PUNE RESEARCH SCHOLAR ISSN 2455-314X
AN INTERNATIONAL MULTIDISCIPLINARY JOURNAL VOL 8, ISSUE 5

COMPARATIVE STUDY OF TRANSMISSION LINE TOWER WITH DIFFERENTBRACING PATTERNS USING RESPONSE SPECTRUM AND PUSHOVER ANALYSIS

RAJSHRI RAJENDRA LOKHANDE#[1], DR. V. R. RATHI#[2]

[#1]ME Student, Civil Engineering Department, Savitribai Phule Pune University, Pune

[#2]Professor, Civil Engineering Department, Savitribai Phule Pune University,Pune

Abstract— Electricity consumption is day by day increasing for each and every application. A transmission tower also known as an electricity pylon is a tall structure used to support an overhead power line. Transmission line towers constitute about 28 to 42 percent of the total cost of the transmission line. The main objective of this study is to determine the most economical section of tower and its configuration as per Indian Standard IS-802. In this project the study is carried on transmission line tower in SAP2000 software. There is comparative study of analysis of transmission line tower with different bracing patterns and study their progressive collapse behavior of transmission line tower using response spectrum and time history method. A standard kind of transmission line tower is selected as case examine is analyzed and modeled by using SAP2000 software. The present work describes the analysis and design of four legged self-supporting 220 KV double circuit power. The transmission tower has a height of 40 m and square base width of 11.5 m. Steel optimization has been carry out to find the most suitable and economical section for the design. Loads acting on the tower are wind load, dead load and earthquake load of the structure as per IS 1893: 2016. All the considered towers will be analyzed for gravity and lateral loads (IS: 875 (part-III)). The comparative study is presented with respective to base shear, self-weight, modal time period and weight of tower. From overall analysis, it is concluded that from stability point of view double bracing tower gives more strength and more efficient. From economical point of view from single and knee bracing transmission tower, knee bracing shows good performance as compared to single bracing.

Keywords: *Transmission Line Tower, Response Spectrum, time history Earthquake Loading, Loading, Wind Loading.*

1. INTRODUCTION

General Introduction

A steel transmission line tower is also known as steel pylon which acts a supporting unit for the overhead transmission lines that usually distributes electricity supply for the people all over country. The selection of an optimum outline together with right type of bracing system, height, cross arm type and other parameters contributes to a large extent in developing an economical design of transmission line tower.

Transmission tower lines are one of most important life-line structures. Transmission towers are necessary forthe purpose of supplying electricity to various regions of the nation .This has led to the increase in the building of power stations and consequent increase in power transmission lines from the generating stations to the different corners where it is needed. Transmission line should be stable and carefully designed so that theydo not fail during natural disaster.Transmission tower are modeled by using different bracing patterns. Axial forces, deflections and weight of tower vary with bracing pattern. Certain bracing pattern reduces weight of tower. The major components of a transmission line consist of the conductors, ground wires, insulation,towers and foundations. Most of the time transmission lines are designed for wind in the transverse direction.

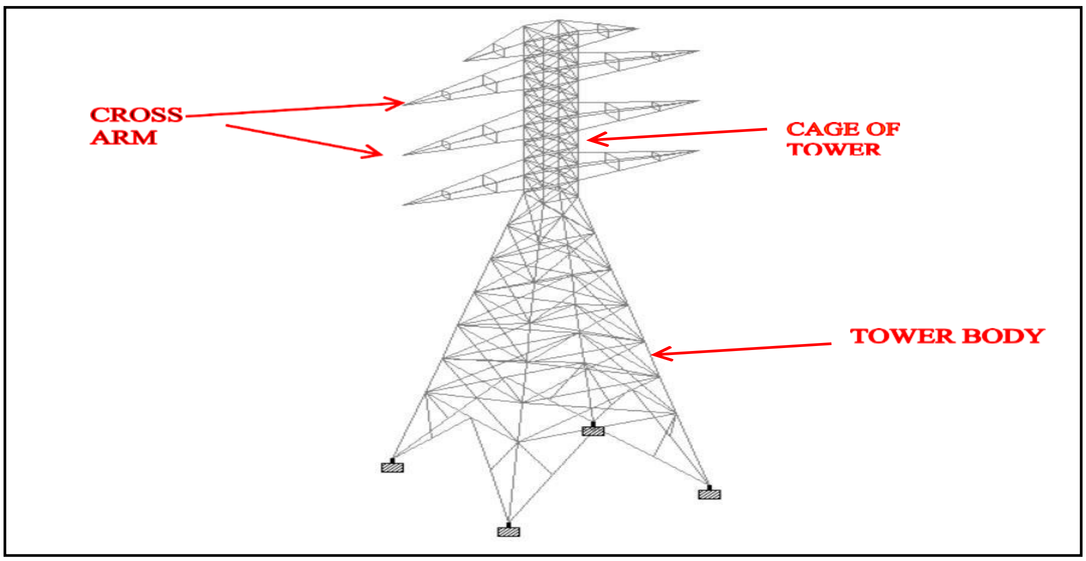


Fig.- 1 Transmission line Tower

2. RESEARCH METHODOLOGY

Response spectrum method

This method is applicable for those structures where modes apart from the elemental one affect significantly the response of the structure. during this method the response of multi degree of freedom system is expressed because the superposition of modal response, each modal response being determined from the spectral analysis of single degree of freedom system, which is then combined to match the entire response. Modal analysis of the response history of structure to specified ground motion; however, the strategy is sometimes utilized in conjunction with a response spectrum

Time history analysis

It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear. It is a step by step analysis of the dynamic response of a structure to a specified loading that may vary with time. To perform such an analysis, a representative earthquake time history is required for a structure being evaluated. Time history analysis is a step-by step analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine theseismic response of a structure under dynamic loading of representative earthquake.

Seismic Base Shear

According to IS 1893 (Part-I): 2002, Clause 7.5.3 the total design lateral force or design seismic base shear(VB) along any principal direction is determined by

$Vb = Ah * W$

Where,

Ah is the design horizontal acceleration spectrumW is the seismic weight of building

Design Horizontal seismic coefficient

For the purpose of determining the design seismic forces, the country (India) is classified into four seismic zones (II, III, IV, and V). Previously, there were five zones, of which Zone I and II are merged into Zone II in fifth revision of code. According to IS 1893: 2016 (Part 1), Clause6.4.2 Design Horizontal Seismic Forces Coefficient Ah for a structure shall be determined by following expression

3. PROBLEM FORMULATION

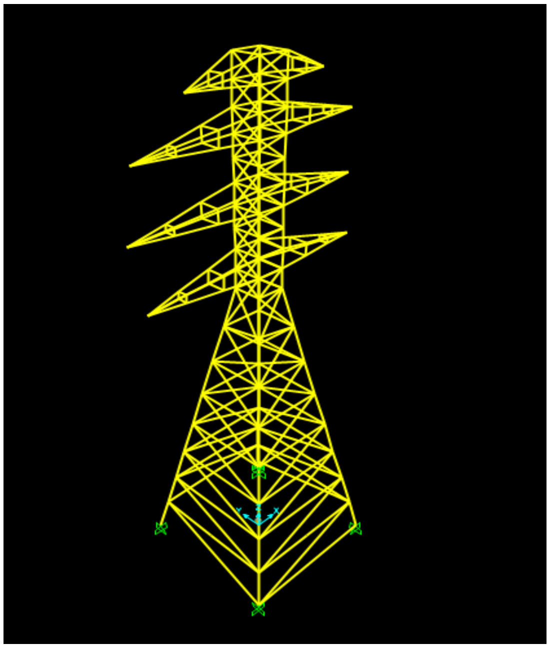
In this title of parametric investigation, a detailed study of analysis of transmission line tower using IS codes has been presented

Table No I: Detail Features of tower

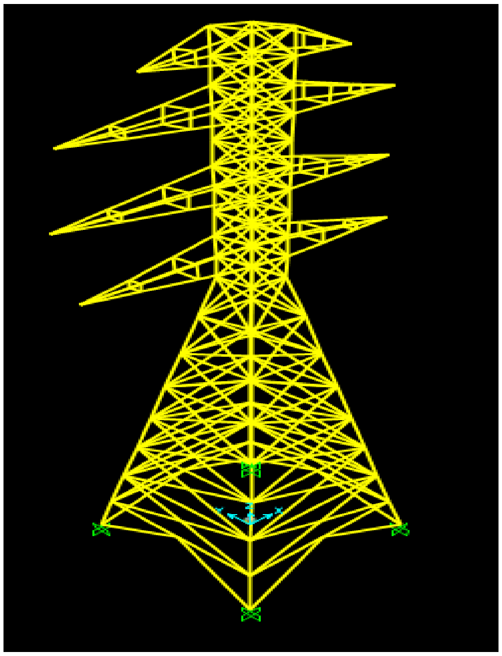
Sr .No	Parameters	Values
1	Material Used	Steel Grade Fe-250
2	Plan Dimension	11.5m *11.5 m
3	Total height of tower	40m
4	Unit weight Of steel	78.50 KN/m3
5	Poisson Ratio	0.2-Concrete And 0.15-Steel
6	Code Of Practice Adopted	IS800:2007 , IS1893:2002 IS875-part –III
7	Seismic Zone For IS1893:2002	IV
8	Importance Factor	1
9	Response Reduction Factor	5
10	Foundation Soil	Medium
11	Earthquake Load	As Per IS 1893-2016
12	Size Of section	ISA 90x90x10, ISA 65x65x8, ISA 55x55x8
13	Ductility Class	IS1893:2002 SMRF

PUNE RESEARCH SCHOLAR ISSN 2455-314X
AN INTERNATIONAL MULTIDISCIPLINARY JOURNAL VOL 8, ISSUE 5

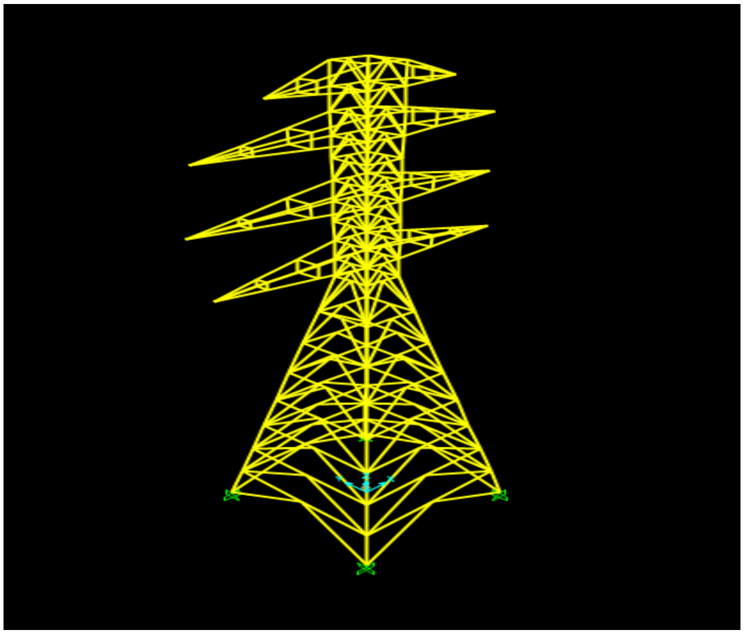
Transmission Line Tower Single Bracing:



Transmission Line Tower Double bracing



Transmission line tower knee bracing



PUNE RESEARCH SCHOLAR ISSN 2455-314X
AN INTERNATIONAL MULTIDISCIPLINARY JOURNAL VOL 8, ISSUE 5

4. RESULTS

4.1. Base shear Results -

A. Response Spectrum Method results

Table 4.1 single bracing transmission tower

Type of load	A_h	Weight KN	Base Shear KN
EQ+X	0.026057	1060.072	27.623
EQ-X	0.026057	1060.072	27.623
EQ+Z	0.028759	1060.072	30.487
EQ-Z	0.028759	1060.072	30.487

Table 4.2 Double bracing transmission tower

Type of load	A_h	Weight KN	Base Shear KN
EQ+X	0.026057	1060.072	27.623
EQ-X	0.026057	1060.072	27.623
EQ+Z	0.028759	1060.072	30.487
EQ-Z	0.028759	1060.072	30.487

B. Time History Method

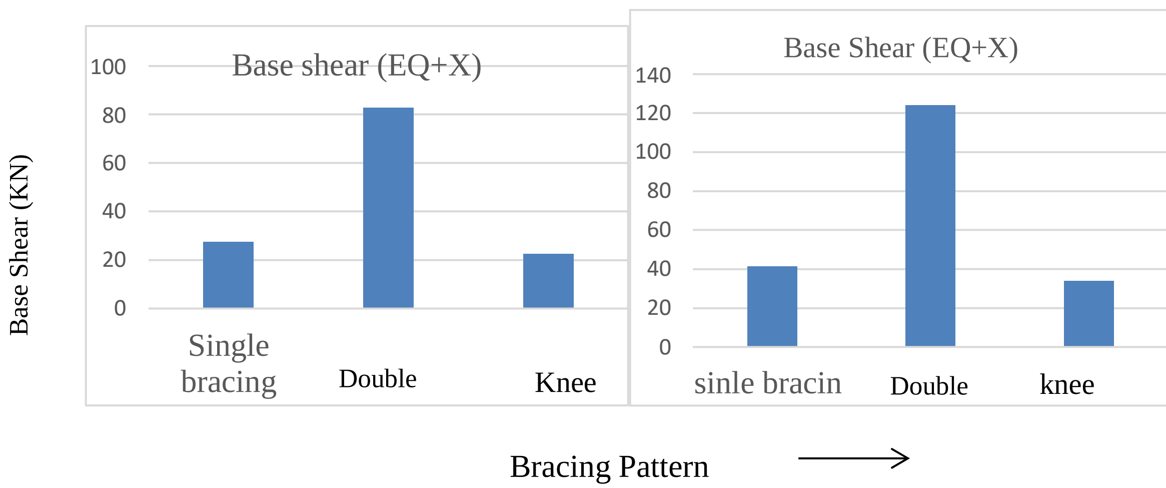
Type of load	A_h	Weight KN	Base Shear KN
EQ+X	0.039086	1060.072	41.434
EQ-X	0.039086	1060.072	41.434
EQ+Z	0.043139	1060.072	45.731
EQ-Z	0.043139	1060.072	45.731

Type of load	A_h	Weight KN	Base Shear KN
EQ+X	0.09	1379.958	124.196
EQ-X	0.09	1379.958	124.196
EQ+Z	0.09	1379.958	124.196
EQ-Z	0.09	1379.958	124.196

Table 4.3 Knee bracing transmission tower

Type of load	A_h	Weight KN	Base Shear KN
EQ+X	0.026364	858.801	22.641
EQ-X	0.026364	858.801	22.641
EQ+Z	0.026868	858.801	23.074
EQ-Z	0.026868	858.801	23.074

Type of load	A_h	Weight KN	Base Shear KN
EQ+X	0.039545	858.801	33.962
EQ-X	0.039545	858.801	33.962
EQ+Z	0.040302	858.801	34.611
EQ-Z	0.040302	858.801	34.611



Graph 4.1 base shear vs. bracing (single, double and knee)

4.2. Modal Time period and frequencies by response spectrum method –

Table 4.4 – single bracing transmission tower Table 4.5 – Double bracing transmission tower

TABLE: Modal Periods And Frequencies

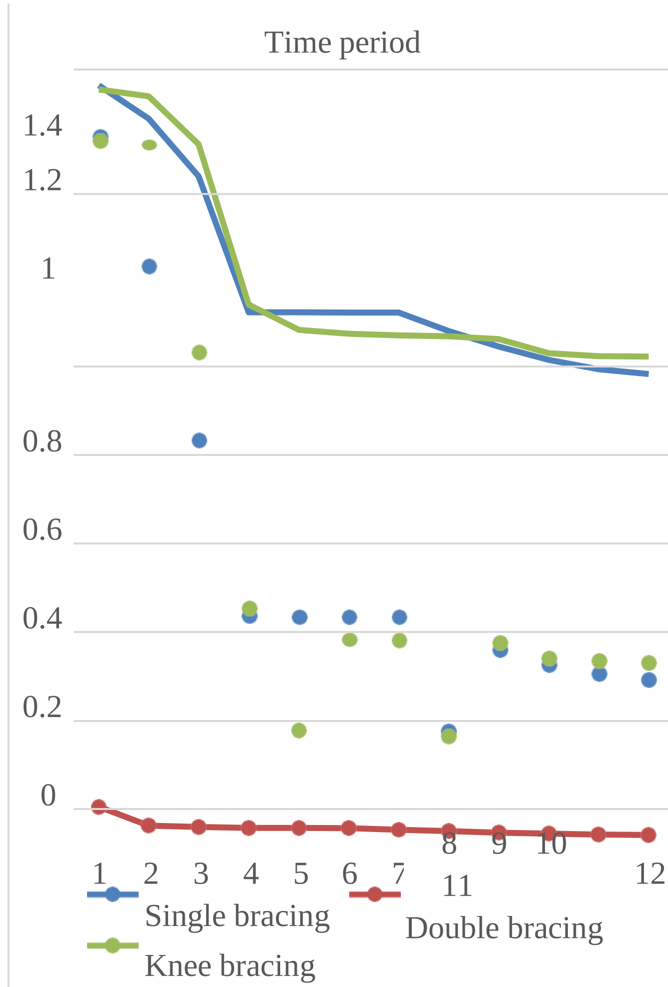
Mode	Period sec	Frequency Cycle/ sec
MODE 1	1.25262	0.7983279
MODE 2	1.13493	0.8811115
MODE 3	0.93161	1.0734077
MODE 4	0.45083	2.2181195
MODE 5	0.45035	2.2204946
MODE 6	0.45027	2.2208991
MODE 7	0.45024	2.2210236
MODE 8	0.38437	2.6016549
MODE 9	0.32967	3.0333521
MODE 10	0.28242	3.5408132
MODE 11	0.25012	3.998091
MODE 12	0.2326	4.2992593

TABLE: Modal Periods And Frequencies

Mode	Period Sec	Frequency Cycle/sec
MODE 1	0.11863	8.4294904
MODE 2	0.05127	19.503427
MODE 3	0.04721	21.184336
MODE 4	0.04396	22.749956
MODE 5	0.04337	23.056732
MODE 6	0.04241	23.577455
MODE 7	0.03643	27.447071
MODE 8	0.03284	30.453006
MODE 9	0.02663	37.558506
MODE 10	0.02384	41.943183
MODE 11	0.02029	49.275664
MODE 12	0.01888	52.970287

Table 4.6 – Knee transmission tower

TABLE: Modal Periods And Frequencies		
Mode	**Period Sec**	**Frequency Cycle/sec**
MODE 1	1.23807	0.8077089
MODE 2	1.21483	0.8231604
MODE 3	1.0452	0.9567562
MODE 4	0.47831	2.0906912
MODE 5	0.38874	2.5723967
MODE 6	0.37566	2.6620019
MODE 7	0.36943	2.706888
MODE 8	0.36603	2.7320112
MODE 9	0.35622	2.8072197
MODE 10	0.30567	3.2715092
MODE 11	0.2956	3.3829857
MODE 12	0.29421	3.3989396



Graph 4.2– Time period Vs Bracing pattern

4.3. Modal time period and frequency by time history method -

Table 4.7 – Single transmission tower

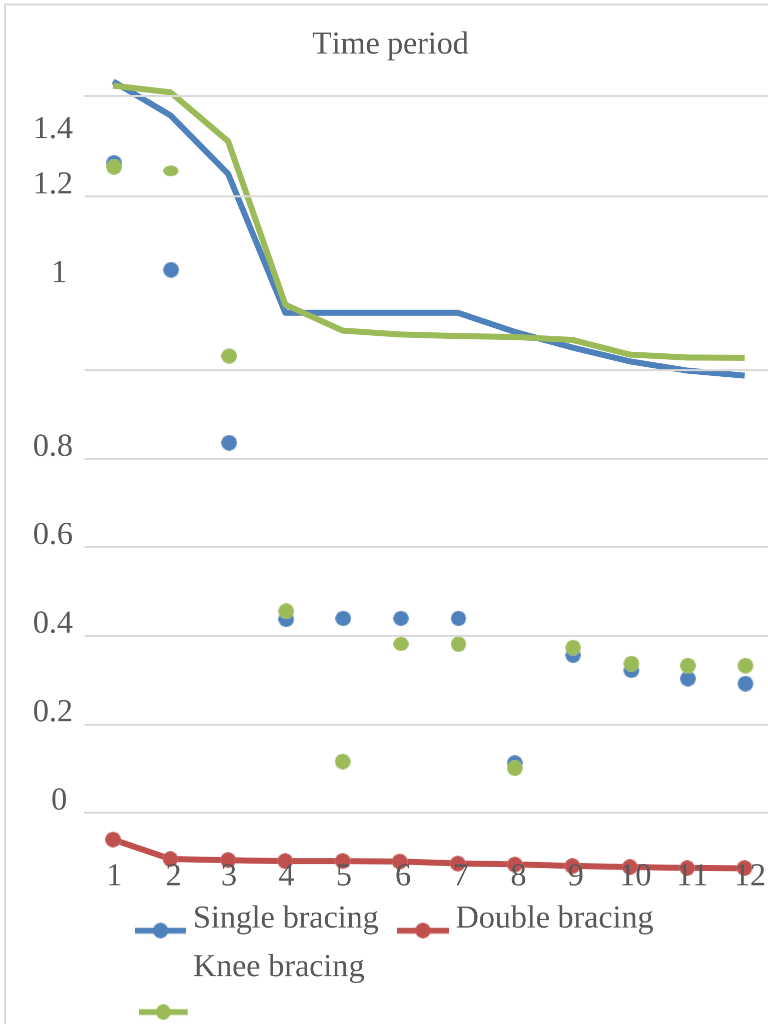
TABLE: Modal Periods And Frequencies		
Mode	**Perio dSec**	**Frequenc yCycle/ sec**
MODE 1	1.252618	0.798327909
MODE 2	1.13493	0.881111524
MODE 3	0.931612	1.073407723
MODE 4	0.450832	2.218119452
MODE 5	0.45035	2.220494645
MODE 6	0.450268	2.220899122
MODE 7	0.450243	2.221023565
MODE 8	0.384371	2.601654881
MODE 9	0.329668	3.033352119
MODE 10	0.282421	3.540813168
MODE 11	0.250119	3.998091027
MODE 12	0.232598	4.299259303

Table 4.8– Double transmission tower

TABLE: Modal Periods And Frequencies		
Mode	**Period Sec**	**Frequency Cycle/sec**
MODE 1	0.11863	8.4294904
MODE 2	0.05127	19.503427
MODE 3	0.04721	21.184336
MODE 4	0.04396	22.749956
MODE 5	0.04337	23.056732
MODE 6	0.04241	23.577455
MODE 7	0.03643	27.447071
MODE 8	0.03284	30.453006
MODE 9	0.02663	37.558506
MODE 10	0.02384	41.943183
MODE 11	0.02029	49.275664
MODE 12	0.01888	52.970287

Table 4.9 – Knee transmission tower

TABLE: Modal Periods And Frequencies		
Mode	**Period Sec**	**Frequency Cycle/sec**
MODE 1	1.23807	0.8077089
MODE 2	1.21483	0.8231604
MODE 3	1.0452	0.9567562
MODE 4	0.47831	2.0906912
MODE 5	0.38874	2.5723967
MODE 6	0.37566	2.6620019
MODE 7	0.36943	2.706888
MODE 8	0.36603	2.7320112
MODE 9	0.35622	2.8072197
MODE 10	0.30567	3.2715092
MODE 11	0.2956	3.3829857
MODE 12	0.29421	3.3989396



Graph 4.3 –Self weight Vs bracing pattern

4.4. Self- weight of tower –

Table 4.10.- Self-weight of single bracing tower.

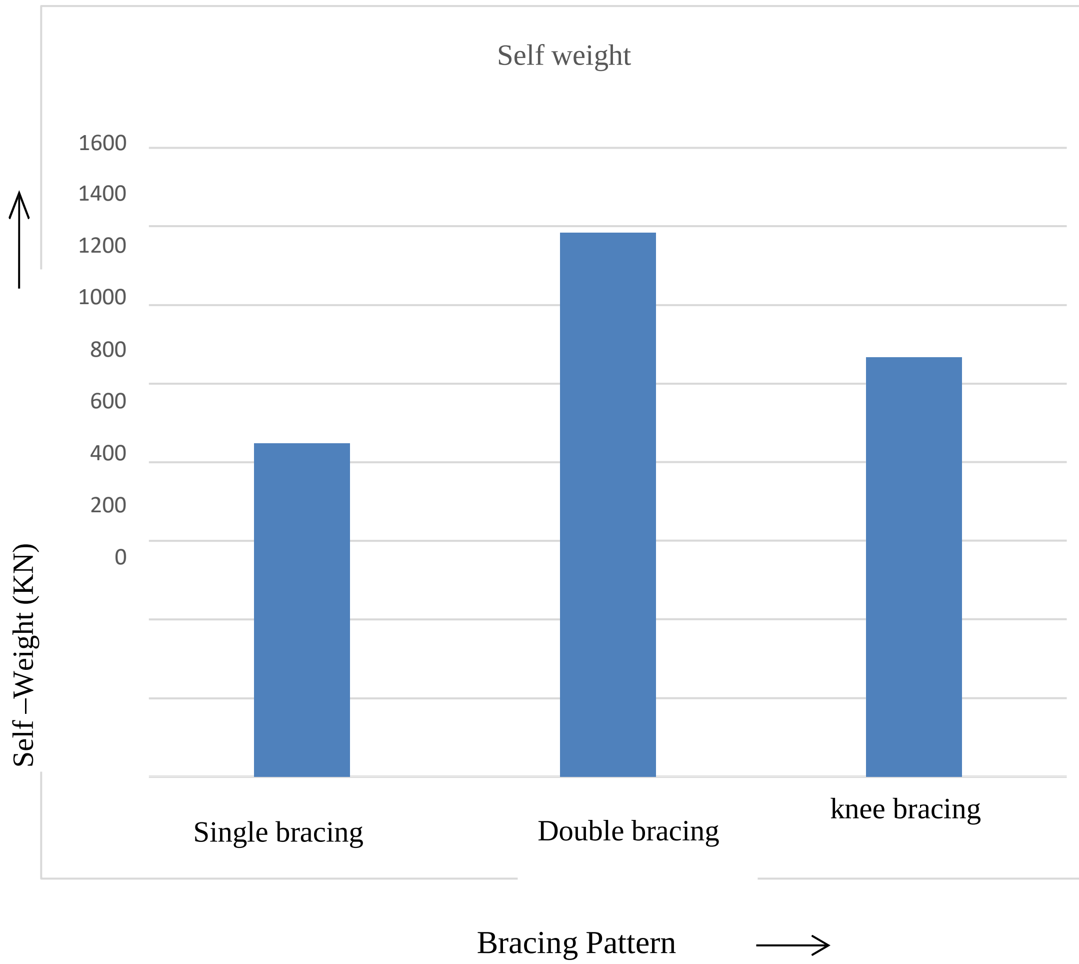
Table: Masses And Weights					
Group Name	**Self-Mass**	**Self-Weight**	**Total Mass X**	**Total Mass Y**	**Total Mass Z**
Unit	KN.s^2/m	KN	KN.s^2/m	KN.s^2/m	KN.s^2/m
ALL	108.67	1065.677	108.67	108.67	108.67

Table 4.11-. Self-weight of double bracing tower .

Table: Masses And Weights					
Group Name	**Self-Mass**	**Self-Weight**	**Total Mass X**	**Total Mass Y**	**Total Mass Z**
Unit	KN.s^2/m	KN	KN.s^2/m	KN.s^2/m	KN.s^2/m
ALL	141	1382.742	141	141	141

Table 4.12. Self-weight of knee bracing tower .

Table: Groups 3 - Masses And Weights					
Group Name	**Self-Mass**	**Self-Weight**	**Total Mass X**	**Total Mass Y**	**Total Mass Z**
Unit	KN.s^2/m	KN	KN.s^2/m	KN.s^2/m	KN.s^2/m
ALL	86.45	847.743	86.45	86.45	86.45

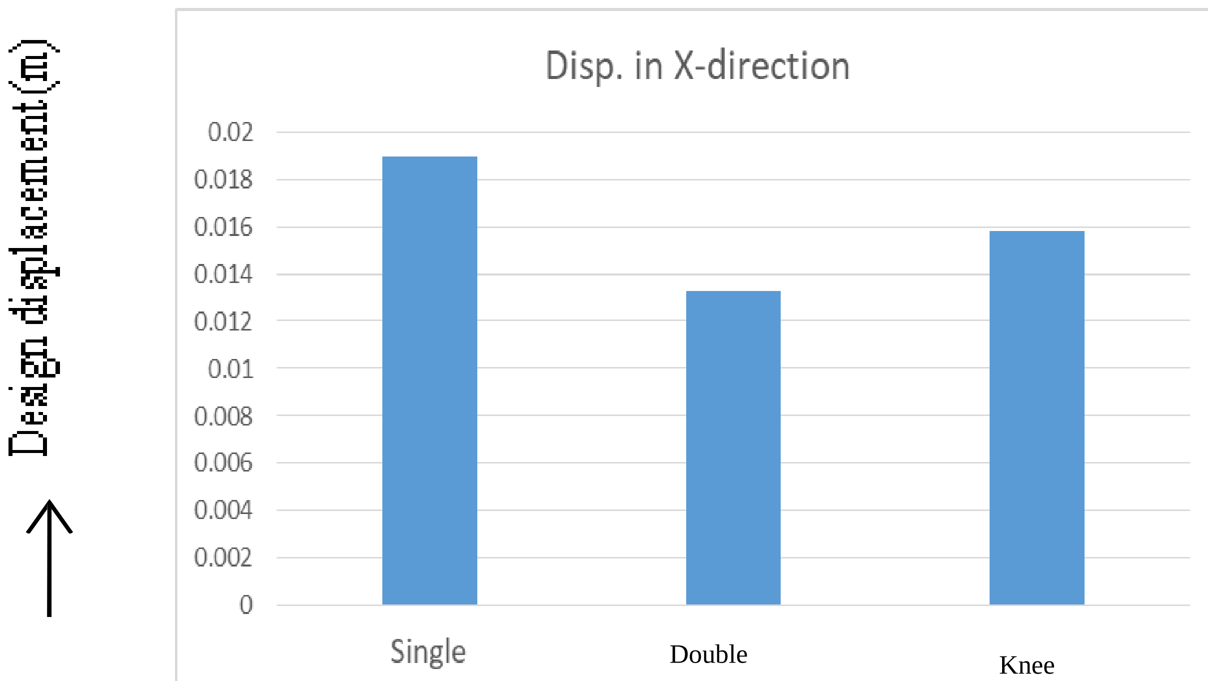


Graph 5.6. Self-Weight Vs. Bracing (single bracing, double bracing and knee bracing)

4.5. Pushover Analysis Results –

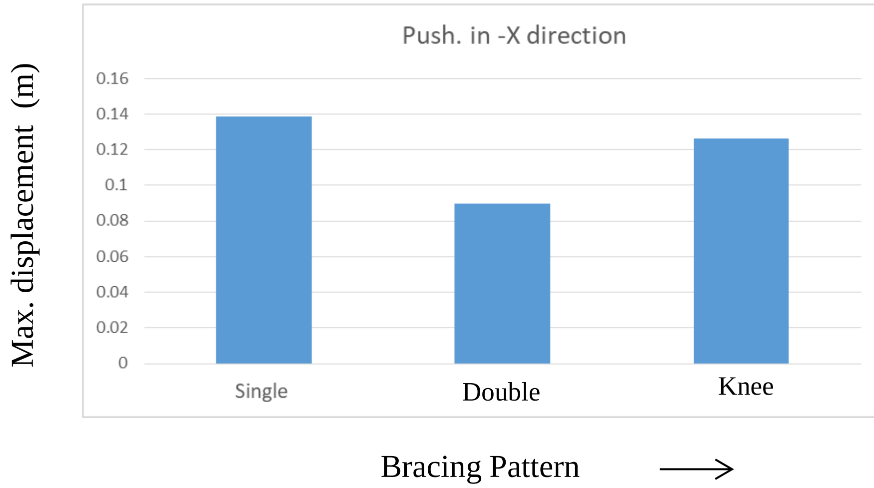
Table 4.13- pushover analysis overall result-

Type of bracing	**Design Load KN**	**Maximum load for pushover (KN)**	**Design Displacement (m)**	**Maximum displacement for pushover(m)**
Single Bracing	33.438	35.188	0.0189	0.13845
Double Bracing	174.67	181.67 4	0.0132 4	0.08954
Knee Bracing	63.495	65.495	0.0158 3	0.1263



Graph 5.7. Design displacement vs bracing pattern

PUNE RESEARCH SCHOLAR ISSN 2455-314X
AN INTERNATIONAL MULTIDISCIPLINARY JOURNAL VOL 8, ISSUE 5



Graph 5.8 Maximum displacement for pushover vs bracing pattern

5. CONCLUSION

Based on the analysis results following conclusions have been drawn –

1. By response spectrum analysis of transmission line tower with various bracing in zone IV. The base shear in x- direction, single and knee bracing base shear is closely spaced, while double bracing base shear increased 3.65 times as compare to knee bracing system.
2. Transmission line tower with various bracing. The natural time period of single bracing and knee bracing are closely spaced, while single bracing time period increased 10.43 times as compare to double bracing .
3. Comparing single bracing with knee bracing, the knee bracing shows quite good performance in natural time periods.
4. From time history analysis, the base shear of double bracing tower is 3 times greater than single bracing tower and base shear of single bracing is 1.22 times greater than knee bracing tower.
5. From overall results, it is concluded that from stability point of view double bracing tower gives

more strength and more efficient. From economical point of view from single and knee bracing transmission tower, knee bracing shows good performance as compared to single bracing.

6. From pushover analysis, it is clear that for single bracing the maximum displacement for pushover is

   7.33 times than design displacement. For double bracing maximum displacement is 6.75 times than design displacement. For knee bracing, maximum displacement is 7.97 times greater than design displacement.

6. REFFERENCES

1. Balaji Patil, K. S. Upase et. Al (2020), "Design and analysis of transmission line tower using STAAD-PRO". International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 07 July 2020 www.irjet.net p-ISSN: 2395- 0072
2. R.Muthuminal, M.N.A. Gulshan Taj (2020), "Behaviour of Steel Transmission Line Towers under Earthquake Loads using Lab view". International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-9 Issue-5,March 2020.
3. B. Vidya, G. Tirumala Rao, S.Varahula (2019), "Comparative study of four legged transmission tower with different bracing sections". International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES) Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585 Volume 5, Issue 05, May-2019.
4. Anshu Kumar Pal, M. Suneel, P.V. Rambhau (2019), "Comparative Analysis of Transmission Tower Using XX and XBX Bracing Systems in Different Wind Zones" International Journal of Recent Technology and Engineering (IJRTE), Volume-8 Issue June2019.
5. D. Leela, Dasarathy, Leshmi Mohan (2019), "Static and dynamic analysis of transmission line tower". International Journal of Engineering and Advanced Technology (IJEAT) ISSN:2249 – 8958, Volume-9 Issue-1S, October 2019.
6. Manu L, Sowjanya G.V. (2019), "Analysis of transmission tower". International Research Journal of Engineering and Technology (IRJET), Volume 6 Issue 8, August 2019.
7. Santhosh.D, Adarsh.J.A (2018), "Analysis of Transmission Tower for Seismic Loading Considering Different Height and Bracing System". International Journal

for Research in Applied Science and Engineering Technology,Vol 4, ,2016.

8. Tanvi G. Londhe, Prof. M.S.Kakamare (2018) "Review Paper on Comparative Study of Dynamic Analysis of Transmission Towers". International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 08 | Aug 2018 www.irjet.net p-ISSN: 2395-0072.
9. Shubham Kashyap, Sumit Pahwa (2018), "A Review Study of Transmission Line Tower Structure by FEM" International Journal of Research and Scientific Innovation (IJRSI), Volume V, Issue August 2018.
10. Rambhau Dadi (2018), "Progressive collapse study of 220 KV transmission line tower with different bracing pattern". International Journal of Scientific & Engineering Research Volume 9, Issue 10, October-2018 1185 ISSN 2229-5518.
11. IS 875(part 1-3)-code of practice for structural safety of structural loading standards.
12. IS 875, "Code of practice for design loads (other than earthquake) for building and structures - Part 2: Imposed loads", Bureau of Indian Standards, New Delhi, 1987.
13. IS 800-2007, "Indian Standard Code of Practice for steel structure", Bureau of IndianStandards, New Delhi, 2000
14. IS: 802 (Part 1/sec-1): 1995 "Code of practice for use of structural steel in over headTransmission line towers" Bureau of Indian Standards, New Delhi.
15. IS 1893 (Part I) : 2016, "Criteria for Earthquake Resistant Design of Structures", Bureau ofIndian Standards, New Delhi, 2002.