Reliability of Billboards Fixing Constructions in the Operational Period

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Abstract. In the article the control actions providing reliability of billboard fastening during the whole term of operation is proved. Also correction of the operational period of billboard fixing constructions is justified. The example of testing calculation of a billboard rack diameter, which satisfies the permissible values of tension in the rack basis under loading of wind force is given. Due to the frequent cases of billboards falling under the wind load influence in the different cities all over the world, inspection actions for control of thickness of supporting rack are offered.

1. Introduction

Various advertising structures are established both within the cities, and out of city areas, bearing the function of drawing the population attention to the advertised products. The way the construction is made, installation sites of this kind of constructions and ways of their fastening are various. Billboards or another advertising structures can be located in close proximity to highways and streets of the cities, in parks or in residential quarters. They can be made in the form of the constructions which are located separately on the ground or they can have frontage arrangement. But in all cases any advertising structures have to meet safety conditions throughout all term of operation. Safety conditions first of all are understood as reliability of a design, which allows it to be steady under the influence of the weather phenomena, not to collapse, not to fall under the influence of wind load on passersby or cars. Speaking of billboards, safety is ensured by calculation of wind loads. Material selection and thickness of the bearing structural elements has to guarantee their long safe operation.

2. Problem statement

Design, production and installation of billboards has to be carried out according to the building regulations, technical regulations and other normative documents containing requirements for each type of the advertising structure. In spite of that fact the collapses of billboards doing harm to human health and causing material damage are regularly fixed all over the world [1]. The task of this research is justification of introduction of the additional requirements and control actions providing reliability of billboards fastening during the operational period and also correction of the operational period itself in connection with a trend of climatic parameters change in different regions of the country.
3. Methods and algorithm of the task solution
The critical analysis of the billboard fastening reliability throughout the operational period is carried out. The example of testing calculation of a billboard rack diameter (sign) satisfying to permissible values of tension in the rack basis under the influence of wind force is given. Justification of correction of the operational period of the advertising structures in connection with a trend of change of climatic parameters in different regions of the country is given.

4. Analytical part
The Billboards consist of a frame (framework) which is upholstered with steel sheets, after that the frame is covered by substances which are steady against temperature differences and air humidity. Billboard fastens on a support. Design documentation provided calculation of wind loads for ensuring reliable operation of the bearing structural elements. Materials and thickness of the bearing structural elements have to maintain wind loads and the weather phenomena. Therefore they are usually made of stainless steel, nonflammable composite materials and the certified plastic materials.

Annually fixed collapses of the advertising structures [1] demonstrate that development of additional actions for ensuring safe operation of these designs throughout terms of their operation is necessary. Fallings of the boards established along highways with dense traffic are dangerous. Especially falling of the big by the size billboards can lead to major accidents with the human victims. Falling of boards if they are established in places of constant presence of people (near the shopping centers, gas stations, hotels) are also very dangerous. Fall of road signs is less dangerous because of the small sizes of signs.

Judicial proceedings on indemnification from falling of billboards on cars [2] and people [3] were analyzed. This analysis allowed to allocate the non-compliance with regulatory requirements as the main reasons for collapses. That is "the human factor" remains the main reason for all troubles. Non fixing or improperly fixing of billboards are the most often refer to "a human factor". Bad weather conditions are the second reason of falling of the advertising structures. Due to the climate change trend on the planet, the abnormal phenomena in rather "quiet" regions happen even more often. Therefore wind load specified in regulatory documents is not relevant. [4-6] Additional control of pre critical condition and monitoring of climatic characteristics in different regions of the country is necessary [7].

To provide reliability of fastening of the billboards throughout all the term of operation, it is offered to control annually a condition of fastening by city services. The necessity of introduction of similar control appeared in the city of Chelyabinsk after the collapse of a massive billboard with the advertising "Tractor" [8] when collapse was the result of washout of the soil with water. Supporting rack was pulled out the ground so the section in the rack basis was extremely dangerous.

Below calculation of the billboard rack wall thickness of t [9] experiencing wind load of 1500 Pa is carried out.

Basic data: billboard (Fig.1) is fixed on a metal rack of external diameter of d=80mm. Determine the required pipe wall thickness t at the allowed load [σ]=80 MPa, if wind load on billboard is q=1500 Pa.

Having carried out the procedure of reduction of forces distributed on a board to the center of gravity, we determine the value of resultant force F=q∙A=450N. Direction of the moments Mx and My is shown on fig. 1: twisting moment Mx corresponds to torsion deformation, and bending moment My corresponds to bend deformation of a rack in the horizontal plane. In the dangerous section located in the rack basis, Mx = 450·0,7 = 315 N∙m m Mx = 450·1,8 = 810 N∙m. The biggest normal tension σ and tangent tension τ appear in points of this cross section, where σ = Mx/Wy and τ = Mx/Wp

Wy and Wp are geometrical characteristics of cross section of a rack at a bend and torsion: Wy – resistance moment relatively an axis Y, Wp – polar moment of resistance.
Figure 1. diagrams of bending moment $M_y$, twisting moment $M_x$ moment on rack height and distribution of $\sigma$ and $\tau$ in dangerous rack section [10, 11].

As by criterion of the largest tangent tension equivalent tension is $\sigma_{eq} = (\sigma^2 + 4 \tau^2)^{1/2} \leq [\sigma]$, than

$$\sigma_{eq} = \left( \frac{(\frac{M_y}{W_y})^2 + 4 \frac{(\frac{M_x}{W_p})^2}{W_p}}{W_y} \right)^{1/2} \leq [\sigma]$$

As $W_p = 2W_y$, equivalent tension is $\sigma_{eq} = (\frac{(M_y^2 + M_x^2)^{1/2}}{W_y}) \leq [\sigma]$. than $W_y = (\frac{M_y^2 + M_x^2}{W_y})^{1/2} = 11 \cdot 10^{-6}$ m$^3$. For pipe $W_y = \frac{\pi d_{ext}^3}{32} (1 - \alpha^4) = 12 \cdot 10^{-6} m^3$ and ratio of diameters is $\alpha = \frac{d_{int}}{d_{ext}} = 0.94$, where internal diameter and external diameter are respectively equal $d_{int} = 0.94$ m and $d_{ext} = 0.075$ m. Finally we define that the minimum thickness of a wall of a pipe capable to sustain this wind load is equal $t = \frac{d_{ext} - d_{int}}{2} = 2.4$ mm.

The calculation above shows a possibility of stability monitoring of the billboards under the wind load by means of assessment of a supporting rack wall thickness in its basis. Need of development of additional control actions is confirmed by statistics of the incidents and accidents connected with the collapse of various billboards which sizes can be essential. Not only violation of construction regulations and inadequate fastening of designs can be the main reason for collapse, but also the climatic changes all over the world which are not considered fully [12]. Strong winds, storms, tornadoes, pouring rains, floods are currently recorded in regions where there was rather quiet climate before. These phenomena affect the processes of soil erosion and soil flooding, weakening the bases of fastening advertising structures, causes corrosion of metal racks and other fastening structural elements.

Deterioration of structural elements in such conditions is difficult to determine by calculation, however the wear is capable to become the main reason for destruction and lead to collapses [13,14]. Under the influence of corrosion of a metal rack thinning of thickness of its wall in the basis can become not admissible [15]. Other control methods for identification of defects and assessment of tension of designs, for example, a method of fragile strain-sensitive coverings [16, 17] or neural network approaches [18] are difficult in application.
5. Conclusions
Hurricanes, winds of storm force, tornados, pouring rains, floods and the other abnormal phenomena appear in regions where there was rather quiet climatic situation before, due to global climate change around the world. These phenomena affect the safe operation ensuring of the advertising structures installed in crowded places of and along highways, threatening with collapses.

In order to enhance safety in the billboards operation, it is proposed to exercise additional control over the state of the degree rack wall thickness thinning in the basis throughout the entire life of the structure.

It is recommended to introduce additional coefficients into the regulatory documentation regarding wind loads calculating at the design stage. These coefficients should take into account the trend of climate change and the increase in wind loads on structures.

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