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COMPREHENSIVE VERIFICATION CONSTRUCTION COMPLIANCE CONTROL AS THE DEVELOPER'S PROJECT RISK REDUCTION TOOL

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ABSTRACT

The article shows the value of the building control device of the Developer (Technical customer) as an effective tool to reduce the level of potential risks in the implementation of investment construction projects. A study of the experience of building control in the Russian Federation and other countries, such as the United Kingdom, the United States, Germany, etc., is presented. The main features of the interaction between the Customer and the General Contractor in the field of quality management of construction products in Western countries are revealed. The probabilities of mistakes made by construction participants affecting the safety of construction and product quality and the participants in the investment and construction process, which account for the greatest likelihood of various errors, are considered. The role of the quality management system for construction products in the conditions of growth of technological and technical complexity of objects, volumes of works performed, including specialized ones, use of technical personnel, construction materials and equipment from different countries is determined. In *general, the practice of involving organizations for building control, the need for an integrated, systematic approach to the acceptance process are described. Practical significance lies in the proposed verification verification scheme, including laboratory confirmation of the Contractor's data with the aim of optimizing and improving the control function, which is analyzed using existing statistical methods. At the same time, the ways of determining the qualitative and quantitative characteristics of the sample (verification control) from the general array of the general population (the initial control of the Contractor) were marked with observance of the condition of representativeness. Control plans, grades of quality level and types of control in terms of responsibility are defined.*

Key words: Construction technology, construction compliance monitoring, building authorities, risk, verification control, laboratory quality control, quality of finished construction products.

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1. INTRODUCTION AND LITERATURE REVIEW

Upon the implementation of various investment projects in the territory of the Russian Federation, regardless of the funding sources, the Developer is obliged to carry out construction compliance monitoring independently or with the assistance of a specialized organization [1]. In fact, the Developer, not being an expert of industrial and civil construction, in accordance with the requirements of the RF Town Planning Code authorizes a specialized structure – the Technical Customer Service (may be both legal and physical person) – to ensure a full support on his behalf of the whole construction and investment process, from the preparation of the design documentation through the commissioning of completed construction buildings. It is particularly in the interests of the Technical Customer, the authors developed a comprehensive construction compliance monitoring methodology to optimize and improve control functions.

The Customer's construction compliance monitoring when building capital construction facilities, including unique and technically complex buildings, allows tracing the technological sequence of construction works, technological operations, control the volume and timeliness of the Contractor's input control of construction products, materials and equipment. In their control activities, representatives of the Technical and Construction Supervision Service accept the work actually performed by the General contractor, check their compliance with the current regulatory framework, technical regulations, results of engineering researches, requirements of the site development plan and project instructions ("D" and "DD" stages). In this case, the contractors submit the post-completion documentation, which shall confirm the compliance of the finished building products with project target parameters and regulatory requirements, but in practice, the Customer has often reasonable doubt as to the correctness of the provided charts, quality certificates and test reports. Here, we talk about potential and very significant risks arising when implementing investment projects, which may be reduced by qualitative, timely referential construction compliance monitoring performed by a Technical Customer in the required volume of quantitative and qualitative parameters.

In a number of reviewed foreign countries [2], Customers of building products practice the operation of the Construction Supervision Service in one form or another, despite the fact that its necessity is not everywhere regulated by the legislation (Table 1). In addition, modern legislation, both in Russia and globally, does not require from the Construction Supervision Service to conduct random instrumental, geodetic measurements and, especially, verification laboratory support of construction in the course of its control activities. Given that the construction compliance monitoring undertaken by the Customer should include checking the correctness, completeness and compliance with the deadline established by the Contractor of the input control and the reliability of documenting of its results, meeting these requirements is virtually impossible due to non-transparent schemes of many studies and tests performed at the construction site.

Table 1 Practice of the Customer's Construction Supervision Service operation in some foreign countries

No.	Country	Summary of construction supervision approach specifics on behalf of the Customer
1	Russian Federation	Internal or external construction supervision service
2	Belarus	Internal or external construction supervision service
3	United Kingdom	Written assurance of the General contractor on the application of an effective system of quality control of products with the appointment of a quality manager. Contractors' self-certification system is in practice.
4	Germany	Quality assurance system, Qualitatssicherungs system (QSS), the key principle of which is "to produce quality not to monitor it"
5	Sweden	There is no construction supervision service as such. An external expert is usually invited to assess the quality of finished construction facilities.
6	Georgia	The construction supervision on behalf of the Customer is voluntary.
7	New Zealand	The construction supervision on behalf of the Customer is voluntary.
8	USA	The construction supervision on behalf of the Customer is voluntary. The customer is responsible for the constructed facilities during the whole period of maintenance

In the works by V. A. Kotlyarevsky and A. V. Zabegaeva [3], it is found that the causes of accidents of buildings and structures are critical defects in combination with human error in the design, manufacture, installation and operation of structures. There have been estimated error probabilities of the construction participants (Table. 2), with the greatest probability of various errors subsequently affecting the safety of construction operations and quality of finished construction products falls on the Contractor. The proposed method to minimize them is the development of an organizational and technological model [2] of construction compliance monitoring, which will assess and improve the maintenance order, evaluate a set of the Customer's potential risks during the project implementation and reduce such risks using the comprehensive verification construction compliance monitoring method.

Table 2 Error probabilities of construction process participants affecting the safety of construction operations and quality of products

Event	Event probability	
	Western Europe	RF
Fault of the architect	0.10	No research
Fault of the designer	0.40	0.20
Fault of the manufacturer	0.50	0.50...0.60
Fault of the controlling entity	0.10	No research
Operating error	0.02	0.10...0.15
Structure overloading	0.02	App. 0.05
Weak material	0.02	App. 0.20

2. COMPREHENSIVE VERIFICATION CONSTRUCTION COMPLIANCE MONITORING

That is why, in the global construction practice, many Technical Customers during the construction supervision enter into contracts with accredited laboratories to obtain test data and determine the competence and integrity of laboratory control of the Contractor. On the other hand, normative documents do not regulate either the nature of such control by the Customer (random or continuous) or control parameters, nor the necessary number of control reference tests, nor measurement methods or a defined list of mandatory types of laboratory control. We may suggest as a solution of this issue is to develop a methodological normative-technical basis of the construction supervision Service operations with regard to the functions of the geodesic center and test laboratory in part of confirming qualitative and quantitative characteristics of materials, products and finished building products. Organizations engaged in construction supervision activities may use simultaneously several lines of action:

- Desk work with project and authorization documentation;
- Compliance monitoring of organizational and technological parameters;
- Compliance monitoring of work performed to requirements of project estimate and operating documentation and normative regulatory framework.
- Selective geodetic control and monitoring;
- Selective monitoring of physical-mechanical and chemical characteristics of building materials, products, grounds and structures at input, operational and acceptance control stages.

One of the advantages of such an organization would be the integrated provision of services and relevant reduction of potential risks of the Developer arising from the decentralization of control functions of the construction process participants (the Customer and the General contractor) [4].

The lack of allocation of responsibilities and the concentration of control functions "in the hands of a single person" shall allow maximum quickly correctly receiving full information on the volume and quality of construction processes and timely taking necessary organizational and technological decisions based on the identified data results. The theory of an integrated construction compliance monitoring approach of the Customer as a strategy to prevent production and financial losses in order to avoid the creation of unsuitable products and other risks, poses the task of the verification of measurement results of various controlled construction parameters carried out according to the developed and regulatory approved methods of measurements with a given accuracy. Moreover, it is possible to solve this task using a statistical tool.

With the Customer's inspection control, there is probably no need to duplicate the continuous assessment of the quality of regulated indicators performed by the General contractor according to current standards. In the absence of the normative and technical support, it is possible to determine the required and sufficient for the Contractor's data verification number of tests performed by the Construction Supervision Service laboratory using the methods of mathematical statistics. This scheme will allow reducing the cost, the number of inspectors, the length and complexity of control processes.

3. DETERMINING QUALITATIVE AND QUANTITATIVE PARAMETERS OF VERIFICATION CONTROL

Let us take as a finite general universe a set of homogeneous facts of measurements of a certain controlled parameter of construction products by the General contractor's laboratory, allowing taking estimate actions and based on selective data use them to prepare post-completion documentation. Let us name the sampling or samples (sample elements) those units (samples) or product measurement results that were selected for a definite purpose out of this universe. Let us consider two characteristics of the metrological compatibility of the sampling: qualitative (the choice of the sampling method and selection of objects in a necessary part of the general universe) (Table 3) and quantitative (actually, the sample size or, in other words, the representative part of the sample set).

Table 3 Sampling formation methods [5]

No.	Sampling methods	Summary
1	Sampling using random numbers	Using tables of random numbers/ It is not appropriate to apply this method in case of finished construction products.
2	Multistage sampling	The sampling is dome by stages; product units at each stage are randomly selected from units selected at a previous stage. It is not appropriate to apply this method in case of finished construction products.
3	Random sampling	The sampling may randomly contain product units from different parts of the controlled general universe irrespective of subjective assumptions of the controller as to the quality of selected units.
4	Systematic sampling	Units are randomly selected between certain time intervals or via a certain number of products in the flow.

At that, the indicator of a correctly selected set and a guarantor of successful verification control shall be the representativeness — compliance of sampling characteristics to the General population as a whole, allowing, while using a small array of data, to make a conclusion, from which representative elements were selected.

Having defined the mass sampling representatives (Table 3), we calculate quantitative characteristics of this sampling by an alternative symptom (Table 4) according to random control plan (Table 5) based on Acceptable quality level (AQL) (Table 6) assuming that the construction supervision of the General contractor was initially correct and with an ability to turn to an enhanced monitoring or the system of timely sanctions against the work performer in case of detecting using this scheme the quality reduction or the presence of irrelevant control (see Table 7).

Sampling quality control - a certain control plan, which sets the sampling volume from the general universe and the required acceptance criteria (acceptance and rejection numbers).

Table 4 Sampling control plan forms

No.	Sampling control plan forms	Summary
1	By alternative attribute	More simple form of the statistical control, when a unit of finished construction products or a unit of volume of the material at the acceptance control stage is classified only as appropriate or inappropriate. Next is the counting of the number of discrepancies for each type of products in accordance with the established requirement.
2	By quantitative attribute	A form of statistical sampling procedure, when a unit of finished construction products or a unit of the volume of the material at the acceptance control stage is classified based on the measurement of the established quality characteristic of each product unit in the sample.

Table 4 Used sampling control plan forms

No.	Used sampling control plan forms	Summary
1	Single-stage sampling plan (whole acceptance number)	The plan view is represented by three numbers: the sample size, the acceptance number and the rejection number
2	Two—stage sampling plan	If the quality of the first sampling us interim, the second sampling control is applied
3	Multistage sampling plan	Up to seven stages of sampling control
4	Plans with fractional acceptance number	-
5	Variable plans	The sampling plan is not kept for all consecutive sets

Table 5 Quality level indicators

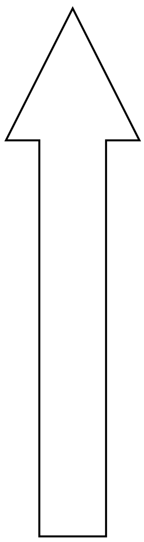
No	Name	Accepted Latin designation of quality level indicator in mathematical statistics	Abbreviation of quality level indicator in mathematical statistics	Gradient of strengthening requirements to products
1	Acceptable quality level (Acceptance defect level) Stated in spec. for products.	Acceptance Quality Limit	AQL	
2	Average outgoing quality	Average Outgoing Quality	AOQ	
3	Average Outgoing Quality Limit	Average Outgoing Quality Limit	AOQL	
4	Consumer's Risk Quality (Technical Customer)	Consumer's Risk Quality	CRQ	
5	Producer's Risk Quality	Producer's Risk Quality	PRQ	
6	Limiting Quality (Rejectable quality level)	Limiting Quality	LQ	

Table 6 Type of control by level of responsibility

No.	Type of control by level of responsibility	Summary
1	Loose	The application of the sampling plan with the sample size smaller than for the normal type. The product acceptance criteria are comparable with the normal type.
2	Normal	The application of the sampling plan with a level of quality equal to the acceptable level of quality.
3	Tightened	The application of the sampling plan with tighter acceptance criteria compared to the normal type.

The acceptable quality level (AQL) taken as a reference point is a level of quality that, when considering a continuous sequence of batches, is the boundary of a satisfactory average quality level (maximum allowable percentage of defective products is called acceptable quality level).

Let us adopt a single-stage sampling plan by an alternative method as the most simple one. Although the calculations by the quantitative attribute have several advantages, within the scale of this experiment, the selected method is fully justified. The control type by the level of responsibility – normal (a most common scheme, in the absence of a specific reference to other terms of statistical analysis).

Determining the quantitative characteristic of the average sampling when checking laboratory test data, we have the following. The sampling volumes, i.e. in our case, the number of verification measurements to be done by the laboratory of the Customer's Construction Supervision Service is calculated in accordance with the uniform measurements of the General contractor's laboratory adopted as the general distribution of the set of values (Table 8).

Table 7 Number of verification measurements (sampling volume)

No.	**General distribution volume (number of measurements made by the General Contractor's laboratory)**		**Sampling volume (number of verification measurements made by the Customer's laboratory)**
	From	**To (inclusive)**	
1	2	8	**2**
2	9	15	**3**
3	16	25	**5**
4	26	50	**8**
5	51	90	**13**
6	91	150	**20**
7	151	280	**32**
8	281	500	**50**
9	501	1200	**80**
10	1201	3200	**125**
11	3201	10000	**200**
12	10001	35000	**315**
13	35001	150000	**500**
14	150001	500000	**800**
15	500001	∞	**1250**

4. CONCLUSIONS

Thus, the laboratory control as part of the Customer's comprehensive construction compliance monitoring will reduce the risk of fraud measurements when testing constructions and during the input control of materials, equipment and supplies. It will also allow avoiding the incorrect preparation of post-completion papers that may result in commissioning finished construction products with latent defects or made of defective materials and semi-finished products. The verification sampling control from the general universe of made measurements according to the developed and approved reference method or a full centralization of integrated control functions in the hands of the Customer may be defined as an additional barrier against errors to ensure the accuracy, correctness and sufficient number of measurements, and in fact, excluding a corruption component. These additions to the qualimetric methods of determining the quality of finished construction products will significantly enhance the compliance with the requirements when creating the product in a timely manner.

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