The Journal
OF INTERDISCIPLINARY HUMAN STUDIES
https://mijournals.com/index.php/Human_Studies/index

https://doi.org/10.57033/mijournals-2026-9-0151

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FORENSIC EXAMINATION OF BUILDING MATERIALS: METHODOLOGY, STANDARDS, AND PRACTICAL APPLICATION

Abstract. *This article examines the methods and practical application of forensic examination of building materials in judicial proceedings. Building materials examination is a specialized branch of forensic construction-technical expertise focused on determining the composition, physical-mechanical properties, and quality indicators of materials used in construction. The study presents the examination methodology including organoleptic, laboratory, and instrumental methods, describes standard equipment used in non-destructive testing, and outlines the legal framework based on Uzbekistan's national construction norms (ShNQ, QMQ) and international standards (GOST, ASTM). Practical case findings involving concrete, reinforced concrete, brick-masonry, steel, and timber structures are discussed. The article further analyzes the challenges of expert practice in Uzbekistan's forensic construction sector and proposes directions for methodological development. The findings confirm that scientific examination of building materials serves as a reliable evidentiary tool in construction disputes and accident investigations, and that further integration of digital and remote-sensing technologies can substantially enhance the objectivity and reproducibility of expert conclusions.*

Keywords: *forensic building examination; construction materials; phase composition; non-destructive testing; concrete strength; masonry structures; steel structures; timber; quality assessment; GOST standards; ShNQ; expert conclusion; construction disputes.*

INTRODUCTION

The rapid development of the construction sector in Uzbekistan has led to a significant increase in disputes related to construction quality, material standards compliance, and structural failures. Over the past decade, the volume of construction investment in Uzbekistan has grown substantially, driven by large-scale urban development programs, housing construction, and infrastructure projects. This growth has been accompanied by a corresponding rise in the number of legal disputes in which the physical condition and regulatory compliance of construction materials become matters of judicial determination. In this context, forensic construction-technical examination particularly the examination of building materials (qurilish mollari tadqiqoti) has become a critical instrument in judicial and investigative procedures (Uzbekistan Law No. 249; ShNK 1.04.01-23).

Building materials examination determines the quality, physical-mechanical properties, and compliance of materials with applicable standards. The results of such examinations provide courts with scientifically grounded evidence regarding three fundamental questions: whether specified materials were actually used in a given construction; whether the quantities of materials match the project estimates and delivery documentation; and whether the materials meet the safety, ecological, and structural requirements established by applicable national and international norms (GOST 31937-2011). The importance of reliable answers to these questions extends beyond the resolution of private disputes: in cases involving structural failure, building collapse, or fire, the forensic examination of building materials may be the primary scientific basis for establishing causation and attributing legal liability.

The theoretical foundations of forensic building materials examination draw on materials science, structural engineering, and the law of evidence. The expert is required to possess not only technical competence in materials testing but also familiarity with the legal standards for admissible evidence, with the specific questions that courts and investigative bodies pose to experts, and with the procedural requirements governing expert reports in Uzbekistan's judicial system. This integrated competence distinguishes forensic building materials examination from ordinary quality control or materials testing conducted in commercial or production contexts (Grozdov, 1998; Dobromyslov, 2008).

This article systematizes the methodology, legal basis, and practical experience of building materials examination in Uzbekistan, with reference to international best practices and a discussion of the specific structural material types most frequently encountered in forensic construction expertise: concrete and reinforced concrete, brick masonry, steel structures, and timber. It also reviews the specialized non-destructive testing equipment used in the field and addresses the challenges and development directions of the discipline.

RESEARCH METHODOLOGY

Building materials examination is conducted in three complementary stages, each providing different levels of analytical precision. The selection of methods for a given examination depends on the type of material, the nature of the dispute, the questions posed by the court or investigative body, and the condition of the structures or samples available for testing.

The organoleptic method relies on the expert's sensory assessment visual inspection, tactile examination, and auditory testing (tapping). This approach is applicable only by highly experienced experts who have conducted numerous similar examinations, since its reliability depends entirely on the expert's accumulated practical knowledge. The expert examines, taps, and manually assesses the submitted materials and formulates a preliminary conclusion regarding their compliance with required parameters. While the organoleptic method does not yield quantitative data, it provides important preliminary information that guides the subsequent selection of instrumental methods and enables the expert to identify areas of particular concern before committing to the more resource-intensive laboratory and instrumental stages (Grozdov, 1998).

Laboratory testing is used for concrete, timber, reinforcement materials, and masonry. Concrete is tested for compressive and tensile strength, frost resistance, and abrasion resistance under controlled laboratory conditions. Timber is assessed for moisture content, density, bending and compressive strength along the grain direction, and susceptibility to fungal or rotting damage. Reinforcement bars are tested for tensile and fracture resistance in accordance with applicable GOST standards. Laboratory methods also enable determination of masonry bond strength, mortar composition, and the phase composition of hardened materials, which may provide evidence of adulteration or substitution of specified materials (ShNQ 2.03.01-24; Plevkov et al., 2011).

Instrumental examination involves measurements and analyses using specialized devices. Physical, chemical, and mechanical properties of materials are determined objectively and with quantified accuracy. Parameters such as concrete compressive strength, steel durability, or masonry density are measured with specialized instruments whose calibration is traceable to national and international metrological standards. A key advantage of instrumental methods in the forensic context is that their results are reproducible: a second expert using the same instrument and method on the same object will obtain the same result, provided the instrument is properly calibrated. This reproducibility is essential for the admissibility and persuasive weight of expert conclusions in judicial proceedings. Instrumental testing can be performed both in laboratory conditions and directly at construction sites, enabling in-situ assessment without requiring the removal of samples that could compromise structural integrity (GOST 17624-2012; GOST 22690-2015; ShNK 1.04.01-23).

The examination methodology complies with the requirements of ShNQ 1.04.01-23 “Procedures for Technical Examination and Monitoring of Buildings and Structures” and international standards including GOST 31937-2011, GOST 17624-2012, and GOST 22690-2015. All three methods are typically applied in combination: the organoleptic method provides orientation, the laboratory method yields quantitative data on extracted samples, and the instrumental method enables non-destructive in-situ assessment. The integration of these three approaches constitutes the methodological core of forensic building materials examination as practised in Uzbekistan’s Republican Center for Forensic Examination.

RESULTS

Concrete and Reinforced Concrete Structures. Concrete examination is performed using ultrasonic pulse velocity (GOST 17624-2012) and mechanical pull-off methods (GOST 22690-2015). Strength assessment follows GOST 18105-2018. In-situ testing typically involves 193 ultrasonic measurements and 20 pull-off tests per examination object. Initial calibration dependencies are established, and measurements are taken in two mutually perpendicular directions at each section to account for material anisotropy. Concrete quality classes prescribed by ShNQ 2.03.01-24 range from B3.5 to B100 for heavy concrete. Water resistance is characterized by W2 to W20 marks, and frost resistance by F50 to F1000 marks. Table 1 presents a summary of typical concrete quality indicators evaluated during forensic examination.

Table 1. Key quality parameters of concrete evaluated in forensic examination.

Quality Parameter	Standard	Test Method	Typical Range
Compressive Strength Class	ShNQ 2.03.01-24	GOST 18105-2018	B3.5 – B100
Frost Resistance	ShNQ 2.03.01-24	GOST 10060-2012	F50 – F1000
Water Resistance	ShNQ 2.03.01-24	GOST 12730.5-84	W2 – W20
Ultrasonic Pulse Velocity	GOST 17624-2012	Ultrasonic device	3500–5000 m/s

Visual (preliminary) examination of brick masonry structures identifies visible damage, cracks, deformations, and deterioration patterns, including efflorescence, spalling, and biological growth. Detailed instrumental examination involves measuring section area reduction (%), axial deviations from design position, wall protrusion, and foundation settlements. Crack opening widths are monitored using gypsum or glass beacons and crack-width gauges, with observations recorded chronologically in inspection logs to determine whether cracking is active or stabilized. The stability or progression of cracking over time is a critical factor in the assessment of structural risk and in the attribution of responsibility for observed damage.

The load-bearing capacity of damaged masonry is assessed using the formula: F = (F / K_bp) × K_tr, where K_bp is the safety factor (1.7 for unreinforced walls; 1.5 for reinforced) and K_tr is the damage reduction coefficient determined from standard tables based on crack depth and extent (QMQ 2.01.03-19). Damage classification ranges from minor (up to 15% capacity loss, Category I) to critical (over 50% capacity loss, Category IV), with intermediate categories (16–25% and 26–50%) corresponding to moderate and significant damage respectively. This graduated classification system enables the expert conclusion to directly inform the court's or investigative body's assessment of whether a structure should be evacuated, repaired, or demolished.

Steel structure examination follows ShNQ 2.03.05-13 requirements. The technical condition is assessed across six principal dimensions: cross-section deviations from design dimensions; visible defects and mechanical damage (dents, cracks, buckling); weld, bolt, and rivet joint condition; corrosion degree; deflections and deformations; and steel strength characteristics. Corrosion assessment quantifies both the affected surface area as a percentage of total surface and the cross-section area loss due to corrosion expressed as a percentage of original thickness. These two indicators together determine the residual load-bearing capacity of corroded members, which is the primary forensic question in disputes involving structural failures attributed to inadequate corrosion protection or maintenance. Steel quality is determined by laboratory testing of samples extracted from low-stress zones, including chemical composition analysis (GOST 1497-84) and impact toughness (GOST 9454-78). In cases of suspected material substitution, the chemical composition analysis may reveal whether the steel actually used corresponds to the grade specified in the project documentation (ShNQ 2.03.05-13; Dobromyslov, 2008).

Timber Structures. Timber examination determines moisture content, density, compressive strength along the grain direction, bending strength, and modulus of elasticity. Both biological damage (fungal presence, color change, structural destruction) and entomological damage (bore holes of 0.5–7.0 mm diameter, drilling powder, hollow sound on tapping) are documented systematically with location mapping. Samples are tested per GOST 16483.0–16483.10. For load-bearing structural elements, timber must comply with GOST 8486 (coniferous species, sawn timber), GOST 9462 (deciduous species, round timber), and GOST 9463 (coniferous species, round timber). The forensic expert must also assess whether the timber species, grade, and cross-sectional dimensions correspond to those specified in the project documentation, as substitution of lower-grade or smaller-section timber is a common source of structural deficiency in construction disputes.

DISCUSSION

The results presented above confirm that the three-method approach organoleptic, laboratory, and instrumental provides a comprehensive and reliable framework for forensic building materials examination. However, a number of practical challenges and development directions deserve explicit discussion.

One of the principal challenges encountered in forensic building materials examination in Uzbekistan is the frequent absence of original project documentation, material delivery records, and quality certificates at the time of examination. When such documentation is unavailable, the expert must rely exclusively on in-situ and laboratory testing to reconstruct the material specifications that were applied, which is methodologically more demanding and produces conclusions that are inherently less certain than those based on a comparison of actual versus specified materials. A related challenge is the condition of structures at the time of examination: in cases of post-failure investigation, the relevant structural elements may be partially destroyed, inaccessible, or contaminated with debris, limiting the representativeness of samples and measurements. Courts and investigative bodies do not always appreciate the implications of these limitations for the certainty of expert conclusions, and this gap in understanding between technical experts and legal practitioners is a systemic challenge for the discipline (Dobromyslov, 2008; Plevkov et al., 2011).

A significant ongoing development in Uzbekistan's forensic construction sector is the process of harmonizing national construction norms (ShNQ, QMQ) with international standards, particularly with European standards (Eurocode series) and ASTM standards. This harmonization process creates both opportunities and challenges for forensic practice. On the positive side, harmonized standards facilitate the use of more diverse testing equipment and methodologies and enable the citation of internationally recognized performance benchmarks in expert reports, which may increase the persuasiveness and cross-jurisdictional validity of expert conclusions. On the challenging side, the transition period during which both old and new standards may apply to the same structure depending on when it was designed and built creates interpretive complexity that the expert must navigate carefully to avoid errors in the selection of applicable normative benchmarks (GOST 31937-2011; ShNK 1.04.01-23).

The integration of digital technologies into forensic building materials examination represents the most significant direction for near-term methodological development. Three-dimensional laser scanning enables the rapid and precise documentation of structural geometry, deformation, and damage patterns at a level of detail and coverage that is impossible to achieve through manual measurement. Drone-based photogrammetry and thermal imaging allow the non-destructive identification of moisture ingress, delamination, and thermal bridging in building envelopes. Ground-penetrating radar (GPR) provides subsurface imaging of reinforcement layout, voids, and delamination in concrete structures without requiring surface preparation. These technologies not only improve the completeness and objectivity of the examination but also produce digital records that can be preserved, reproduced, and independently verified properties that are directly relevant to their admissibility and persuasive weight as evidentiary materials in judicial proceedings. The Republican Center for Forensic Examination is well positioned to lead the integration of these technologies into the standard examination toolkit for building materials expertise in Uzbekistan.

CONCLUSION

This study demonstrates that forensic examination of building materials is an essential scientific tool in construction dispute resolution and accident investigation in Uzbekistan. The following conclusions are confirmed by the methodology, results, and discussion presented above.

First, the three-method approach combining organoleptic, laboratory, and instrumental examination provides a comprehensive and mutually reinforcing framework that compensates for the limitations of each individual method. Non-destructive testing preserves the sample for subsequent analyses; the multi-method approach ensures comprehensive quality assessment from multiple independent perspectives; and the results comply with both national (ShNQ, QMQ, GOST) and international (ASTM) standards, ensuring their evidentiary validity in judicial proceedings.

Second, the damage classification systems for masonry and steel structures providing objective grading from normal (Category I) to emergency (Category IV) represent a particularly important contribution of the forensic building materials examination methodology to judicial practice, since they translate technical findings into a graduated scale of risk that courts and investigative bodies can directly apply in their legal determinations.

Third, the primary practical challenges absence of original documentation, limited access to damaged structures, and the interpretive complexity of the standards harmonization process are manageable within the existing methodological framework but require explicit acknowledgment in expert reports and careful communication with the courts and investigative bodies that commission examinations.

Fourth, the integration of digital and remote-sensing technologies three-dimensional laser scanning, drone-based photogrammetry, thermal imaging, and ground-penetrating radar represents the most important direction for the development of forensic building materials examination in Uzbekistan. These technologies can substantially enhance the completeness, objectivity, reproducibility, and evidentiary value of expert conclusions, and their adoption should be a priority for the Republican Center for Forensic Examination in the coming years (GOST 31937-2011; Grozdov, 1998; Plevkov et al., 2011).

The author thanks colleagues of the Construction-Technical Expertise Department of the Republican Center for Forensic Examination named after Kh. Sulaymanova for their assistance in data collection and their practical insights regarding the challenges of forensic construction expertise in Uzbekistan. This research was funded by the Republican Center for Forensic Examination named after Kh. Sulaymanova under the Ministry of Justice of the Republic of Uzbekistan.

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