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DEVELOPMENT OF AN AUTOMATED SYSTEM FOR ANALYZING THE STRESS-STRAIN STATE OF THE GRAIN STORAGE BUILDING, TAKING INTO ACCOUNT THE ADMISSIBILITY OF GRAIN BATCHES PLACEMENT

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Abstract. An automated system for determining the stress-strain state of a typical precast reinforced concrete silo body via finite element method, depending on the distribution of products in the structure, has been developed.
Keywords: automatic system, stress-strain state, grain storage building, finite element method.

Introduction and problem formulation.

Ukraine has a growing agricultural sector, particularly in grain production and handling [1], [2]. Grain storage facilities in Ukraine can be broadly categorized into ground warehouses, metal silos, and prefabricated concrete silo structures.

Sufficient attention has been given to the issues of operational reliability and current repairs of grain storage structures. For instance, the causes of damages and methods of restoration of such structures have been discussed by authors in [3]. Modern data collection methods enable the monitoring of structural conditions. For example, in [4], a list of possible sensor systems for tracking loads on buildings is provided.

Modern software tools are widely used for building analysis. In [5], analytical calculations of a concrete silo are compared with software calculations, concluding the equivalence of the obtained results. Additionally, the work in [6] presents an experimental dependence of pressure on enclosing structures as a function of the distance from the silo axis. However, according to existing standards [7], the grain pressure can be considered evenly distributed.

These structures, built in the 1970s and 1980s, have undergone significant physical wear and tear over time. Construction consists of individual compartments called silos, and while they were designed with a specific filling sequence in mind, that's not always followed in practice. However, ensuring safe and rational operation of these structures is crucial.

The research aimed to assess the impact of different filling sequences on the stress-strain state of these structures. An automated system was developed for this purpose, taking into account the operating conditions of the structure.

Automated system for analyzing stress-strain state (sss).

The automated system allows us to determine the numerical characteristics of the SSS as the loading of individual silos changes. By varying the order of grain loading, it is possible to identify a rational loading scheme for a specific amount of additional grain. The system is built using the .NET framework and C# programming language. The inputting the grain mass for each silo via user interface is pictured on Fig.1. The "Start Investigation" button initiates the SolidWorks software for analysis.

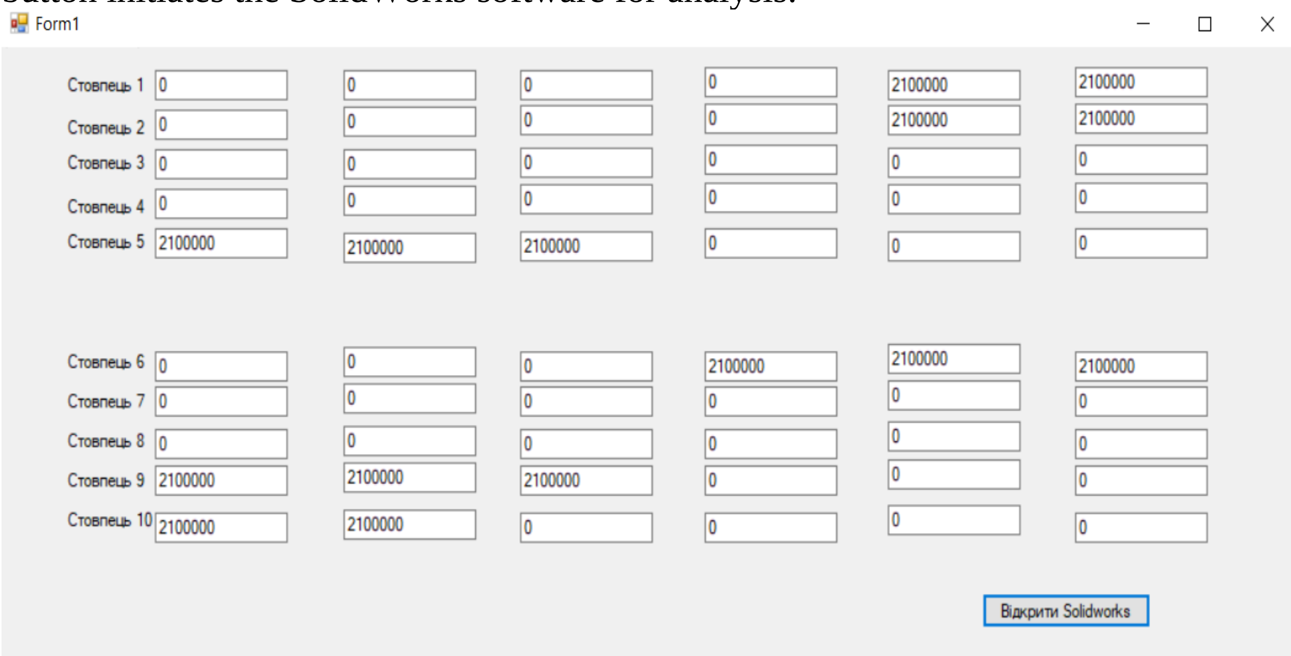

Fig. 1. Screenshot of Program Interface

Algorithm for determining SSS.

The logic and workflow sequence are visualized on Fig 2. An overview of the steps involved in the algorithm is:

- Start: Initialization and data entry.
- Launching SolidWorks: Triggered by clicking the "Start Investigation" button.
- Adding Initial Data: Importing information into the SolidWorks simulation study.
- Start Simulation: Run the simulation within SolidWorks.
- Output Data Obtaining: Gather the results of the analysis.
- End: Complete the process.

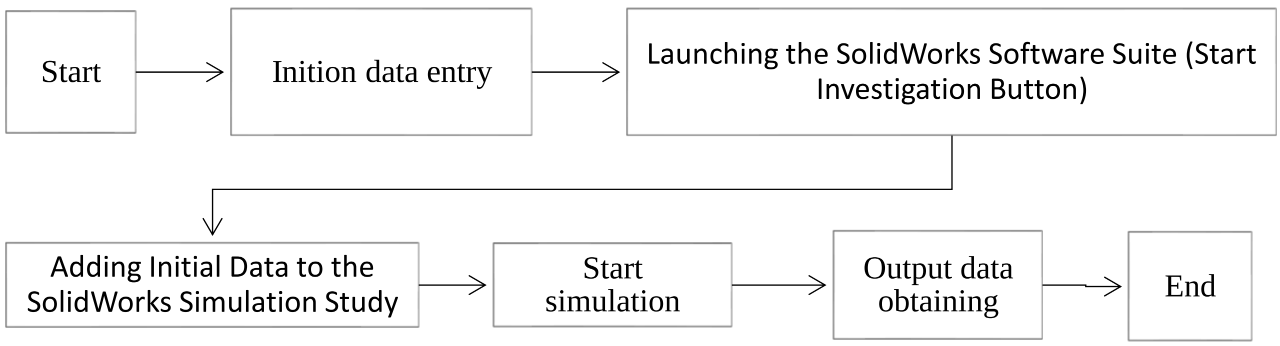

Fig. 2. Algorithm of the Automated System Operation

Silo structure modeling, assembling and analysis.

For the research, the precast reinforced concrete silo structure designed by the Central Research and Design Institute for Grain Processing Equipment in 1981 was used. Separate models of the column with capital, silo bottoms, and silo walls in CAD/CAE SOLIDWORKS based on the available project documentation was built. The complete silo structure is assembled from these individual elements (Fig. 3.)

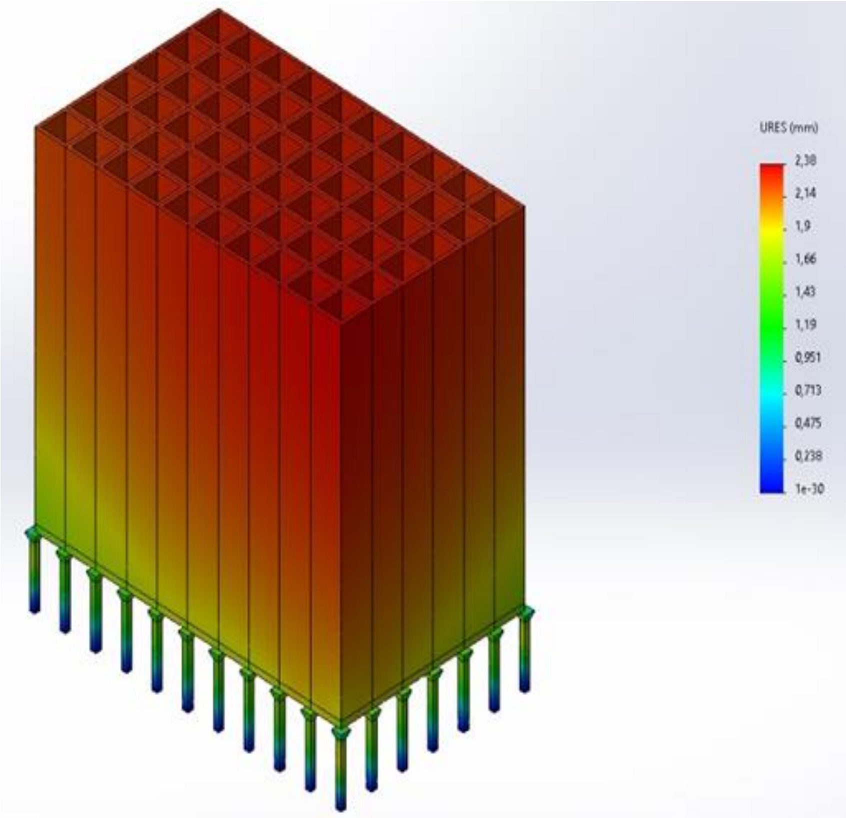

Fig. 3. Displacements in the properly loaded grain storage building

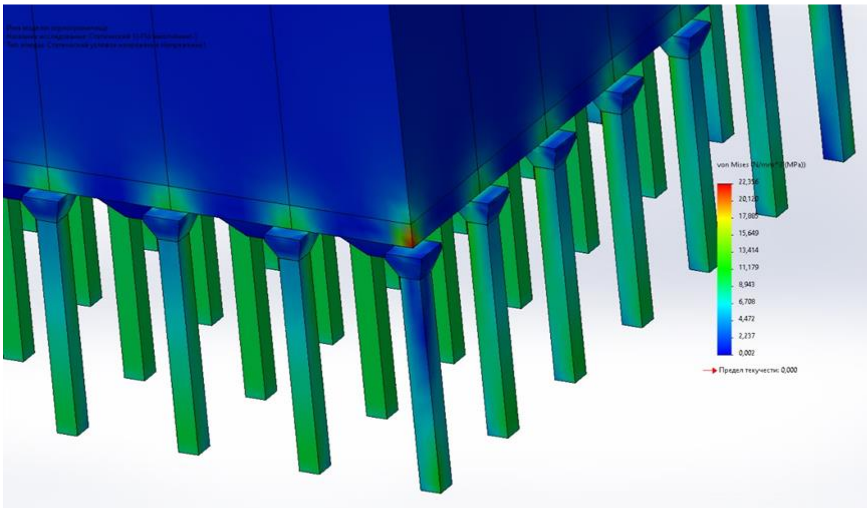

Fig. 4. Stresses in the grain storage building with proper grain placement

The loads on each element were considered of its self-weight and the full load of wheat grain in the silo (Fig. 4.).

To guarantee sufficient accuracy with efficient computation, the results of the Finite Element Method (FEM) with different mesh sizes were compared. Fig. 3. shows the relationship between accuracy and mesh size. A mesh element size of 40x2x2 sm is suitable for our calculationns.

Grain placement configurations.

Various configurations of grain placement in the silo structure, used for comparison, are shown in fig. 4..6. Red indicates filled silos, and light gray indicates empty silos. In this part of the study, it is necessary to take into account the existing restrictions related to the placement of grain lots, including:

- Various types of grain crops: they cannot be placed together.
- Features of the design of silos: some designs have openings that should ensure the redistribution of grain flow from one silo to another.
- Technological requirements related to future reception and shipping: they must be taken into account when choosing accommodation options.

During the analysis, these factors must be taken into account in order to obtain a reliable stress-strain state of the structure.

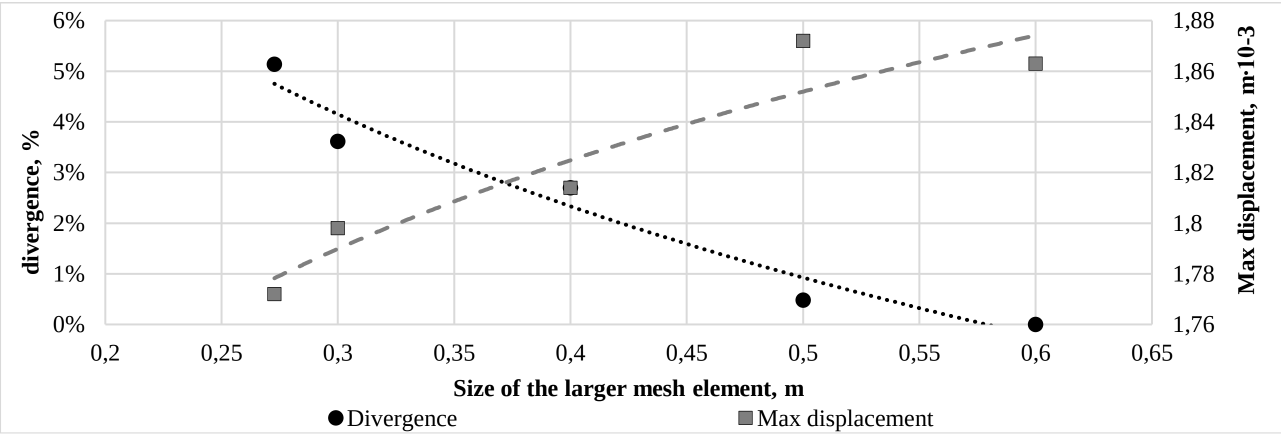

Fig. 4. Combined diagram assessing the convergence of FEM results (individual silo)

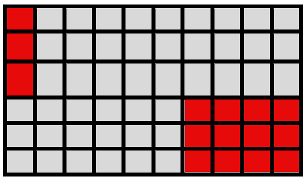

***Fig. 4.** Incorrect Configuration #1 of Grain Placement*

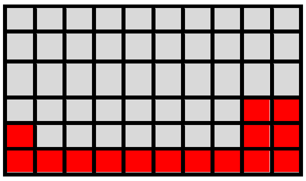

***Fig. 5.** Incorrect Configuration #2 of Grain Placement*

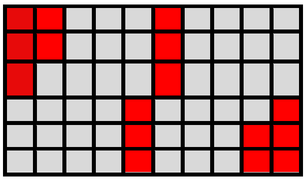

***Fig. 6.** Correct Configuration of Grain Placement*

Comparison of results. Fig.7 graphically presents comparisons of maximum stresses and displacements for different grain placement options. The data are normalized for clarity, with the SSS parameters of a fully loaded silo taken as 100%.

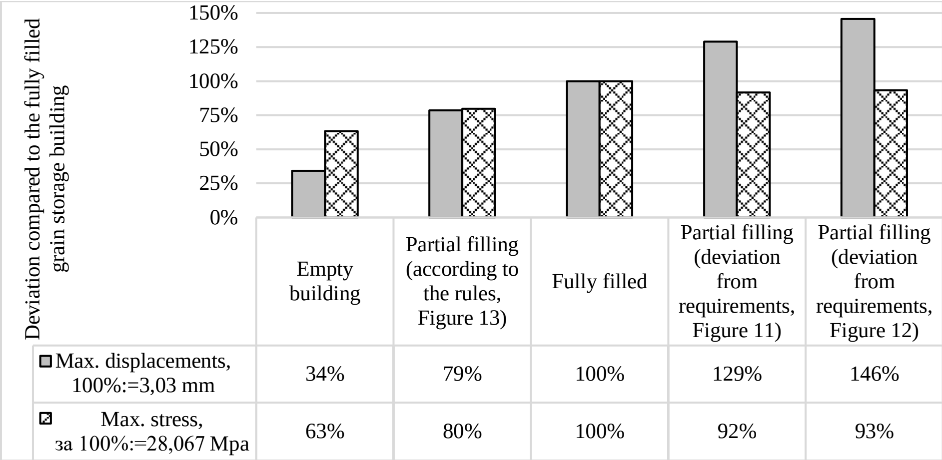

Fig. 5. Results under different loading schemes of the grain storage building

The analysis reveals a significant increase (45%) in displacements for a silo loaded with grain in violation of the recommended sequence, compared to a fully loaded one. However, the stresses obtained in this case do not exceed those in a fully loaded structure.

Conclusions. The automated system to determine the stress-strain state in a grain storage building under various silo loading schemes during operation was development. The research investigated the influence of different loading schemes on the state of the structure. It's evident that certain incorrect loading schemes, especially for small grain volumes, can lead to a 45% increase in displacements compared to a fully loaded structure. Such scenarios could potentially create critical situations related to the building inclination. The automated system lays the foundation for designing an artificial intelligence system of determining a rational sequence for loading and unloading the structures, paving the way for safer and more efficient operation of these vital agricultural infrastructure components.

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TECHNICAL AND OPERATIONAL CHARACTERISTICS OF A HIGH-SPEED SYNCHRONOUS GENERATORFOR AUTONOMOUS POWER SUPPLY SYSTEMS

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