Quality control of building materials

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Abstract. The purpose of the work is to assess the influence of the state of the technological process of production on the error of deciding on the suitability of the batch under control. Information is provided about the values of the error of representativeness at assessing the quality of building materials using ceramic brick as an example. It is shown that the rules for acceptance of the relevant normative documents for construction products should indicate the required number of samples for testing, taking into account the probability of an error-free forecast.

1 Introduction

When controlling the quality of building materials, in accordance with the current normative documentation, the controlled parameters are determined and compared with acceptable values. In the case of selective control, not the whole general set is used, but only some part of it. Based on the measurement results, a conclusion is made about the suitability of the product and rejection [1-2].

However, the result does not necessarily coincide with the result that could have been obtained by studying general set.

It should be noted that in the existing normative documents on building materials is not specified indicator of the reliability of control. Reliability of control - the probability of compliance of the control results with the actual values of the controlled parameter.

As estimates of reliability of control, concepts of probability of errors of the 1 and 2 kind are introduced.

The situation when a product that is actually suitable according to the results of the inspection is deemed unfit ("false marriage") is called a mistake of the first kind. And vice versa, a situation where a product that is actually unusable in accordance with the results of control is deemed to be suitable ("undetected marriage") is called a mistake of the second kind. The probability of obtaining the correct control result: $P_{pr} = 1 - (P_1 + P_2)$, where P_1 and P_2 are the probabilities of errors of the 1 and 2 kind [3-5].

Indicators and average values should serve as a reflection of actuality, for what it is necessary to determine the degree of their reliability.

When conducting selective studies, the result obtained does not necessarily coincide with the result that could be obtained by examining the entire general set. There is a certain difference between these values, called the error of representativeness, i.e. this is an error due to the transfer of the results of a sample study to the entire general set [6-9].

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Representativeness errors can be random and systematic. Random errors arise due to the fact that the set of selected observation units does not fully reproduce the entire set as a whole. Systematic errors arise due to a violation of the principles of random selection of units of the studied population. The regularities of the law of large numbers are devoted to the study of the laws of random sampling errors. These regularities are most fully disclosed in the theorems of P. L. Chebyshev and A. M. Lyapunov.

For assess the error of representativeness, the indicators of the average sampling error and the marginal sampling error are used.

The average error of a sign during random selection is determined by the formula

$$m = \sqrt{\frac{\sigma^2}{n}} \quad (1)$$

where σ is the standard deviation;

n is the number of observations.

The marginal error of a random sample is calculated by the formula

$$\Delta = t \sqrt{\frac{\sigma^2}{n}} \quad (2)$$

where σ^2 is the variance;

n is the sample size

A given degree of probability (P) of an error-free forecast corresponds to a certain value of the criterion t substituted into the formula. With the probability of an error-free forecast $P = 99.7\%$, the value of t is $t = 3$, and at $P = 95.5\%$, the value $t = 2$.

The formula for determining the confidence limits of average values has the form

$$X_{gen} = X_{sam} \mp \Delta \quad (3)$$

where X_{gen} - the average value of the indicator of the general set;

X_{sam} - the average value of the sample;

Δ is the error of representativeness.

The error of representativeness and, accordingly, confidence intervals with a certain degree of probability of an error-free forecast, as follows from (1), (3), is determined by the value of the standard deviation and the state of the process, i.e. stability and reproducibility [10-13].

2 Materials and methods

Consider the error of representativeness in the quality control of brick brand M100 in accordance with the current regulatory documentation. According to GOST 530-2012 "Ceramic brick and stone. General specifications" the average value of compressive strength is determined by testing 10 bricks. Consider 3 options.

1 option. According to the sampling results, the average value of the compressive strength does not coincide with the middle of the tolerance field and is $= 111 \text{ kgf / cm}^2$, the standard deviation is $\sigma = 5.3 \text{ kgf / cm}^2$.

2 option. The average value of the compressive strength does not coincide with the middle of the tolerance field and is $= 108 \text{ kgf / cm}^2$, the standard deviation is $\sigma = 6.2 \text{ kgf / cm}^2$.

3 option. The average value of the compressive strength coincides with the middle of the tolerance field and is $= 112.5 \text{ kgf / cm}^2$, the standard deviation is $\sigma = 4.1 \text{ kgf / cm}^2$.

3 Research results

The calculation results are shown in Table 1

Table 1. The value of the marginal error of the sample depending on the probability of an error-free forecast *P*

Option Number	The probability of an error-free forecast <i>P</i> = 95%		
	Confidence Interval, MPa	Marginal sampling error, MPa	The average error of the arithmetic mean, MPa
1	107.48-114.52	3.5156	1.7578
2	103.89-112.11	4.112	2.056
3	109.8-115.2	2.7	1.35
The probability of an error-free forecast <i>P</i> = 99.73%			
1	105.73-116.27	5.2734	1.7578
2	101.83-114.17	6.168	2.056
3	108.45-116.55	4.05	1.35

It was established with a probability of an error-free forecast *P* = 95% that the average value of the strength of a brick in a batch (of the general set) will be in the range from 107.48MPa to 114.52MPa (1 option), i.e. the average value of brick strength in a batch of less than 107.48 MPa and more than 114.52 MPa is possible no more than in 5% of cases of the general set.

With a probability of an error-free forecast of 99.7%, the average value of the strength of a brick in a batch (general set) will be in the range from 105.73 MPa to 116.27 MPa (1 option), i.e. the average value of brick strength in a batch of less than 105.73 MPa and more than 116.27 MPa is possible no more than in 0.3% of cases of the general population. If you take a batch of bricks in the amount of 1000 pieces, then this is 30 pieces of bricks, whose compressive strength in the batch is less than 105.73 MPa and more than 116.27 MPa.

For determine the required sample size, its marginal error and the probability that this error will not exceed the specified limit must be specified. The calculation of the required sample size can be performed by the formula

$$n = \frac{t^2 \sigma^2}{\Delta^2} \tag{4}$$

In accordance with formula (4), the value of the normative value standard marginal error Δ should be determined taking into account the normative value of the standard deviation.

Given that six sigma should be placed in the tolerance field of the quality indicator, i.e. six values of the standard deviation, we accept for brick grade M100 the standard value of the standard deviation equal to $\sigma = 4.1$ MPa. The calculation results of the required sample size for determining compressive strength taking into account the data (3 options) are given in Table. 2.

An analysis of the data (Table 2) shows that at probability of an error-free forecast is *P* = 99.7% (3rd version) , when the standard deviation is equal to normative value, the number of samples corresponds to GOST 530-2012 “Ceramic brick and stone. General specifications”. For the 1 and 2 options, with the probability of an error-free forecast *P* = 99.7%, the number of test samples should be increased.

Table 2. The number of samples for testing the compressive strength of ceramic bricks depending on the probability error forecast P

Version number	The estimated number of samples for testing with the probability of an error-free forecast $P = 95\%$	The estimated number of samples for testing with the probability of an error-free forecast $P = 99.7\%$
1	7	16
2	10	21
3	4	10

If the probability of an error-free forecast is $P = 95\%$, the number of samples can be reduced.

4 Conclusion

Thus, the studies and calculations show that in the rules for acceptance in the relevant normative documents for construction products should indicate the required number of samples for testing, taking into account the probability of an error-free forecast.

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