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Refinement of Building Digital Model Parameters Based on Engineering Geodetic Data

*M. Yakovenko, I. Ben, Y. Zorin, Y. Zelenko, O. Lisenyi
(*State Research Institute of Building Constructions*)

SUMMARY

Current methods for assessing the technical condition of buildings increasingly rely on finite element modelling. At the same time, the reliability of the obtained results largely depends on how accurately the computational model represents the actual condition and spatial position of the structural elements. This issue is particularly relevant for buildings affected by accidental, seismic, and war-related impacts, where partial structural failure and residual deformations can significantly alter the behaviour of the structural system. This study proposes a methodological approach to refining digital models of buildings based on engineering geodetic survey data. The approach was validated using a multi-storey building damaged by a missile strike as a case study. At the initial stage, a digital model was developed taking into account the destroyed structural elements. Engineering geodetic measurements of the floor slabs revealed fundamentally different deformation patterns: no significant deformations were detected below the impact zone, whereas the floor slabs above the impact zone exhibited substantial residual deformations. The obtained geodetic data were used to refine the digital model by incorporating the actual spatial positions of the structural elements. The refined model significantly affected the results of the computational analysis, enabling more accurate identification of critical areas and influencing engineering decisions regarding the stabilization and subsequent restoration of the building. The results confirm the effectiveness of integrating engineering geodetic measurements into the digital modelling of buildings with significant localized damage.

Keywords: Engineering geodetic monitoring; Digital modelling; Finite element method; Model calibration; Damaged buildings; Stress-strain state.

Corresponding Author: yakovenko122mi@gmail.com

Introduction

Digital modelling using the finite element method is one of the effective tools for assessing the technical condition of buildings and structures. Computational models are used to determine the stress-strain state of structural elements, assess their load-bearing capacity, and substantiate engineering decisions regarding further operation, strengthening, or restoration. At the same time, the reliability of digital modelling results directly depends on how accurately the adopted computational model represents the actual condition of the structural system.

This issue is particularly relevant for buildings subjected to accidental, seismic, or war-related impacts. Partial failure of load-bearing elements, residual deflections, and spatial displacements of structural elements can significantly alter the geometry and behaviour of the structural system. Under such conditions, relying solely on design documentation and visual inspection results when developing a digital model does not always ensure that its geometry adequately represents the actual spatial positions of the structural elements.

Current research focuses on the integrated use of geodetic, photogrammetric, and other instrumental methods for assessing the technical condition of damaged buildings (Danyliv et al., 2026; Gajaria et al., 2026; Glukhovskyi et al., 2025; Yakovenko et al., 2026). Another research direction involves the development of digital twins using LiDAR and HBIM technologies (Kyryliuk & Bondarenko, 2026), as well as finite element model updating based on field measurements (Chen et al., 2025). Methods for updating digital models and predicting their behaviour based on monitoring data are also being actively developed using modern computational approaches (Tian et al., 2025). However, the direct use of engineering geodetic measurements for calibrating digital models of buildings following localized damage to the structural system requires further development.

The aim of this study is to develop and validate a methodological approach to refining the digital model of a damaged building based on engineering geodetic survey data in order to improve the reliability of its stress-strain state assessment and to substantiate engineering decisions regarding its restoration.

Method and Theory

The proposed approach is based on the sequential integration of field inspection results, engineering geodetic measurements, and digital modelling. Its key feature is the use of geodetic data not only for the quantitative assessment of structural deformations but also as input data for refining the digital model according to the actual spatial positions of the structural elements.

At the first stage, an initial finite element model of the building is developed based on the design documentation and inspection results. For buildings subjected to localized damage, the computational model accounts for the actual loss or damage of structural elements identified during the inspection. The initial analysis makes it possible to assess changes in the behaviour of the structural system following localized damage and to preliminarily identify critical areas.

The next stage involves engineering geodetic measurements. For the building under study, the actual vertical positions of the floor slabs below and above the missile impact zone were determined. The geodetic data made it possible to determine the nature and spatial distribution of residual deformations that could not be quantitatively assessed from visual inspection alone.

The vertical deviation of a control point from the adopted reference horizontal plane is determined as follows (1):

$$\boldsymbol{\Delta H_i = H_i - H_{ref}} \qquad (1)$$

where $\boldsymbol{H_i}$ is the actual elevation of the $\boldsymbol{i}$-th control point determined from engineering geodetic measurements; $\boldsymbol{H_{ref}}$ is the elevation of the adopted reference horizontal plane; and $\boldsymbol{\Delta H_i}$ is the vertical deviation of the control point.

The resulting field of vertical deviations is used to refine the geometric parameters of the digital model. Thus, the initial computational model, which accounts for the nature of the localized damage to the building, is supplemented with information on the actual spatial positions and residual deformations of the structural elements. After refinement of the model, the stress-strain state is recalculated, and changes in the calculated internal forces and displacements, as well as the localization of critical areas, are analysed.

Thus, the proposed workflow includes the following stages: inspection of the damaged building, development of the initial digital model, engineering geodetic measurements, calibration of the model using actual geodetic data, repeated analysis, and use of the obtained results to support engineering decision-making.

Results

The proposed approach was validated during the assessment of the technical condition of a multi-storey residential building damaged by a missile strike. The blast impact caused localized failure of several vertical load-bearing structural elements and floor slabs, resulting in changes in the spatial behaviour of the structural system. To assess its condition, a three-dimensional finite element model was developed in the LIRA-SAPR software package, taking into account the destroyed and damaged structural elements.

The initial analysis made it possible to assess the redistribution of internal forces following the localized structural failure and to identify potentially critical areas. However, the initial model did not account for the actual residual deformations of the structural elements that remained after the blast impact.

To determine their actual positions, engineering geodetic measurements were performed on the floor slabs below and above the missile impact zone. The results revealed fundamentally different deformation patterns. No significant residual deformations were detected in the floor slabs below the impact zone, indicating that their positions remained close to the design geometry. In contrast, significant residual deformations were recorded in the investigated floor slabs above the impact zone.

The largest deformations were observed in the 25th-floor slab. Deviations of its surface from the reference horizontal plane reached 241 mm (Figure 1). The maximum deviations were concentrated within axes 1–4/E–K, directly in the impact zone, whereas the minimum deviations, which remained within the construction tolerances, were recorded near the elevator core and within axes 1–5/D–E. The relative difference in vertical displacements of the floor slab was 0.0448, compared with the allowable value of 0.005, thus exceeding the adopted limit by approximately nine times in accordance with DSTU B V.1.2-3:2006.

The field of vertical deformations obtained from the engineering geodetic measurements was used to refine the model fragment corresponding to the 20th–25th floors. Figure 1 illustrates the relationship between the field measurements and computer modelling: the left part shows the actual distribution of vertical deformations determined from the geodetic survey; the upper-right part shows the initial model without incorporating the geodetic data; and the lower-right part shows the model after refinement based on the geodetic measurements.

Comparison of the initial and refined models showed that incorporating the actual spatial position of the floor slab significantly changes the representation of its deformed state. The refined model more accurately reflects the localization of maximum deformations within the missile impact zone and the spatial behaviour of the structural elements identified from the field measurements.

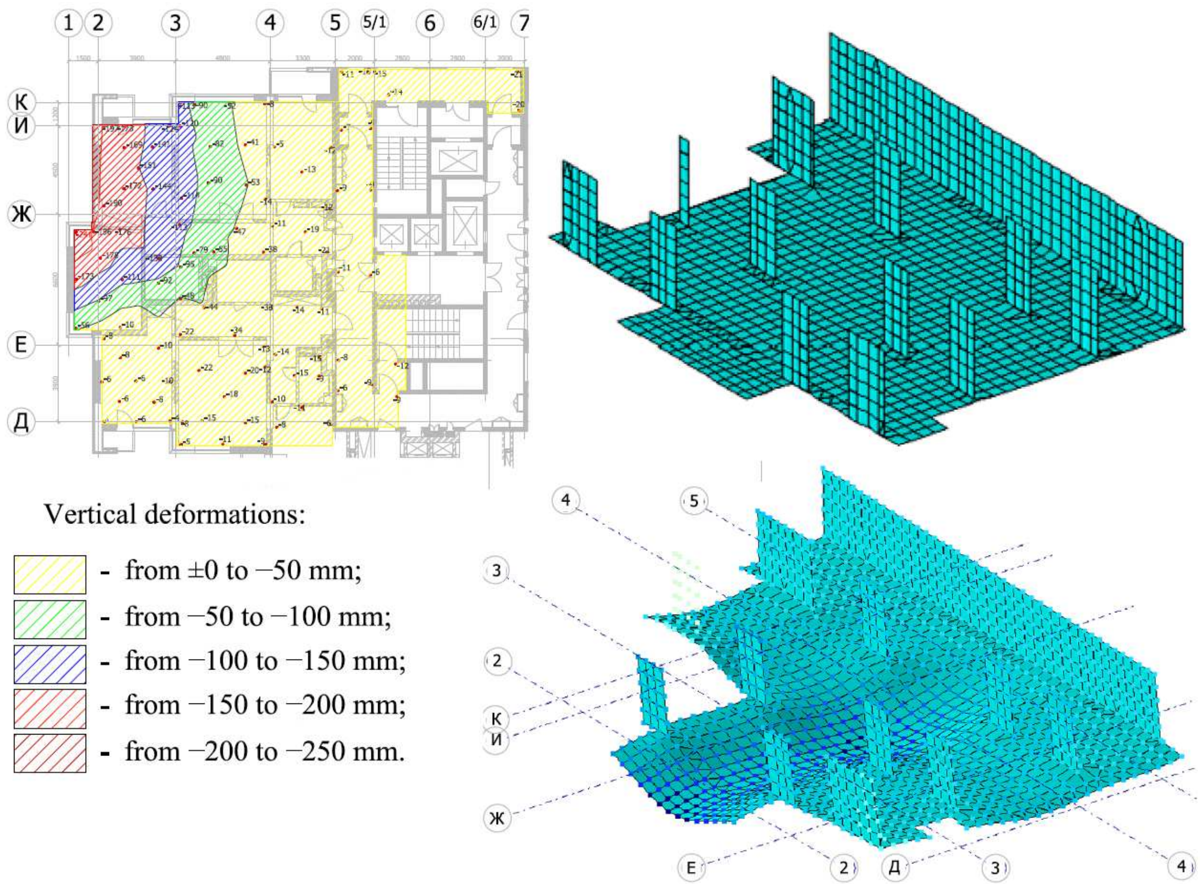

Figure 1. *Refinement of the digital model of the 25th-floor slab using geodetic data: measured vertical deformations (left), initial model without geodetic data (upper right), and refined model incorporating geodetic measurements (lower right)*

Incorporating the geodetic data into the subsequent analysis of internal forces and stresses made it possible to refine the assessment of the stress-strain state of the structural system and the localization of critical areas. The obtained results were directly used to support engineering decisions regarding priority emergency stabilization measures to ensure structural stability and the subsequent restoration of the building.

Thus, in the case under study, the engineering geodetic measurements served not only as a means of monitoring but also as input data for refining the digital model. This enabled a transition from a computational model developed primarily on the basis of design documentation and inspection results to a model that additionally accounts for the actual deformed state of the structural system.

Conclusions

A methodological approach to refining models of damaged buildings by integrating engineering geodetic monitoring results into the digital modelling process is proposed. The key feature of the approach is the use of the actual spatial positions of structural elements not only to assess deformation magnitudes but also as input data for refining the geometric parameters of the computational model. The case study of a multi-storey building damaged by a missile strike revealed a significant difference in the deformation behaviour of the floor slabs below and above the impact zone. The maximum deviations of the 25th-floor slab reached 241 mm, while the relative difference in vertical displacements was 0.0448, approximately nine times the adopted allowable value of 0.005. Refinement of the digital model based on engineering geodetic measurements made it possible to account for the actual deformed state of the structural elements, refine the results of the digital analysis, and improve the localization of critical areas. The obtained results confirm the effectiveness of incorporating engineering geodetic measurements into the development and updating of computational models of damaged buildings. The proposed approach can be used to improve the reliability of technical condition assessments of damaged buildings and to provide a more robust basis for engineering decisions regarding emergency stabilization, structural strengthening, and subsequent restoration.

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