A PARAMETRIC STUDY ON GUYED MAST TOWER

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Abstract- Access to telecommunication and broadcasting services is the main purpose of using telecommunication masts, especially in difficult times such as after a severe earthquake. By taking into consideration this important role that telecommunication infrastructure play as critical links of communication, especially in post-disaster situations, one can easily see the value of their preservation and even necessity in the earthquake prone regions of the world. The recent development in telecommunications industries have led to an extensive use of tall guyed towers. The dynamic analysis of this structure under seismic loading is a much understudied field that requires investigation. The complex nature of their analysis arises from the nonlinear force deflection relationship of the cable supports. Masts are usually designed by equivalent static methods for wind and earthquake loading. One of the parameters significant to the dynamic response of the structure is the guy pre-load value. 10 % of the ultimate stress pretension is applied in all cable for study purpose as it is recommended in many researches and standards. In current study analysis of guyed mast has been carried out by using widely used software SAP2000. For study purpose guyed mast of different height having different mast supporting cable radius has been considered and to investigate the behavior of mast, the obtained results are compared in form of time period, base shear, displacement, cable forces and mast forces. The research aims is to gain an understanding into the distribution and magnitudes of forces developed during typical wind and seismic load.

Keywords- guyed tower, mast, Steel, wind load, earthquake load, Model analysis

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I. Introduction

Access to telecommunication and broadcasting services is the main purpose of using telecommunication masts, especially in difficult times such as after a severe earthquake. By taking into consideration this important role that telecommunication infrastructure play as critical links of communication, especially in post-disaster situations, one can easily see the value of their preservation and even necessity in the earthquake prone regions of the world. The recent development in telecommunications industries have led to an extensive use of tall guyed towers.

Guyed masts are specialized structured that are most often used to support telecommunications equipment for broadcasting. Although similar to other freestanding towers, their behavior is very different. The presence of pre-stressed cables supporting a number of spans of the structure allows the lattice frame of a guyed mast to be significantly smaller in both geometry and member size. The reduction in overall weight of the frame makes the guyed mast a popular design option for towers of considerable height. The material cost saving typically becomes important when comparing freestanding versus guyed tower options in the 100m to 150m range. Above this range the material cost saving far outweighs the added design and manufacturing complexities, and a guyed mast is usually preferable.

This work is based on the analysis of the tower and main objective of the work to analyze the tower under wind and seismic force and compare result in form of time period, frequency, cable force. Here in this study, material used for the tower is steel. Parametric comparison carried out for different height of 70m, 90m, 110m, 130m, 150m and for the different cable distance from the base of the tower is 20m, 40m, 60m.

II. Need Of Study

A failure of tower will itself cause a considerable economic loss as well as possible loss of lives. So extreme care should be given to the design of these structures especially guyed mast towers which show nonlinear response because of guy assembles. Guyed towers are characterized by their light weight, flexibility and often large size. All these characteristics make them very sensitive to time dependent loading such as wind and earthquake loadings. In emergency situations like especially after a severe earthquake, the access to telecommunication and broadcast services is one of the main advantages of using telecommunication masts.

There are several reasons for the complexity of guyed masts. Some of them are due to the static system of a mast shaft as a column subjected to bending moments and elastically supported by non-linear guys, which stiffness besides the actions on the mast are dependent of the loading directly on the guys themselves. Guyed tower experience a non-linear behavior even under working conditions. This non-linearity's result from the changes in support stiffness with the change in the guy tension due to applied loads or even original design pre-tensions. The nonlinear force deformation relationship of the structure, and the large displacements experienced even under normal design loads makes them more vulnerable. The slenderness of the mast (beam- column effects), together with the sag of the cable means that the structure exhibits significant nonlinear characteristics even under working conditions.

Guyed masts are subjected to a wide range of dynamic loadings that typically arise from wind, earthquakes, sudden rupture of guys, galloping of guys, sudden shedding of ice from guys, etc. Since 1959, here have been approximately 100 documented collapses of towers (both guyed and freestanding) in the United States alone. This is a clear indicator that the behavior of this family of structures is not fully understood and needs to be investigated further. Fig.1 shows failure of guyed tower under lateral load.

In freestanding towers the dynamic behavior is characterized by the first few fundamental Natural frequencies, which allows for a more simplified approach to the assessment of Dynamic loading. Guyed masts however, exhibit high modal participation across many Modes, and determining the important modes can be extremely complicated.

Fig. 1 Failure of guyed tower

III. Behavior Of Guyed Mast Tower

For most applications, fully modeling the behavior of cables is a fairly complex task. The self-weight and the lack of flexural rigidity of the cable dictate that a cable is never straight except in a vertical position. Additionally, dynamic excitation of cable modes can cause highly nonlinear response. A considerable amount of research has gone into the development of simplified cable models that still maintain adequate accuracy for dynamic analyses. There have not been many studies of cable models that examine the slack to taut transition and its effect on the behavior of structures. While most analyses with guyed structures use a tension-only formulation of the guy element, the specific consequences of this modeling decision are rarely examined.SAP 2000 has a facility to model a cable nonlinear element.

There are two phase of behavior in use of cable structure. The first phase includes the deployment and initial pre tensioning of cables and is characterized by being highly nonlinear. The second phase is the so called in-service phase during which various static and dynamic loads are superposed on the pre tensioned configuration. The response in this second phase can be either linear or non linear depending on the relative magnitudes of the pre tensioning and service loads. These two phases of load application are presented in Figure

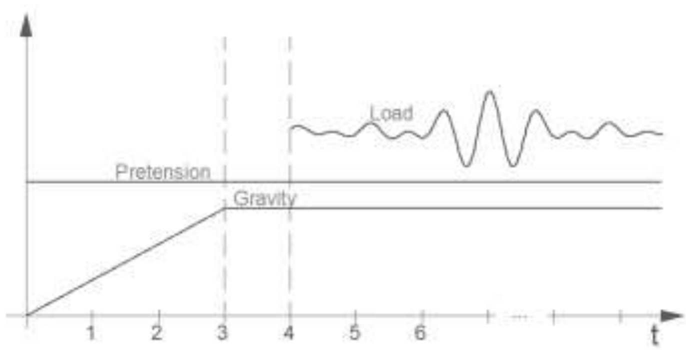


Fig. 2 Temporal load application

IV. Problem Defination

Height of tower is very essential parameter for the design and analysis of tower. Behavior of guyed mast tower is very complex which depends on mast configuration, cable stays number and its position along with base cable radius. Guyed Mast of different varying height 70m, 90m, 110m, 130m, 150m is considered. Base cable radius also plays vital role in behavior of guy ed mast so, to consider its effect different model of guyed mast has been prepared with different base radius20m, 40m and 60m of tower from the base tower.

The steel mast is square in plan of size 70 cm x 70 cm for the full height from ground level and was built-up using four steel angles of size ISA60 x60 x6 mm as verticals. Steel angles of size ISA50 x50x 6 mm constitutes the inclined bracing at 70 cm spacing on all faces. The mast is supported by guys at level 20 m interval levels from ground. Mast is supported by guys from four directions. Support of guys is considered as fixed while of mast is considered as pinned.

V. MODELING OF GUYED MAST TOWER

Tower mast is prepared as a three dimensional space truss with the rectangular shape for different height where individual members of the mast are modeled as straight members connected at joints producing only axial forces in the members. Modeling of guyed tower is carried out using SAP 2000 as shown in fig 3. It is basically a discretization technique, where continues system is divided into a finite number of discrete elements.The cables were modelled by existing cable element in Sap 2000.The program models the cable as a catenary to represent the behaviour of a cable subjected to its own weight. Its behaviour is nonlinear and takes into account the P-Δ effects as large displacements and large deformation are accounted for. A cable without tension is not stable and has not an unique position, so all cables should be loaded. The Canadian standard CSA S37-01 requires that values of the initial tension in the cables should be between 8% and 15% of the final cable capacity. So, for current study 10% of cable capacity Pretension is considered for all models.

Frame element has been considered for the modelling of main member and bracing of guyed tower. ISA 60X60X6 and ISA 50X50X6 section is consider for the main member and bracing member respectively. For current study purpose the computer program Sap 2000 has a special feature to model the cable as a cable element so, for current study purpose same has been used. The material properties of cable is mentioned in Table -1

Fig. 3 Model of guyed mast tower

Table 1- cable material properties

Property of material	Value
Cable diameter	8 mm
Modulus of elasticity (E)	1.965×10^{8}
Poisson ratio	0.3
Co-efficient of thermal expansion (A)	1.170×10^{-5}
Yield stress (Fy)	1600 N/mm^2

VI. Analysis of tower using sap.

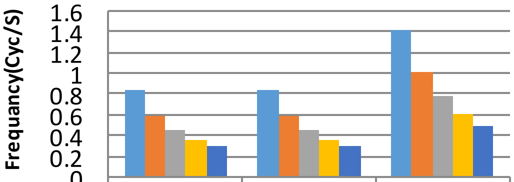
In order to simulate typical load conditions, three loads were taken into account: weight (gravitational load), pre-stress on the cables and dynamic and static loads in form of Seismic and Wind load. Static Wind and earthquake load are calculated as per Indian Standards. The pretension is applied at the beginning and holds during the whole calculus.

Each of the towers was subdivided to panels according to geometries of towers and wind load under static equivalent analysis approach were separately calculated for each panel. The calculated wind loads for each panel were assigned as nodal loads for respective tower models. While the SAP2000 automatically calculate the seismic load as per Indian standards considering Zone V. After applying loads analysis of guyed mast is carried out using widely used software SAP2000, Results obtained are compared in form of Time period, frequency, Supports base reaction and Maximum joint displacement of each tower for the Seismic and wind load.

VII. Result

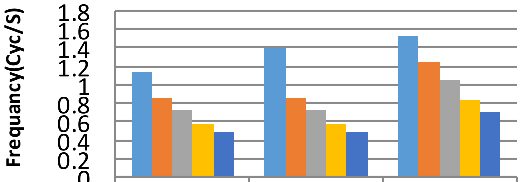
Natural vibration frequency analysis:

Frequency analysis for different height tower system has been carried out with the change cable distance from the base of the tower. The results obtained in form of frequency for 20m, 40m and 60m cable base radius are shown in Figure 4,5,6 From the results it concludes that the frequency reduces with increase in mast height while increase with increase in base cable radius.



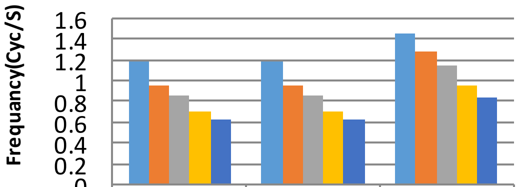
	Mode-1	Mode-2	Mode-3
70M	0.84355	0.84366	1.41926
90M	0.59124	0.59133	1.02712
110M	0.46368	0.46373	0.79855
130M	0.35816	0.3582	0.61063
150M	0.30378	0.3038	0.4995

Fig. 4 Frequency analysis for radius of cable is 20M



	Mode-1	Mode-2	Mode-3
70M	1.14141	1.4141	1.54146
90M	0.86044	0.86059	1.26497
110M	0.72898	0.72904	1.06493
130M	0.57533	0.5754	0.84847
150M	0.49917	0.49917	0.72259

Fig. 5 Frequency analysis for radius of cable is 40M

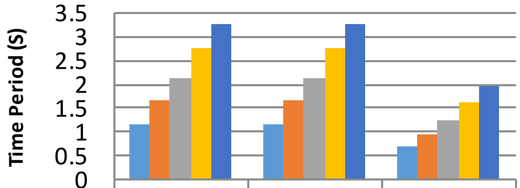


	Mode-1	Mode-2	Mode-3
70M	1.19274	1.19289	1.45942
90M	0.95816	0.95835	1.28578
110M	0.8694	0.86947	1.14925
130M	0.70862	0.70871	0.96233
150M	0.63486	0.63491	0.85141

Fig. 6 Frequency analysis for radius of cable is 60

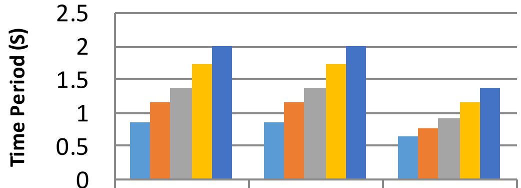
Time period analysis:

Time period obtained from modal analysis are compared for different mast height and base cable radius. Comparison is carried out for the first three mode of mast. As the height is increase the value of time period is increase which is due to reduction in stiffness. As the radius of the cable location is increase the value of time period is decrease.



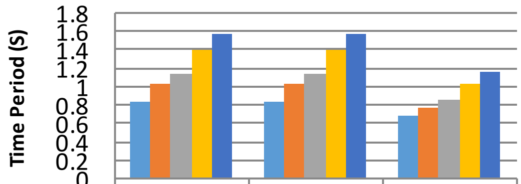
	Mode-1	Mode-2	Mode-3
70m	1.18547	1.18531	0.70459
90m	1.69136	1.69111	0.97359
110m	2.15665	2.15642	1.25227
130m	2.79203	2.79173	1.63765
150m	3.2919	3.29159	2.00202

Fig. 7 Time period analysis for radius of cable is 20M



	Mode-1	Mode-2	Mode-3
70m	0.87611	0.876	0.6487
90m	1.1622	1.16199	0.79053
110m	1.37179	1.37167	0.93903
130m	1.73812	1.73793	1.17859
150m	2.0035	2.0035	1.38391

Fig. 8 Time period analysis for radius of cable is 40M

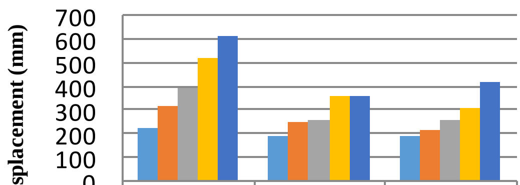


	Mode-1	Mode-2	Mode-3
70m	0.83841	0.8383	0.6852
90m	1.04367	1.04346	0.7774
110m	1.15022	1.15013	0.87014
130m	1.4112	1.41102	1.03914
150m	1.57516	1.57502	1.17453

Fig. 9 Time period analysis for radius of cable is 60M

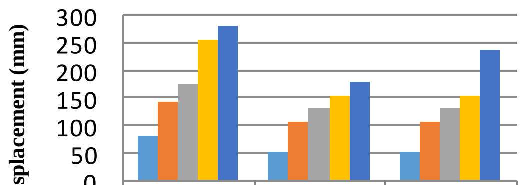
Mast Maximum Displacement

Displacement obtained from seismic analysis for the different cable base radius are shown in Figure 10 . While Displacement obtained from Wind analysis for the different cable base radius are shown in Figure 11. Connection of the cable at the mast is 20m regular interval for the different height of tower. Results indicates that the displacement increase with the height of mast and reduce with the increase in base cable reduce.



	R=20M	R=40M	R=60M
70M	224.05	196.04	196.03
90M	324.07	252.05	216.04
110M	396.08	264.05	264.04
130M	520.11	364.25	312.23
150M	618.53	360.23	420.07

Fig. 10 Displacement for different mast due to earthquake load

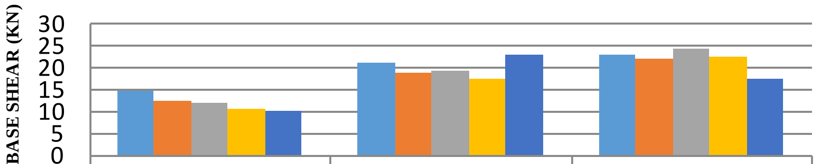


	R=20M	R=40M	R=60M
70M	83.94	55.95	55.96
90M	143.92	107.94	107.95
110M	175.91	131.94	131.95
130M	257.18	155.97	155.98
150M	281.48	179.96	239.98

Fig. 11 Displacement for different mast due to windload

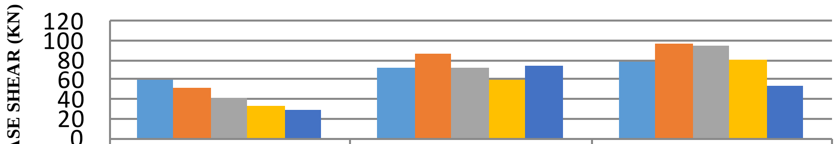
Base Shear Analysis:

Analysis of the base shear is calculated under the different loading condition. Base shear is calculated for the 70m, 90m, 110m, 130m, and 150m height of the tower with varying the radius of cable location from the base of tower. It is observe that height of tower decreases the value of base shear. While in increase of radius of cable location from the base of tower, increase the value of base shear. Wind load generates more base shear than the seismic load.



	R=20M	R=40M	R=60M
70M	14.861	21.182	23.226
90M	12.634	18.967	22.286
110M	11.932	19.449	24.578
130M	10.681	17.583	22.81
150M	10.296	23.234	17.384

Fig. 11 Base shear due to earthquake load

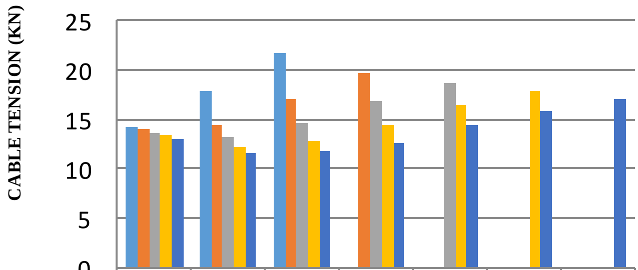


	R=20M	R=40M	R=60M
70M	59.955	72.472	78.173
90M	50.781	85.979	97.653
110M	40.405	73.123	95.245
130M	32.327	59.405	81.603
150M	28.397	74.912	52.93

Fig. 12 Base shear due to wind load

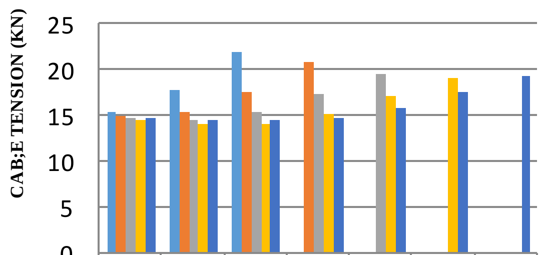
Cable tension:

Cable tension obtains for various loading condition such as seismic load and wind load. Location of cable for various height of mast is 20m regular interval and top 10m part of mast is cantilever. Notation of cable is A, B etc. from base of mast. Tension in cable is increase with increase the height of cable location from base of mast.



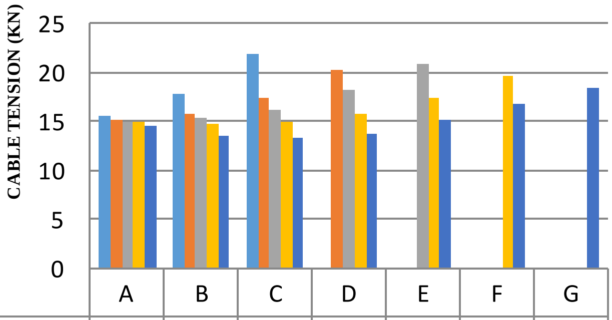
	A	B	C	D	E	F	G
H70R20	14.19	17.88	21.74				
H90R20	13.93	14.50	17.16	19.73			
H110R20	13.60	13.15	14.67	16.87	18.72		
H130R20	13.36	12.28	12.86	14.43	16.45	17.93	
H130R20	13.08	11.63	11.68	12.69	14.33	15.84	17.00

Fig. 13 Cable tension for R=20m (EQ)



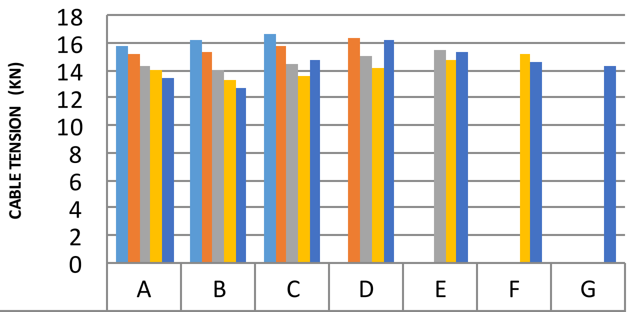
	A	B	C	D	E	F	G
H70R40	15.3	17.8	22.0				
H90R40	14.8	15.4	17.4	20.7			
H110R40	14.6	14.5	15.3	17.2	19.5		
H130R40	14.5	13.9	14.0	15.0	17.0	19.1	
H150R40	14.8	14.4	14.3	14.7	15.8	17.4	19.3

Fig. 14 Cable tension for R=40m (EQ)



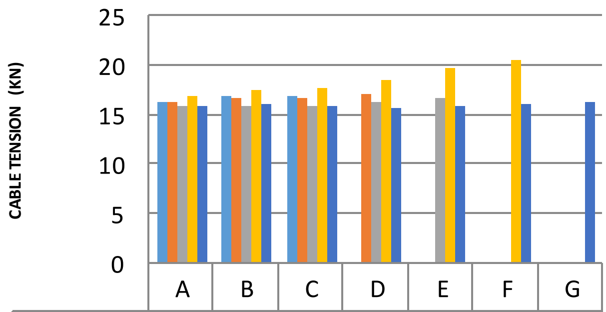
	A	B	C	D	E	F	G
H70R60	15.59	17.91	21.92				
H90R60	15.12	15.76	17.33	20.35			
H110R60	15.00	15.28	16.27	18.27	20.91		
H130R60	14.87	14.75	14.93	15.77	17.49	19.73	
H150R60	14.45	13.62	13.28	13.76	15.09	16.78	18.44

Fig. 15 Cable tension for R=60m (EQ)



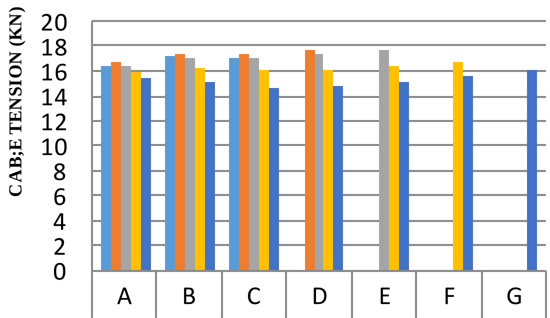
	A	B	C	D	E	F	G
H70R20	15.76	16.31	16.63				
H90R20	15.16	15.29	15.78	16.32			
H110R20	14.39	14.08	14.47	15.06	15.53		
H130R20	14.04	13.35	13.55	14.15	14.81	15.27	
H150R20	13.42	12.78	14.73	16.28	15.29	14.59	14.37

Fig. 16 Cable tension for R=20m (WL)



	A	B	C	D	E	F	G
H70R40	16.3	16.8	16.8				
H90R40	16.3	16.6	16.6	17.1			
H110R40	15.7	15.9	15.9	16.2	16.6		
H130R40	16.7	17.5	17.7	18.5	19.6	20.5	
H150R40	15.8	16.1	15.7	15.7	15.8	16.0	16.3

Fig. 17 Cable tension for R=40m (WL)



	A	B	C	D	E	F	G
H70R60	16.5	17.2	17.1				
H90R60	16.7	17.5	17.3	17.7			
H110R60	16.4	17.1	17.1	17.3	17.7		
H130R60	15.9	16.3	16.1	16.1	16.4	16.8	
H150R60	15.4	15.1	14.7	14.8	15.2	15.6	16.0

Fig. 18 Cable tension for R=60m (WL)

Conclusion and Discussion

Guyed mast tower is made for the different height. In this work comparative study is presented addressing the influence of the tower using various engineering parameters which is as follows:

- It seems that time period is influenced by height of the tower. Value of time period is increase with increase the height of tower.
- Value of time period is decrease with increase the cable radius from the base of tower for all category of tower.
- Value of base shear is increase with decrease the value of time period in case of seismic load.
- Fundamental frequency is decreases with increase in tower height. Frequency is also increase with increase in cable radius.
- Deflection is increase with increase the height of tower. But at the cable location deflection is decrease.
- Value of base shear increase with increase with the cable radius from base of mast and reduce with increase in height of mast is increase.
- Tension in cable is increase with increase the radius of cable location from base of mast. Tension value in cable is also increase the cable location height of mast.

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