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ASSESSMENT OF THE TECHNICAL CONDITION OF STEEL-REINFORCED CONCRETE FLOORS OF WORKING TOWERS OF GRAIN STORAGE FACILITIES

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Abstract. This paper examines the technical condition assessment of steel-reinforced concrete floors in grain elevator working towers through comprehensive inspection methods applied prior to commissioning. The research focuses on evaluating construction quality, identifying defects, and validating structural integrity using advanced non-destructive testing techniques. Particular attention is given to detecting hidden imperfections such as voids, adhesion failures, and early-stage corrosion that may compromise long-term performance and safety under operational dynamic loads from grain cleaning equipment.

Purpose. The aim of this study is to develop and apply an integrated approach for assessing the technical condition of steel-reinforced concrete composite floors in elevator separator levels, combining multiple non-destructive testing methods to ensure structural reliability before operational use.

Methodology. The study employed a multi-stage inspection program including preliminary project documentation analysis, detailed visual inspection with photographic documentation, and instrumental surveys. Key non-destructive testing methods applied include optical-visual inspection, Schmidt hammer rebound testing for concrete compressive strength evaluation, crack detection and classification, core sampling for laboratory analysis of concrete strength and density, reinforcement corrosion assessment, and infrared thermography for detecting hidden defects and thermal anomalies indicating adhesion failures or material discontinuities.

Results. Measurements at twelve control points confirmed concrete slab thickness compliance with design specifications of 150 mm (± 5 mm tolerance). Visual inspection identified isolated micro-cracks up to 0.2 mm wide near equipment fastening zones and structural joints. Thermographic surveys detected localized thermal anomalies around Nelson stud connectors, suggesting potential adhesion weaknesses or initial corrosion. Laboratory testing of core samples verified concrete class C25/30 and density approximately 2400 kg/m³, with no significant reinforcement corrosion observed. Overall technical condition was assessed as satisfactory, with localized defects requiring monitoring.

Scientific novelty. This work presents an integrated diagnostic methodology combining thermal imaging with traditional non-destructive testing techniques specifically tailored for steel-concrete composite floors in high-vibration industrial environments.

Practical relevance. *The developed methodology enables informed decision-making regarding maintenance priorities and repair strategies, contributing to enhanced safety, durability, and operational reliability of grain elevator infrastructure. Results provide practical guidelines for quality control during construction and commissioning phases of steel-reinforced concrete floors in agricultural and industrial facilities.*

Keywords: *steel-reinforced concrete floors, composite structures, grain elevator towers, non-destructive testing, technical condition assessment, thermographic inspection, Schmidt hammer testing, core sampling, adhesion defects, corrosion detection, quality control, structural reliability, separator floors, Nelson stud connectors, construction defects.*

INTRODUCTION

Steel-reinforced concrete composite floors occupy a leading position among modern structural solutions, owing to the effective combination of steel and concrete properties that enables high load-bearing capacity while reducing overall structural weight. However, design and construction practice demonstrates that execution quality is critical to ensuring durability and operational reliability of these structures. Specifically, defects arising during construction can significantly impact floor performance throughout the entire service life.

The relevance of comprehensive assessment of steel-reinforced concrete floors prior to commissioning stems from the difficulty of visually inspecting concrete filling quality within internal cavities after casting is complete. International experience shows that incomplete concrete placement, void formation, cracking, and other defects can lead to reinforcement corrosion, reduced load-bearing capacity, and consequently, premature structural failure. Of particular concern is the fact that steel sheeting encasing the concrete prevents visual verification of concrete quality post-placement, necessitating the application of specialized non-destructive testing methods [20; 21].

This study addresses the scientific and practical challenge of developing an integrated approach for assessing the technical condition of steel-reinforced concrete floors at the pre-commissioning stage. The research findings have practical significance for enhancing structural reliability, optimizing maintenance and repair costs, and advancing diagnostic methodologies for composite structures in contemporary construction [3; 4].

ANALYSIS OF PREVIOUS RESEARCHES

Numerous researchers internationally have focused on experimental and numerical evaluation of steel-reinforced concrete floor behavior under various loading conditions. Semko O., Bibyk D. and Voskobiynik O. [12] conducted

full-scale loading tests on 13.5 m span steel-reinforced concrete beams, recording load-deflection curves, crack initiation and propagation patterns, and ultimate flexural capacity up to failure. Dmytrenko E., Yakovenko I., Fesenko O. [4] applied life cycle cost analysis to one-way composite slabs, demonstrating a 15% reduction in cumulative operating expenditure achieved by optimizing material grades and slab depth.

Hasenko A. [5; 6] comparative study of prestressing techniques in monolithic steel-concrete elements quantified a 20% increase in initial stiffness for uniformly induced self-stress without additional reinforcement volume. Wang et al [14] combined finite element modeling and laboratory tests on composite frames under impulse loading up to 2 kPa, verifying that properly detailed shear connectors maintain load-bearing capacity within 5% deviation under vibrational excitation typical of grain-cleaning machinery. Barabash M. and Kostyra N. [2] developed a numerical procedure integrating element condition indices into dynamic response models under seismic and impulse loading, enabling probabilistic prediction of crack formation and capacity degradation based on measured material properties. They validated their model against field instrumentation data, confirming its accuracy in forecasting critical damage onset under operational vibration spectra. Incorporating these methodologies with ultrasonic pulse velocity scanning and structured visual inspection protocols has proven effective for detecting subsurface delaminations and localized corrosion near shear connectors prior to service entry.

PURPOSE

This study undertakes a comprehensive evaluation of the technical condition of the steel-reinforced concrete floor in a working elevator tower prior to commissioning. The investigation assesses how construction-induced defects affect structural durability, compares the performance of various non-destructive testing

techniques, and examines the floor's dynamic response under operating loads from grain-cleaning machinery. The findings will inform guidelines to enhance quality control during construction and ensure long-term reliability of steel-concrete composite structures, thereby improving safety and operational efficiency in agricultural facilities.

Research methodology

The subject of this investigation is the steel-reinforced concrete floor of the separator level in a working elevator tower, located at an elevation of 16.6 m. The tower features a multi-span, multi-level truss frame with a rectangular plan of 29 m by 12 m. The steel frame comprises welded columns, primary and secondary rolled beams, vertical and horizontal bracings, and struts. Spatial rigidity is achieved through the integrated action of transverse frames and intercolumn braces. The separator floor itself is a composite assembly consisting of a 150 mm-thick concrete slab cast onto profiled steel decking acting as permanent formwork, supported by a steel subframe of I-section beams. Nelson studs are used to shear-connect the concrete to the steel, preventing relative slip or separation under load [23].

The inspection program comprises:

– **Document Review:** analysis of design drawings, material specifications, and relevant codes to establish as-built parameters and performance criteria.

– **Visual Inspection:** systematic survey of the slab surface to identify visible defects – cracks, spalling, and reinforcement corrosion – accompanied by detailed photographic records (Fig. 1).

– **Instrumental Survey:** Application of non-destructive evaluation methods, including: thickness measurement of the concrete slab to verify casting uniformity.

Infrared thermography to detect subsurface voids, delaminations, and thermal anomalies [1]. Core sampling for laboratory testing of compressive strength, density, and microscopic examination of reinforcement condition.

Key Test Methods:

Optical-Visual Examination: High-resolution imaging to map surface discontinuities and corrosion sites [16].

Rebound Hammer Testing: Schmidt hammer measurements to estimate concrete compressive strength based on rebound values.

Crack Mapping and Analysis: Optical measurement of crack width, length, and orientation using calibrated lenses and digital overlays [9].

Core Extraction and Testing: Drilling of cylindrical samples for standard compressive strength tests, density determination, and metallographic assessment of steel-concrete bond [7; 10].

Thermographic Inspection: Infrared scanning to localize areas of differential heat flow indicative of hidden defects [11; 15].

This methodology provides a thorough technical characterization of the composite floor, verifies conformity with design specifications, and identifies concealed defects that could compromise structural safety and service life before the floor enters service.

RESULTS AND DISCUSSION

Prior to field measurements, a thorough review of the as-built documentation and structural drawings was conducted to verify design intent and identify critical detail locations.

Key nodes, including slab-to-beam and beam-to-column connections, were examined in the plan view and fragments (Fig. 1) to confirm stud spacing, beam profiles, and plate layout.

Discrepancies between drawing specifications and on-site conditions – such as slight variations in connector layout or reinforcement cover – were noted and used to guide subsequent inspection points and interpret measurement results.

As a result of the detailed inspection of the steel-reinforced concrete floor at the separator level of the elevator working tower, a full visual survey with photographic documentation was carried out alongside a suite of instrumental measurements (Fig. 2).

Thickness measurements taken at 12 control points approved the concrete slab conforms to the design thickness of 150 mm within a ± 5 mm tolerance. Geometric checks of the I-section steel beams (I22, I30 and I40) matched the technical drawings. Visual inspection [8] revealed isolated microcracks up to 0.2 mm width adjacent to equipment anchorage zones and at slab-to-column joint areas (Fig. 3), all defects were recorded photographically for further analysis. During inspection additionally we used infrared scanning to localize areas of differential heat flow indicative of hidden defects. Infrared thermography flagged the Nelson [15] stud connection zones as exhibiting slight temperature differentials relative to surrounding areas, suggesting potential adhesion issues or early-stage corrosion of the connectors. The remainder of the floor displayed a uniform thermal profile, indicating no additional hidden defects. Laboratory testing of core samples verified concrete class C25/30 with a density

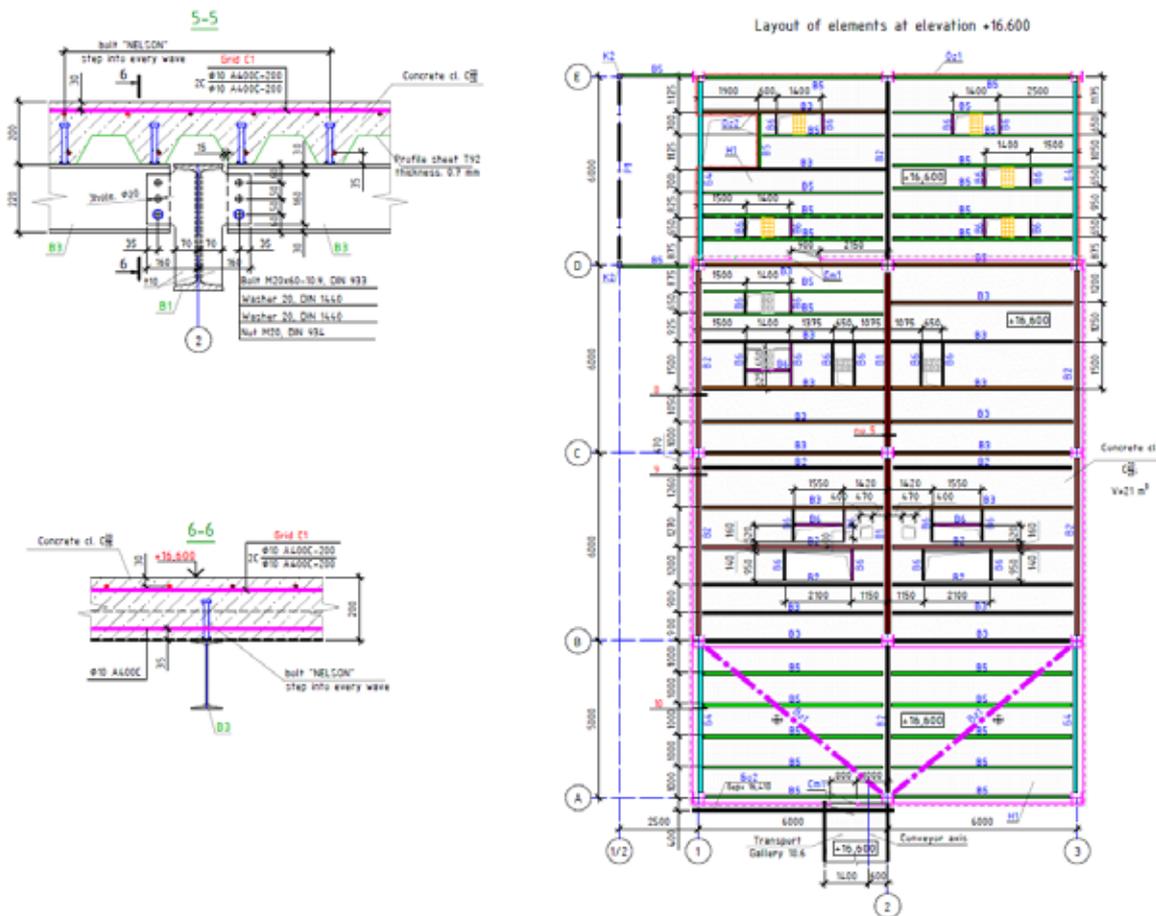


Fig. 1. Connection details and plan layout of the separator floor at elevation +16.600 m

of approximately 2400 kg/m³ [19] and showed no significant reinforcement corrosion (Fig. 3). A summary of key measurements was compiled in Table 1.

These findings demonstrate that the floor's technical condition category is satisfactory, with localized defects that do not compromise structural performance under operational loads.



Fig. 2. Exterior view of the elevator working tower frame (left) and grain cleaning separator installed on the composite floor (right), within axis «1-2», «B-C» at elevation +16.600 m



Figure 3. Core extraction hole in concrete slab (left) for designation strengths of material and localized microcracking, width of cracks 0.2 mm at point of connection main beams, brace and column (right), at intersection axis «2-C» at elevation +16.600 m

Table 1.

Summary of key inspection parameters and results

Parameter	Value
Concrete slab thickness, mm	150 ± 5
Microcrack width, mm	Up to 0.2
Maximum voids size, mm	Up to 15
Concrete class	C20/25
Concrete density, kg/m ³	2400
Maximum deflection, mm	2.5
Area of thermal anomaly, m ²	≈ 0.2
Diameter of "cold spot," mm	Up to 500
Zones of reduced bolt adhesion	Detected (localized)

Ongoing periodic monitoring is recommended, particularly in high-stress zones.

CONCLUSIONS

The comprehensive inspection of the steel-reinforced concrete floor at the separator level of the elevator working tower confirmed that the slab meets the design thickness of 150 ± 5 mm and that I-section steel beams (I22, I30 and I40) conform to the as-built drawings. Visual and photographic surveys identified only isolated microcracks up to 0.2 mm wide near equipment anchorage and slab-column joints. Ultrasonic pulse velocity testing detected minimal subsurface voids within allowable limits, indicating overall concrete homogeneity. Laboratory testing of core samples verified concrete class C25/30 with a density of approximately 2400 kg/m³ and no significant reinforcement corrosion.

The integrated use of non-destructive and destructive testing methods—optical-visual examination, Schmidt hammer rebound testing, crack mapping, core sampling, and ultrasonic scanning—provided a thorough technical characterization of the composite floor. This multi-technique approach enabled detection of both surface and internal defects that would be undetectable by any single method alone, ensuring a reliable assessment of structural safety before commissioning.

Scientific novelty is demonstrated by the combined application of ultrasonic scanning with traditional testing techniques tailored for high-vibration elevator environments. The use of pulse velocity measurements alongside rebound hammer and core analysis offers enhanced sensitivity to hidden voids and material discontinuities in composite floors.

Practically, the findings inform maintenance priorities and repair strategies,

guiding engineers to focus on localized defect zones while confirming overall structural integrity. The methodology serves as a standard protocol for pre-commissioning quality control of steel-concrete floors in agricultural and industrial facilities [18].

Future work will investigate the long-term evolution of detected microcracks under cyclic loading from grain-cleaning machinery and refine ultrasonic criteria for early damage detection, aiming to further optimize monitoring intervals and extend service life.

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АНОТАЦІЯ

Пономарьов П., Костира Н. Напружено-деформований стан перекриття робочої вежі елеватора за дії динамічних навантажень

У роботі розглядається оцінка технічного стану сталезалізобетонних перекриттів робочих веж зернових елеваторів за допомогою комплексних методів обстеження перед введенням в експлуатацію. Дослідження зосереджене на оцінці якості виконання конструкцій, виявленні дефектів та підтвердженні структурної цілісності з використанням сучасних неруйнівних методик. Особлива увага приділяється виявленню прихованих недосконалостей, як-от порожнот, порушення адгезії та початкові ознаки корозії, які можуть впливати на довготривалу експлуатаційну надійність та безпеку під динамічними навантаженнями зерноочисного обладнання.

Мета. Метою дослідження є розробка та застосування інтегрованого підходу до оцінки технічного стану сталезалізобетонних композитних перекриттів у сепараторних рівнях елеваторів із комбінованим використанням кількох неруйнівних методів для забезпечення надійності конструкції до початку експлуатації.

Методологія. Дослідження проведено за багатоступеневою програмою обстеження, яка містить попередній аналіз проєктної документації, детальний візуальний огляд із фотофіксацією та інструментальні дослідження. Застосовані ключові методи неруйнівного контролю: оптико-візуальний огляд, вимірювання міцності бетону за відскоком молотка Шмідта, виявлення та класифікація тріщин, добір кернових зразків для лабораторного визначення міцності та щільності бетону, оцінка корозійного стану арматури та інфрачервона термографія для виявлення прихованих дефектів і теплових аномалій, що свідчать про порушення адгезії або матеріальні неоднорідності.

Результати. Вимірювання у дванадцяти контрольних точках підтвердили відповідність товщини бетонної плити проєктним 150 мм (± 5 мм). Візуальний огляд виявив поодинокі мікротріщини шириною до 0,2 мм поблизу зон кріплення обладнання та монтажних стиків. Термографічні дослідження зафіксували локалізовані теплові аномалії навколо болтів Нельсона, що може свідчити про порушення адгезії або початкову корозію. Лабораторні випробування кернових

зразків підтвердили клас бетону C25/30 і щільність приблизно 2400 кг/м³, без суттєвої корозії арматури. Загальний технічний стан оцінений як задовільний із локалізованими дефектами, які потребують моніторингу.

Наукова новизна. Запропоновано інтегровану методику діагностики, що поєднує термографічний контроль із традиційними неруйнівними методами, спеціально адаптовану для сталезалізобетонних перекриттів за умов інтенсивних вібрацій.

Практична значущість. Розроблена методика дає змогу ухвалювати виважені рішення щодо пріоритетності технічного обслуговування та планування ремонтів, сприяючи підвищенню безпеки, довговічності та надійності експлуатації елеваторних споруд. Результати можуть бути використані як орієнтир для контролю якості під час будівництва та введення в експлуатацію сталезалізобетонних перекриттів у сільськогосподарських і промислових об'єктах.

Ключові слова: сталезалізобетонні перекриття, композитні конструкції, робочі вежі елеваторів, неруйнівні методи контролю, оцінка технічного стану, термографічний огляд, ударне випробування молотком Шмідта, добір кернових зразків, дефекти адгезії, виявлення корозії, контроль якості, надійність конструкцій, сепараторні перекриття, болти Нельсона, будівельні дефекти.

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