Reliability of Quality of Dry Building Mixtures

V I Loganina1,a
1Penza State University of Architecture and Construction, Russia, 440028, Penza, street Titova, 28
E-mail: loganin@mail.ru

Abstract. Information about the results of calculating the quality assurance of dry building mixes, based on the requirements of regulatory documents, is provided. An example of calculating the reliability of quality control of raw materials, operational and acceptance control is provided. It is shown that the normative security of the quality of dry construction mixtures is 0.9447957, which implies a probability of a defect 5.52%. To ensure a higher level of dry building mixtures quality, the application of the six sigma methodology is proposed.

1. Introduction

For finishing of the walls of buildings, dry building mixtures (DBM) are widely used [1-3]. It is known that the volume of finishing works of exterior walls of buildings is about 30% of all total expenditures during construction. Given the high labor expenditures, it is important to reliably assess the quality of dry construction mixtures created. Despite a significant amount of research in the field of creating and managing the quality of the DBM, many issues require further consideration [4-7]. In particular, it is practical interest to improve system of control, which, in addition to existing indicators, will allow a more objective assessment of the DBM quality [8-10].

As a rule, product control involves incoming control of raw materials, operational and acceptance control. Any manufacturing process is associated with variations in its parameters, caused by a large number of factors affecting it. It is known that the variability of the properties of building materials obeys the normal distribution law. The values of quality indicators of the DBM are random variables and also obey the normal distribution law.

Considering the normal distribution law and that "the zone of satisfactory condition of the quality index contains “6 sigma "distributions, each indicator of raw materials, operational control and production provides a quality assurance equal to 99.73% [11-13]. Consequently, the quality of the final product - DBM will be determined by a set of individual indicators of raw material quality, operational control and products.

2. The research methods

The structural diagram of the reliability of the system "production" can be represented as a combination of series-connected elements. The object consists of m sequentially connected subsystems, the i-th subsystem consists of n_i sequentially connected elements of the same type. The failure of the object occurs when any subsystem fails. The formula for calculating the probability of failure is as follows
\begin{equation}
P(t) = P_1(t) * P_2(t) ... P_n(t) = \prod_{i=1}^{n} P_i(t)
\end{equation}

where \( P_i \) - probability of failure-free operation of the \( i \)-th element; the index \( i \) corresponds to the elements of the \( i \)-th subsystem.

3. The results of research
Consider the normative reliability of production in the DBM in accordance with GOST 31356-2013 "Dry building mix on a cement binder. Methods of testing". For this purpose, the reliability block diagram method can be used (GOST R 51901.14-2005). This method is one of the methods for analyzing the risks of technical and technological systems.

Input control involves the control of cement, sand, additives, operational control-the correctness of dosing components, mixing time, humidity of sand. Control of cement provides for the determination of brand of cement, setting time. Sand control - size, humidity of sand, content of clayey grains.

Properties of dry mixtures are characterized by indicators of the quality of mixtures in the dry state, mixtures ready for use, and solidified mortar (concrete).

The main indicators of the quality of dry mixtures are:
- humidity;
- the largest size of aggregate grains;
- content of grains of the largest size;
- bulk density (if necessary).

The main indicators of the quality of ready-to-use mixtures are:
- mobility (except for glutinous, for glutinous - if necessary);
- viability;
- water retention ability;
- the volume of air (if necessary).

The main indicators of the quality of the solidified mortar (concrete) should be:
- compressive strength (except for glutinous);
- water absorption;
- frost resistance (except for mixtures for internal works);
- strength of adhesion to the substrate (adhesion);
- watertightness (for waterproofing mixtures and if necessary);
- abrasion (for floor mixes and if necessary);
- frost resistance of the contact zone (except for mixtures for internal works).

We will assume that the controlled parameters are normally distributed random variables with a mathematical expectation that coincides with the nominal value and the given mean square deviation \( \sigma \). The maximum permissible deviation from the nominal value is \( \pm 3\sigma \). When calculating the probability of compliance with technology, it is assumed that the parameters are independent of each other [14-20]. Based on the structural-probabilistic analysis, let's consider the scheme for obtaining a DBM. Enter the notation: event \( A \) - DBM will be obtained; \( A_1 \) - the necessary properties of raw materials are provided; \( A_2 \)-production technologies are provided; \( A_3 \)-the necessary properties of DBM are provided.

\begin{equation}
A = A_1 A_2 A_3
\end{equation}

The corresponding component \( A_i \) provides the required quality level with probability \( P(A_i) \). By the multiplication theorem, since the events are independent \( A_i \), we have

\begin{equation}
P(A) = P(A_1)P(A_2)P(A_3)
\end{equation}
The results of the calculations are given in Table 1, 2, 3.

The standard reliability of DBM production was 0.9447957. This means that the probability of a defect is 5.52%. As the DBM quality indicators provided for in regulatory documents increase, the probability of defects will increase, depending on the DBM purpose area.

To reduce the level of defects, we can recommend using the six Sigma methodology. If 6, 8, 10 or 12 sigma are placed in the tolerance field, the probability of the defectiveness level will be small (Table 4). If the number of standard deviations in the tolerance field is 8, the probability of the defect level is 0.15%.

Table 1. Reliability of incoming control.

| Name of raw materials | Number of indicators | Reliability of individual indicator | Reliability of subsystems | Reliable control of raw materials |
|-----------------------|----------------------|------------------------------------|---------------------------|----------------------------------|
| Cement                | brand                | 0.9973                            | 0.9946                    | 0.9865671                        |
|                       | mixing time          | 0.9973                            |                           |                                  |
| Sand                  | size                 | 0.9973                            | 0.994609                  |                                  |
|                       | humidity             | 0.99865                           |                           |                                  |
|                       | Content of clayey, silty particles | 0.99865 | | | |
|                       | Water-retaining additive | 0.9973   | 0.9973                          |                                  |

Table 2. Reliability of operating control of production.

| Name of indicators | Reliability individual indicator | Reliability of operational control |
|-------------------|----------------------------------|------------------------------------|
| Precision of cement dosing | 0.9973 | 0.9865725                          |
| Precision of sand dosing | 0.9973 |                                   |
| Precision of the additive dosing | 0.9973 |                                   |
| Humidity of sand | 0.9973 |                                   |
| Mixing time | 0.9973 |                                   |

Table 3. Reliability of acceptance control.

| Name of indicators | Reliability individual indicator | Reliability of acceptance control |
|-------------------|----------------------------------|-----------------------------------|
| Humidity | 0.99865 | 0.9786141                          |
| Density | 0.9973 |                                   |
| Water retention ability | 0.99865 |                                   |
| Fluidity | 0.9973 |                                   |
| Retentivity of fluidity | 0.9973 |                                   |
| Compressive strength (except for glue) | 0.9973 |                                   |
| Water Absorption | 0.9973 |                                   |
| Frost resistance (except for mixtures for internal works) | 0.9973 |                                   |
| Strength of adhesion to the substrate (adhesion) | 0.9973 |                                   |
Frost resistance of the contact zone (except for mixtures for internal works) 0.9973

Table 4. Probability appearance of defect.

| Number of standard deviations in the tolerance field | Product quality reliability | Probability appearance of defect, [%] |
|-----------------------------------------------------|----------------------------|-----------------------------------|
| 6                                                   | 0.9447957                 | 5.52                              |
| 8                                                   | 0.9984007                 | 0.15                              |
| 10                                                  | 0.99988                    | 0.012                             |

4. Conclusions
Thus, the application of the "six sigma" methodology allows to significantly reduce of the defectiveness level, improve the competitiveness of products.

5. References
[1] Kozlov V V 2000 Dry building mixtures (Moscow) Association of Construction Universities
[2] Loganina V I 2014 Evaluation reliability of the control building materials and products for stability technological processes of production Contemporary Engineering Sciences 7(36) 1927-1933
[3] Loganina V I, Kuimova E I, Uchaeva T V 2014 Application of the Method of Multivariate Analysis to Assess the Quality of Coatings Contemporary Engineering Sciences 7(35) 1853-1859
[4] Loganina V I, Skachkov J P and Uchaeva T V 2016 Assessment of the Stability of the Staining Process of Building Products and Constructions International Journal of Applied Engineering Research 11(9) 9727-9729
[5] Loganina V I 2014 Maintenance of quality of paint and varnish coverings of building products and designs Contemporary Engineering Sciences 7(36) 1943-1947
[6] Loganina V I, Kruglova A N 2014 To a question on a reliability of control during a concrete manufacturing International Journal of Management, Information Technology and Engineering 2(1) 79-82
[7] Loganina V I, Khustalev B B, Uchaeva T V 2013 Statistical management of production of building products East-European Journal of Advanced Technologies 1(3) 65-67
[8] Loganina V I, Kamberg V G, Makarova L V, Bodazhkov N J 2014 Mehod of Building Optimization of Composites Based on the Criterion Analysis Contemporary Engineering Science 7 1555-1563
[9] Burr I R 1976 Statistical Quality Control Methods Marcel Dekker (New York)
[10] Gmurman V E 2005 Theory of probability and mathematical statistics (Moscow) High school
[11] Pugachev V S 1968 Introduction to the theory of probability (Moscow) Nauka
[12] Hahn G J 1970 Statistical Intervals for a Normal Population Part 1 Tables Examples and Applications Journal of Quality Technology 2 115-125
[13] Aitchison J 1986 The Statistical Analysis of Compositional Data Chapman & Hall (London)
[14] Wronkowicz A, Dragan K, Lis K 2018 Assessment of uncertainty in damage evaluation by ultrasonic testing of composite structures Composite structures 203 71-84
[15] Ilya Kuselman, Francesca R Pen necchi, Ricardo J N da Silva 2018 Total risk of a false decision on conformity of an alloy due to measurement uncertainty and correlation of test results TALANTA 189 666-674
[16] Raiteri G, Bordone A, Ciuffardi T 2018 Uncertainty evaluation of CTD measurements: a metrological approach to water-column coastal parameters in the Gulf of La Spezia area *Measurement* **126** 156-163

[17] Odeh R E 1982 Critical values of the sample product-moment correlation coefficient in the bivariate normal distribution *Commun. Stat. Simul. Comput.* **11** 1-26

[18] Recommendation M I 2004 1317 State System for Ensuring the Uniformity of Measurements, Results and Characteristics of Measurement Errors, Forms of Representation, Methods of Use for Testing Samples of A Product and Control of Their Parameters All-Russian Research Institute of Metrological Service (VNIIMS) (Moscow)

[19] Pendrill L, Karlson H, Fischer N, Demeyer S, Allard A 2015 EURAMET: A Guide to Decision-making and Conformity Assessment - A Report of the EMRP Joint Project NEW04 Novel Mathematical and Statistical Approaches to Uncertainty Evaluation

[20] GOST R 8.736-2011 State system for ensuring the uniformity of measurements (ICG) Direct measurements are multiple Methods for processing the results of measurements Basic Provisions