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Research Article

Research on Basic Wind Pressure Calculation Method for Lacking Long-Term Wind Speed Data

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In engineering structural design, wind load is of particular importance, and the basic wind pressure is the basis for wind load calculation. Specifications of many countries fail to use the given method to calculate the basic wind pressure for areas or engineering projects with only short-term wind speed data. At the same time, there are few studies on short-term wind speed data fitting by using the extreme value Type III distribution as the distribution law. In this study, the extreme value Type III distribution with variable substitution method and least square method as parameter estimation method is used to fit and analyze the daily, weekly, and monthly maximum wind speed data of 13 major cities in China, when using the Kolmogorov–Smirnov test method to test the results of the fit, it finds that in the wind speed samples of most cities, only the monthly maximum wind speed data obeys the extreme value Type III distribution. By comparing the optimal criterion of estimation, it can be seen that the extreme value Type III distribution fits well with the monthly maximum wind speed data of each city, and the variable substitution method is the most optimal parameter estimation method. The above results show that in areas where long-term wind speed data are insufficient, short-term wind speed data is an available option. Taking the extreme value Type III distribution as the probability distribution, the method of calculating the basic wind pressure of different return periods based on short-term wind speed data is summarized by comparing the specifications of various countries in the world.

1. Introduction

According to the survey and analysis, the losses caused by wind disasters include the damage and collapse of engineering structures. Therefore, it is extremely important to reasonably determine the design value of wind load for structural design [1, 2]. The basic wind pressure is an important indicator of the wind load value. It is necessary to find an optimal load fortification level [3].

Depending on fluid mechanics, the basic wind pressure is linked to the distribution of the maximum wind speed in years. Selecting the correct maximum wind speed probability distribution function and determining the maximum wind speed during its service time are the main subjects to solve the wind pressure issue. In order to solve the matter of the maximum wind speed, the existing wind speed distribution law is generally used to calculate the maximum wind speed that is recorded in existing wind speed statistics. One of the earliest scholars who utilized probability and statistics to study the maximum wind speed during the design reference period by Davenport [4], he proposed using various distribution models for statistical analysis of wind speed data. Because the extreme value Type I distribution has the features of the original distribution of random variable exponential type, it is commonly used in the specifications of various countries [5]. However, in recent years, some scholars [6–8] have discovered the boundedness of extreme wind speed, which is contrary to the infinite physical property of the right tail of the extreme value Type I distribution, and that the extreme value Type III distribution, as a bounded extreme value distribution, is consistent with its right tail. At the same time, the extreme value Type III distribution itself has good scalability and can describe various wind speed distributions well [9]. Therefore, the extreme value Type III distribution is widely used and introduced into the research field of wind energy [10–15]. At the same time, due to the excellent performance of the extreme value Type III distribution, it is written into the WASP wind energy evaluation software [16–19].

At present, most countries in the world generally use the annual maximum wind speed data as a sample for statistical analysis in places with long-term wind speed observation records. For areas without long-term wind speed data, it is of great significance to provide a reasonable basic wind pressure for design reference based on limited short-term wind speed data. Currently, based on short-term wind speed data, scholars [20, 21] use the annual and monthly maximum wind speed data as samples to calculate the wind pressure during the design reference period, but there are relatively few studies using the weekly and daily maximum wind speed data as sample for calculation, and there is a lack of research using both data calculate the basic wind pressure. Meanwhile, most of the existing studies are based on short-term wind speed data to focus on a certain city or region, but the rules summarized according to a certain region or city are not necessarily suitable for every region. In addition, there is no reference value for wind pressure with a return period of less than one year in the code. As a result, numerous projects with a short design life, such as demolition projects, do not have a suitable reference value for basic wind pressure.

In order to improve the theory and method of calculating basic wind pressure using short-term wind speed data. This paper studies the basic wind pressure based on the short-term wind speed data through the extreme value Type III distribution and provides a reference for the wind load calculation of regional projects lacking long-term wind speed data and projects with a short design life. The reminder of this study is outlined as follows: Section 2 compares the specifications of several countries in the world, and briefly introduces the conversion method of wind speed data adapted to various countries by using the Chinese code. Section 3 introduces the probability distribution and the corresponding parameter estimation method used to obtain the maximum wind speed data and three indicators to test the optimal criterion of estimation for determining the reasonable maximum wind speed calculation method, also introduces the basic wind pressure calculation method. Section 4 makes a statistical analysis of the short-term wind speed data from 13 cities in China according to the extreme value Type III distribution and its parameter estimation method, the optimal criterion of estimation was used for comparison. Being dependent on the analysis and comparison results, the basic wind pressure of each city with different return periods is calculated by the Bernoulli formula, and a method to calculate the basic wind pressure based on short-term wind speed data is proposed.

2. Wind Speed Statistics and Basic Wind Pressure Calculation Method

2.1. Comparison of National Specifications. Wind speed is the foundation for calculating the basic wind pressure. To calculate the correct basic wind pressure, we must first determine a reasonable wind speed value. Before statistical analysis of wind speed, the required wind speed data should be collected first, and the collected original wind speed data should be reviewed to make sure it meets the standards stipulated in the code. In order to compare the wind speed or wind pressure in different regions, the landforms and observation height in different regions are stipulated. The wind speed and wind pressure determined in accordance with relevant specifications are called basic wind speed and basic wind pressure. Depending on the definition of the basic wind speed in various countries, the main difference in determining the basic wind speed lies in the difference in the time distance and return period of the wind speed. For the wind speed time distance, Vietnam (TCVN2737 : 1995) and the United States (ASCE7-10) both use 3 s, China, European countries (EN1991-1-4), and Japan (AIJ-2004) use 600 s. For the return period, China and European countries adopt 50 years, Vietnam adopts 20 years, and Japan adopts 100 years. In the United States, in the latest 10 additions, major changes have taken place in the selection of return periods. The new edition is to divide the return period level according to the different risk levels of the building. The return period corresponding to build risk level I is 300 years, the return period corresponding to levels I and III is 700 years, and the return period corresponding to level IV is 1700 years. When using unique specifications for wind load calculation, a certain conversion relationship can be established by synthesizing the difference between time and return period. Therefore, the ratio of basic wind speed in China, Vietnam, Europe, and Japan is 1 : 1.306 : 1:1.06. When selecting the return period corresponding to Class III in the American loads, the basic wind speed ratio between China and the United States is 1 : 1.86 [22].

2.2. Extreme Value Type III Distribution and Parameter Estimation. Before statistical analysis of wind speed, the required wind speed data should be collected first, and the representativeness, accuracy, and continuity of the collected data should be reviewed and processed. Finally, make them meet the code wind speed required by the specification before they can be directly used for statistical analysis.

The probability distribution of wind speed that can be used in the statistical analysis is the Pearson Type III distribution, normal distribution, extreme value Type I distribution, extreme value Type II distribution, and extreme value Type III distribution. Through long-term research, a large number of examples show that the frequency curve of the Pearson Type III distribution often deviates from the empirical point at both ends, in which case the corresponding value with a small probability is generally smaller than that of the empirical point, which is unsafe. The range of variables in the normal distribution is from $-\infty$ to $+\infty$, which is not consistent with the physical meaning of maximum wind speed. The maximum wind speed value is given by the extreme value Type II distribution is generally small. The extreme value Type I distribution and the extreme value Type III distribution are better than the extreme value Type II distribution. Because the infinity of the right tail of the extreme value Type I distribution is opposite to the boundedness of extreme value wind speed, this study selects the extreme value Type III distribution for statistical analysis of the wind speed data.

The extreme value Type III distribution is otherwise known as the Weibull distribution. Weibull distribution can be apparent as a degenerate form of generalized extreme value distribution (GEV), which can get better calculation results [23]. Some scholars [24] use a two-parameter model when using the extreme value Type III distribution for research. However, the two-parameter model generally ignores the influence of location parameters, so this paper selects a more accurate three-parameter Extreme value Type III distribution for research [25–28]. Several expressions of the extreme value Type III distribution are introduced below [29].

Distribution function formula $F(x)$:

$$F(x) = 1 - \exp\left[-\left(\frac{x-u}{a}\right)^{\gamma}\right]. \tag{1}$$

Distribution probability density function formula $f(x)$:

$$f(x) = \frac{\gamma}{a}\left(\frac{x-u}{a}\right)^{\gamma-1}\exp\left[-\left(\frac{x-u}{a}\right)^{\gamma}\right]. \tag{2}$$

The maximum wind speed formula x_R when the return period is R:

$$x_R = u + \exp\left\{\frac{1}{\gamma}\ln\left[\ln(R)\right] + \ln a\right\}, \tag{3}$$

where x is the samples from wind speed statistics; u is the location parameter; a is the scale parameter, $a > 0$; γ is the shape parameter, it is also called tail length, $(\gamma > 0)$; R is the return period.

In formula (3), when different types of wind speed data are utilized to analyze, the value of R is different. For example, when the annual maximum wind speed data is employed to analyze, the return period is 50 years, and $R = 50$ can be taken. If monthly maximum wind speed data are used for analysis, the return period is 50 years, then, $R = 12 \times 50 = 600$. When taking daily and weekly maximum wind speed data, the method of taking R is analogous.

The extreme value Type III distribution usually uses these methods for parameter estimation: the moment estimation method, maximum likelihood method, least square method, and variable substitution method. The moment estimation method and the maximum likelihood method cannot give the analytical expressions of the parameters in many cases, and it is very difficult to solve the complex nonlinear equations numerically [30]. Therefore, when estimating the parameters of the extreme value Type III distribution, this paper chooses the variable substitution method and the least square method.

The variable substitution method mainly aims at some complex multivariate models, introducing new variables, and simplifying the mathematical structure to simplify complex problems. The variable substitution method is convenient to use, and the parameters obtained are more accurate. The method of variable substitution is as follows:

$$y = \ln\left(\frac{x-u}{a}\right). \tag{4}$$

Then, the probability density function of variable y is

$$f(y) = \gamma\exp\left[\gamma y - \exp(\gamma y)\right]. \tag{5}$$

Using Γ function, we can obtain expectations $E(y)$ and variances $\sigma^2(y)$ about y:

$$E(y) = \int_{-\infty}^{+\infty} y f(y)\mathrm{d}y = -\frac{c}{\gamma}, \tag{6}$$

$$\sigma^2(y) = E\left(y^2\right) - [E(y)]^2 = \frac{\pi^2}{6\gamma^2}, \tag{7}$$

where c is Euler's constant, $c = 0.57722$.

From formulas (4), (5) and (6), we can get

$$\gamma = \frac{\pi}{\sqrt{6\sigma^2[\ln(x-u)]}}, \tag{8}$$

$$a = \exp\left\{\frac{C}{\gamma} + E[\ln(x-u)]\right\}. \tag{9}$$

Because of $x > u$, u is less than each value which is in the wind speed statistics sample, namely, $u < x_{\min} = \min\{x_i\}$, $[ii] = 1, 2, \ldots, n$, x_i is the sample value, n is a sample capacity of wind speed data, the formula of u is

$$u = x_{\min} - \varepsilon(\varepsilon > 0). \tag{10}$$

Related to $\ln(x-u)$ mathematical expectations $E[\ln(x-u)]$ and variances $\sigma^2[\ln(x-u)]$:

$$E[\ln(x-u)] = \frac{1}{n}\sum_{i=1}^{n}(x_i - u), \tag{11}$$

$$\sigma^2[\ln(x-u)] = \frac{1}{n}\sum_{i=1}^{n}\left[\ln(x_i-u)\right]^2 - \left[\frac{1}{n}\sum_{i=1}^{n}\ln(x_i-u)\right]^2. \tag{12}$$

By substituting formulas (11) and (12) into formulas (8) and (9), the values of γ and a can be determined. By formula (10), we know the value of $u$is associated with ε, so adjusting the value ofε can obtain different the value of u, then the value of u substitutes formulas (8) and (9), a and γ corresponding to u can be identified, constantly adjusting valueε, the values of u, a and γ can be got series. According to the optimal criterion of estimation, a set of more optimal parameter values can be extended.

The least square method follows the minimum principle of the sum of deviations of squares when calculating the parameters of the equation. According to the principle least square method, the original probability distribution function $F(x)$ needs to be linearly transformed when choosing a linear function $Y = BX + A$ fits the probability distribution.

Linear transformation formula of the extreme value Type III distribution:

$$\ln\{-\ln[1-F(x)]\}=\gamma\ln(x-u)-\gamma\ln a, \quad (13)$$

where a is the scale parameter; u is the positional arguments; γ is the shape parameter.

Calculating the $F(x)$ in the formula (13) needs to start with samples from the wind speed statistics to arrange $x_1, x_2, x_3\cdots, x_i,\cdots, x_n$ in order from smallest to largest: $x_1^*\le x_2^*\le x_3^*\le\cdots\le x_i^*\le\cdots\le x_n^*$, obtains:

$$F^*(x_i)=\frac{i}{n+1}, i=1,2,\cdots,n. \quad (14)$$

The sample values in wind speed statistics can be obtained by formula (14). Parameter A and parameter B in the linear function $Y=BX+A$ is expressed as follows:

$$A=\frac{\sum_{i=1}^n X_iY_i\sum_{i=1}^n X_i-\sum_{i=1}^n Y_i\sum_{i=1}^n X_i^2}{\left(\sum_{i=1}^n X_i^{\,2}-n\sum_{i=1}^n X_i^2\right)}, \quad (15)$$

$$B=\frac{\sum_{i=1}^n X_i\sum_{i=1}^n Y_i-n\sum_{i=1}^n X_iY_i}{\left(\sum_{i=1}^n X_i^{\,2}-n\sum_{i=1}^n X_i^2\right)}. \quad (16)$$

By comparing formula (13) with the linear function $Y=AX+B$, it can be obtained: γ corresponds B, $-\gamma\ln a$ corresponds A, $\ln\{-\ln[1-F(x)]\}$ corresponds Y, $\ln(x-u)$ corresponds X. There are three parameters in formula (13), which cannot be directly solved by a linear function, and it needs to be given the value of $u$first, that u is assumed u_0, and $u_0<x_{\min}$. Through the given the value of u_0, a set of sample values for wind speed statistics x_i and $F^*(x_i)$, a set of parameters (u_0, a, γ) is related to extreme value distribution can be obtained by using formulas (15) and (16). Different the values of u_0 can be obtained through the formula $u_0=x_{\min}-t$, so that many groups (u_0, a, γ) can be obtained, and the group (u_0, a, γ) with the best fit as the parameter value.

2.3. Optimal Criterion of Estimation. For the unknown parameter, different probability distributions can be selected to calculate it, and it becomes a problem to choose a probability distribution for which calculating can get better parameter results. In addition, for the same set of parameters in the probability distribution, different parameter estimation methods can be selected for estimation, and the advantages and disadvantages of the parameter estimation results need to be measured to determine a more appropriate parameter estimation method [31]. To solve the abovementioned two problems, the optimal criterion of estimation is generally selected for testing. In this paper, the optimal criterion of estimation is selected as standard deviation of fit, relative deviation of fit, and Kolmogorov moderation of fit.

Standard deviation of the fit σ:

$$\sigma=\sqrt{\frac{\sum_{i=1}^n(x_i-\hat{x}_i)^2}{n-1}}. \quad (17)$$

Relative deviation of the fit V:

$$V=\frac{1}{n}\sum_{i=1}^n\left|\frac{x_i-\hat{x}_i}{\hat{x}_i}\right|, \quad (18)$$

where x_i is sample values in wind speed data; $\hat{x}_i$ is the fitted values of wind speed data and probability distribution.

The formula $\hat{x}_i$ of the extreme value Type III distribution:

$$\hat{x}_i=u+a\left[-\ln\left(1-F_{\mathrm{III}}(x_i)\right)\right]^{1/\gamma}=u+a\left[-\ln\left(1-\frac{i}{n+1}\right)\right]^{1/\gamma}. \quad (19)$$

Kolmogorov moderation of the fit:

$$D_n=\max\left\{\left|F_n^*(x)-F(x)\right|\right\}, \quad (20)$$

where $F(x)$ is the theoretical distribution function; $F_n^*(x)$ is the empirical distribution function, it is also called sample distribution function; D_n is the maximum deviation of the theoretical distribution $F(x)$ and the sample distribution $F_n^*(x)$.

Starting with samples from the wind speed statistics to arrange $x_1, x_2, x_3\cdots, x_i,\cdots, x_n$ in order from smallest to largest: $x_1^*\le x_2^*\le x_3^*\le\cdots\le x_i^*\le\cdots\le x_n^*$, the sample distribution function $F^*(x)$is expressed as follows:

$$F_n^*(x)=\begin{cases}0, & x\le x_1^*,\\ \frac{i}{n}, & x_i^*\le x\le x_{i+1}^*,\\ 1, & x>x_n^*.\end{cases} \quad (21)$$

Samples using wind speed statistics can be obtained from (21). After using the sample distribution to fit the theoretical distribution, a scientific and objective method is needed to check whether the actual overall distribution of the wind speed data conforms to the theoretical distribution. The Kolmogorov–Smirnov test is always chosen as it is a widely-used test method. Differentiating from other test methods, which usually only test the deviation between the sample distribution function $F_n^*(x)$ and the theoretical distribution function $F(x)$ within the interval, the Kolmogorov–Smirnov tests the deviation of the theoretical distribution function $F(x)$ and the sample distribution function $F_n^*(x)$ corresponding to each sample point, which is more accurate, scientific and practical [32]. Kolmogorov theory can be used to obtain the Kolmogorov moderation of fit test index K_f [33]:

$$K_f=D_n\sqrt{n}. \quad (22)$$

When Kolmogorov proposed the Kolmogorov theory, it was proved that for any real numbers $k>0$, there is

$$\lim P(Dn\sqrt{n}<k)=\theta(k)=\sum_{\lambda=-\infty}^{\infty}(-1)^{\lambda}[ee]^{-2\lambda^2k^2}, \quad (23)$$

or

$$\lim P\left(Dn\sqrt{n} \geq k\right) = 1 - \theta(k) = 1 - \sum_{\lambda=-\infty}^{\infty} (-1)^{\lambda} [ee]^{-2\lambda^2 k^2}. \tag{24}$$

If the population of the sample x_i conforms to the theoretical distribution $F(x)$, the maximum deviation D_n between the theoretical distribution $F(x)$ and the empirical distribution $F_n^*(x)$ with a capacity of n will be small, and the probability of a large value of D_n will be small. Therefore, if a small probability α is given, according to the Kolmogorov statistics and formula (25):

$$1 - \theta(k) = 1 - \sum_{\lambda=-\infty}^{\infty} (-1)^{\lambda} [ee]^{-2\lambda^2 k^2} = \alpha. \tag{25}$$

The threshold value $K_\alpha/\sqrt{n}$ of the Kolmogorov–Smirnov test can be calculated given a small probability α and a sample size of n can be calculated. If the measured $D_N > K_\alpha/\sqrt{n}$ indicates that the difference between the theoretical distribution $F(x)$ and the empirical distribution $F_n^*(x)$ is too large, according to the Kolmogorov theory, the sample is considered to not obey the theoretical distribution $F(x)$, otherwise it is considered that it does not refuse to obey [34]. In this study, the Kolmogorov–Smirnov test was utilized to test and select wind speed data. α(reliability) was taken to be 5%. $K_\alpha = 1.35$ can be found from Kolmogorov statistics. Therefore, the samples in the wind speed data can be considered to obey the extreme value Type III distribution when $K_f < 1.35$. Otherwise, it does not obey.

Among the optimal criterion of estimation, the standard deviation of fit σ has the highest precision. The relative deviation of the fit V and Kolmogorov moderation of the fit D_n have lower precision, so generally the smallest standard deviation of the fit σ is the best. Compared relative deviation of the fit V and Kolmogorov moderation of the fit D_n when the standard deviation of fit σ is the same [35, 36]. Therefore, the standard deviation of fit σ is the primary indicator of the fit effect, and the smaller standard deviation of fit σ, the better the fit effect.

2.4. Basic Wind Pressure Calculation Method. China, Vietnam, the United States, Europe, and Japan all calculate the basic wind pressure according to the Bernoulli formula. Considering the differences in air density values between countries, the basic wind pressure ratio in China, Vietnam, the United States, Europe, and Japan is 1 : 1.675 : 2.594 : 1 : 1.096.

The building structure load code (GB50009-2012) gives the calculation formula of the basic wind pressure:

$$w_0 = \frac{1}{2}\rho v_0^2, \tag{26}$$

where: w_0 is the basic wind pressure (kN/m^2); ρ is the air density (t/m^3); v_0 is the maximum wind speed (m/s).

From formula (26), we know, determination of basic wind pressure is related to the maximum wind speed and the air density. According to the code, the calculation formula of air density is

$$\rho = \frac{0.001276}{1 + 0.00366t}\left(\frac{p - 0.378e}{100000}\right), \tag{27}$$

where: ρ is the air density (kg/m^3); t is the air temperature (℃); p is the air pressure (Pa); e is the water vapor pressure (Pa).

At the same time, the Code stipulates that the air density can also be approximated by the following formula according to the altitude:

$$\rho = 0.00125e^{-0.0001z}, \tag{28}$$

where: z is the altitude (m).

3. Results and Discussion

Short-term wind speed data from 13 cities in seven regions of China were used for statistical analysis and parameter estimation. The calculation results of the extreme value Type III distribution and the fit of daily, weekly, and monthly maximum wind speed data are shown in Tables 1–3. The basic wind pressure with a return period of 6 months, 50 years, and 100 years was calculated by using the variable substitution method and the least square method.

As shown in Table 1, the extreme value Type III distribution is used for statistical analysis of the daily maximum wind speed data. First, the Kolmogorov moderation of fit test index is calculated by the formula (22). From the second part, we can know that when $K_f < 1.35$ ($D_n < 0.0316$), the daily maximum wind speed data of each city obeys the extreme value Type III distribution. It can be seen from Table 1 that among the 13 cities for statistical analysis, only the daily maximum wind speeds data from Yanji and Lhasa obey the extreme value Type III distribution, and the daily maximum wind speed data of the other cities do not obey the distribution.

As shown in Table 2, the extreme value Type III distribution is used for statistical analysis of the weekly maximum wind speed data. According to the above principles, when $K_f < 1.35$ ($D_n < 0.0817$), the weekly maximum wind speed data of each city obey the extreme value Type III distribution. Among the 13 cities, only the weekly maximum wind speed data of Yanji, Hohhot, and Lhasa obey the extreme value Type III distribution, and the weekly maximum wind speed data from other cities do not obey the distribution.

As shown in Table 3, the extreme value Type III distribution is used to conduct statistical analysis on the monthly maximum wind speed data. According to the Kolmogorov moderation of fit test index, the monthly maximum wind speed data of each city obeys the extreme value Type III distribution when $K_f < 1.35$ ($D_n < 0.174$). The monthly maximum wind speed data of all 13 cities in the table obey the distribution.

In Tables 1–3, based on short-term wind speed data, the daily, weekly, and monthly maximum wind speed data of 13 cities in China were statistically analyzed by the extreme value Type III distribution, and the scale parametersα, position parameters$u$, shape parameters γ, standard deviation of fit σ, relative deviation of fit v, and Kolmogorov

Table 1: The calculation results of the extreme value Type III distribution and the fit of daily maximum wind speed data.

City	Parameter estimation method	a	u	γ	σ	V	Dn
Yanji	VS*	7.26	4.4099	2.2323	0.0872	0.66%	0.0189
	LS*	7.2566	4.4199	2.2135	0.0958	0.74%	0.0195
Shenyang	VS	4.7894	4.4039	2.5841	0.1573	1.34%	0.0384
	LS	4.8181	4.3799	2.5993	0.1596	1.37%	0.0393
Urumqi	VS	3.9357	5.6129	2.4141	0.4875	3.14%	0.1155
	LS	3.967	5.6029	2.3715	0.7471	4.73%	0.118
Xi'an	VS	4.8994	3.6289	2.5022	0.2577	1.72%	0.0498
	LS	4.9179	3.6159	2.5062	0.2584	1.74%	0.0506
Shijiazhuang	VS	3.2313	8.4059	2.1006	0.191	0.75%	0.0337
	LS	3.2489	8.3919	2.1125	0.1926	0.77%	0.0345
Hohhot	VS	6.2218	8.7849	2.337	0.2493	1.38%	0.0447
	LS	6.2378	8.7759	2.3435	0.2521	1.40%	0.0458
Kunming	VS	3.7543	7.0639	2.3413	0.2339	1.57%	0.0675
	LS	3.7821	7.0449	2.3426	0.2377	1.58%	0.0693
Lhasa	VS	3.3198	6.5579	2.9891	0.0636	0.49%	0.0245
	LS	3.3497	6.5319	3.0109	0.0617	0.48%	0.0236
Senya	VS	5.9426	7.5379	2.2553	0.543	2.63%	0.0832
	LS	6.0709	7.5379	2.0781	0.5819	2.99%	0.0791
Nanning	VS	3.2061	6.5509	2.4054	0.3154	1.57%	0.0541
	LS	3.2213	6.5399	2.4129	0.3156	1.59%	0.0549
Ganzhou	VS	3.298	6.1549	2.7314	0.1549	0.88%	0.047
	LS	3.3168	6.1409	2.7312	0.1572	0.90%	0.0483
Changsha	VS	4.3571	6.2259	2.5488	0.2935	2.20%	0.0768
	LS	4.3691	6.2249	2.5325	0.2928	2.25%	0.0777
Hefei	VS	3.1286	8.7679	3.0101	0.2171	1.05%	0.0692
	LS	3.1708	8.7339	3.0253	0.2173	1.02%	0.0666

*VS: variable substitution method, LS: least square method.

Table 2: The calculation results of the extreme value Type III distribution and the fit of weekly maximum wind speed data.

City	Parameter estimation method	a	u	γ	σ	V	Dn
Yanji	VS*	8.7566	5.4199	2.4567	0.5476	3.76%	0.0796
	LS*	9.2648	5.3422	2.6313	0.5657	3.78%	0.0811
Shenyang	VS	8.8681	5.7028	2.3687	0.3705	2.96%	0.7778
	LS	8.8735	5.6731	2.7184	0.3816	3.07%	0.8045
Urumqi	VS	6.9354	6.3229	2.4357	0.7994	7.91%	0.107
	LS	8.867	6.3027	2.6715	0.8543	8.33%	0.1214
Xi'an	VS	6.8742	4.2246	3.4324	0.6352	4.04%	0.1149
	LS	7.4394	4.1264	3.6152	0.6542	4.17%	0.1494
Shijiazhuang	VS	4.3613	8.7029	2.2543	0.6737	4.47%	0.0959
	LS	4.4889	8.5932	2.4125	0.6942	4.58%	0.0984
Hohhot	VS	6.3678	10.4219	2.0435	0.5932	2.27%	0.0708
	LS	7.5818	9.3479	2.3237	0.6215	2.34%	0.0731
Kunming	VS	3.8327	7.9638	2.4876	0.6774	5.47%	0.1185
	LS	4.1627	7.2946	2.2435	0.69	5.50%	0.1207
Lhasa	VS	3.3497	7.1638	2.7362	0.326	1.95%	0.0789
	LS	3.7412	6.8432	2.8763	0.2936	1.84%	0.0735
Senya	VS	7.8315	7.7846	1.9781	0.6543	3.56%	0.1166
	LS	8.2514	8.5469	2.0442	0.6625	3.58%	0.1217
Nanning	VS	3.9061	7.4518	2.1132	0.8167	5.95%	0.153
	LS	4.0213	7.4314	2.1243	0.8049	5.82%	0.1491
Ganzhou	VS	3.7287	7.3462	2.9205	0.6782	4.24%	0.1236
	LS	4.0176	7.2673	3.1213	0.6871	4.36%	0.1324
Changsha	VS	5.4682	7.3268	2.1377	0.6256	4.14%	0.0923
	LS	4.6782	7.1253	2.2234	0.6186	4.14%	0.0894
Hefei	VS	3.1286	9.7668	2.5347	0.7948	4.42%	0.1691
	LS	3.1708	9.6228	2.7542	0.7978	4.44%	0.1703

*VS: variable substitution method, LS: least square method.

Table 3: The calculation results of the extreme value Type III distribution and the fit of monthly maximum wind speed data.

City	Parameter estimation method	a	u	γ	σ	V	Dn
Yanji	VS*	10.7297	7.9199	2.6035	0.2816	1.53%	0.0551
	LS*	12.5165	5.434	2.8414	0.332	1.77%	0.0621
Shenyang	VS	9.1274	7.2659	2.2133	0.318	2.27%	0.0884
	LS	10.6874	6.1209	2.5877	0.3454	2.38%	0.0937
Urumqi	VS	10.117	7.2659	2.3035	0.3591	1.82%	0.0642
	LS	13.1631	3.9859	2.8104	0.3524	1.63%	0.0543
Xi'an	VS	8.9304	5.9759	3.5229	0.4521	1.80%	0.0541
	LS	9.7207	4.4959	4.1276	0.4565	2.19%	0.0567
Shijiazhuang	VS	5.7371	9.2359	2.4019	0.2701	1.63%	0.0635
	LS	6.0397	8.9969	2.7218	0.2997	1.65%	0.0671
Hohhot	VS	6.7599	14.125	2.8765	0.6117	2.15%	0.1362
	LS	8.0277	11.873	2.9556	0.6429	2.17%	0.1389
Kunming	VS	4.3619	8.4259	1.4933	0.1783	1.04%	0.0476
	LS	4.8667	7.8209	1.6473	0.2049	1.22%	0.0502
Lhasa	VS	3.9446	8.8459	1.8874	0.2805	1.85%	0.142
	LS	4.6393	7.7459	2.1572	0.2538	1.81%	0.1413
Senya	VS	8.1103	11.521	1.5773	1.221	4.73%	0.137
	LS	9.1552	10.971	1.7315	1.2864	4.46%	0.1223
Nanning	VS	4.2108	8.9149	1.8408	0.21	1.49%	0.0705
	LS	4.356	8.8149	1.9759	0.2295	1.89%	0.0754
Ganzhou	VS	4.2557	7.9109	2.7334	0.2619	1.94%	0.0894
	LS	4.7813	7.3869	3.0732	0.2873	2.09%	0.0948
Changsha	VS	3.3544	10.39	1.2958	0.3971	1.73%	0.0559
	LS	3.4189	10.345	1.3204	0.3908	1.73%	0.0573
Hefei	VS	4.864	11.306	2.3222	0.5463	1.14%	0.1066
	LS	5.1122	11.153	2.6242	0.5658	2.71%	0.1381

*VS: variable substitution method, LS: least square method.

moderation of fit D_n were calculated. Because the fitting degree of probability distribution and wind speed data determines the accuracy of wind pressure calculation results, it is very important whether wind speed data obey probability distribution or not. In short-term wind speed data, the daily and weekly maximum wind speed data of most of the 13 cities do not obey the extreme value Type III distribution. Therefore, the fitting results of monthly maximum wind speed data and the extreme value Type III distribution in 13 major cities were chosen for the following study. In the case of short-term wind speed data, a better parameter estimation method can be obtained by further comparing the parameters of 13 cities whose maximum wind speed data obey the extreme value Type III distribution. Since σ has the highest accuracy, compare σ first, and choose the smaller σ as the best. When σ is the same, compare the values of V and D_n. According to the above principles, it can be seen from Table 3 that among the 13 cities subject to the extreme value Type III distribution, four cities are optimized by the least square method, and 9 cities are optimized by the variable substitution method, so the effect of variable substitution method is better than that of the least square method. Therefore, in the case of short-term wind speed data, it is better to choose the variable replacement method as the parameter estimation method for the cities in which the maximum monthly wind speed data conforms to the extreme value Type III distribution and when the extreme value Type III distribution is used for the statistical analysis of the monthly maximum wind speed data. According to the results of the comparative analysis, the monthly maximum wind speed data were fitted by the extreme value Type III distribution, and the basic wind pressure of 13 major cities with different return periods was calculated based on the short-term wind speed data by variable substitution method. Put the parameters calculated by the variable substitution method in Table 3 into formula (3) to get the annual maximum wind speed of each city with the return periods of 50 years and 100 years, then, put the calculated wind speed into formula (26) to get the basic wind pressure of each city with different return periods. Specific wind pressure results are presented in Table 4.

Comparing the basic wind pressure value calculated by the extreme value Type III distribution based on short-term wind speed data with the specification value of basic wind pressure given by the code, the comparison results are shown in the figure below.

As shown in Figures 1 and 2, it can be seen that the calculated values of most cities are consistent with the specification values. When the return period was 50 years, only 3 cities' calculated values were more than the specification values; when the return period was 100 years, only 2 cities' calculated values were more than the specification values. In general, the calculated value is lower than the specification value, but the difference is not too large. In the

Table 4: Basic wind pressure calculation based on the extreme value Type III distribution.

Serial number	City	Basic wind pressure at different return periods		
		Six months	Fifty years	One hundred years
1	Yanji	0.28	0.546	0.578
2	Shenyang	0.228	0.501	0.537
3	Urumqi	0.235	0.51	0.546
4	Xi'an	0.155	0.253	0.264
5	Shijiazhuang	0.17	0.291	0.306
6	Hohhot	0.282	0.41	0.424
7	Kunming	0.114	0.287	0.314
8	Lhasa	0.088	0.163	0.173
9	Senya	0.338	0.894	0.979
10	Nanning	0.134	0.26	0.277
11	Ganzhou	0.107	0.164	0.171
12	Changsha	0.152	0.372	0.408
13	Hefei	0.192	0.305	0.319

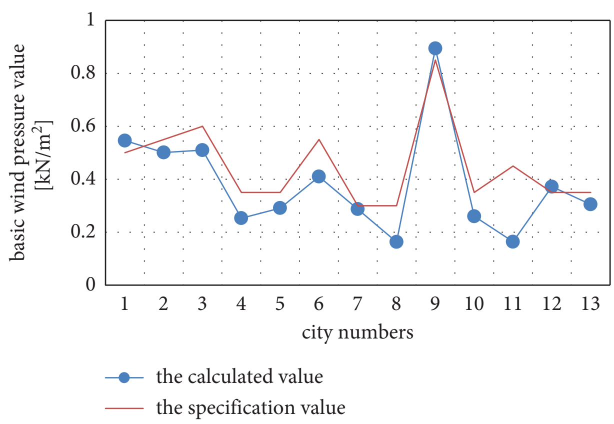

Figure 1: The comparison between the calculated value of the basic wind pressure and the specification value with a return period of 50 years.

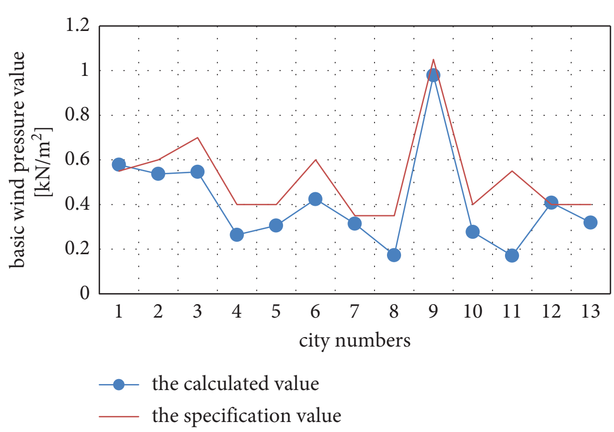

Figure 2: The comparison between the calculated value of the basic wind pressure and the specification value with a return period of 100 years.

code, the value calculated by annual maximum wind speed data and the extreme value of Type I distribution fitting is selected as the specification value of basic wind pressure, which is relatively conservative. That is to say, the specification value of basic wind pressure given by the code is relatively large, which increases the cost of actual projects to a certain degree. Therefore, by combining the fit effect of the extreme value Type III distribution with the results of the comparison between the calculated value and specification value, it can be concluded that it is a feasible method to calculate the basic wind pressure based on the monthly maximum wind speed data by using the short-term wind speed data and the extreme value Type III distribution as the probability distribution in areas lacking long-term wind speed data.

4. Conclusions

In this study, the extreme value Type III distribution is selected as a known probability distribution, and variable substitution method and least square method are used as parameter estimation methods to conduct statistical analysis of daily, weekly, and monthly maximum wind speed data of 13 major cities in China. Through analysis, the following conclusions are drawn:

(1) The Kolmogorov–Smirnov test is used to test the fitting results of the extreme value Type III distribution and wind speed data. It is found that the daily and weekly maximum wind speed data of most cities do not obey the extreme value Type III distribution. In contrast, the monthly maximum wind speed data of all cities obeys the extreme value Type III distribution.

(2) When the maximum wind speed data of 13 major cities in China are statistically analyzed by the extreme value Type III distribution, variable substitution method is chosen as better parameter estimation method.

(3) The basic wind pressure with a return period of 6 months, 50 years, and 100 years in 13 major cities was calculated by extreme value III distribution, among which the basic wind pressure with a return period of 6 months, which can provide a reference for projects with a short design life (such as

demolition projects). Compared with the specification values, the calculated basic wind pressure with a return period of 50 years or 100 years is basically consistent in most cities. Therefore, it is a feasible method to calculate the basic wind pressure based on the monthly maximum wind speed data.

Due to the limitations of time and statistical data, there are some problems in this article that have not been further studied systematically. In this study, the extreme value Type III distribution was only selected as the probability distribution. For areas where short-term wind speed data does not conform to this extreme value distribution, more probability distributions can be used for research.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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