Basic Snow Pressure Calculation

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Abstract. As extreme weather rising in recent years, the damage of large steel structures caused by weather is frequent in China. How to consider the effect of wind and snow loads on the structure in structural design has become the focus of attention in engineering field. In this paper, based on the serious snow disasters in recent years and comparative analysis of some scholars, influence factors and the value of the snow load, the probability model are described.

1. Introduction

In 2007, Liaoning Province suffered the biggest snow disaster since the meteorological record, which caused great economic losses to the economy and heavy casualties of Liaoning Province. In contrast, similar incidents had occurred in Tibet in 1956, most parts of northern China in 1977, the southern region of Xinjiang in 1983 and the snow disaster in southern China in 2008.Through investigating and analyzing the common characteristics of such events are caused by excessive snow load, so the related problems about snow load in structure design should be concerned widely [1, 2].

2. Data processing of relevant materials

The snow pressure data can be obtained from the local meteorological bureau's weather statistics for the past years and the result is the closest to the local actual situation. It can also be calculated based on basic snow pressure value in the current load code in China. On the basis of the old code, the present load code for the design of concrete building structure has added to the basic snow pressure data in recent years, the basic snow pressure value in some areas has been increased, which accords with the actual situation of frequent accidents caused by abnormal snow load in recent years. In addition, in the absence of snow pressure record, the following two methods can be used to calculate the basic snow pressure:

(1) The relationship between the snow depth h, density ρ and the basic snow pressure s can be calculated by the following formula:

$$s=h\rho g. \tag{1}$$

In the formula: h —The snow depth, vertical depth from the surface of the snow to the ground(m).

ρ —The density of snow(t/m^3), the specification in the appendix to all regions of China has carried on the provisions.

g —Acceleration of gravity,9.8m/s^2.

(2) The snow pressure is calculated indirectly by converting precipitation into snow depth. The snow pressure is calculated indirectly by converting precipitation into snow depth. The daily average temperature is 3.1ºC as the critical temperature value, the rainfall can be used as the snowfall data when the temperature is less than or equal to 3.1ºC, ensuring snowfall rate is 98.5% and the rainfall data into snow depth with 1:10 conversion ratio.

3. The calculation method of annual maximum snow pressure

3.1. Establishment of snow load probability distribution model

According to the content of the code of structural design in China, the probabilistic model of live load on the floor, wind load and so on is assumed to be based on the stationary binomial stochastic process, that is to translate the sample data in the process of the stochastic load into a data model of equal time period, so the snow load probability model will use a stationary binomial stochastic process, the steps are as follows [3]:

   (1) The building design reference period is T, which is divided into r equal time periods;
   (2) The probability of occurrence of snow load is p, and the probability of non-occurrence is q=1-p within any period of time;
   (3) In any time period, the probability distribution function of snow load at any time point is equal to the cumulative distribution function of snow load and the amplitude of snow load on each time period is independent and identically distributed;
   (4) The probability of the occurrence of snow load and the amplitude of snow load in different time periods are independent of each other.

The probability distribution of the maximum annual snow pressure is based on the probability distribution of the extreme value type I according to the specification. The distribution function is:

$$F（x）=\exp\left\{-\exp\left[-\alpha(x-u)\right]\right\}(\alpha>0, -\infty<u<\infty) \tag{2}$$

In the formula: x —The annual maximum snow sample
   u —The positional parameters of the distribution, the value of the sample distribution;
   α —The size parameter of distribution;
   σ —The standard deviation of the sample;
   μ —The average of the samples.

The maximum snow pressure with a return period of R is determined as follows:

$$x_R = u - \frac{1}{\alpha}\ln\left[\ln\left(\frac{R}{R\text{-}1}\right)\right] \tag{3}$$

3.2. Parameter estimation of α and μ in extreme value distribution

The methods of estimating the parameters of the extreme value type I probability distribution is the moment method, the maximum likelihood method and the Gumbel method [4-6].

   (1) The moment method

Moment estimation method is to estimate the parameters of the whole numerical characteristics by using the moments of samples. It is intuitionistic and practical in mathematical calculation. The newest load specification in China uses this method to estimate the parameters of α and μ, the formula is as follows:

$$\alpha = \frac{1.28255}{\sigma} \tag{4}$$

$$u = \mu - \frac{0.57722}{\alpha} \tag{5}$$

   (2) The maximum likelihood method

According to the sample, constructs the likelihood function. Each group of samples is brought into the likelihood function, and then the maximum likelihood estimator is obtained as the parameter of the model. The parameter estimation formula is:

$$\sum_{i=1}^{n} \exp[-\alpha x_i + 1/(n-1) + (-\alpha/n)\sum_{i=1}^{n} x_i] - n = 0 \tag{6}$$

$$\mu = 1/[\alpha(n-1)] + 1/n\sum_{i=1}^{n} x_i \tag{7}$$

In the formula: x_i —The i-th observed value of the sample

This method is widely used in various parameter estimations and has a good fit, especially for the case when the sample size is small.

(3) The Gumbel method

Gumbel method is the combination of empirical guarantee function and the actual parameters to estimate the parameters. The annual maximum snow assumed to be an ordered sequence: $x_1 \leq (\geq) x_2 \leq (\geq) x_3 \leq (\geq)\cdots \leq (\geq) x_n$ then the experience guaranteed function is:

$$F(x_i) = \frac{i}{n+1} \tag{8}$$

The probability of equal or large (small) to the i-th value is about i / (n+1). when n samples of max (small) values are arranged from large (small) to small (large) is about F (x_i) = F^(x_i). from the law of large numbers, we know that when the number of samples is large enough, the empirical guarantee function will approximate the population distribution function. Similar to the moment method, we can get this formula:

$$\alpha = \frac{\sigma(y)}{\sigma(x)} \tag{9}$$

$$\mu = E(x) - \frac{E(y)}{\alpha} \tag{10}$$

3.3. Evaluation of the results of parameter estimation
It is usually used to fit the test index of Kolmogorov to test the parameters of the parameter estimation. The formula is as follows:

$$K_f = D_n\sqrt{n} \tag{11}$$

In the formula: n—The size of a sample

D_n—At all points, the maximum value of the difference between the theoretical distribution of the empirical distribution and the hypothesis.

$$D_n = \max\left\{\left\|F\ \overset{\wedge}{(x_i)} - F\ (x_i)\right\|\right\} \tag{12}$$

When the value of the index is smaller, it means that the fitting effect is better.

4. Analysis of Calculation Results
Taking Dalian, Shenyang, Dandong, Dalian and Chaoyang four cities in Liaoning province China as examples, the maximum snow pressure statistics are obtained from the data collected through the Internet. The data are plotted in two years as shown in the following figure. The parameters of the parameters estimation are evaluated by the method of moment estimation and Gumbel method, and then use the Kolmogorov fitting test to test the parameters.
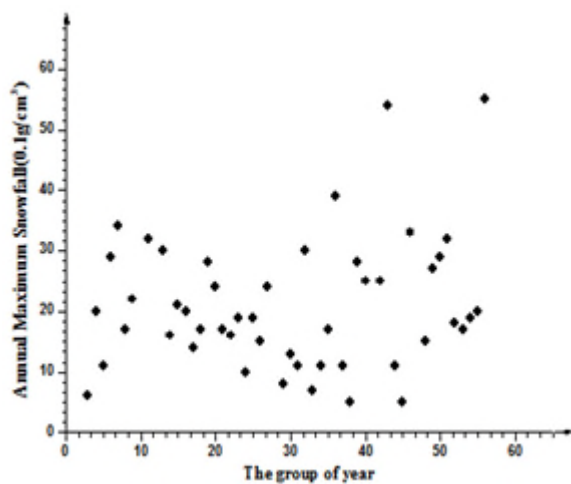
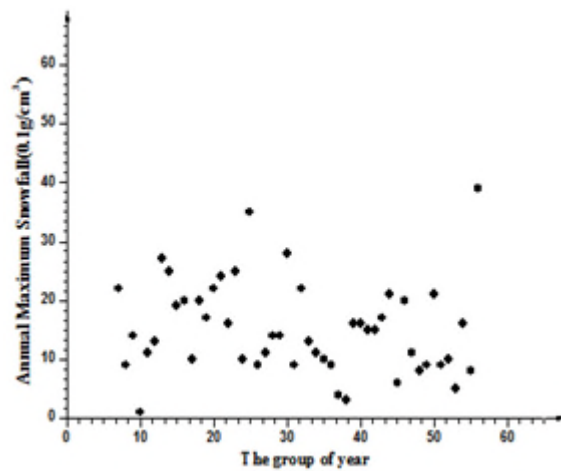**Figure 1.** The annual maximum snowfall of Shenyang.
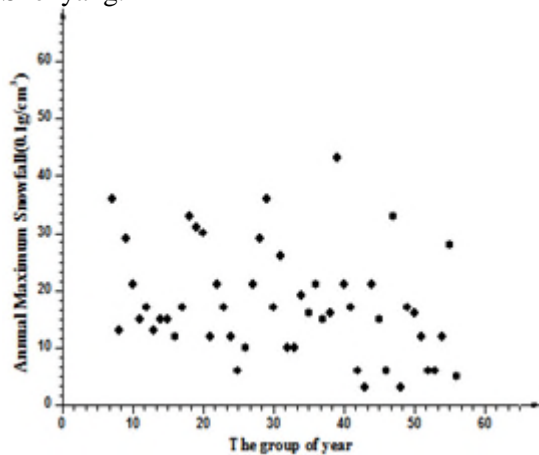

Figure 2. The annual maximum snowfall of Dandong.
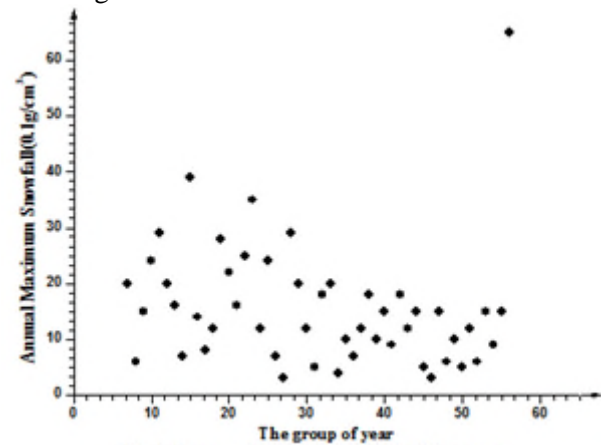

Figure 3. The annual maximum snowfall of Dalian.

Figure 4. The annual maximum snowfall of Chaoyang.

Table 1. Comparison of the basic snow pressure calculation results.

City	The moment estimation method		The Gumbel method		The value in the code		K_f	
	n=10	**n=30**	**n=10**	**n=30**	**n=10**	**n=30**	**Moment**	**Gumbel**
Shenyang	0.45	0.51	0.41	0.50	0.40	0.50	0.543	0.451
Dandong	0.27	0.31	0.29	0.34	0.35	0.49	0.787	0.623
Dalian	0.32	0.34	0.33	0.37	0.40	0.57	0.583	0.453
Chaoyang	0.32	0.34	0.33	0.32	0.40	0.50	1.291	1.211

The calculation results in the table are obviously larger than the specified value in the load specification. The reason is that the average value and the standard deviation of the samples are not correctly treated for unrecorded values and abnormal values.

5. Conclusion

1. It can be used to estimate the parameters directly in the calculation and also suitable for most cities in Liaoning Province, Otherwise, some regions can be calculated by convenient moment estimation method.

2. Analysis on the calculation results of other cities in Liaoning province is not listed in the paper found that most of the cities' basic snow pressure value after the revision of the new building load code, it can be applied to the engineering practice.

3. For the default values and outliers in the samples, the final calculation results will have a great impact because of the influence of local temperature and altitude on the snow depth during the basic snow pressure statistics lead the accumulation of errors. How to deal with such problems still needs studying.

References

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