Doi: 10.33644/01101

УДК 624.04:69.058

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FEATURES OF SIMPLIFIED CALCULATIONS FOR EXISTING BUILDINGS CIVIL STRUCTURES SURVEYS (ADMISSIBILITY AND VALIDITY ISSUES)

ABSTRACT

The relevance of the discussed problem is shown. The recent researches and publications on the topic are analyzed. The tasks are developed for the specified goals achievement. For the most commonly used load-bearing structures the specific features of simplified calculations in the process of buildings and structures technical state inspection are considered. The civil structures simplified calculations are classified and systematized. The simplifications systematization and their admissibility justification are carried out, which promote the achievement of the calculations reliability and efficiency maximum level. The simplifications in the design schemes drawing up and existing loads and impacts determination, as well as the simplified calculations execution are analyzed. The area of simplified calculations admissibility is identified. The algorithm (stages) for civil structures simplified calculations is developed. Some example questions to a forensic expert are considered. The questions can be predicted and resolved based on the materials of this paper by means of the civil structures simplified calculations in the course of civil engineering forensic studies. Recommendations for further researches on the topic are provided. The study purpose is to substantiate the simplified calculations permissible range for the most commonly used load-bearing structures. The scientific novelty of the work is that for the first time the validity, admissibility and systematization problems of the load-bearing civil structures simplified calculations are considered. The study results are of practical importance for the construction engineering researches on the structures technical state assessment and forensics examinations.
KEY WORDS: design scheme, loads and actions, support links, survey, defects and damages, limit states, existing development, simplifications systematization.

ОСОБЕННОСТИ УПРОЩЕННЫХ РАСЧЕТОВ ПРИ ОБСЛЕДОВАНИИ СТРОИТЕЛЬНЫХ КОНСТРУКЦИЙ СУЩЕСТВУЮЩИХ ЗДАНИЙ (ПРОБЛЕМЫ ДОПУСТИМОСТИ И ОБОСНОВАННОСТИ)

АННОТАЦИЯ

Отмечены тезисы актуальности рассматриваемых проблем. Выполнен анализ последних

исследований и публикаций по данной тематике. Разработаны задачи для достижения поставленной цели. Рассмотрены особенности проведения упрощенных расчетов наиболее часто используемых несущих строительных конструкций в процессе обследования технического состояния зданий и сооружений. Проведена классификация и систематизация упрощенных расчетов строительных конструкций. Выполнена систематизация упрощений и обоснование их допустимости, что способствует достижению максимального уровня достоверности и оперативности расчетов. Проведен анализ упрощений при составлении расчетных схем, определении действующих нагрузок и воздействий, а также выполнения упрощенных расчетов. Определена область допустимых упрощенных расчетов. Разработан алгоритм (этапы) выполнения упрощенных расчетов строительных конструкций. Рассмотрены примеры вопросов судовому эксперту, которые можно прогнозировать и решать при помощи упрощенных расчетов строительных конструкций при проведении судовых строительно-технических исследований с учетом материалов данной статьи. Приведены рекомендации для дальнейших исследований по данной тематике. Целью исследования является обоснование допустимой области применения упрощенных расчетов наиболее часто встречаемых несущих строительных конструкций. Научная новизна работы заключается в том, что впервые рассматриваются проблемы обоснованности и допустимости, а также систематизации упрощенных расчетов несущих строительных конструкций. Результаты исследования имеют практическую значимость при проведении строительно-технических исследований по оценке технического состояния и проведении судебных экспертиз.

КЛЮЧЕВЫЕ СЛОВА: расчетная схема, нагрузки и воздействия, опорные связи, обследование, дефекты и повреждения, предельные состояния, старая постройка, систематизация упрощений.

ОСОБЛИВОСТІ СПРОЩЕНИХ РОЗРАХУНКІВ ПРИ ОБСТЕЖЕННІ БУДІВЕЛЬНИХ КОНСТРУКЦІЙ ІСНУЮЧИХ БУДІВЕЛЬ (ПРОБЛЕМИ ДОПУСТИМОСТІ ТА ОБҐРУНТОВАНОСТІ)

АНОТАЦІЯ

Відмічені тези актуальності проблеми, що ми розглядаємо. Виконаний аналіз останніх досліджень і публікацій за даною тематикою. Розроблені задачі для досягнення поставленої мети. Розглянуті особливості проведення спрощених розрахунків найбільш часто використовуваних несучих будівельних конструкцій в процесі обстеження технічного стану будівель та споруд. Проведені класифікація і систематизація спрощених розрахунків будівельних конструкцій. Виконані систематизація спрощень і обґрунтування їх допустимості, що сприяє досягненню максимального рівня достовірності та оперативності розрахунків. Проведений аналіз спрощень при складанні розрахункових схем, визначенні діючих навантажень і впливів, а також виконання спрощених розрахунків. Виявлена область допустимості спрощених розрахунків. Розроблений алгоритм (етапи) виконання спрощених розрахунків будівельних конструкцій. Розглянуті приклади питань судовому експерту, що можуть прогнозуватися і вирішуватися за допомогою спрощених розрахунків будівельних конструкцій при проведенні судових будівельно-технічних досліджень з урахуванням матеріалів даної статті. Надані рекомендації щодо подальших досліджень по даній тематиці. Метою дослідження є обґрунтування допустимої області застосування спрощених розрахунків несучих будівельних конструкцій, що найбільш часто зустрічаються. Наукова новизна роботи полягає в тому, що вперше розглядаються проблеми обґрунтованості і допустимості, а також систематизації спрощених розрахунків несучих будівельних конструкцій. Результати дослідження мають практичну значимість при проведенні будівельно-технічних досліджень з оцінки технічного стану та проведення судових експертиз.

КЛЮЧОВІ СЛОВА: розрахункова схема, навантаження і впливи, опорні зв'язки, обстеження, дефекти та пошкодження, граничні стани, стара забудова, систематизація спрощень.

INTRODUCTION

The building technical state level determination based on visual examinations and field studies may not be sufficient for conducting the building technical survey (TS). Often, the execution of civil structures strength and deformability in-process calculations, including simplified ones, is necessary.

The urgency of the problem is related to the following factors:

- in the existing development there is a large number of projects having defects and damages, which do not meet the modern building standards and require prompt calculation checks;
- insufficient regulatory, scientific and methodological support of the correct transition from the civil structures real work to the simplified structural designs;
- some specialists do not have the sufficient knowledge of civil structures analysis computer software for prompt engineering decisions making in the process of technical state survey;
- a wide variety of tasks for carrying out the structural and technical expert surveys to identify the possible safety of load-bearing structures further operation.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS on this topic showed that the methods of the civil structures load-bearing capacity calculations during the construction projects technical surveys are given a sufficient attention in the Ukrainian and foreign works [7 and 8]. Much less attention is paid to simplified calculations [7, 9, 10, 13 and 14]. Practically, in the normative literature such issues are hardly considered, with the exception of partial descriptions in DBN and DSTU-N [1-6, 11 and 12]. The issues of the simplified calculations admissibility and validity have not been practically addressed in the mentioned sources.

PROBLEM FORMULATION

The purpose of this work is to conduct a scientific study related to the validity of limitations and assumptions when performing the individual load-bearing structures simplified calculations in the process of the existing buildings technical state surveys.

To achieve this goal, the following tasks are considered:

- features, nature and scope analysis, systematization and classification of simplified calculations by various characteristics (types of calculations, purpose, stages of study, levels of calculations completion etc.) in the process of technical survey; the simplified calculations advantages and disadvantages analysis, the simplifications admissibility comparative analysis;
- analysis of simplifications types and their impact on the civil structures behavior real patterns; the algorithm development (refinement) for the simplified calculation during structures technical state survey;
- features of the simplified calculations use during the forensic civil engineering expert investigations.

BASIC MATERIAL AND FINDINGS

In modern practice, in the buildings technical surveying and designing the different types of civil structures simplified calculations, including preliminary, verification and checking calculations are used. Under the preliminary simplified calculation, the authors accept the civil structure calculation aimed at identifying the need for the further expert actions on the structure detailed analysis. The verification calculation is often understood as the determination of the design parameters conformity to the building regulations requirements [1-22]. The checking calculation is a simplified calculation for checking the previously performed manual or computer-aided calculations. It is necessary to combine the mentioned terms in the concept of a civil structure simplified calculation (CSSC). In this work the civil structure simplified calculation (CSSC) is used to mean the civil structure load-bearing capacity (strength and/or deformability) calculation during the existing buildings technical survey process with an allowance for a reasonable simplification sufficient level. This calculation allows to quickly check the surveyed structures compliance with the existing regulations requirements. In Table 1 the civil structures simplified calculations are systematized by various characteristics in order to analyze their use possibilities.

During the CSSCs a need can arise to justify the admissibility of the following simplifications: deviation of the simplified design scheme from the civil structure actual operation; deviation of the simplified design scheme from the traditional one; geometric dimension simplifications compared to real ones; loads and actions simplifications compared to real ones; simplifications of loads distribution types, which do not comply with the real distribution.

It is worthwhile to consider the CSSC execution features for some of the most common structural elements when examining the objects technical state. An analysis of the simplifications and their justification and validity extent is given below in Tables 2 and 3.

The authors developed the following algorithm (stages) of the CSSC carrying out:

- study and analysis of the initial design, executive, entitling and registration technical documentation for an object under study;
- preliminary visual inspection of the structures, taking into account measures to ensure the spatial rigidity of the building as a whole;
- the necessity and feasibility analysis regarding a simplified calculation carrying out at an early stage of the survey, including the Terms of Reference drafting for the survey contract;
- identification of structures that require the justifying calculation carrying out, the simplified design scheme development based on the initial visual inspection and the analysis of the investigated structure relationships with the structural system of the building as a whole (conformity category and impact on the building overall spatial rigidity);
- structure actual work analysis, classical and simplified design schemes, accepted assumptions and simplifications assessment;
- effective loads detection based on the regulatory data and customer initial data (technological loads related to the production technological features), including actual and simplified ones, and the preliminary assessment of the accepted loads assumptions and simplifications impact on the calculations final results;
- static structure calculation, including the forces determination in accordance with the simplified design scheme (bending moments; longitudinal and lateral forces);
- design calculation taking into account the building materials properties; comparative analysis of

Table 1 - CSSC classification and systematization

№	Feature	Variation	Feature description (purpose)	Simplifications explanation and validity
1	2	3	4	5
1.1	1. Type of calculation	Static /dynamic	The internal forces determination (moments and longitudinal and transverse forces)	Elements of design scheme, loads and actions
1.2		Structural	Intersection sufficiency check (depending on the structure material)	The justification of the transition from the actual plastic model of constructive element work to the elastic one
1.3		Mixed	Forces determination and intersection sufficiency verification	
2.1	2. Type of simplification (supporting links, elements intersections, loads and actions	Design schemes	Creating a design scheme with simplified geometry and support links	The justification of the real or classic design replacement with the simplified one
2.2		Loads and actions	Transformation of the complex actual types of loads with the simplified ones	The real loads replacement with the simplified ones; the allowable load determination
2.3		Other (structure)	The dynamic loads and actions replacement with the static ones etc.	The justification of the transition from dynamic actions to simplified static ones
3.1	3. Calculation justification and completeness levels	Complete	All assumptions/simplifications are considered and justified	The possibility of accepting the results as final ones
3.2		Partial	The assumptions/simplifications justification is partial	The civil structure simplified calculation is impossible or incomplete
3.3		Not available	The assumptions/simplifications are not justified	
4.1	4. Limit state	Strength	The design parameters are determined by simplified mechanics models	See the above justifications
4.2		Deformability		
5.1	5. Base of comparison	Building codes	The parameters comparison with normative ones	The correctness of the TS regulatory requirements
5.2		Design data	The parameters comparison with design ones	Taking into account defects and damages
5.3		Other base	Specific requirements of a customer and rational mind	With the requirements expediency justification

Table 2 - Simplifications and assumptions used during the simplified design schemes formation

Structure	Simplification	Assumption
Single span beam (beam slab)	The real supports replacing with hinge ones	With free rest on the walls**
	Rigid fixing replacement with hinged one	With taking into account a moment on the reinforced concrete beams support
Multispan beam (cast-in-place beam slab)	Multispan beam replacement with a single span beam	
	Indirect determination of supports moments from the spanned ones	Provided that the moment on the support is accepted equal to the bending moment in restraint
Column (pillar or partition wall)	Structural scheme features of the building as a whole	For the justification of structural scheme with the rigidly joined elements
	Replacement of real support links with hinged ones or restrained within a storey	With taking into account the loads off- centered application
Edge supported reinforced concrete slab	Replacement with a beam plate on two supports along the less span	The support moment is equal to the moment in the scheme of one span beam with restrained and hinged support
Lintel above the slot	Real supports replacement with hinged ones**	See Note
Retaining wall***	Real support replacement with restrained one	See Note

Notes to Tables 2:

***The rigid structural scheme of a building as a whole should mean a scheme with an upper support taken without any displacements.**

**** The free support denotes a support without restraints.**

*****The stand-alone retaining wall does not have any upper support.**

Table 3 - Current loads features and assumptions for the buildings structures calculations

Structure	Simplification	Assumption
1	2	3
Single span beam (beam slab)	Replacing the real loads (with a complex contour in plan) affecting the beam with the loads evenly distributed or focused in the contour center	Provided that a uniformly distributed load is equivalent to the total actual loads
Multispan beam (cast-in-place beam slab)		
Column (pillar or partition wall)	Only the vertical loads with an eccentricity (if any) are considered	Provided that the horizontal loads are taken by the lateral rigid structures
Edge supported reinforced concrete slab	Replacement of real loads (with complicated contour in plan) with evenly distributed ones	Provided that the evenly distributed load is equivalent to the total actual one
Lintel above the slot	Replacement of the load modelling a work like beams on elastic base with an even distribution	With taking into account the floor load in the case of arrangement within a conditional triangle
Stand-alone retaining wall***	The actual lateral load replacement with a trapezium or triangular ones	Provided that it is possible to justify the load by a linear law

Notes to Tables 3:

***The rigid structural scheme of a building as a whole should mean a scheme with an upper support taken without any displacements.**

**** The free support denotes a support without restraints.**

*****The stand-alone retaining wall does not have any upper support.**

the mathematical calculation results and the existing regulatory documents permissible parameters; conclusions drawing based on the calculations results with the obligatory presentation of the accepted assumptions and simplifications certainty degree analysis.

The scope of each simplified calculations type is recommended, as a rule, for individual, not mass cases. CSSCs can be used as the preliminary design justifications of existing building structures. For a more accurate computational research of the building structures actual work, it is necessary to adopt for the building a computer-based spatial design scheme.

CSSCs are widely used in construction engineering studies, such as forensic examinations. As a rule, when carrying out forensic civil engineering studies, the necessity of checking the building structures conformity with the regulatory requirements (strength, rigidity, stability, reliability etc.) should be found. To do this, a forensic expert must calculate the strength independently or use the services of a specialized organization that has the relevant permits. The second way is related to the need for prompt expert research. As practice shows, for a forensic expert of 10.6. specialty it can be sufficient to carry out simplified calculations. However, there are no appropriate recommendations in the regulatory or scientific and methodological literature for such calculations applications.

It is reasonable to consider some example questions to forensic expert that can be predicted and resolved by means of CSSC when conducting forensic civil engineering studies based on this paper material.

1. Does the structure design in the operated building correspond to the existing regulatory requirements for reliability and safety?
2. Is the class of responsibility of the floor load-bearing structure (covering, staircase, rafters, masonry partitions, columns etc.) reasonably accepted when carrying out the building technical state surveys and certification?
3. Is the building collapse due to the load-bearing structures technical state, if so, which structures specifically?
4. Was it necessary to calculate the load-bearing structures strength for the building technical state survey and certification? If yes, was a simplified calculation permissible?
5. Is it reasonable to accept the civil structures simplified calculations when surveying the building technical state? If no, could this have caused the collapse (material damage to the owner)?
6. Was the class of responsibility of load-bearing structures of flooring, cover, staircase, rafters, masonry partitions, pillars etc. reasonably accepted, when conducting the building technical state survey and certification?
7. Is the building collapse due to the load-bearing structures technical state, if so, which structures specifically? Was the use of civil structures simplified (estimated) calculations reasonable for the building technical state survey? If it was not, could this have caused the collapse (material damage to the owner)?

FINDINGS AND PROSPECTS FOR THE FURTHER DEVELOPMENTS

1. The paper proposes an approach that allows to reasonably accept the civil structures simplified calculations when carrying out the technical state of the building examined structures.
2. Preliminary developments have been made to determine the rational region for the civil structures simplified calculations use when surveying their technical state for various purposes, for instance, as part of forensic expert studies.
3. The possible questions to a forensic expert, the resolution of which requires strength calculations, including the simplified ones, are foreseen.
4. It is recommended to carry out the further researches on this topic within the framework of the simplified calculations use enhancement with the involvement of specialists in the fields of structural mechanics, civil structures or technical surveying, and forensic experts.

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Стаття надійшла до редакції 16.01.2020 року