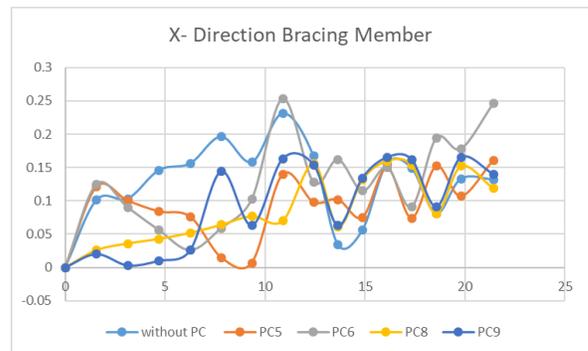
**Graph.7 X- Direction Leg Member**

Above graph shows displacement in x direction for leg member in zone 3. different conditions of leg member are considered. Progressive collapse condition 1 has the higher displacement than the other leg conditions.



**Graph.5 Z- Direction Bracing Member**

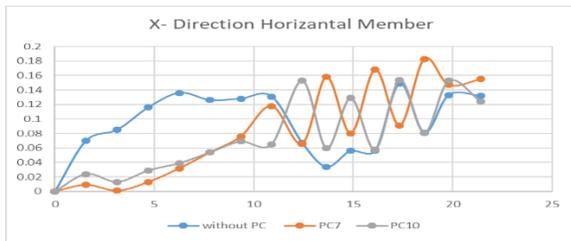
Above graph shows displacement in z direction for Bracing member in zone 2. different conditions of Bracing member are considered. Progressive collapse condition 9 has the higher displacement than the other Bracing conditions.



**Graph.8 X- Direction Bracing Member**

Above graph shows displacement in x direction for Bracing member in zone 3. different conditions of Bracing member are considered. Progressive collapse condition 9 has the higher displacement than the other Bracing conditions.

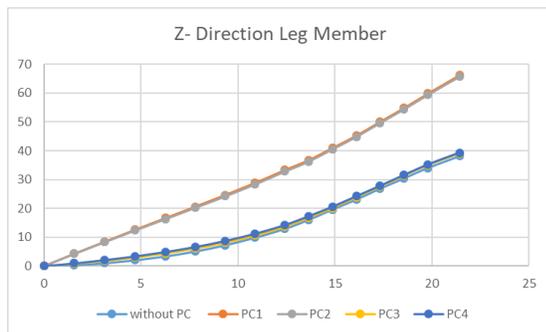
member are considered. Progressive collapse condition 6 has the higher displacement than the other Bracing conditions.



**Graph.9 X- Direction Horizontal Member**

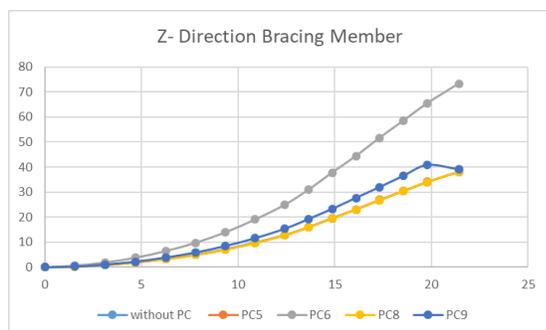
Above graph shows displacement in x direction for Horizontal member in zone 3. different conditions of Horizontal member are considered. Progressive collapse condition 10 has the higher displacement than the other Horizontal conditions.

**4. Progressive Collapse Zone 3 Condition (Z- Direction)**



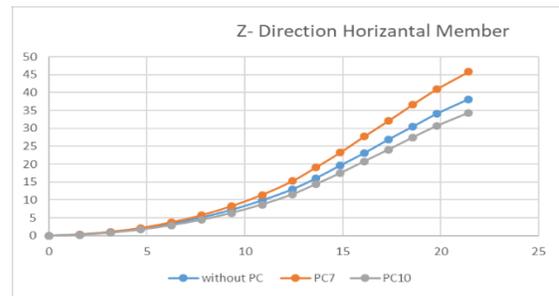
**Graph.10 Z- Direction Leg Member**

Above graph shows displacement in z direction for leg member in zone 3. different conditions of leg member are considered. Progressive collapse condition 1 has the higher displacement than the other leg conditions.



**Graph.11 Z- Direction Bracing Member**

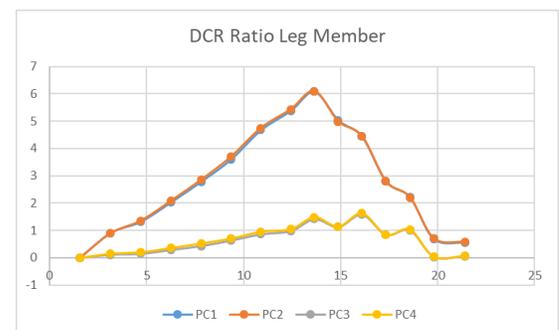
Above graph shows displacement in z direction for Bracing member in zone 3. different conditions of Bracing member are considered. Progressive collapse condition 6 has the higher displacement than the other Bracing conditions.



**Graph.12 Z- Direction Horizontal Member**

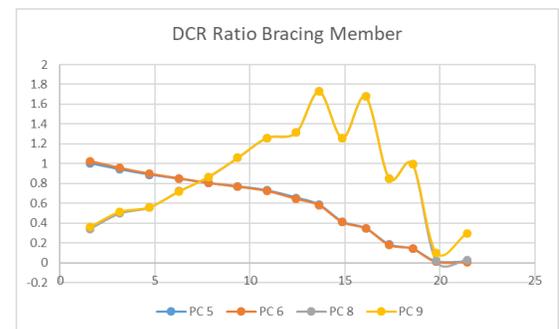
Above graph shows displacement in z direction for Horizontal member in zone 3. different conditions of Horizontal member are considered. Progressive collapse condition 7 has the higher displacement than the other Horizontal conditions.

**5. Progressive Collapse Zone 2 Condition DCR Ratio**



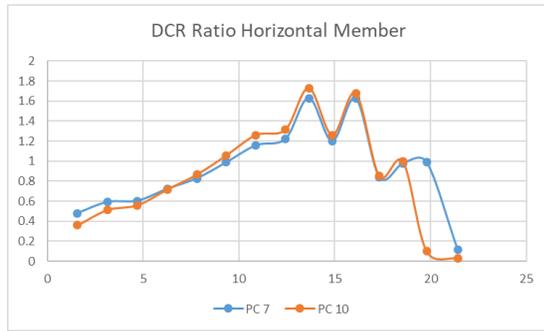
**Graph.13 DCR Ratio Leg Membrane**

Above graph shows DCR in leg member in zone 2. different conditions of leg member are considered. Progressive collapse condition 2 has the higher DCR Ratio than the other leg conditions.



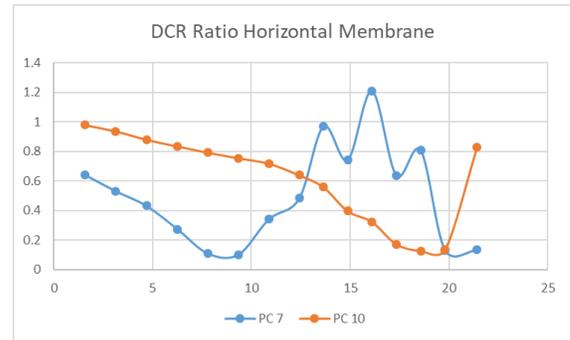
**Graph.14 DCR Bracing Membrane**

Above graph shows DCR in Bracing member in zone 2. different conditions of Bracing member are considered. Progressive collapse condition 6 has the higher DCR Ratio than the other Bracing conditions.



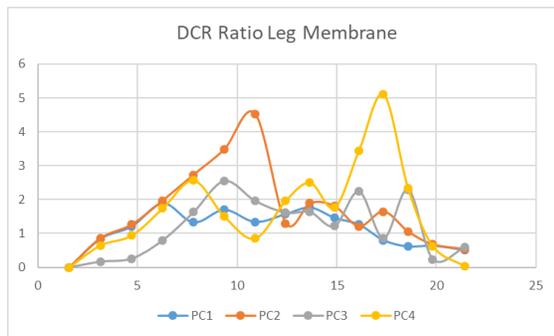
**Graph.15 DCR Ratio Horizontal Membrane**

Above graph shows DCR in x direction for Horizontal member in zone 2. different conditions of Horizontal member are considered. Progressive collapse condition 7 has the higher DCR Ratio than the other Horizontal conditions.



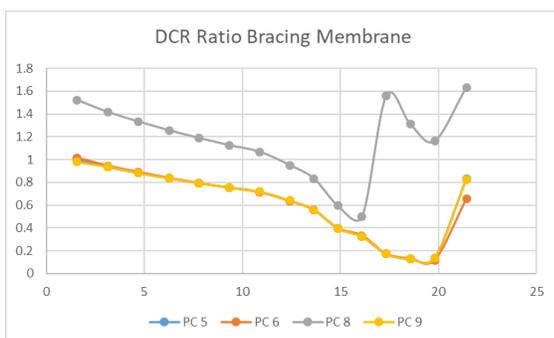
**Graph.18 DCR Ratio Horizontal Membrane**

Above graph shows DCR in x direction for Horizontal member in zone 3. different conditions of Horizontal member are considered. Progressive collapse condition 10 has the higher DCR Ratio than the other Horizontal conditions.



**Graph.16 DCR Ratio Leg Membrane**

Above graph shows DCR in leg member in zone 3. different conditions of leg member are considered. Progressive collapse condition 3 has the higher DCR Ratio than the other leg conditions.



**Graph.17 DCR Bracing Membrane**

Above graph shows DCR in Bracing member in zone 3. different conditions of Bracing member are considered. Progressive collapse condition 8 has the higher DCR Ratio than the other Bracing conditions.

**VI. CONCLUSION**

1. Displacement in x direction for leg member in zone 2. different conditions of leg member are considered. Progressive collapse condition 2 has the higher displacement than the other leg conditions.
2. displacement in x direction for Bracing member in zone 2. different conditions of Bracing member are considered. Progressive collapse condition 9 has the higher displacement than the other Bracing conditions.
3. Displacement in z direction for leg member in zone 2. different conditions of leg member are considered. Progressive collapse condition 2 has the higher displacement than the other leg conditions.
4. Displacement in z direction for Horizontal member in zone 2. different conditions of Horizontal member are considered. Progressive collapse condition 10 has the higher displacement than the other Horizontal conditions.
5. Displacement in x direction for Bracing member in zone 3. different conditions of Bracing member are considered. Progressive collapse condition 6 has the higher displacement than the other Bracing conditions.
6. DCR in leg member in zone 2. different conditions of leg member are considered. Progressive collapse condition 2 has the higher DCR Ratio than the other leg conditions.
7. DCR in Bracing member in zone 2. different conditions of Bracing member are considered. Progressive collapse condition 6 has the higher DCR Ratio than the other Bracing conditions.
8. DCR in Bracing member in zone 3. different conditions of Bracing member are considered. Progressive collapse condition 8 has the higher DCR Ratio than the other Bracing conditions.

9. DCR in x direction for Horizontal member in zone 3. different conditions of Horizontal member are considered. Progressive collapse condition 10 has the higher DCR Ratio than the other Horizontal conditions.

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