

Comparative Analysis of Concrete Strength Control in China, USA and Europe

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Abstract: This paper compares and analyses the differences in concrete strength control regulations in China, the United States and Europe. By comparing the inspection and acceptance standards of different countries' regulations, the differences in curing and solidification of standard specimens and statistical acceptance are analyzed. The principles and mechanisms of concrete strength control regulations in different countries are studied, and the similarities and differences in concrete strength control between China, the United States and Europe are compared. The results show that although there are some similarities, there are still significant differences in sampling frequency, acceptance standards, inspection effectiveness and strength control among different countries. Through comparing and analyzing the regulations of different countries, this paper better grasps the principles and experiences of different countries in concrete strength control, providing a global perspective and promoting the reasonable formulation of concrete strength inspection regulations in various regions for researchers and practitioners in the concrete industry.

Keywords: Statistical tests, Test criteria, Intensity control, Comparative analysis.

1. Introduction

The main controlled property of concrete is its compressive strength, as it relates both to the safety of the building structure and to the durability and serviceability of the elements constructed from it. The United States and Europe have a strong world influence in the control of concrete strength, firstly because concrete research started in the United States and Europe, and secondly because many countries have adopted their regulations due to the lack of their own. Currently in China, the control of concrete compressive strength is based on the requirements of GB/T 50107-2010 Standard for Concrete Strength Inspection and Evaluation, which provides a clear set of guidelines for inspection and evaluation to ensure that the quality of concrete meets the expected standards for concrete projects in China. However, given the increasing level of concrete production in China and the growing development of concrete engineering technology worldwide, the standard needs to be kept up to date. By comparing the control of concrete strength in China, the USA and Europe, we will analyze the similarities and differences between the standards and understand the strengths and innovations in the control of concrete strength in each country, so as to further optimize the control of concrete strength in China.

2. Inspection And Evaluation of Different Standards

2.1. Standard specimens and conservation curing

The most used method in the world for assessing the compressive strength of concrete in structures is the compression test of cubic or cylindrical specimens. A standard specimen is a specimen that is made and cured by a standard method and has a guaranteed rate of not less than that specified, measured in accordance with a standard experimental method at a specified age. Although the process

of making and curing standard specimens in current Chinese, American and European codes is very similar, there are some differences, as shown in Table 1.

These differences may have an impact on the determination of early and 28-day concrete strengths, mainly arising from differences in temperature, environment and weather requirements and strength requirements at the time the specimens are cast in the completed mould. In specimen standards, China uses cubic specimens, the United States uses cylindrical specimens, and Europe has both cubic and cylindrical specimens. China GB 50010 and Europe EN 206-1 in the specification of the compressive strength of concrete with a guaranteed rate of not less than 95%, the United States does not have a clear guaranteed rate of concrete strength to make clear provisions in the ACI 214 allows no more than 10% of the strength of the test is lower than the design strength of the concrete, i.e., the guaranteed rate of not less than 90%.

2.2. Statistical tests of concrete strength

In all 3 criteria, the first step in the assessment of compressive strength is the statistical validation of the normal distribution of the individual results. The quality characteristics being examined must obey, or approximately obey, a normal distribution, since the theoretical basis is based on a formulation under the theory of normal distribution. The normal distribution assumption is not universal and is applicable to most concrete with strengths not exceeding 70 MPa, so a normality test is required before sampling the characteristic strengths.

2.2.1. Frequency of testing

The overall situation is inferred by examining the concrete sampling samples. High sampling frequency leads to an increase in workload, sampling frequency is less likely to chance factors can not reflect the actual situation, so the concrete sampling should be reasonable. Comparison of concrete sampling frequency in the three standards of China, the United States and Europe is shown in Table 2.

Table 1. Differences in curing and maintenance of concrete specimens in China, USA and Europe

Regulations	Standard specimens (mm)	In-mould time (h)	Maintenance time	Temp (°C)	Curing environment	Other requirements
GB/T 50081	150 ×150 ×150	24h-48h	28d	20±2	Humidity ≥ 95% in a standard maintenance room or in a saturated solution of non-flowing calcium hydroxide.	The mould is inside a room with a temperature of 20°C±5°C and a relative humidity of ≥50%.
ASTM C511	Φ150*300 or Φ100*200	Initial conservation 48h	28d	23±2	In a greenhouse at ≥95% relative humidity.	Initial curing, concrete strength <40mpa at a temperature of 16°C-27°C to save 48h. concrete strength ≥40mpa at a temperature of 20°C-26°C to save 48h
EN 12390-2	150 ×150 ×150 or Φ150*300	16h-72h	28d	20±2	water, or in a greenhouse at ≥95% relative humidity.	The inner temperature of the mould is 20±5°C (25±5°C in hot climates).

Table 2. Comparison of concrete sampling frequency in China, USA and Europe

Regulations	Frequency of testing
GB/T 50107	<ol style="list-style-type: none"> 1) For every 100 trays of concrete with the same mix ratio <100 m³, the number of samples taken is >1. 2) When the concrete with the same proportion mixed in each working shift is <100 trays or <100 m³, the number of samples taken is ≥1. 3) When a continuous pouring of the same proportion of concrete > 1000 m³, every 200 m³ sampling ≥ 1. 4) For house building, each floor, the same proportion of concrete, sampling ≥ 1.
ACI 318	<ol style="list-style-type: none"> 1) At least once a day. 2) At least once for each 150 yd³ of concrete. 3) At least once for each 5000 ft² of surface area for slabs or walls.
EN 206	<ol style="list-style-type: none"> 1) For initial production of concrete (minimum 35 test results valid) for the first 50m³ of concrete produced, sampling at least 3 times; for subsequent production of more than 50m³ of concrete, with production control certification, sampling 1 time per 200m³ or 1 time per 3 production days. 2) For continuous production of concrete (minimum 35 test results valid), with production control certification, 1 sample per 400m³ or 1 sample every 5 production days. 3) Without production control certification, 1 sample per 150m³ or 1 sample per production day.

As can be seen from the table, all three regions take into account the building structure. The thresholds for standard sampling in China are mainly based on the total amount of concrete, continuous pours, and floors, with the number of samples adjusted accordingly. The U.S. standard sampling thresholds are based on total concrete volume and structural surface area. The European standard sampling thresholds are based on initial production, continuous production, and the presence or absence of production control certification, which plays a key role in sampling frequency. From the sampling frequency of China compared to the United States and Europe sampling frequency is more to ensure the comprehensiveness and representativeness of the sampling, the United States and Europe provide for sampling frequency is relatively more flexible, more emphasis on the production control

certification and the impact of the specific situation. Overall, concrete sampling regulations in China, the US and Europe are designed to ensure that the quality of concrete is monitored and controlled to meet the structural and performance requirements of the building.

2.2.2. Statistical acceptance

Statistical acceptance is based on probability theory and mathematical statistics, using the ideas and methods of management and economics to carry out statistical sampling test. China, the United States and European standards in the form of statistical acceptance of concrete strength and statistical coefficients of the value of the gap is large, as shown in Table 3.

Table 3. Statistical acceptance criteria for concrete strength in Central America and Europe

Rule	standard deviation	sample size	Mean value provisions	Minimum provision
GB/T 50107	Known Previous inspection lot ≥ 45	3	$m_{f_{cu}} \geq f_{cu, k} + 0.7\sigma_0$	$f_{cu, min} \geq f_{cu, k} - 0.7\sigma_0$ Concrete strength grade $\leq C20$ 时, $f_{cu, min} \geq 0.85f_{cu, k}$ Concrete strength grade $> C20$ 时, $f_{cu, min} \geq 0.90f_{cu, k}$
	uncharted	n=10~14 n=15~19 n \geq 20	$m_{f_{cu}} \geq f_{cu, k} + 1.15S_{f_{cu}}$ $m_{f_{cu}} \geq f_{cu, k} + 1.05S_{f_{cu}}$ $m_{f_{cu}} \geq f_{cu, k} + 0.95S_{f_{cu}}$	$f_{cu, min} \geq 0.90f_{cu, k}$ $f_{cu, min} \geq 0.85f_{cu, k}$ $f_{cu, min} \geq 0.85f_{cu, k}$
ACI 318		Every average of any three	$m_c \geq f'_c$	$f'_c \leq 35\text{MPa}, f_{ci} \geq f'_c - 3.5\text{MPa}$ $f'_c \geq 35\text{MPa}, f_{ci} \geq 0.90f'_c$
EN 206-1	Known Previous inspection lot ≥ 35	15	$f_{cm} \geq f_{ck} + 1.48\sigma$	$f_{ci} \geq f_{ck} - 4$

One sample strength is a representative value of the strength of each group of concrete, in China, the average of the strength of 3 specimens is taken as a representative value of the strength of each group of specimens, in the United States, it is the average of 2 $\Phi 150\text{mm} \times 300\text{mm}$ or $\Phi 100\text{mm} \times 200\text{mm}$ specimens tested, and the results of the European test are obtained from the same age test of one specimen. The results are derived from the average of the results of 2 or more specimens made. As can be seen from Table 3, in the form of the Chinese norms are divided into two kinds of parent standard deviation known and unknown, the European norms only parent standard deviation known, all three methods are based on the principle of measurement type once sampling statistics calculated, while the United States used the sliding average test. All three statistical tests use the method of mean and minimum synergy test.

3. Comparative Analysis of Inspection and Evaluation Criteria

3.1. Forms of testing

As can be seen from Table 3, China, the United States and Europe in the statistical test of concrete strength in the form and statistical coefficients of the gap is large. Chinese standards for continuous production of concrete in a long time to maintain stability, can be calculated by the previous test batch of not less than 45 groups of specimens to get the parent standard deviation, the parent standard deviation of the known test assessment. Poor production continuity or short production cycle, cannot get the parent standard deviation, can be used in batches of not less than 10 groups of samples, calculated sample standard deviation for the parent standard deviation of unknown test assessment.

Same as the Chinese standard, Europe in the initial production, because of the short production cycle cannot get valid data, the use of non-statistical tests for judgement, subject to the following conditions: First, any single value must be $\geq f_{ck} - 4\text{MPa}$, and secondly, the average strength of the three consecutive test results should be $\geq f_{ck} + 4\text{MPa}$, and based on the non-overlapping results of the test to establish the conformity criterion. When a continuous production standard is established with at least 35 test results in 3 months,

the parent standard deviation can be calculated based on 35 and more test results for the inspection and evaluation of concrete.

The U.S. standard does not distinguish between known and unknown methods of standard deviation, and the sliding average and minimum values of concrete after sampling in accordance with the standard are examined, i.e., if there are five groups of test specimens, the average value of each of the three groups of test specimens in groups 1, 2 and 3, 2, 3 and 4, and 3, 4 and 5 is greater than the design value of the strength, and each group of test specimens shall comply with the minimum value test. According to ACI 214, it is not feasible to specify an absolute minimum strength because of the possibility of very low concrete compressive strengths due to random deviations even when the concrete is well controlled. In order to determine the minimum required average strength, the variability of concrete strength needs to be estimated, and the strength tests used to estimate the standard deviation or coefficient of deviation should be recorded for a minimum of 30 tests, and when the number of tests is less than 30, a more conservative approach is required by allowing the standard deviation to be estimated using the records of 15 tests, provided that the standard deviation of the estimation is increased by 16 per cent.

In summary, the Chinese and European standards for continuous and stable production of concrete can be established for continuous and stable production of concrete with a known parent standard deviation of the test assessment, when the information is insufficient Chinese standards can also be used to assess the sample standard deviation, while the United States of America does not have a parent standard deviation of the establishment of the standard deviation of the sample standard deviation of no fewer than 15 groups of tests to determine the average strength of the minimum requirements.

3.2. Statistical coefficient

3.2.1. Chinese norm

China's parent standard deviation of the known mean judgement criteria is stipulated $u_0 = f_{cu, k} + 1.645\sigma, u_1 = f_{cu, k}, \alpha=0.05, \beta=0.1$, by the parent standard deviation of the known measurement of a sampling test formula [1] calculates

that n is 3.16, k is 0.72 Since n can only take integers, so n = 3, k to take the approximate value of 0.7, which constitutes the Chinese parent standard deviation is known when the test of the mean, this judgement standard under $\alpha=0.05, \beta=0.11$. China's parent standard deviation of the statistical coefficients in the unknown, to take a strict control of the risk of the users of β , and appropriate care of the risk of the production side Appropriate care of the production side risk β principle [12].

Concrete strength inspection and evaluation standard stipulates acceptable quality level $AQL = f_{cu, k} + 1.645\sigma$. Limit quality level $LQ = f_{cu, k} + 0.2533\sigma$, according to the sample size and the value of statistical coefficients can be calculated by using a non-central t-distribution in different cases of α and β , and the risk changes under different values of statistical coefficient The change in risk at different values of t is shown in Table 4.

Table 4. Changes in risk under different conditions

Sample size n	Statistical coefficient t	α (%)	β (%)
10	1.15	10.2974	1.6528
11	1.15	9.3434	1.2308
12	1.15	8.4887	0.9198
13	1.15	7.7213	0.6894
14	1.15	7.0307	0.5180
15	1.05	3.0572	0.7456
16	1.05	2.6748	0.5866
17	1.05	2.3426	0.4623
18	1.05	2.0535	0.3648
19	1.05	1.8015	0.2883
20	0.95	0.4904	0.5333
21	0.95	0.4088	0.4400
22	0.95	0.3411	0.3632
23	0.95	0.2847	0.3002
24	0.95	0.2378	0.2482

With the increase of the sample size, the statistical coefficient decreases in segments, and the risk of the production side and the risk of the user are gradually reduced, basically can be controlled at about 5%, when the sample size is small, although the risk of the production side is larger, but the risk of the user can be controlled within 5%, to ensure the safety of the concrete structure.

3.2.2. European norm

The Eurocode assesses the compressive strength of concrete by means of an initial production control and a continuous production control, where the average strength of the three consecutive test results should be $\geq f_{ck} + 4$ MPa for the initial production control, and establishes conformity criteria based on non-overlapping test results. Therefore, moving average of consecutive results increases the risk of rejection. When consecutive production criteria are established and the parent standard deviation is established for at least 35 test results within a 3-month period, the average of 15 or more consecutive results obtained within a period not exceeding 3 months shall be $\geq f_{ck} + 1.48\sigma$, where f_{ck} is the standardized value of concrete strength and σ is the parent standard deviation. The European statistical coefficients for concrete strength are similar to the Chinese method of determining statistical coefficients, with "unsafe zones" and "uneconomical zones" based on characteristic strengths, and when experimental results are "correlated", they are determined by fixing the sample size. When the experimental results have "correlation", the statistical coefficient is determined by fixing the sample capacity and using the sampling characteristic curve tangent to the unsafe region.

3.2.3. American Norm

The U.S. code, on the other hand, uses a sliding mean where the average of any three consecutive strength tests is greater than or equal to the concrete strength class. The overall concrete strength is $N(\mu, \sigma^2)$, and the sliding mean

m_{cn} of n consecutive sets of tests obeys the normal distribution $m_{cn} \sim N(\mu, \sigma^2/n)$ according to the normal distribution function:

$$\begin{cases} \mu = f_c' + Z\sigma \\ \mu = m_{cn} + Z_1 \sigma / \sqrt{n} \end{cases}$$

Because the deviation factor $V = \sigma/m_{cn}$. So, the above equation is collapsed to give:

$$m_{cn} = \frac{1 - V Z_1 / \sqrt{n}}{1 - VZ} f_c'$$

Where n is the number of consecutive sampling, V is the concrete strength deviation coefficient, Z is the overall concrete strength assurance rate coefficient, Z_1 is the sample assurance rate coefficient, f_c' , for the standard strength of concrete.

Provided that $\alpha = 2\%$, the permissible failure rate of concrete $p = 10\%$ (concrete strength guarantee of 90%), concrete deviation coefficient $V = 0.15$, the calculation of 3 consecutive groups of test samples can be obtained $m_{c3} = 1.02f_c'$, this is the U.S. specification provides for the average of 3 consecutive groups of samples to be greater than or equal to the theoretical basis of the design strength. In ACI 214 it is stated that the evaluation and acceptance of concrete may be determined upon receipt of test results during the course of the work, and that even if the concrete is of satisfactory strength and uniformity, there is an occasional probability of about 1 per cent that a strength test will not meet these criteria. According to the ACI 214 equation for determining the minimum required mean strength, when the experimental requirement of 30 consecutive strengths is met, the acceptance statistical mean rating, based on a normally distributed probability density function, can be changed to $f_{cr} \geq f_c' + 1.34S_s$, and the minimum rating to $f_{cr} \geq f_c' + 2.33S_s - 3.5$ for design strengths ≤ 35 MPa, and $f_{cr} \geq 0.90f_c' + 2.33S_s$, for design strengths > 35 MPa, where f_{cr} , is the minimum required mean strength, f_c' , is the design

strength of concrete, and S_S is the sample standard deviation.

3.3. Checking efficacy

3.3.1. Tolerance

Chinese standard when the standard deviation of the parent is known, $\alpha=0.05, \beta=0.11$, α is the risk of the production side, which is related to the economy, and β is the risk of the user side, which is related to the safety of the structure, but from the values taken, the risk of the production side is controlled very low, and the risk of the user side is However, from the values taken, the producer risk is controlled very low and the user risk is high, which is not conducive to the safety of the structure. The US code only considers α , not β and α control is very strict for 2%, but the US tolerance is very strict, and the probability that the strength is not expected to meet the design value is only 1%. ACI 214 stipulates that the probability that the average of three consecutive strength test results is less than the design value is 1%, because the probability distribution of 1% is lower than the average value, and the probability distribution of 1% is higher than the average value. The positive too probability distribution is 2.33 standard deviations below the mean, which is expressed as:

$$f'_{cr} \geq f'_c + \frac{2.33}{\sqrt{3}} S$$

S is the standard deviation calculated from the results of 30 or more groups of strength tests, and the acceptance expression when the Chinese standard deviation is known according to the American test principle:

$$m_{f_{cu}} \geq f_{cu, k} + \frac{1.21}{\sqrt{3}} \sigma_0$$

1.21 standard deviations correspond to an assurance rate of about 90 per cent, which is a larger tolerance than in the United States. In Europe, a one-size-fits-all test is used for initial production, and when continuous production is established, the statistical coefficients and sample sizes are higher than in China.

3.3.2. Sampling characteristic curve

The standard deviation calculated from the results of 30 or more strength tests in the United States approximates the parent standard deviation, and the sampling scheme roughly corresponds to a measure-type primary sampling under $u_0 = f_{cu, k} + 1.645\sigma$, $u_1 = f_{cu, k} + 1.0364\sigma$, $\alpha=0.05, \beta=0.05$ Test. Under the same sampling programmed, the rate of nonconforming products is different, the acceptance probability of the batch is also different, the smaller the rate of nonconforming products, the greater the acceptance probability, and vice versa the larger the rate of nonconforming products, the smaller the acceptance probability, with the horizontal coordinate represents the rate of nonconforming products, and the vertical coordinate represents the acceptance probability, the curve is called the sampling characteristic curve. Comparison of sampling characteristic curve of concrete strength for statistical acceptance in China, the United States and Europe is shown in Figure 2.

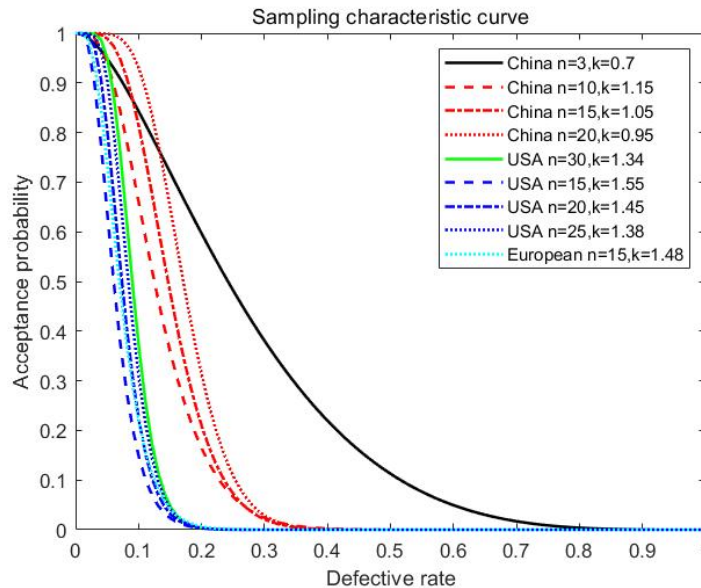


Figure 2. Comparison of sampling characteristic curves in China, USA and Europe

Ideal sampling characteristic curve is when the batch quality is good, with a high probability of acceptance; batch quality becomes bad, the probability of acceptance decreases rapidly; batch quality bad to a certain limit, with a high probability of rejection. As can be seen from the figure, China's sampling characteristic curve is gentler, cannot play a good test effect, Europe and the United States of America's sampling characteristic curve is more ideal, the test effect is better.

4. Comparative Analysis of Concrete Strength Control

4.1. Standard deviation and coefficient of variation

There are four main views on the relationship between the standard deviation σ and the coefficient of deviation V of concrete strength and the mean value of strength u . The generally accepted concept D .

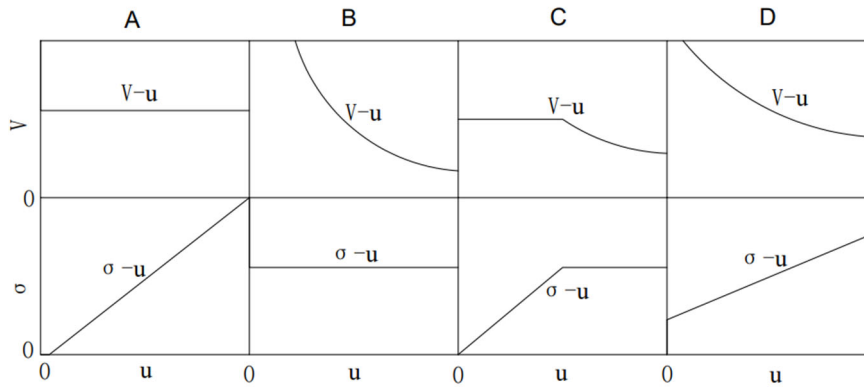


Figure 2. Map of the four perspectives

From the figure, it can be seen that both the standard deviation and the coefficient of deviation change with the change of the mean value of intensity, the standard deviation decreases with the decrease of the mean value of intensity, and the coefficient of deviation increases with the decrease of the mean value of intensity. When it is assumed that the coefficient of deviation does not vary with the mean value of strength, the minimum value of control strength = standard value of strength/(1-ZV), Z is the coefficient of strength guarantee rate, and the difference between the standard value of strength and the minimum value of control strength becomes larger as the standard value of strength becomes larger. When it is assumed that the standard deviation does not change with the average value of strength, the minimum value of control strength = standard value + Zσ, which is the form used to control the strength of concrete in China and Europe. At this time, when the standard value of strength is low, the minimum value of control strength obtained by the calculation is large, which results in economic waste, and when the standard value of strength is high, the result of the minimum value of control strength is small, which is unfavorable to the safety of the structure.

China and Europe acceptance standards only standard deviation control, the United States standard deviation and coefficient of deviation common control, according to the standard deviation formula and the coefficient of deviation formula calculated respectively the minimum strength requirements to take the maximum value of the two to control the concrete strength.

4.2. Mean value control

Mean value control for concrete strength testing is an important part of ensuring concrete quality and performance, and is used in China, the United States and Europe to test whether concrete strength is stable within an acceptable range. Mean value control differences caused by two factors, one is the water-cement ratio changes, material properties, etc. caused by the batch differences; the second is the maintenance differences, experimental process, etc. caused by the intra-batch differences. So to carry out mean value control to determine the potential quality risk of concrete and determine the statistical coefficient. From 2.3 statistical coefficients, it can be seen that China, the United States and Europe in the determination of the principle of the coefficient of determination of the mean value of concrete strength is not the same, China's parent standard deviation is known, the provisions of the two quality indicators and the two probabilities of error, according to the nature of the normal distribution to calculate the coefficient of determination and

the sample size, parent standard deviation is unknown, according to the non-central t-distribution calculation of the sample size and statistical coefficients to meet the requirements. In the United States, the location of the mean and other values is predicted based on the probability of the confidence interval of the normal random variable, and the statistical coefficients are derived by determining the values of the coefficient of variation and the producer's risk. In Europe, "unsafe areas" and "uneconomic areas" are defined according to the intensity of the characteristics, and when the experimental results are "correlated", the statistical coefficients are determined by fixing the sample size and targeting the OC curves to the unsafe areas with the OC curves. When the experimental results are "relevant", the statistical coefficient is determined by fixing the sample size and using the tangent of the OC curve to the unsafe area. The principle of statistical coefficients in the Chinese, American and European norms is different, but they are all based on statistical theory to determine the risk factor and carry out numerical calculations, and the common principle is based on the probability of taking the value under the normal distribution. So, the control of the average value is based on the change of risk-taking value under normal distribution.

4.3. Minimum value control

China, the United States and Europe concrete strength test evaluation using the average and minimum value of the joint control programmed, the minimum value can play a role in preventing the concrete from local decline, which is conducive to the production side. The minimum value test in the United States and Europe are based on the principle of counting a sampling test under the development, the principle is as follows.

The inspection programmed is determined by the sample size n and the number of receipts Ac two parameters, usually expressed as (n, Ac), n samples from the batch N, of which the number of rejects is less than or equal to Ac, the batch of products can be considered as a qualified batch. Batch of concrete failure rate of p, qualified rate of 1-p, take n samples containing d unqualified specimens have C_n^d kinds of cases, set to take n groups of specimens below the standard strength of not more than Ac group to be considered the batch of concrete qualified, acceptance probability L (p) according to the binomial distribution cumulative probability of:

$$L(p) = \sum_{d=0}^{Ac} C_n^d p^d (1-p)^{n-d}$$

In the form of China's parent standard deviation is known,

the minimum value of $f_{cu, k} - 0.7\sigma_0$ and $\lambda f_{cu, k}$ is used as the lower limit of the minimum value test, λ for the minimum value of the assessment coefficient, when the concrete grade is not higher than C20, $\lambda=0.85$, higher than C20, $\lambda=0.9$; parent standard deviation of the unknown, the minimum value of $\lambda f_{cu, k}$. When the standard deviation of the parent is unknown, the minimum value is $\lambda f_{cu, k}$, at this time, λ takes the value according to the sample capacity, when the sample capacity <15 , $\lambda=0.9$, when the sample capacity ≥ 15 , $\lambda=0.85$. The United States of America, the minimum test is also based on the strength of concrete grades to divide the different forms of testing, when the standard value $\leq 35\text{MPa}$, the minimum value of the standard value minus the fixed value of 3.5MPa, when the standard value $\geq 35\text{MPa}$, the minimum value of the minimum value of the 0.9 times the

standard value. Europe uses the standard value minus the fixed value of 4MPa "one-size-fits-all" method to determine the minimum value. Fixed value of 3.5MPa is because the United States ACI214 committee to develop specifications from the site concrete data found in the concrete standard deviation roughly close to 3.5MPa, converted into a side length of 150mm cube for 4.2MPa, so the U.S. standard value minus a fixed value of 3.5MPa is equivalent to $f_{cu, k} - \sigma_0$. The parent standard deviation assumptions are known, take the value of 3.5MPa and 4MPa, each concrete strength class, the minimum value of 0.9 times the standard value to determine. 4MPa, the ratio of the minimum value taken at each concrete strength class to the standard value is shown in the following table.

Table 5. Comparison of the ratio of the minimum value to the standard value

	China $\sigma_0 = 3.5\text{MPa}$	China $\sigma_0 = 4\text{MPa}$	USA	European
C15	0.850	0.850	0.767	0.733
C20	0.878	0.860	0.825	0.800
C25	0.902	0.900	0.860	0.840
C30	0.918	0.907	0.883	0.867
C35	0.930	0.920	0.900	0.886
C40	0.939	0.930	0.900	0.900
C45	0.946	0.938	0.900	0.911
C50	0.951	0.944	0.900	0.920
C55	0.955	0.949	0.900	0.927
C60	0.959	0.953	0.900	0.933
C65	0.962	0.957	0.900	0.938
C70	0.965	0.960	0.900	0.943
C75	0.967	0.962	0.900	0.947
C80	0.969	0.965	0.900	0.950

From the table, it can be seen that the ratio of the minimum value taken in China to the standard value is larger than that in Europe and the United States, indicating that the acceptance difficulty in China is higher than that in Europe and the United States in the minimum value test, and the risk of the producer is also higher than that in Europe and the United States. As the standard deviation increases, the ratio becomes smaller, and the acceptance difficulty becomes smaller. When the standard deviation is not big, it is mainly controlled by the lower limit of the minimum value obtained by $f_{cu, k} - 0.7\sigma_0$. When the concrete grade is $\leq C20$, when $\sigma_0 > 0.14f_{cu, k}$, the lower limit of the minimum value is transformed into $0.85f_{cu, k}$; when the concrete grade is $> C20$, when $\sigma_0 > 0.21f_{cu, k}$, the lower limit of the minimum value is transformed into $0.9f_{cu, k}$ the lower limit of the minimum value is transformed into $0.9f_{cu, k}$ control, so when the degree of Chinese concrete discrete is too large, it can still play a good control effect.

5. Conclusions

This paper compares and analyses the concrete strength test control in China, the United States and Europe, and obtains the following conclusions.

(1) China, the United States and Europe have different types of standard specimens, China is a cubic specimen, the United States is a cylindrical specimen, and Europe has both.

Curing in the United States is divided into initial curing and final curing, according to the standard value of concrete strength of different temperature adjustment, Europe according to the external climatic environment to adjust the curing temperature, China did not refine the strength and the external environment on the maintenance of the impact.

(2) There are similarities and differences between China, the United States and Europe in concrete sampling regulations. The similarities consider the structural factors of the building and the relationship between sampling frequency and total volume. Differences, China provides for a relatively large number of samples, the United States and Europe focus on the impact of production control certification on the sampling frequency, while the Chinese regulations are not explicitly mentioned.

(3) concrete strength test statistical coefficients to determine the principle of different risk values and guarantee rates are also different, resulting in the United States and Europe there are large differences in inspection and evaluation standards. Concrete strength test efficacy, China's concrete strength guarantee rate is higher than the United States, but the allowable deviation is lower, the statistical coefficient and the sample size is lower than the United States and Europe, the sampling characteristics of the curve is flatter, cannot play a good test efficacy.

(4) Standard deviation and coefficient of deviation are related to the average value of strength. Chinese and European acceptance standards only control the standard

deviation, which is unfavorable to the economy and structural safety, and the United States adopts the common control of standard deviation and coefficient of deviation, which increases the safety of the structure.

(5) Concrete strength control, China, the United States and Europe have adopted the average value and the minimum value of common control. The average value control of the three standards is based on the risk of taking the value of change under normal distribution. China's minimum value inspection on the acceptance of the difficulty is higher than the United States and Europe, the production side of the risk is also higher than the United States and Europe, when the degree of concrete discrete is too large, can still play a good control effect.

In summary, there are differences between the Chinese standard and the American and European standards, which require further refinement of the effects of maintenance curing and standard specimens on strength, as well as the establishment of production licensing certification to improve the quality control of concrete. Concrete strength control, the Chinese standard makes the risk of the user too high, the tolerance is too large, the test efficacy is poor, not conducive to the assurance of strength, and only the control of the standard deviation, the strength of the average value is too large or too small will affect the risk of change, it is recommended to increase the control conditions of the coefficient of deviation and to improve the value of the risk of the value of the control conditions and to improve the risk of the value of the control.

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