The dataware of building structures reliability calculations under temperature effects

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Abstract: The statistical characteristics of random process of atmosphere air changes, needed for building structures reliability calculations, were generalized. The effects of additional geographical factors, influencing the temperature regime of the locality were analyzed: geographical altitude, proximity to the sea, long-term interannual temperature changes. Recommendations were given as to calculation of atmosphere air statistical characteristics, needed for estimated values normalization and for assessment of building structures reliability indicators.

Keywords: statistical characteristics of temperature, quasi-stationary random process, reliability of building structures.

1. Introduction

Atmosphere air temperature changes significantly influence building structures, in particular, induce forces and shifts in load-bearing structures, lead to damages due to freeze resistance loss of building materials, cause thermal failures of frame fillings, and also affect the processes of erection of buildings and structures. Energy saving issues occupy one of the central places among scientific problems of modern building industry. Taking into account stochastic variations of atmosphere air temperature and their study play the leading role in solving of the above mentioned problems. That is why it is essential to take into account temperature effects both in construction design, in planning construction processes, and during probabilistic calculations of building structures reliability.

Probabilistic calculations require temperature effects representation in the form of random variables or random processes, as well as the creation of representative database of statistical characteristics of random variables and processes of atmosphere air temperature changes. Despite the existence of developed methodology of research, probabilistic representation and normalization of climatic loads and effects [3, 4], as well as the considerable volume of meteorological air temperature monitoring results [1, 2], the creation of representative database of statistical characteristics of temperature effects, needed for reliability calculations, is not complete for Ukraine's territory. Besides, the effects of additional geographical factors (rugged terrain, seaside territory, long-term interannual variability trends etc.) must be analyzed and taken into consideration.

This work was aimed at generalized representation of statistical characteristics of random process of atmosphere air temperature changes, allowing for the above mentioned additional geographical factors.

2. Main body of the abstract

The results of measurements of average daily temperature of air at 485 monitoring stations of Ukraine, which were published in specialized meteorological editions, were used *as basic data*. The results of these observations were mainly analyzed in monograph [2]. The considerable volume of used data ensures the validity of the results, and allocation of monitoring stations in different regions and geographical conditions (flat country and rugged terrain, continental and seaside territories) allow analyzing and taking into account the effect of geographical conditions on atmosphere air temperature regime.

Seasonal and interdiurnal air temperature variability is described with the probabilistic model of quasi-stationary random process. Its possibility of usage in representation of climatic loads and effects was substantiated in [2]. For such a description we need to define the annual functions of mathematical expectation M (t), standard S (t) and asymmetry parameter A (t). Effective frequency value ω = 0,6 1/24hrs is fixed in time and invariable for the whole territory of Ukraine.

The territorial variability of air temperature statistical characteristics is represented on zoning maps of average temperatures of the coldest (January) M_1 and the warmest (July) M_7 months of the year. The obtained from the maps values of average January and July temperatures in the specified geographical point set the annual fluctuation amplitude of air temperature, and enable to calculate the average annual temperature value,

$$M_P = \frac{M_1 + M_7}{2} \tag{1}$$

and set the mathematical expectation function of air temperature M(t) according to sinusoidal law

$$M(t) = \frac{M_1 + M_7}{2} - \frac{M_7 + M_1}{2} \cos\left(\frac{t - 15}{57.3}\right) \tag{2}$$

where M_1 and M_7 are the average July and January temperatures from the zoning maps; *t* is time counted off in days starting from the 1st of January.

The analysis has shown that such an approach ensures satisfactory accuracy, as for 90% of monitoring stations the difference between the factual data and the results, obtained from the maps and formulas (1), (2), is no more than 1°C.

The functions of standard $S(t)$ and asymmetry parameter $A(t)$ are approximately estimated through the mathematical expectation function $M(t)$ and using the formulas:

$$S(t) = 5{,}5\, e^{-0{,}026\, M(t)} \tag{3}$$

$$A(t) = -0{,}3\, e^{-0{,}1\, M(t)} \tag{4}$$

Expressions (3), (4) are satisfactory accurate and have absolutely predictable asymptotic behavior, which allows them to be used in reliability calculations.

Distribution law of the ordinate of the random average daily air temperature process at any moment of time during the year is described by the mixed Gumbel-Gauss law with probability density

$$f(x) = \frac{C}{0.78S}\exp\left[y - \exp(y)\right] + \frac{1-C}{S\sqrt{2\pi}}\exp\left[-\frac{(x-M)^2}{2S^2}\right] \qquad (5)$$

where M, S, A are mathematical expectation, standard and asymmetry parameter of ordinate distribution at a particular moment of time according to formulas (2), (3), (4);

$C = -0{,}8775\ A$ – weighting factor;

$y = \frac{\mathrm{x} - M}{0.78\ S} - 0.577$ – Gumbel distribution argument.

Probability density expression (5) allows for asymmetry parameter $A \le 0$ practically in all cases. This is ensured by the formula (4).

Ordinate distribution may also be approximately described by the Gaussian normal distribution law.

Geographical altitude effect was analyzed using the data from 43 monitoring stations, located in the region of the Crimean Mountains, and 74 monitoring stations in the Carpathian Mountains. The length of the observation series varies from 8 to 100 years. 87 monitoring stations are located at altitudes of up to 500 meters above sea level and therefore can be considered flat. 30 monitoring stations are located at altitudes of up to 1500 meters above sea level.

The average January temperature decreases by 4 ... 5°C, and the average July temperature decreases by 6 ... 7°C per every 1 km increase of altitude. Correction for altitude for estimated values of temperatures of the warmest and the coldest days, with different recurrence periods, also fluctuate between 4 ... 7°C per 1 km of altitude above sea level.

The conducted research also confirmed the possibility of using the correction known from the literature for altitude above sea level (-6°C per 1 km of altitude) both for average and for estimated values of atmosphere air temperature.

Seaside territories are characterized by milder temperature conditions, due to heat-accumulating influence of significant masses of sea water.

For 74 monitoring stations, located on the territory of the Crimean peninsula and in the coastal zone of the Black and Azov seas, with a width of up to 100 km, the distance from the nearest seashore and the parameters of the air temperature were determined:

M_1 – the average temperature in January (the coldest month of the year); M_7 – the average temperature in July (the warmest month of the year); M_p – the average annual air temperature; n_p – the average annual quantity of average daily air temperature transitions through 0 ºC.

An analysis of dependency of these parameters on the distance to sea shore enabled to discover the following regularities:

The average temperatures of July M_7, January M_1, and the average annual air temperature M_p tend to decrease with moving from the seashore. With increase of distance L to 100 kilometers they generally decrease by 0,5...2 ºC. In addition, in the charts of dependencies of M_1 and M_p on L, there is also a sharp increase in temperatures in the zone 5 ... 10 km from the seashore. The value of M_1 increases approximately by 3...4°C, and the value of M_p – by 2°C.

The number n_p of transitions of average daily air temperature through 0ºC on average on the continental territory amounts to 12...14 transitions per year, but in 10-kilometers coastal zone decreases to 6...10 transitions per year. The reduction of freezing-thaw cycles positively affects the freeze resistance of building materials.

According to the results of the conducted research, it is recommended, when determining the parameters of the temperature regime for areas located up to 10 km from the seashore, to use the data of the nearest meteorological stations, which are also located in the 10-kilometer coastal zone. When using the zoning maps the average January temperatures in 10-kilometer coastal zone may be increased by 3...4°C (towards warmer temperatures).

Long-term air temperature changes are generally consistent with the known trend of global warming. According to the results of recent 20-year observations at 25 weather stations of Ukraine, the changes in time of average annual air temperature values have been analyzed, as well as the minimum and maximum values, recorded during each of the years of observation. These data characterize the changes in average temperatures, as well as the minimum (winter) and maximum (summer) estimated values of temperature. By approximating the obtained sequences with linear functions, it has been established that the values of annual increments of temperature in general are negligible and vary in different meteorological stations within the interval –0,13°C ... +0,20°C.

State building codes and standards are reviewed every 5-10 years. Thus, during the 10-year period between the regular revisions of norms, the average and estimated values of the air temperature change by no more than 2,0 °C, Such changes will not have any significant influence on the work of frame filling, heating and air conditioning systems. In order to increase reliability, it is recommended to increase the estimated maximum summer air temperature values by 1,0°C, and accordingly reduce the minimum estimated air temperature values by 1,0°C, based on available meteorological data at the time of norms development or revision.

3. Conclusion

1. Changes of average daily atmosphere air temperature are represented in the form of quasi-stationary random process, statistical characteristics of which may be calculated using the developed zoning maps of average January and July temperatures with the help of the above stated formulas.
2. The obtained statistical characteristics of quasi-stationary random process of average daily air temperature changes are close to real results of statistical data analysis of monitoring stations, and may be used for solving of building structures reliability problems.
3. The small annual increments of temperatures allow us to take into account the phenomenon of global warming by adjusting the estimated values of air temperature at regular revisions of the norms of loads and influences, with allowance for the results of observations during the recent years.

4. References

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