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Mathematical Models for Calculating Structures under a Combination of Loads

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Abstract:

The chosen direction of work, the loads acting on the structure, including some long-term ones, are of a random temporary nature. An unfavorable combination of several random loads over time has a low probability. The work of combinations of snow loads is devoted to solving the problem of combining loads. The combination coefficients largely determine the magnitude of the loads on the structure, and therefore its parameters, material consumption and cost on the one hand; on the other hand, the correct assignment of these coefficients ensures the reliability of the structures.

Keywords: Beam, support moments, load, moment of inertia, recurrence relation, conditional probability.

1. Introduction

At present, when Uzbekistan is tasked with creating cost-effective structures of optimal reliability, the theoretical justification of building codes and regulations is acquiring important national economic significance.

During the survey, among a number of characteristics of the snow cover, the height and density of the snow are determined, which, in turn, serve as the basis for calculating the water reserve in the snow. The water reserve in snow, expressed in mm, corresponds to the weight of the snow cover in kg/or snow load [1].

Calculations of probabilistic values of snow cover weight were carried out using a statistical series consisting of annual maximums of water reserves in snow with a repetition period of 2, 5, 10 and 20 years [1,2].

2. Materials and methods

If the snow load is the only load acting on the structure, then we are only interested in the distribution law for the maximum value of the snow load during the winter. This distribution is usually assumed to be double exponential.

$$F_0(x) = H_{3,0}\left(\frac{x-a}{b}\right) = \exp\left(-\,exp\left(-\frac{x-a}{b}\right)\right) \quad (1)$$

The notation is adopted in (22). $H_{3,0}(x) = \exp(-e^{-x})$ The numerical values of parameters a and b for Moscow are given in [4]. $a = 931\frac{\text{Н}}{\text{м}^2}$, $b = 365\frac{\text{Н}}{\text{м}^2}$

Let us show the possibility of representing the snow load for the winter period in the form of a sample volume $X_1, X_2, \ldots, X_n$ n where X_i independent random variables with the same distribution law. The time interval τ corresponding to each random variable will be clarified later. The random process of snow load X(t) is represented as a step function:

$$X(t) = X_i\ ,\quad t \in [(i-1)\tau : i\tau)],\quad i = 1, 2,\ \ n \qquad (2)$$

Next, we make the following assumptions, which do not contradict common sense:

1. There are n independent and identically distributed random variables $X_{n:n}$ with a distribution law $F(x)$ such that their order statistics $X_{1:n}, X_{2:n}, \ldots, X_{n:n}$ are observable snow accumulation processes.

2. Random values of load increment $U_2 = X_{2:n} - X_{1:n}$, ... $U_n = X_{n:n} - X_{n-1:n}$ independent.

From assumption 2 it follows that the law of distribution of random variables $X_1, X_2, \ldots, X_n$ is exponential, i.e. $F(x) = 1 - e^{-\lambda x}$. Evidence of this fact was given by J. Galambos.

Based on this theorem, it is easy to prove that for a sequence of independent random variables $X_1, X_2, \ldots, X_n$ with a distribution function of $F(x) = 1 - e^{-x}$. limit distribution law is double exponential, i.e.:

$$\lim_{n\to\infty} P\{Z_n < a_n + b_n y\} = \exp(-e^{-y})\ , \qquad (3)$$

a_n, b_n - normalizing constants, equal

$$.\ a_n = \ln n\ u\ b_n = 1\ , \qquad (4)$$

If

$F(x) = 1 - e^{-\lambda x}$, то

$$a_n = \frac{\ln n}{\lambda}\ ,\quad b_n = \frac{1}{\lambda} \qquad (1.15)$$

$b = b_n$ we consider known $b = 365\frac{\text{Н}}{\text{м}^2}$. The value λ is obtained from the relation $\lambda = \frac{1}{b} = 0{,}00274$.

Let's adjust the value $a = a_n$ a little compared to (3) so that the number $n = \exp(\frac{a}{b})$ is equal to an integer.

We get $n = 13$, $a = 936{,}113\frac{\text{Н}}{\text{м}^2}$.

For the obtained value, it is quite plausible to assign a value equal to 10 days to the time interval, and a value equal to 130 days to the duration of winter.

To substantiate our model, we can give the following reasoning. Let $X_1, X_2, \dots, X_n$ be an independently identical distribution of a quantity with a distribution function $F(x)$.

Let $X_{1:n}, X_{2:n}, \dots, X_{n:n}$ be the order statistics corresponding to the random variables X_j $(1 \le j \le n)$. Let's put $U_1 = X_{1:n} U_2 = X_{2:n} - X_{1:n}$, ... $U_n = X_{j:n} - X_{j-1:n}$, $j \ge 2$.

$F(x) = 1 - e^{-\lambda x}$; $X_1, X_2, \dots, X_n$; $F(x)$; U_j $(j \ge 1)$; $F(x) = 1 - e^{-\lambda x}$.

Now a model is proposed that necessarily follows if we accept the assumption of independence of snow load increments over a time interval of $\tau = 10$ days.

3. Results and Discussion

The disadvantage of the proposed model is the constancy of the snow load increment and, as a consequence, the discreteness of the random value of the maximum snow load.

We will assume that at *n* time points the snow load increases by the value U_i (i=1, 2, … ,n). The number of jumps is a random variable with mathematical expectation. As mentioned above, from the assumption of independence of random variables U_i. It follows that their distribution law is exponential.

$n = \bar{n}$; $\tau = T/(n+1)$

The law of distribution of the maximum snow load during the winter

$$F(x) = e^{-\bar{m}} \sum_{i=0}^{\infty} \frac{\bar{n}^i}{i!} \left[1 - e^{-\lambda_1 x}\right]^i, \qquad (15)$$

It is easy to show that the distribution function $F_1(x)$ и $F_2(x)$ in expressions (14) and (15) are comparable Parameters λ_1 и $\bar{n}$ can be selected from the condition that functions $F_1(x)$ и $F_2(x)$ and distribution function $F_0(x)$ from (9) are comparable.

4. Conclusion

Thus, models of a random process with independent increments for random times of load surges and non-random times of these surges can be considered little different from each other.

A model based on the application of the theory of order statistics is actually identical to a process model with random increments at non-random points in time.

The good agreement of all these models is an argument in favor of their adequacy.

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