TEKA Kom. Mot. Energ. Roln. – OL PAN, 2010, 10, 340–345

IMPROVEMENT OF THE DESIGN OF MOBILE COMMUNICATION TOWER

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Summary. The article is about the reduction of metal capacity of the construction for mobile communication. The influence of the constructive arrangement of special tower lattice on the load force distribution in the construction belts is considered. Calculation is made and dynamic characteristics of different design models of the tower are determined. Behavior of different design models of the tower taking into account pulsating component of wind load is analyzed.

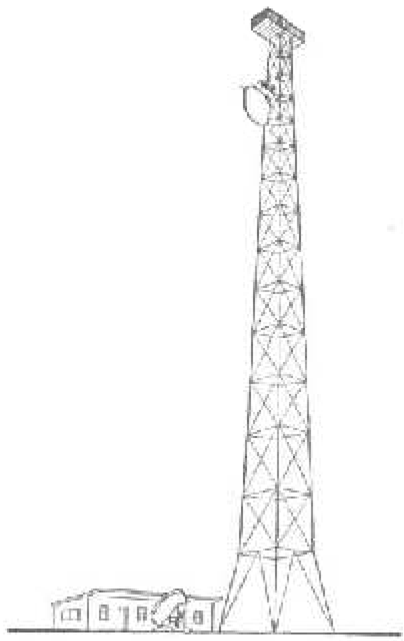
Key words: tower, antenna, design model, method of finite element, starting mark

INTRODUCTION

The rate of mobile communication development has considerably increased for the last ten years in Ukraine. To increase stability of mobile communication new base stations are established. The line of mobile communication consists of receiver-transmitter stations located at a distance of straight visibility of each other (about 40-50 km). Each intermediate strengthens it and transmits it to the next station with the help of parabolic antennas.

Tetrahedral towers (height 35 - 60 m) with the cross lattice from the rigid struts are commonly used as supports of parabolic antennas of mobil communication lines (Fig. 1) [1]

Having highly directional emission both in the vertical and in the horizontal plane; parabolic antennas require such kind of supports where the antenna's beam deviations from the assigned direction were not larger than 10.



Application of standard masts and towers as antennas for mobile connection was developed in the USSR for the relay stations of connection, and now it is not always economically expedient.

As the beginning station towers of 40m height were widespread. Such stations are usually equipped with three - four sectorial antennas that are 1500-2500 mm in height, about six radio relay antennas with the plate 1200 mm in diameter and 4-6 radio relay antennas with the plate of 600 mm in diameter. The signal is transmitted to the antennas by cables, located inside the box 400 mm wide of the mass below 10 kg/m [2].

There is a small van near each tower with expensive equipment to provide the reception and transmittion of signals. The tower should meet the main requirements such as: high operational reliability and the minimization of cost of its production and mounting. Nowadays, it is common to produce forty meter towers from the volumetric starting marks with their subsequent strengthening at the construction site and installation to the foundations in the assembled form [3].

This approach requires producing volumetric starting marks sized adequately to be transported by automobile. Constructively, the tower is a three-dimensional tetrahedron with the break of belt at the height of 28 meters. The bottom base of the tower is 4000 mm and the top base is 1100 mm. It is divided into four blocks in terms of height. The forty meter tower for mobile communication developed by "Steel Project" Gmbh and constructed in the Crimea was accepted as the prototype of our improved tower [4].

The aim of improvement is to reduce strains in the belts at the joint of adjacent blocks over the height of tower due to the change of lattice scheme.

The traditional approach to the calculation of the tower construction involves its subdivision into the framework plane girders which are affected by long forces. In our case, the method of finite element was used in calculating the tower construction. The method was realized in PK "LIRA W.9.4" [5]. This allowed to take into consideration three-dimensional work of the construction.

STRUCTURAL MODELING

A tower model was built as three-dimensional tetrahedron with the break of belt over the height. A constructive scheme of the lattice was carried out in versions with creating calculating model of the tower.

The first block of 8,5 m height consists of four volumetric starting marks joined together in the central part. In the assembled state the block is a truncated pyramid. In both versions there is cross lattice with strut frames in the first block. The second and the third blocks are three-dimensional tetrahedral truncated pyramids 10 m heigh, each of which is made as a unit starting mark. The lattice in the first design model is a cross with the subdivision into the panels in both blocks.

In the second tower model design the first block is performed without any change of the base version. The second block is a cross lattice with the strut frames over the entire height of the block. The fourth block is made in the form of three-dimensional prism 12 m heigh. This block is identical for both design models. Sections of tower elements are made of single steel corner welded to each other. Geometric schemes of both versions of the towers are in Fig. 2.

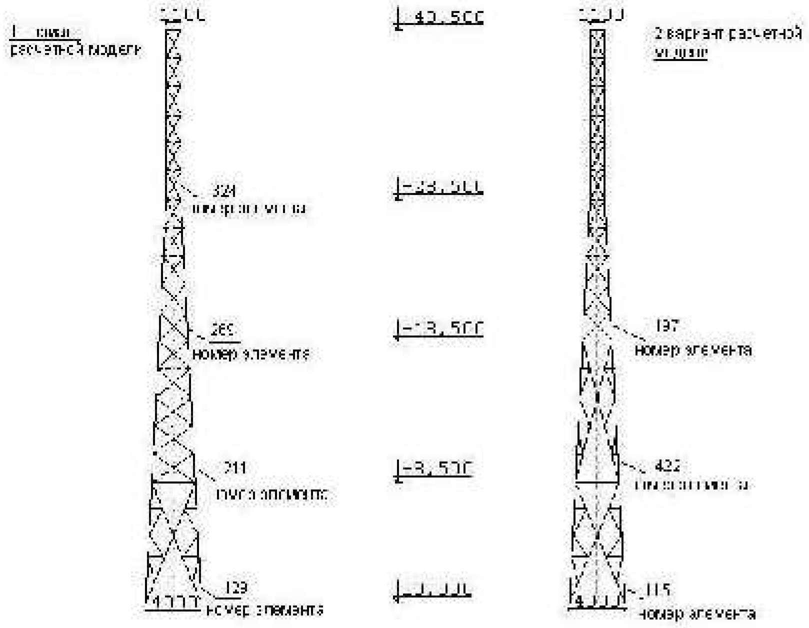


Fig. 2. Geometrical schematics of the design models of towers.
a) base version; b) with the changed lattice

Constant load: self-weight of constructional elements was determined and applied automatically by the program while indicating the sections of the elements [5].

Wind load: the prevailing load on this type of construction is wind load. This load is generated by air mass moving and depends upon wind speed in the region of building. The wind load value is dependable on the surface of the tower rods on which the pressure of air flows acts. The wind load on the second block in the second version of design model had lower values in comparison with the first model as a result of the rarefaction of the lattice. Wind loading was determined according to the prescriptions of current standards [6]. It was applied as concentrated loading to the construction joints at the level of diaphragm being perpendicular to tower facet and goes diagonally across the cross-section (at the angle of 45°).

Seismic load: seismic loading (7 dg.) was applied to the tower models. The loading was determined in accordance with the requirements of actual standards [7]. Seismic action causes inertial forces. Inertial mass determines inertial forces in the self-weight of constructional elements. Self-weight is determined and applied automatically by the program while indicating sections of construction elements. Seismic load was applied in the mutual perpendicular directions, along the X axes OX and Y axes.

Technological load: technological load of tower models is the weight of antennas installed at the levels of 40 m - four antennas GSM (weight of 0,127 kN), two parabolic antennas 0,6 and 1,2 m in diameter (weight 0,367 kN and 0,735 kN); 38 m – 3 parabolic antennas 1.2 m in diameter (weight 0,735 kN); 30 m - one antenna with (diameter 1,2 m, weight 0,735 kN); on the mark - one antenna with a diameter of 1,2 m with weight 0,735 kN [6].

Ice storm load: this load was determined in correspondence with the requirements of actual standards [6].

ANALYSIS OF RESULTS

The method of finite element was used in calculation of towers. It was realized in PK "LIRA W.9.4" It made it possible to take into account the tree-dimensional work of the construction. This calculating approach enabled a careful examination of behavior under pulsating wind and acting under the influence of wind. The dynamic characteristics of design models and the displacement of the top point are given in Tables 1 and 2.

Tabl.1. Dynamic characteristics of design models

		1st design model				2nd design model			
№ of load-ing	№ of the form	Own values	Frequencies		The period	Own values	Frequencies		The period
			Circular frequency	Fre-quency			Circular frequency	Fre-quency	
3	1	0,140	7,154	1,139	0,878	0,137	7,308	1,163	0,860
3	2	0,037	27,355	4,354	0,230	0,036	28,061	4,466	0,224
3	3	0,021	47,919	7,627	0,131	0,021	47,721	7,595	0,132
5	1	0,131	7,610	1,211	0,826	0,129	7,767	1,236	0,809
5	2	0,129	7,770	1,237	0,809	0,126	7,937	1,263	0,792
5	3	0,036	27,839	4,431	0,226	0,035	28,396	4,519	0,221

The calculations showed that the greatest strains in the belts of tower blocks appear in the third form of fluctuation with the wind direction along the diagonal. The results of calculations are given in Tables 3 and 4.

Tabl.2. Displacements of the upper unit of the tower

№ of unit	Movings						№ of loading	Component
	x	y	z	ux	uy	uz		
128	-0,002	-0,005	-0,331	-0,008	0,002	-0,003	1	-
128	256,167	-0,122	-7,642	0,077	14,293	-0,015	2	-
128	-209,669	0,126	6,833	-0,077	-12,811	0,016	3	1
128	256,167	-0,122	-7,642	0,077	14,293	-0,015	3	2
128	216,984	217,030	-12,960	-12,076	12,061	0,083	4	-
128	169,863	-173,172	0,110	10,695	10,486	13,237	5	1
128	-176,224	-179,306	11,595	10,926	-10,724	0,037	5	2
128	216,984	217,030	-12,960	-12,076	12,061	0,083	5	3

Tabl.3. Strains in the belts (1st design model)

№ of an element	№ section	Strains, kN, kN*m				Type of an element	№ of loading	Component
		N	M_k	Q_z	Q_y			
129	1	-384,66	0,02	4,54	0,26	10	5	S
211	1	-436,40	0,001	1,87	-0,03	10	5	S
269	1	-365,62	0,003	0,02	0,01	10	5	S
324	1	-268,73	-0,001	-0,10	0,08	10	5	S

Tabl.4. Strains in the belts (2nd design model)

Number of an element	№ section	Strains, kN, kN*m				Type of an element	№ of loading	Component
		N	M_k	Q_z	Q_y			
115	1	-391,79	0,02	0.436	0.21	10	5	S
197	1	-393,02	-0,03	-0,16	0.04	10	5	S
422	1	-349,00	0,03	0,30	-0.01	10	5	S

The tower behavior under the pulsating influence of the wind in both versions is quite close. Force distribution in the tower elements (2nd design model) under the pulsating influence of the wind (3rd form) is shown in Fig. 3.

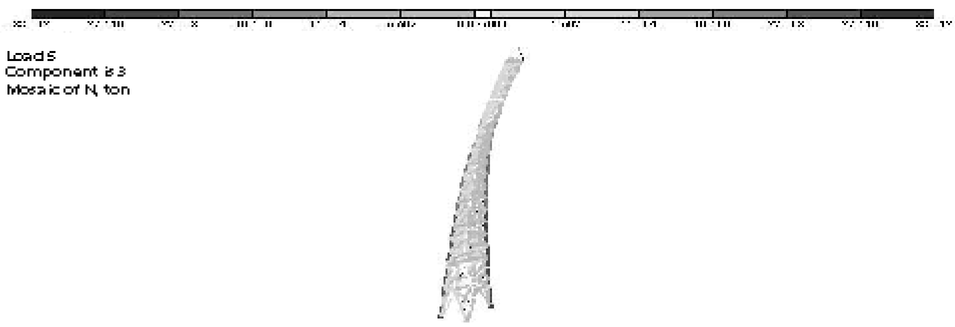


Fig. 3. Force conditions in the elements of tower (2nd design model) under the pulsating influence of wind (3rd form).

The data analysis of calculations carried out for two versions of tower model enabled to reveal the following:

- the change in the angle of slope of the basic struts of cross lattice with the introduction of strut frames in the second block made the strains of wind loading distribute more proportionally in the belts of the first, the second and the third blocks, taking pulsating component into account;

- the maximum strains value in the belts of the first, the second and the third blocks were reduced and they became closer to each other. This allows to use the element of the same section for them;

- the displacement of tower top units for both versions of design models remained within the limits of acceptable values.

CONCLUSION

The change of the connecting lattice construction in three-dimensional tower construction for mobile communication redistributes efforts in tower elements and decrease metal consumption.

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POSZUKIWANIE KONSTRUKTYWNEJ FORMY WIEŻY ZWIĄZANEJ Z RUCHEM O WYSOKOŚCI 40 METRÓW

Streszczenie. Praca poświęcona problemowi obniżenia materiałów konstrukcyjnych ruchomej wieży. Rozpracowano przypadek wpływu konkretnej decyzji dotyczącej przestrzennej kratownicy wieży na rozkład sił. Przeprowadzono obliczenia określające dynamiczne charakterystyki licznych modeli obliczeniowych wież. Przeprowadzono analizę z wielu modeli obliczeniowych biorąc pod uwagę drgania pochodzące od wiatrowego obciążenia.

Słowa kluczowe: wieża, antena, metoda końcowego elementu, model obliczeniowy