Technological Progress Requirement to Inspection of Materials and Technologies

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Abstract: The documents on history of main principles for inspection of materials and technologies both in this country and abroad are collected and summarized. Formation of human knowledge of structure and properties of a substance is demonstrated to have made it possible to improve experimental test procedures, thereby strengthening control over ever-increasing requirements to the product quality. Main factors of both materials and technologies quality control are presented at the design stage, manufacturing process, and industrial activity at the present stage. Qualitative content of standards and norms in the history of production relations is found to have determined the quality of the products made. Specific analysis of compositions and quality of the products made, research of the best raw stock and technological ways of processing thereof, methods of evaluating construction material properties and standardization thereof are the required conditions to improve the practice of product manufacturing in all stages of the technology. Reliability and durability of engineering structures is surely to be accompanied by reliable combined operation of elements thereof without loss of strength, stiffness, reliability and spatial dimensional stability thereof. Methods to control and test the material and the connecting units thereof are to be applied to provide reliability of the structures and nodes. Quality of the material therewith is defined by state of structural constituents thereof both on micro- and macro-levels.

1. Introduction
Science of materials goes back deep in the history. Many scientists think the initial moment in formation of the construction material science is ceramics obtained by special changing of the clay structure at heating and burning thereof: quality of the items was improved first by selection of clay and then by changing the heating and burning mode on an open fire and later – in special elementary kilns.

Much time going on, the humanity got to know native and then ore metals, with strength and hardness thereof being known since 8th millennium B.C. Cold-forged native copper was replace by copper melted out of ores found in nature and in large quantities. Later on other metals were added to copper, therefore, in 3rd millennium B.C. people learnt to get and use bronze as copper and tin alloy, as well as to treat precious metals widely known by that time. The application of metals was expanding and the Bronze Age was followed by the Iron Age as the iron ores were easier to extract than the copper ones. The iron dominating in the 1st millennium B.C. was mastered to merge with carbon by forging in the presence of charcoal. Starting of heat treatment of steel is still to be specified, but Luristan people (Western Iran territory) were known to apply it in their lives and for technical purposes in IX and VIII centuries B.C.
Specific obtaining of new construction materials and item (ceramics, metal) was stipulated by certain progress in production. Deeper understanding of the materials properties, especially strength, forgeability and other qualitative characteristics, as well as of possible changing of properties thereof was required therewith. The Ancient Greek philosophers Democritus (c.460-370 B.C.) and Epicurus (341-270 B.C.) were the first who gave the most probable judgments on the essence of the material quality and constituents thereof. At about the same time the Ancient Greek philosopher Aristotle defined 18 qualities in the materials: melting – non-melting, viscosity – fragility, flammability – nonflammability, etc. Three known states of matter (solid, liquid and gaseous) and relation thereof to energy were expressed by Aristotle through four elements: Earth, Water, Air and Fire.

2. Technologies of the past

The ancient period of the science is specially characterized by indivisibility thereof under separate kinds of the construction materials. General interrelation between quality of materials and atomistic composition thereof is significantly observed therein, although it was too far till true scientific chemical knowledge on the composition and properties. The theory was mainly based on assumptions and intuition but, in the III c. B.C. people knew how to give hydraulic properties to the mortars, i.e. ability to be hardened in water by applying natural additives.

According to Descartes theory (1596—1650) of the Renaissance the nature is continuous entirety of material particles, the motion of the material world is endless and is limited to displacement of small particles, i.e. atoms. Displacement of corpuscles (atoms) formed the basis of the corpuscular theory of structure of matter which was the great achievement in the area of learning compositions, interactions and properties of substances. The research dealing with the internal composition (structure) of materials went slowly, although the ancient philosophers had theories and some experimental data. Among the most prominent papers there was Reaumur (1683-1757) publication on the structure (now called microstructure) of iron and changes thereof. The experiences resulted in new material i.e. malleable cast iron. The “Stoneworks Prikaz” on application of stones, bricks and lime in the construction established in Moscow in 1564 is also referred to the medieval period. This Prikaz played the positive role in the science of materials.

Further period of the construction material science is associated with the names of genius Russian scientists – M.V.Lomonosov and D.I.Mendeleev.

M.V.Lomonosov laid the foundation for the advanced Russian philosophy and science, especially in Chemistry, Physics and Geology. He was the founder of the physical Chemistry and chemical atomism explaining atomic and molecular structure of a matter.

D.I.Mendeleev discovered the most important principle of Nature - the Periodic Law according to which the properties of elements depend on atomic weight thereof.

The initial step of formation and evolution of the construction material science since the ancient times till the beginning of the second half of XIX c is characterized by relatively limited varieties of materials and few experimental data by qualitative characteristics thereof. But great scientists and philosophers of that time using intuition and logics, hypotheses and theories managed to get quite sufficient ideas on the composition of matters, interactions of small particles and properties inside thereof.

Some general dependencies of properties of the matter (mainly mechanical ones) on composition thereof were found shortly with new knowledge in physics and discoveries in chemistry and physical chemistry (the progress of the latter began from Lomonosov’s papers). Dependence of properties on the structure was less studied, although the English scientist Robert Hooke still in 1665 defined typical crystal structure with the metals, i.e. 200 years before discovery of steel microstructure under the microscope by Henry Sorby.

Certain analyses of compositions and quality of the materials produced, survey for the best raw materials and technological methods for processing thereof, methods of evaluation of properties of the construction materials and standardization thereof were considered since the second half of the XIX century only as specific development of mass manufacturing of various construction materials and items. 
directly related to the general progress of industries, electrification, the introduction of new hydraulic facilities, etc., the required criterion for improving the manufacturing process at all stages of technology.

3. Current technologies

Reliability and durability of engineering structures is surely to be accompanied by reliable combined operation of elements thereof without loss of strength, stiffness, reliability and spatial dimensional stability thereof. Structural connection is often provided by integration of all elements thereof. Methods to control and test the material and the connecting units thereof are to be applied to provide reliability of the structures and nodes. Quality of the material therewith is defined by state of structural constituents thereof both on micro- and macro-levels.

Structure of the material is defined by the internal composition thereof. The internal composition of the construction materials is defined by spatial packing of particles of various dispersion (fineness) with entirety of stable interconnections and order of bonds between them. Furthermore, the notion of the composition includes arrangement of pores, capillaries, phase boundary, microcracks and other structural elements.

Quality of construction materials is defined by a set of properties meeting certain demands according to the purpose of certain construction material. The quality level is defined by appropriate values being quantitative characteristic of one or several certain construction materials that define the quality thereof as applied to certain manufacturing and operating conditions. Indicators by a number of characteristic quality values are divided to single and composite ones. Single indicator is characterized by one property only (e.g. durability or strength), while the composite one – even by several important properties of the material. Therewith, the item or the structure is considered to be of good quality if the whole range of properties to be evaluated complies with the specified quality requirements. Specific composite indicators for the material quality are chemical composition, physical and mechanical properties, and micro- and macrostructure thereof. The composite indicators are fixed by regulatory requirements.

The properties of the construction materials specifying quality thereof depend on structure which in its turn depends on chemical composition thereof. Therefore, when testing quality of the construction materials and items the properties and composition are checked and the structure thereof is evaluated.

The product is accepted after compared with admission limits set by regulatory requirements. The indicator should be within the set admission range. Reliability of quality indicators to the construction materials is also known to depend on accuracy of measuring instruments.

Besides, the acceptance decisions are affected by the manufacturing process state. Any process is known to be affected by a number of changeability (variability) reasons. When the system is affected by system variations and specific ones, the state thereof is naturally out of statistical control or unstable one. The indicators characterizing the process capability are the process capability indices $C_p$ and $P_p$ and the process performance indices $C_{pk}$ and $P_{pk}$. Theses indices consider centrality of the results obtained.

It should be mentioned the probability of accepting a false hypothesis is increasing with more indicators thereon. So, when evaluating the brick quality (compressive strength) at capability index of 0.43, the error of the first kind was 2.59%, while at multi-indicator control amounted to ($n=4$) -39.68%.

Therefore, the quality results are to be identified with the consideration of accuracy of measuring instruments and the manufacturing process state.

There are different methods for studying structure of materials. On the whole, macrostructure is characterized by phase composition thereof. As a rule, the macrostructure is studied by organoleptic methods. Areas and zones differed by various porosity, paint, grain composition and other features as well as different macrostructure defects are examined visually. Microstructure is analyzed and examined by different instruments and tools. There are three types of microstructure: crystalline, amorphous and mixed.

Currently, the quality control methods applied to construction materials are divided to destructive and nondestructive ones. There is preliminary, intermediate and final control by quality stages for the construction materials and structures. Quality of initial components is evaluated at preliminary control,
and compliance with the set technological process or structural erection – at intermediate. The final control defines quality of the end product that may be either a construction material, or an item, a structure or a building (facility) and compliance thereof with certain standards. Items and structures with defects or having deviations from standard are considered to be defective.

It is rather the environmental component of any labor product value than the economic one as previously that is the key indicator now. According to international standard ISO 8402 the quality is the ability to satisfy the human needs including the ones meeting environmental criteria, as well as human and environmental safety, on the whole. Environmental safety of polymer construction material, i.e. environmental compatibility thereof, is as important property as heat- and electrical conductivity, strength, temperature resistance, etc.

Industrial quality control is the most important part in the manufacturing control system, with one of the tasks thereof being timely detection of deviations from the technological process, and the main aim being preventing, i.e. possible prediction of any faults, and if detected – timely correction thereof. The arranged control system is the structural instrument in safe manufacturing activity.

The constructional reliability may be achieved through two ways:

• analysis of structure and properties of materials to improve stability of properties using probabilistic methods and application thereof in design activity and methods of the materials acceptance testing;
• increase of inspection and repair quality by crack expansion study within the material at actual level of loading.

Quality control methods as an important part for providing safety to structures of the erected buildings and facilities, especially mechanical properties are to be improved.

The traditional sampling destructive methods for inspection and testing the stress-related properties of concrete are recommended to be replaced by total nondestructive testing when making construction methods for testing, as it will be more efficient for quality and labor intensity in making control thereby:

• enabling total control detecting failed structures and elements that cannot be identified by sampling with nondestructive methods (e.g. due to failure of technology, wrong feeding of concrete mix, gravity separation);
• reducing testing time and inspection costs, but therewith the total nondestructive testing is to affect the reliability of obtained measuring data.

According to researching the application of nondestructive methods only should change an approach to acceptable mechanical indicators, with the strength being guaranteed. The application of outgoing control of the construction process should be thoroughly considered. Solving of this problem is possible by making a complex of control testing including both destructive and nondestructive methods. Such an approach will enable to set up a testing data collection system of improved accuracy.

For the moment quality control for the construction-and-assembling operations is basically the traditional one, where the construction companies are facing the record management problems for each facility which results in extension of schedule for construction-and-assembling operations and in construction costs increase.

Negative phenomena and factors (economic, social, natural) affect the construction process reducing quality thereof when starting construction operations in various city areas, thereby resulting in poor construction-and-assembling operations, breach of process regulations, defects, commissioning of faulty capital facilities. Therewith it requires making repeated operations as well as extra financial and labor costs.

Work control and estimate and schedule assurance review are made under the construction supervision. Construction-and-assembling operations are systematically checked for compliance of the approved project and ASAR with current regulatory requirements, technology, quality, scope of work, methods, costs of work made and structures, items and materials applied.
4. Results
Therefore, construction material science has made great leap forward in its development. Due to this the construction materials and items quality control plays an important role in the construction. Testing of the construction materials, structures, buildings and facilities is the most reliable control for the quality thereof.

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