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Innovative methodology for estimating the impact of assembly imperfections on the safety of internal panel elements in large-panel building structures

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Abstract

The paper presents an original proposal to assess the safety of internal panel elements in buildings implemented in the systemic structural systems of a large panel. The publication, based on the author's shell model of the large-panel building structure, presents an innovative method of assessing the impact of imperfection in internal panel elements on the safety of buildings erected on the basis of industrialized structural systems.

Keywords: reinforced concrete structures, large-panel buildings, prefabrication, FEM

1. Introduction

The issues related to buildings erected in industrialized structural systems, implemented under the banner of a large slab [1,2,3,4] at present arouse a number of interests as well as concerns [5,6,7,8]. The paper presents the author's method of describing the safety status of large-panel buildings – the Continuum States Method [9,10,11], consisting in the use of the mechanics of a continuous medium to describe the phenomena of the composite structure of the material, which is reinforced concrete. Due to the characteristics and complexity of industrialized construction, as well as the executive domain, during the implementation of large-panel construction, imperfections in the form of assembly imperfections (and not only) constituted the percentage of events that affect the secondary stress distribution in the building structure – deviating from the designed one.

Due to the nationwide overtone of the issue, it becomes necessary to propose a methodology for assessing the safety of residential buildings (and not only). In order to implement the plans, a building model of the Wk-70 system was built, based on the construction of the existing facility and full architectural and construction documentation. Using the implemantation contained in the solver of the Robot Analysis Structures computer software, a shell model of the large-panel building structure of the above-mentioned system was created. In order to interpret the results monitored during computer analysis in the aspect of the Continuum States Method, it was proposed to divide into zones: strain, redistribution, compensation and neutralization, secondary stresses resulting from imperfection. The comparative criterion remains the analysis of the results, in the aspect of standard standard stresses in the internal slab elements of large-panel buildings, in accordance with the SGN.

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2. Shell FEM model of large-panel building structure

View of the façade is shown in Fig. 1 a) and b). Shell model of the FEM of the isolated body of the building is shown in Fig. 2.

Fig. 1. Facades: a) southern, b) northern of a residential building constructed in the Wk-70 system

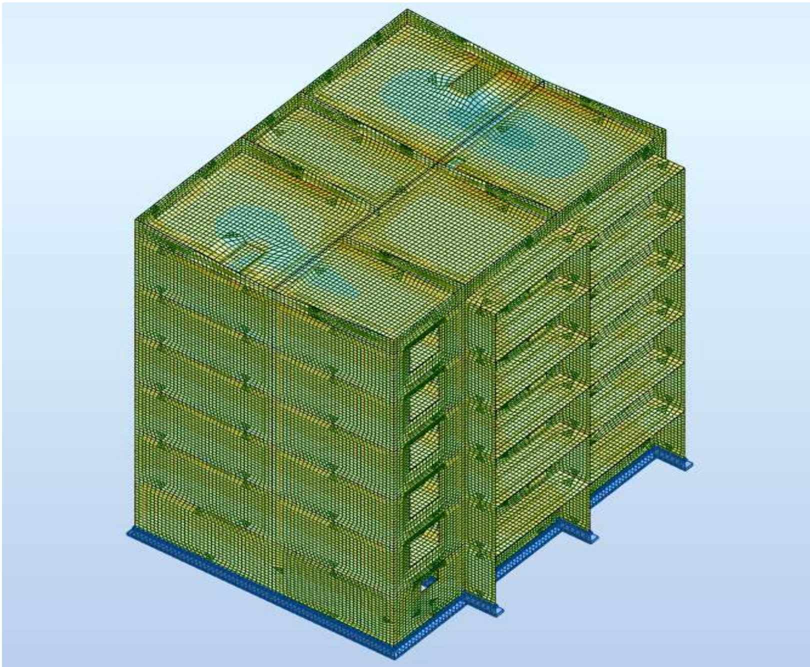

Fig. 2. 3D view of the FEM model of the construction of the separated block of the Wk - 70 building, meshing using Delaunay's composite method, mesh step a = 0.1 m

3. Continuum States Method

Limiting the effects of local destruction by shaping secondary load-bearing systems, which is presented in the description divided into zones of influence of imperfection (or interaction of imperfection), proposed by the author as the Continuum States Method, directly determines the safety of internal slab elements in the structures of large-panel buildings. The method of Continuum States has a very important aspect, namely it shows in a different light the traditional assessment of the safety of the entire structure, as the safety of the relatively weakest element (i.e. showing the lowest ratio of load capacity to the internal force acting).

... The current state of the structure does not yet allow for a wider use of the formation of secondary support systems as a hedge against ordinary loads acting on the structure, but the safety reserves inherent here (in relation to the SGN) are obvious ... writes Ś. P. Profesor Bohdan Lewicki, Warszawa 1979 [2].

A very important motif determining the safety of buildings made of large slabs is included in the computational model of the building structure, which was used in the work. The shell model of the building structure, using the Finite

Element Method algorithms, allowed to obtain realistic results, taking into account the spatial work of the entire building structure for the calculation combinations of the Ultimate Limit State.
When considering the rigid element as spatially cooperating, it was considered that this value is not critical (local exceeding of the SGN) and the reserves resulting from the spatial work of the structural system are able to ensure safety. Considering the structure of a large-panel building as a whole, consisting of rigid prefabricated slab elements, constituting a rigid-spatial system, it can be concluded that even locally / pointwise increased by significant values, normal stresses σx [MPa] are not, despite exceeding the SGN, those values of critical stresses that pose a threat to the global safety of the building structure. In the Continuum States Method, the following zones can be distinguished:

- Focus zone (alternative name), represents values that occur directly in the place of imperfection (e.g. scratches, gaps, hole - not planned in the original design, local material losses, lack of location in the axis of elements - assembly errors). The zone can be divided into edge bands (left and right edges of scratches), contact bands (the result of impact on adjacent prefabricated elements, when edge bands cannot be separated in the stress zone);
- redistribution zone – boundary zone, there is a secondary division of stresses (internal forces) in the band of its interactions, resulting from the impact of the resulting imperfection;
- **c**ompensation zone – border zone. It is a zone of strong stress reduction, in relation to the initial zones and partial stress compensation;
- neutralization zone – neutral zone, there is a complete neutralization of the structure to imperfect influences. The stresses equalize and take on values as for the non-invasive (neutral) state. This is the zone of total equalization of stresses (cross-sectional forces);
- Relaxation zone – self-relaxation zone, is created as a result of the impact of imperfection, which creates a secondary structural system. In the zone, there is a significant reduction in stress compared to the imperfect state. The phenomenon of relaxation is also observed in adjacent prefabricated elements;
- Transformation zone – transformation zone, there is a change of stress sign to contradictory to the original one. It is a very dangerous zone.

4. Analysis results – MES1 and MES2 – eccentric location of the prefabricated ground floor wall on a monolithic basement wall, eccentricity *e* = 80 mm

The most common case of eccentric location of walls is the zone at the level of the ceiling of the first above-ground floor – the ceiling above the basement. It is a zone sensitive to structural changes and at the same time to the technological approach of implementation. In many cases, the underground part of large-panel buildings was made as a monolithic structure and only on it were repeated storeys made of large-size prefabricated elements erected. At the border of these wall structures, errors appeared most often, following this path, this type of imperfection was modeled on the eccentricity e = 80 mm. Example MES1 (without imperfection) fig. 3, while MES2 (with imperfection) is illustrated in Fig. 4. The results are presented for horizontal contact edges, upper and lower prefabricated panels, for the strain, redistribution and compensation zones, Fig. 5÷10. The neutralization zone, for logical reasons, has been put in words.

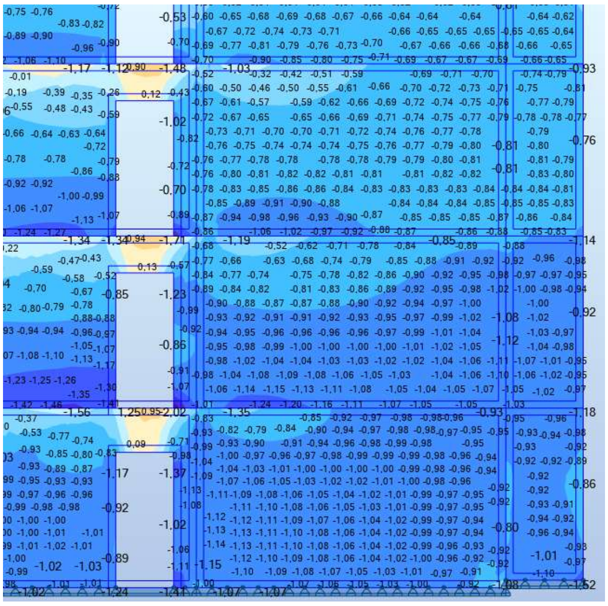

Fig. 3. A fragment of the comparative model FEM1 - analyzed large panel panel - ground floor wall

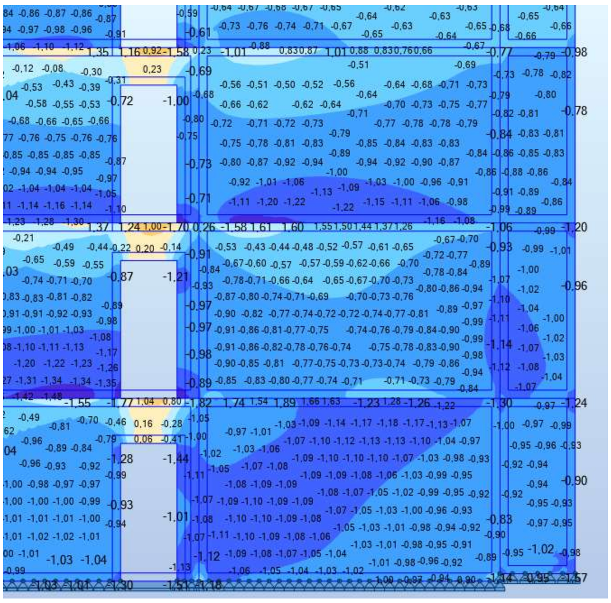

Fig. 4. A fragment of the FEM2 model - a prefabricated wall of the ground floor on a monolithic basement wall - mounting eccentricity e = 80 mm

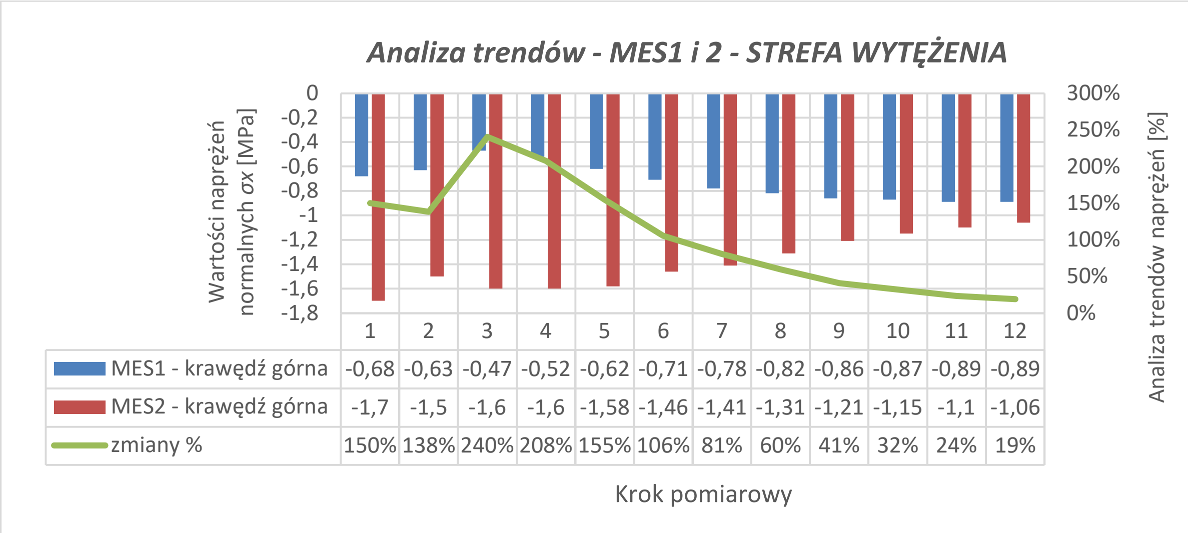

Fig. 5. Trend analysis for FEM1 and 2 models in the effort zone for the upper edge

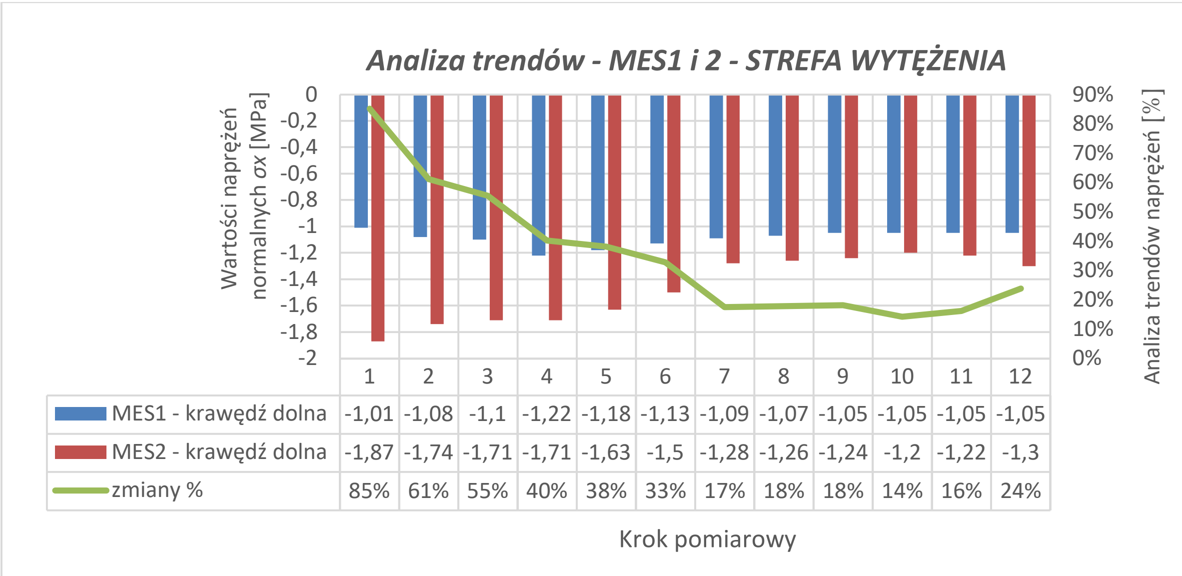

Fig. 6. Trend analysis for FEM1 and 2 models in the effort zone for the bottom edge

The greatest impact of assembly imperfection was monitored in point 3 for the upper contact, eccentrically built in the ground floor plate, the trend value was 240% - the measurement was recorded in the intensity zone (focus). In the redistribution (border) zone, the trend value decreased to 18%, the redistribution zone was located from *a distance of ir* = 0.3 m from the epicenter in the strenuous zone. At a distance *of ik* = 0,6 m, in the compensation zone (border) the percentage difference was already 0 %. At points where no 0 % value is recorded in the compensation zone, this value is achieved in the neutralization (neutralization) zone at a distance *of in* = 0,9 m.

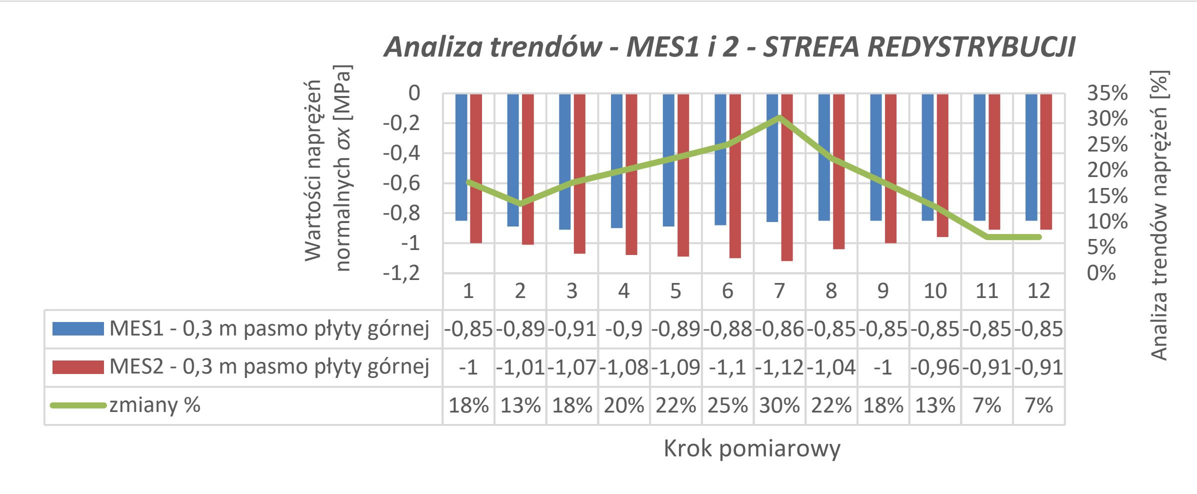

Fig. 7. Trend analysis for FEM1 and 2 models in the redistribution zone for the top band

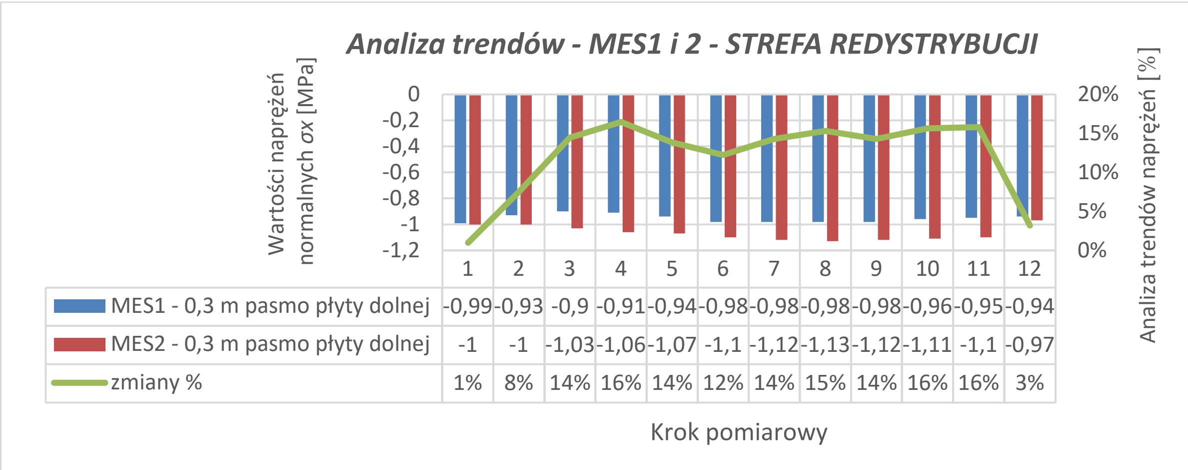

Fig. 8. Trend analysis for MES1 and 2 models in the redistribution zone for the bottom band

On the basis of the developed Continuum States Method for the purpose of computer diagnostics of the safety of internal panel elements in buildings implemented with the help of industrialized system systems, it can be concluded that the global state of building security is not determined by the local exceeding of the Ultimate Limit State (SGN). With the help of the theory of continuous medium mechanics and the application of the FEM shell model of the building structure, a method of safety monitoring was created in the context of the impact of imperfection on the structure of reinforced concrete composite in terms of large-panel structural systems.

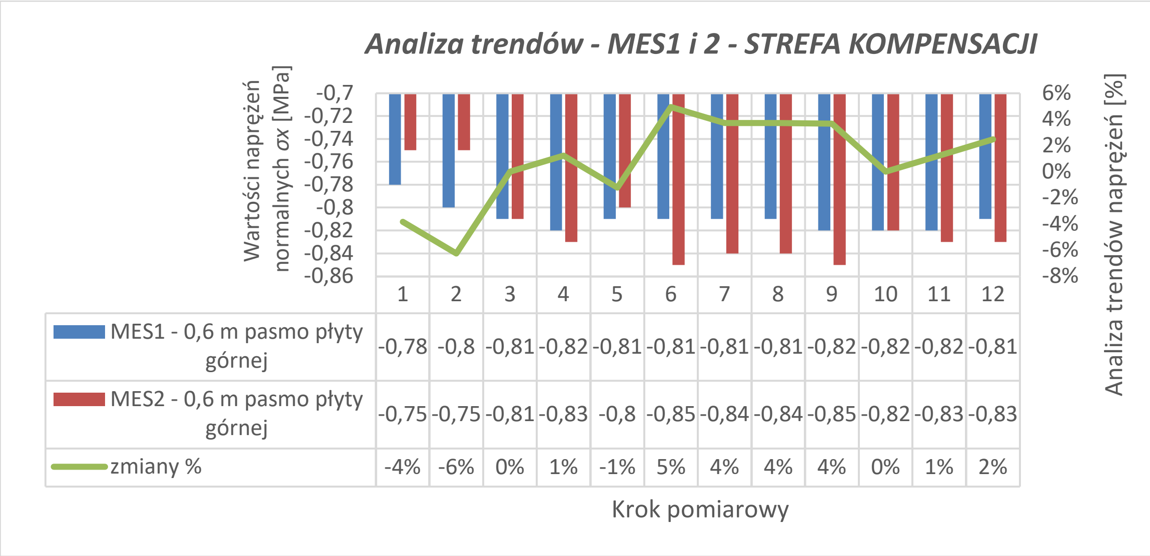

Fig. 9. Trend analysis for FEM1 and 2 models in the compensation zone for the upper band

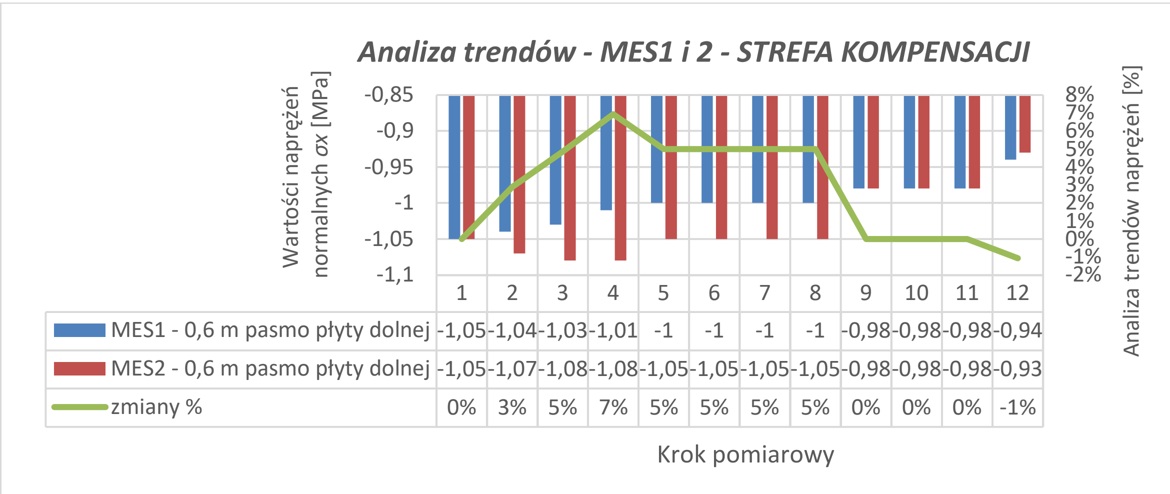

Fig. 10. Trend analysis for MES1 and 2 models in the compensation zone for the bottom band

The next step is to unambiguously confirm the crossing of the SNP using standard formulas for concrete sections (in this case all above-ground storeys) and reinforced concrete (in the underground part of the building) [17].

5. Conclusions

In the era of uncertainty regarding the fate of residential buildings (and not only) implemented in industrialized systems of large-panel systems, the methodology of assessing the safety of the structure becomes indispensable. The method allows to clearly and logically present the impact of various imperfections on the safety of prefabricated buildings. The author proposed the Continuum States Method, which is based on the FEM shell model of the building structure, zonal description of the effects of stress distribution and, in the last step, comparison of results with permissible stresses, in this case standard SGN. The material can be useful for experts, constructors [13,14,15,16] and all enthusiasts of building structures.

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