Definition of Availability Index of Deformed Building Constructions Using the Finite – Element Analysis Package

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Abstract. The paper is devoted to the problem of definition of availability index of deforming building construction in atypical cases. The authors revealed a real applicability of the finite-elements analyses package, such as ANSYS, for engineering testing calculations of building constructions and determination of the sites of increased stresses. It was determined that stresses increased up to 7.75 times in the sites with mechanical defects (for steel crane girder); also, the authors revealed the convergence of the calculation results between the finite element method and a usual decision using the strength of materials (in the limits 2-14% for steel truss frame). The equivalent stresses don't exceed the maximum permissible tension for this type of steel. The building constructions have a limited availability index.

1. Introduction

The determination of the availability index of deformed building constructions is a primal problem of the technical condition inspection. Most cases are typical and described in the Russian normative documents: federal laws, federal rules [1] and recommendations for the estimation of the availability index of building construction based on the exterior signs [2,3].

Widespread defects are connected with the degradation of material properties and misuse. Mechanical collisions with the equipment occur in the industrial buildings. Buildings and constructions suffer loss and metal constructions get curvatures.

This problem can be solved using the finite element method and a specialized software.

The authors E. Markova, O. Chegya [4] analyzed the opportunity of using the ANSYS software to estimate the structural strength of buildings elements. Two methods applied for creating of a finite elements model: geometric modeling and generation of nodes and elements. Nekrasova N., Burkovsky V. and Flavianov V. analyzed the results of the base plates mathematical modeling on the elastic basis and instrumental data [5]. In his paper [6] Volynin A. made a comparison of the software “Obolochka” and ANSYS to research the strength of shells. The estimated manhours of calculation of two methods: manual and using ANSYS were defined in the article of Molchanov A. and Molchanova E. [7].

The authors Tarasenko A., Chepur P., Chirkov S., Tarasenko D. [8] considered the issue of modeling the designs of a vertical steel tank for the storage of commodity oil with a capacity of 20,000 m3.
The authors Shirko A., Kamluk A., Polevoda I., Zainudinova N. in the article [9] consider the environment of strength calculation of reinforced concrete plates in ANSYS. The behavior of the resulting models at the fire is investigated.

The pilot research of a crack in reinforced concrete as a structural member was made Yadrov V. [10].

An international team of Min Chan and D. Dmitrieva considered a problem of optimization of metal framework as nonlinear mathematical programming using ANSYS [11].

The paper of the authors Lihacheva S. and Kozhanov D. was devoted to the deformation of masonry due to the influence of dynamic loading [12].

The authors from Platov South-Russian State Polytechnic University (NPI) Busalo N.A, Alekseev S., Tsaritova N. [13] designed and calculated a modern node spatially rod of building construction using ANSYS.

The calculation optimization using ANSYS for the reduction of labor input and formalization was the task of the article [14] by Karpenko T., Ivanina N. and Golovchenko V.

The use of finite element models in ANSYS program is widespread in design of steel elements S. I. Yevtushenko, M. N. Shutova et al. calculated the axle beam [15].

Shutova M. and Skibin G. made an attempt to formalize the relation between the availability index of deformed building constructions and residual life of buildings [16].

The authors T. Abdo, R. Mabrouk investigated the beam work angle of rotation at the ultimate load for further understanding of the beam behavior under torsion [17].

In the paper [18] of J. T. Zhonk et al. T conveniently assess the performance of the disturbed region of concrete structures using different strut-and-tie models, an evaluation system is proposed. The numerical procedure of the evaluation system is developed based on the ANSYS parametric design language.

In the paper [19] from Vodiannikov M.A. et al. the results of the statistical analysis of corrosion processes and moisture saturation of glued laminated timber structures and their joints in corrosive environment are shown. The study of the relation between the effects of fatigue material data and residual life assessments under high cycle fatigue was made by Y. Gorash, T. Comlekei, D. MacKenzie [20].

2. Analysis of convergence of calculation results using two methods

The research is conducted for a truss frame of the industrial building which was damaged from mechanical influence. To evaluate the convergence of the calculation results between the finite element method and the usual decision using strength of materials, a finite element model of such truss frame of the industrial building was built. The model is a geometrically difficult rod system consisting of the steel angle section (Figure 1).

![Figure 1. A finite-element model of a truss frame with mechanical defects.](image)

The technical condition inspection determined the mechanical damage of truss frame elements (Figure 2a, b, c), these defects were simulated into the truss frame finite element model (Figure 3 a, b, c).
Figure 2. Defects from mechanical influence in the truss frame elements.

Figure 3. The fragments of the finite-element model of the truss frame with mechanical defects.

The settlement scheme of such truss frame includes sole weight, snow weight as a concentrated load. ANSYS calculation is shown in Figure 4.

Figure 4. Equivalent (von-Mises) stresses of truss frame with mechanical defects.

The calculations results are provided in the Table 1.

| Point | Stresses, MPa | Use factor |
|-------|--------------|------------|
|       | Maximum | Minimum | Maximum | Minimum |
| 1     | 29.85   | 6.16    | 0.16    | 0.02    |
| 2     | 205.26  | 60.9    | 0.92    | 0.28    |
| 3     | 102.4   | 18.8    | 0.46    | 0.09    |
| 4     | 27.2    | 7.10    | 0.14    | 0.06    |

The truss frame flat model was created and calculated using the StructureCad program (Figure 5a, b).

The truss frame calculation in SCad determines internal forces in the main elements of frame. In the points with the defects the authors defined the section geometrical characteristics (moment of inertia and section modulus) as well as the stresses in the defect elements.
3. Analysis of a stress raiser value in the parts with mechanical damage
For evaluating the stress raiser value in the parts with mechanical damage of a crane girder the authors created a finite element model of such crane girder before and after deformation. The crane girder is a pivotal support from a welded double tee. The settlement scheme of the crane girder includes a sole weight and two versions of load moving from the crane: load corresponds to the maximum moment (Figure 6a) and maximum share force (Figure 6b).

The technical condition inspection determined the mechanical damage (curvatures) of crane girder elements (Figure 7a, b). These defects were imitated in the crane girder finite element model (Figure 8a, b).
Figure 8. A finite-element model of the crane girder with mechanical defects.

ANSYS calculation is shown in Figure 9.

Figure 9. Equivalent (von-Mises) stresses of the crane girder with mechanical defects.

The calculation results are shown in the Table 2.

| Load | Stresses, MPa | Points |
|------|---------------|--------|
|      | Before deformation | 1     | 2     | 3     | 4     |
| Load 1 | 17.69          | 54.69  | 28.56  | 56.97  |
|      | After deformation | 97.72  | 95.8   | 85.75  | 112.69 |
|      | Exceeding      | 5.52   | 1.75   | 3.0    | 1.98   |
| Load 2 | 18.61          | 26.99  | 17.41  | 14.21  |
|      | After deformation | 47.88  | 75.18  | 28.21  | 41.31  |
|      | Exceeding      | 2.57   | 2.78   | 1.62   | 2.92   |

4. Conclusion
The convergence of the calculation results between the finite element method and usual decision using the strength of materials are from 2 to 14% for equivalent (von-Mises) stresses and 12% for a total deformation. This value of stresses corresponds to the limited availability index. ANSYS calculation provided an opportunity to find the sections with increased stresses (the value of stresses in the elements with defects exceed stresses of the not deformed constructions by 1.98…7.75 times).

This approach allows for the optimization of strengthening of the disabled elements of buildings construction.

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