COMBINED ALLOWANCE FOR WIND LOAD AND HEAVE IN DESIGNING MAST FOUNDATIONS IN PERMAFROST ZONES (FOR DISCUSSION)

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To a considerable extent the parameters of free-standing masts, in particular pylons carrying power lines and their foundations, depend on the wind load. For intermediate pylons (usually 85-95% of the total) the wind load is decisive and forms part of the principal load combination [1, 2].

In permafrost zones the load due to heaving forces* also has an important influence on the type and size of the mast foundations. In certain circumstances this load may amount to half the total or as much as 90% in the case of wood construction.

Both wind and heave loads are short-term [3, 4]; therefore, in accordance with the operative standards, the principal load combination should include only one of them.

However, there are contradictions in the approach to the consideration of wind loading in connection with the analysis of the stability of foundations during the period of activity of heaving forces. Thus, in the standards [1] the wind load is not taken into account, but in the general code of practice relating to foundation design in permafrost zones [4] in one case (5.15) it is neglected, whereas in another (5.21) the possibility of combinations including heaving forces and short-term loads is admitted.†

The result is that different designers proceed from different assumptions: from simple summation of the maximum values of the wind-pressure loading and heave to separate calculations in which these factors are taken individually into account.

How then should the simultaneous action of wind loading and heave shearing forces be taken into account in designing mast foundations in permafrost zones?

We will examine this question for permafrost soils, used in accordance with principle I [4, 3.2], in the presence of a seasonally melting surface layer [4, 2.1] with reference to the example of a foundation in the form of a single pile, either bored or sunk by thawing the soil.

If the foundation is not adequately anchored, as a result of heave action it will begin to move.

This motion reduces the effect of the heaving forces, which in the limit become negligibly small. This applies equally to foundations in both thawed and permafrost soils. However, the reaction of the foundation to external (in particular, wind) loads is different: whereas in thawed soils the frictional resistance of the lateral surface of the pile is quickly restored, in permafrost the restoration (restoration of freezing strength) takes a long time [6].

Because of this characteristic of permafrost soils, in designing the foundations of pylons and other masts it is necessary to take both wind loads and heave shearing forces simultaneously into account.

* Of the two types of heaving forces, normal and tangential, we shall consider only the latter, since the depth of the foundation is usually such as to exclude the action of normal forces.
† It should be stressed that in standards [4] the special characteristics of transmission lines are not considered, while in [1] the specific conditions that prevail in permafrost zones are not taken into account.

TABLE 1

<table>
<thead>
<tr>
<th>Weather station</th>
<th>Wind speed (m/sec) measured by:</th>
<th>Reduction factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wild anemometer</td>
<td>Wild anemometer</td>
</tr>
<tr>
<td>Ashkhabad</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Boz-Su</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Kizil-Argat</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>Zhangiz-Tobe</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td>Kursai</td>
<td>23</td>
<td>34</td>
</tr>
<tr>
<td>Chiganak</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Pervkolov</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Tselinograd</td>
<td>20</td>
<td>24</td>
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<tr>
<td>Talasger</td>
<td>24</td>
<td>34</td>
</tr>
</tbody>
</table>

The combined effect of these loads can be numerically expressed in terms of combination factors. The determination of the action of the heave forces lies outside the scope of this article, and the value of the corresponding load combination factor will not be considered. According to [3], it may be taken equal to 0.9. Thus we shall analyze only the variation of the wind load with time, using the methods of probability theory and mathematical statistics.

Let us consider the changes in average wind speed as the duration of action of the wind increases, for which purpose we employ the results of two different methods of measuring wind speed at the same weather stations: by means of Wild and M-12 anemometers with two- and ten-minute averaging, respectively. The wind speed measured by the Wild anemometer is assumed to be instantaneous, since in designing pylon foundations wind gusts are not taken into account, while that measured by the M-12 is assumed to be long-term both with respect to its properties and in connection with the fact that during the first 100-470 sec of action of the load the freezing strength of permafrost soils falls by a factor of 1.5-3. During the first 50 h it falls by a factor of 3-4 [6]; i.e., after 10 min the subsequent loss of strength is not very great. During this period the wind direction may be assumed constant.

In the table, which is based on Gartsman's data [8], we give values of the wind speeds (and their ratios) measured by the Wild and M-12 anemometers. Since the M-12 records the lesser wind speed, the ratio is called the reduction factor.

We assume that the reduction resulting from the use of the M-12 anemometer is chiefly determined by the difference in averaging periods.

In accordance with the tabulated data we determine the reduction factor on the assumption that its empirical distribution is close to the theoretical normal distribution. In view of the small sample size we make use of the Student integral to determine the limits of the interval containing the grand mean.

The calculations involve the use of the methods of probability theory and mathematical statistics together with expressions derived from [9, 10]:

a) for determining the mean

$$K_c = \frac{\sum_{i=1}^{t_{\text{max}}} K_{c_i}}{n}$$  \hspace{1cm} (1)

b) for determining the rms error

$$\sigma = \pm \sqrt{\frac{\sum_{i=1}^{t_{\text{max}}} e_i^2}{n}}$$  \hspace{1cm} (2)

$$e_i = K_{c_i} - \bar{K}_c$$

c) for determining the mean error

$$\eta = 0.7979 \sigma$$  \hspace{1cm} (3)

d) for determining the limits of the interval containing the grand mean

$$K_v = \bar{K}_v \pm t_{\alpha} \frac{\sigma}{\sqrt{n}}$$  \hspace{1cm} (4)

$$S (t_{\alpha}) = \frac{p + 1}{2}$$

* The correctness of this assumption was confirmed by a check employing the Westergard criterion [9] and the probability criterion of [11]. The calculations have been omitted for lack of space.