SAFETY ENGINEERING OF ANTHROPOGENIC OBJECTS

AUTHOR'S METHOD OF CONTINUUM STATES ON THE EXAMPLE OF IMPERFECTION IN THE CONSTRUCTION OF A LARGE-PANEL BUILDING

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Abstract

The paper presents the results of FEM computer analysis regarding cracking of the wall prefabricated element. The proprietary coating model of the Wk-70 System large-panel building construction was used. For analysis, a construction diaphragm has been separated that is integrally connected to the vertical communication structure. Modeled through the scratch in the attic wall and compared with the wall model without damage. By building the shell model, a real and transparent picture of the static work of the structure was obtained, distinguishing zones: focus, redistribution, compensation and neutralization of stresses, whose genesis results from imperfection - scratches in a reinforced concrete composite. For the first time, the author introduces his own method of assessing the safety status of large-panel buildings - by the States Continuum Method.

Key words: large-panel building, FEM computer modeling, prefabricated reinforced concrete structures, imperfections

INTRODUCTION

EXPERIM The assessment of the technical condition of the building is to determine the building's safety [1,3,4,5,6,7]. Crack is a very important signal about the condition and operation of the structure, as well as the possibility of creating a scheme of secondary system. According to the data contained in the instructions of the Building Research Institute [2], cracks in large-panel buildings can be divided into:

1. • surface scratches that appear in joints between wall panels and also between floor panels,
   • local scratches in the joints of wall panels, as well as in the panels themselves, reaching the entire width of the connector or the thickness of the panel, but limited in scope to only one floor,
   • structural cracks in joints or wall panels, reaching not only the entire thickness of the wall, but passing from one storey to the other and usually connecting with horizontal scratches in the wall under the ceiling.

A COATING MODEL FOR THE CONSTRUCTION OF LARGE-PANEL BUILDING

1. In order to present the secondary distribution of normal stress σ_x [MPa] caused by cracking the reinforced concrete composite, an original FEM coating model of the Wk-70 System multi-panel building structure was built. The theoretical shell model, Fig. 1, not only takes

into account the rigid-spatial global operation of the structure, but also represents cooperation with the elastic half-space of the soil medium [8,9,10,11,12,13]. The last one allows to monitor displacements and, as a result, to determine the place of possible scratch formation - in the zone (s) of the most interactively accumulated displacements caused by subsidence. The housing estate on which the building is erected is illustrated in fig. 2.
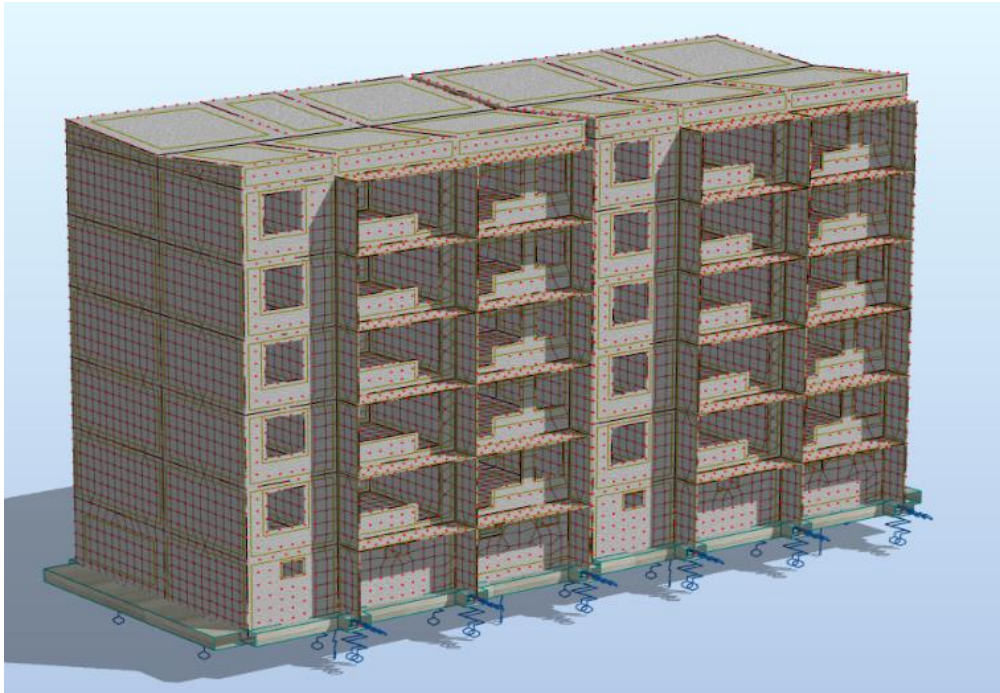
2.

Fig. 1. Residential building of the Wk-70 large-panel system (F.D. Iława) - 5-storey, southern facade - FEM 3D model of the building structure on an elastic foundation (Bieranowski P. 2019)

In the issue of FEM computer modeling, discretization plays a very important role, which has a direct impact on the results obtained. In the described model, triple meshing using the Delaunay composite method, with the mesh side dimension $a = 0.1$ m [10,11,12,13].

3.   **Fig. 2.** Residential building of the Wk-70 large-panel system - V floor, elevation view: a) north, b) south on the left (Bieranowski P. 2018)
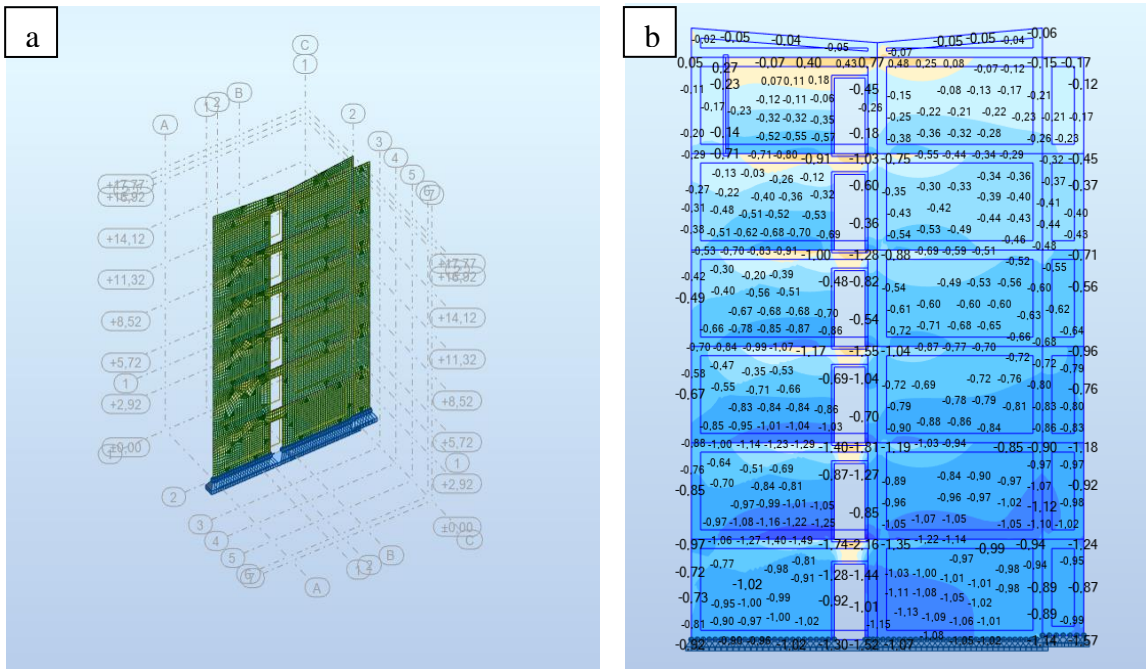
4.

Fig. 3. 3D view of the FEM model of the structure of a separate diaphragm, integrally connected to the vertical communication structure a) triple meshing using Delaunay's complex method, b) FEM map of normal stress
(Bieranowski P. 2019)

RESULTS OF COMPUTER ANALYSIS AND AUTHOR'S PROPOSAL OF DESCRIPTION OF RESULTS - CONTINUUM STATE METHOD

The issue of safety of large-panel buildings concerns significant residential resources of our country. The author proposes and introduces to the assessment of the safety of large-panel buildings the States Continuum Method - a banded method in which the zones can be distinguished: focus, redistribution, compensation and ultimately the neutralization of stress in the global structure of the structure, caused by local construction imperfections.

A very common imperfection, which raises considerable anxiety among hybrids, is scratching, which can be manifested in various forms: surface, local, or structural. The building works during the entire phase of its structural usefulness. Settlement, i.e. the cooperation of the structural structure of the building with the elastic half-space of the soil center, has been located in the place of the largest displacements, less climate changes, which are accompanied by the temperature load of the building body. The reinforced concrete composite structure is very sensitive, but scratches are not always dangerous for the structure, e.g. surface scratches (this could be compared to the perfect structure of human skin, on which you can also see so-called stretch marks, which are not dangerous to us). The problem is through, local scratches - running through the height of one storey and structural (structural) passing through two or more storeys. In the MES8 model, Fig. 5, a local, through-cut pattern with an opening width of = 3 mm was modeled, Fig. 4 shows a comparative fragment of the MES1 model. The scratch was located 1 m from the outer edge on the left side of the construction diaphragm, at the height of the last floor of the building structure. Seven data collection points were located at storey.

Fig. 6 compares the results of normal stresses, which were recorded on the left and right edges of the scratch, in relation to the comparative model MES1, while Fig. 7 shows the percentage comparison of the collected data on the left edge, and so, the largest changes were recorded in point 1, -400%, while min. in point 3, 14%. On the right side, the trend analysis was as follows - Fig. 8, the maximum result was monitored in item 1, i.e. 300 and min. in point 7, 2%. In the redistribution zone - Fig. 9, i.e. 0.3 m from the effort zone (on the left), stress values σx, have already reached much lower values, and so: max percentage change was noted in point 1, 100% and min. in item 3, 7% - fig. 10. On the right side, the following data was obtained - figure 11 - max 267% in item 1 and min. in point 5, - 3%. The summary for the compensation zone (borderline) is depicted in the graph presented in Fig. 12. Fig. 13 compares the results for the left side of the imperfections. On this side the biggest changes - point 5, - 15%, and min. 0% in points 1.2 and 3. On the right, Fig. 14, it is noted: max in point 3 with a value of 38% and zero in point 2. Behind these bands, redistribution, compensation takes place in the neutralization zone - further 0.3 m from the last computationally considered band - complete neutralization of imperfection influences in the rigid-spatial arrangement of the structure of a large-panel building.

In conclusion, it should be noted that already at a distance of 0.6 m from the epicenter of the focal point of effort, for several cases the stress equalized in the comparative aspect of both models, moreover, in the band placed at a distance of 0.9 m, the phenomenon of full neutralization with influence is monitored imperfection – the zone of neutralization.
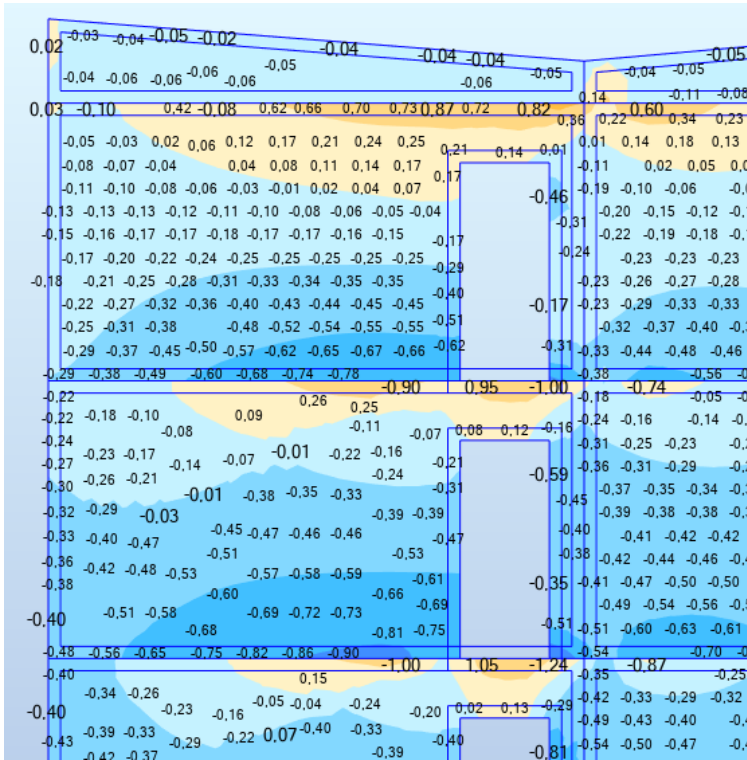
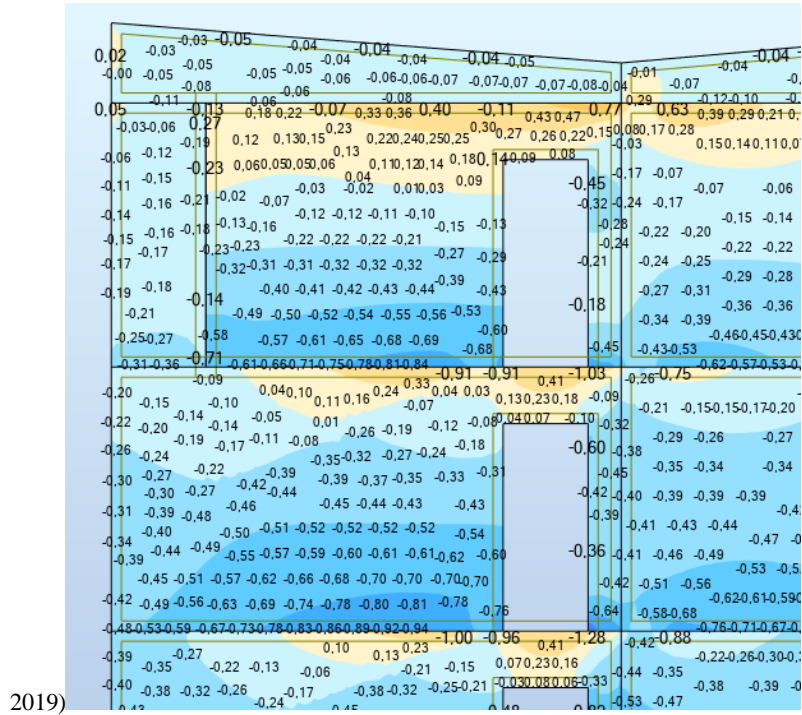**Fig. 4.** A fragment of the MES1 comparative model - analyzed large panel panel - attic wall - (Bieranowski P.

2019)

Fig. 5. A fragment of the MES2 model - a through crack with an opening of $w_k = 3$ mm - through the entire height of the attic wall - (Bieranowski P. 2019)

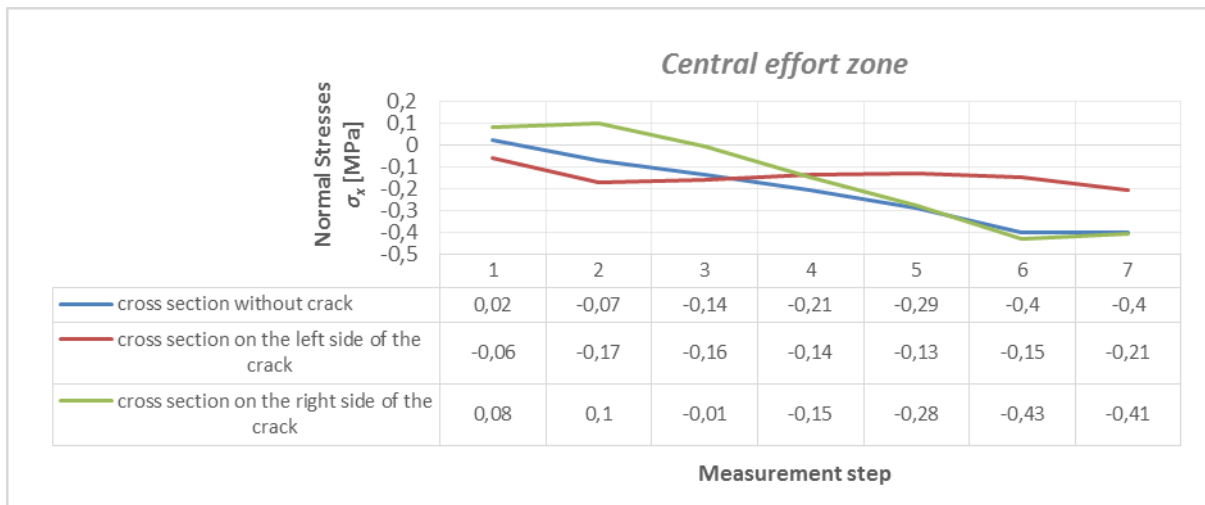|	1	2	3	4	5	6	7
cross section without crack	0,02	-0,07	-0,14	-0,21	-0,29	-0,4	-0,4
cross section on the left side of the crack	-0,06	-0,17	-0,16	-0,14	-0,13	-0,15	-0,21
cross section on the right side of the crack	0,08	0,1	-0,01	-0,15	-0,28	-0,43	-0,41

Fig. 6. Imperfection focus - effort zone. Diagram of normal stresses in the direction of the local x axis for the cross section of a reinforced concrete panel wall, for models MES1 and 2 (Bieranowski P. 2019)

Fig. 7. Trend analysis for MES1 and 2 models - consider combining with **Fig. 6** (Bieranowski P. 2019)

Fig. 8. Trend analysis for MES1 and 2 models - consider joining with **Fig. 6** (Bieranowski P. 2019)

Fig. 9. Border zone - redistribution zone (30 cm from central effort zone). Diagram of normal stresses in the direction of the local *x* axis for the cross section of a reinforced concrete panel wall, for models MES1 and 2 (Bieranowski P. 2019)
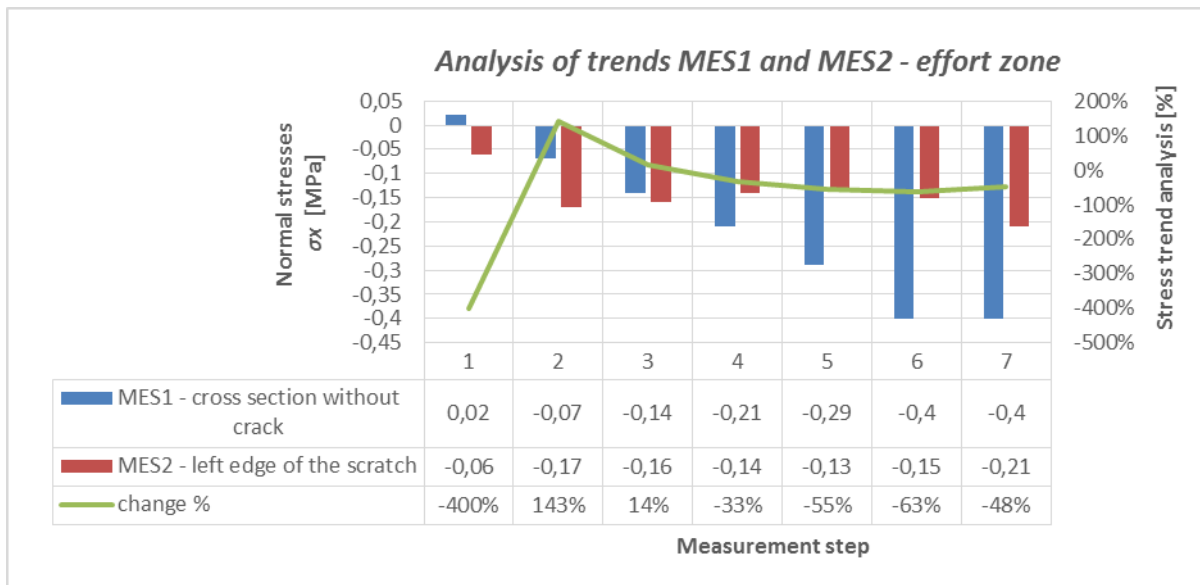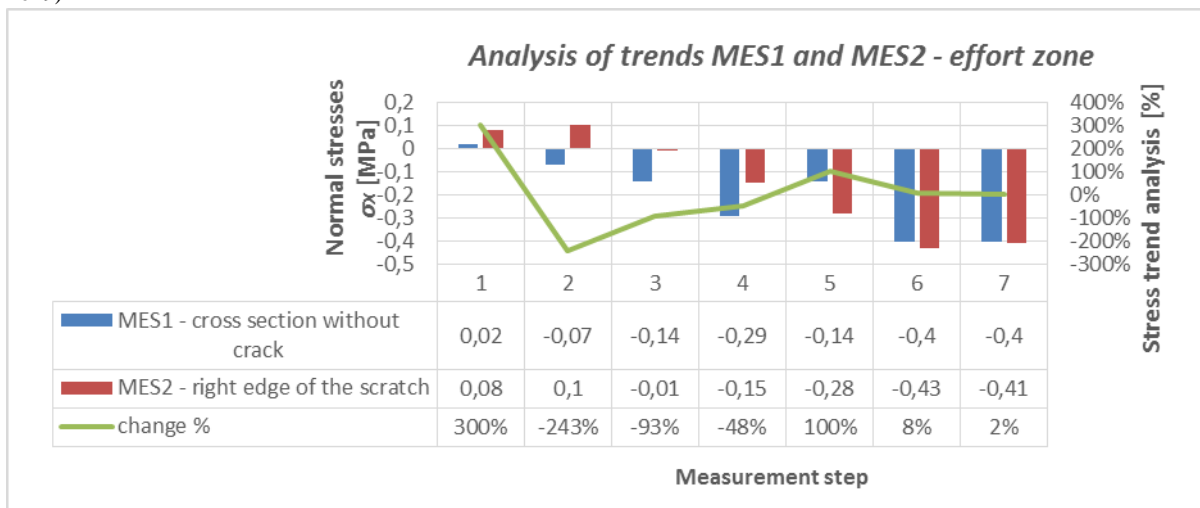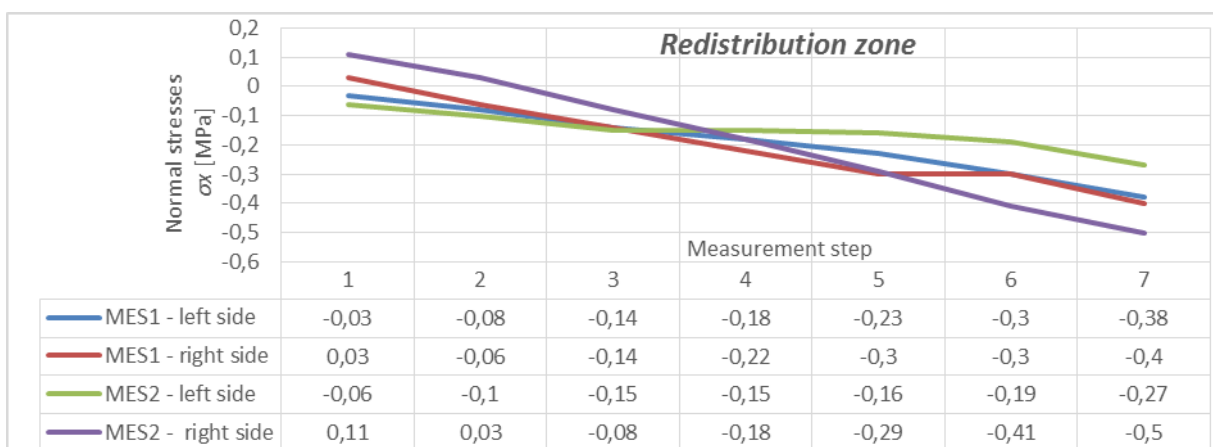
Trend analysis MES1 and 2 - redistribution zone

Measurement step	1	2	3	4	5	6	7
MES1 - 0.3 m band on the right	-0,03	-0,08	-0,14	-0,18	-0,23	-0,3	-0,38
MES2 - 0.3 m band on the right	-0,06	-0,1	-0,15	-0,15	-0,16	-0,19	-0,27
change %	100%	25%	7%	-17%	-30%	-37%	-29%

Fig. 10. Trend analysis for MES1 and 2 models - consider combining with **Fig. 9** (Bieranowski P. 2019)

Trend analysis MES1 and 2 - redistribution zone

	1	2	3	4	5	6	7
MES1 - 0.3 m band on the left	0,03	-0,06	-0,14	-0,22	-0,3	-0,3	-0,4
MES2 - 0.3 m band on the left	0,11	0,03	-0,08	-0,18	-0,29	-0,41	-0,5
change %	267%	-150%	-43%	-18%	-3%	37%	25%

Rys. 11. Trend analysis for MES1 and 2 models - consider combining with **Fig. 9** (Bieranowski P. 2019)

Compensation zone

Mesurement step	1	2	3	4	5	6	7
MES 1 - without imperfection - left side	-0,04	-0,09	-0,13	-0,17	-0,2	-0,26	-0,29
MES 1 - without imperfection - right side	0,09	-0,01	-0,13	-0,16	-0,39	-0,45	-0,49
MES 2 - with imperfection - left side	-0,04	-0,09	-0,13	-0,15	-0,17	-0,2	-0,3
MES 2 - with imperfection - right side	0,12	-0,01	-0,18	-0,2	-0,31	-0,41	-0,5

Fig. 12. Border area - compensation zone (60 cm from central effort zone). Diagram of normal stresses in the direction of the local *x* axis for the cross section of a reinforced concrete panel wall, for models MES1 and 2 (Bieranowski P. 2019)
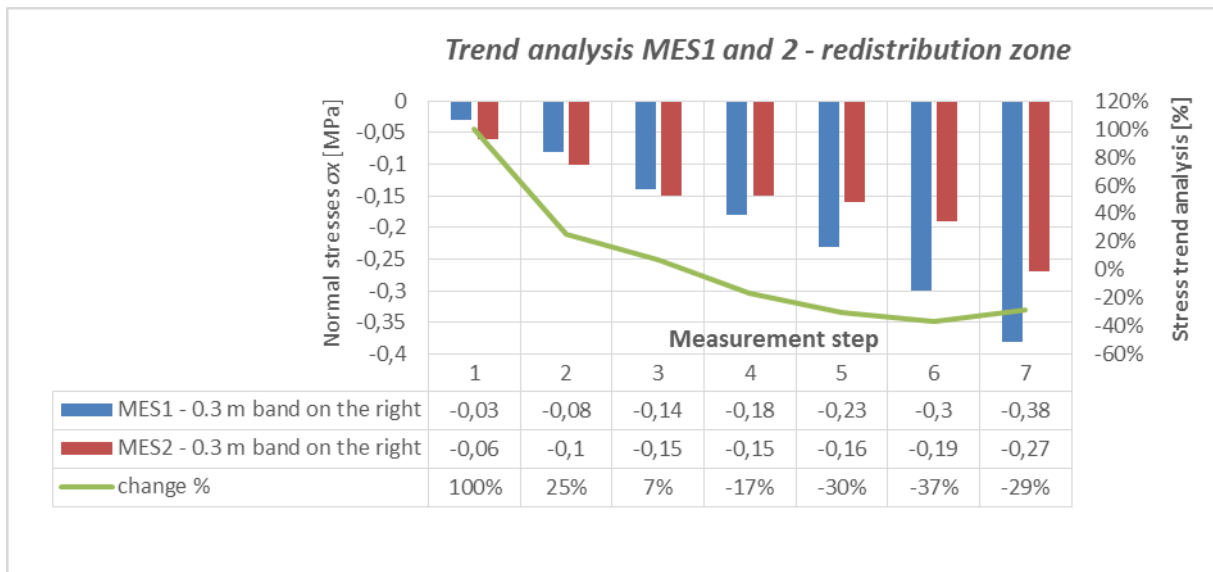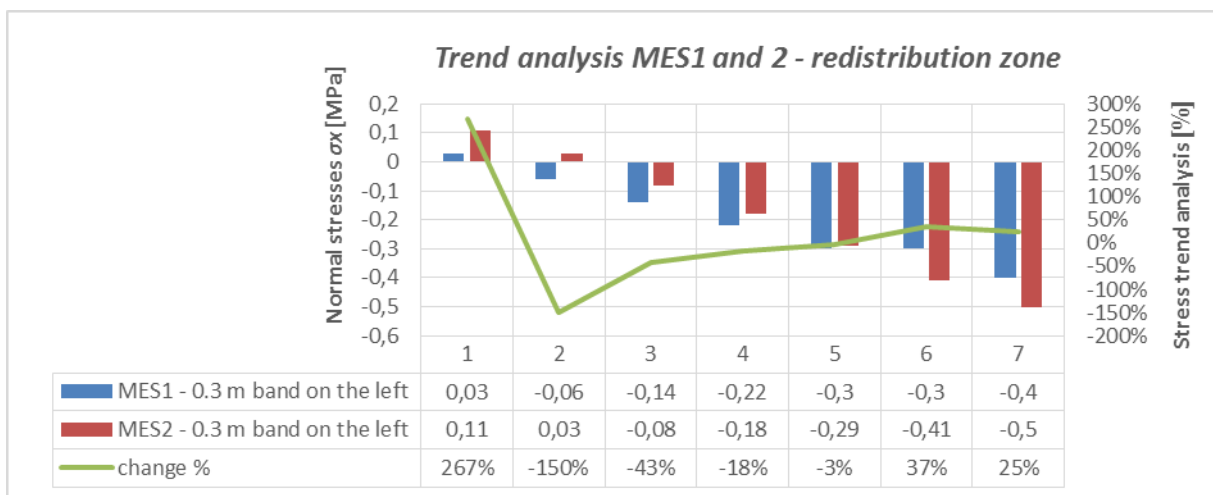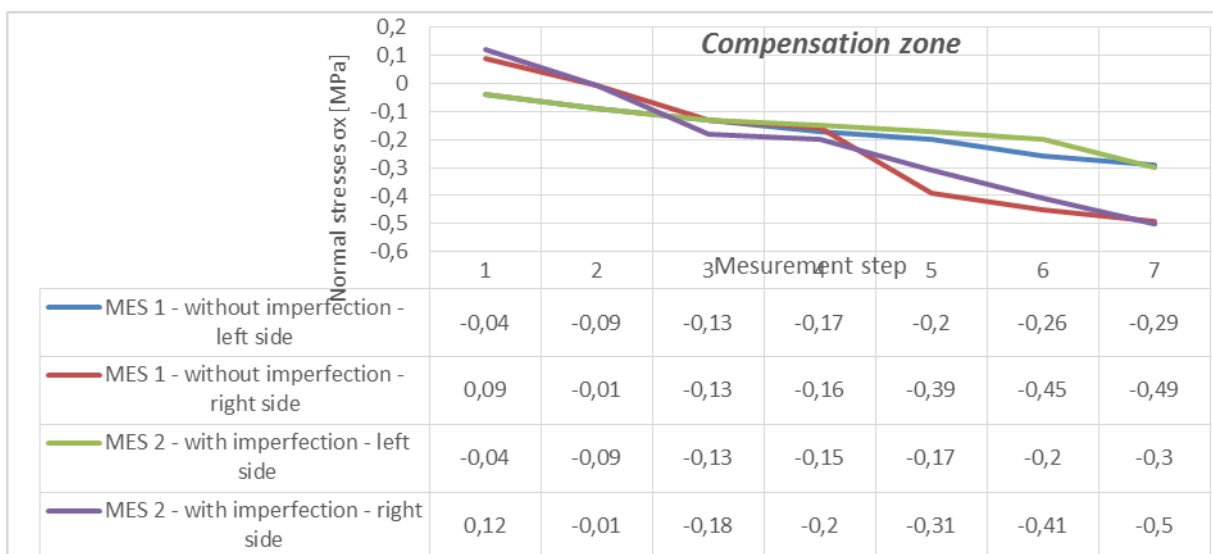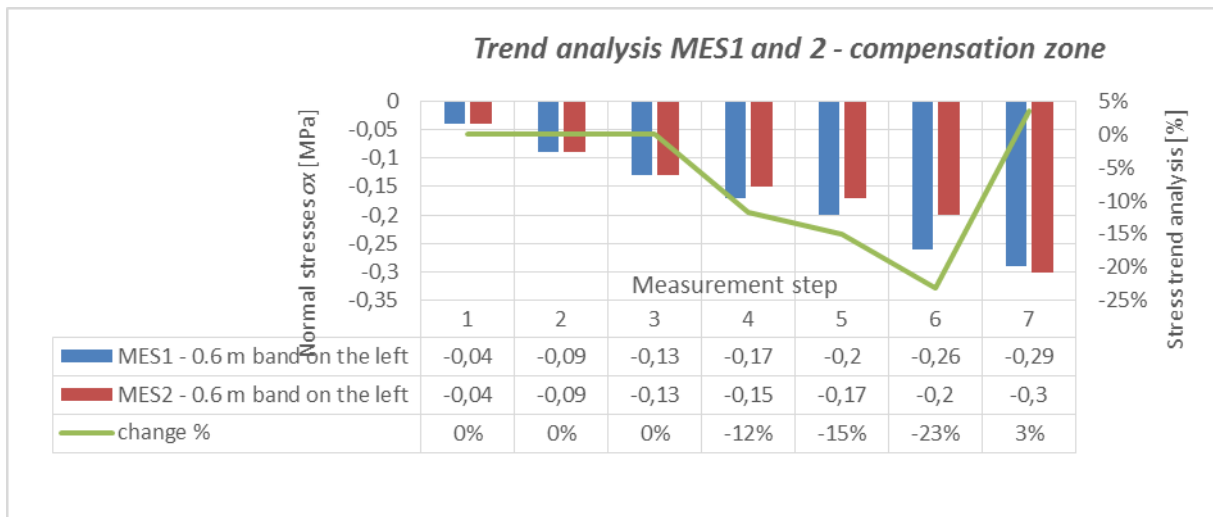
Trend analysis MES1 and 2 - compensation zone

Normal stresses σx [MPa] / Measurement step / Stress trend analysis [%]

	1	2	3	4	5	6	7
MES1 - 0.6 m band on the left	-0,04	-0,09	-0,13	-0,17	-0,2	-0,26	-0,29
MES2 - 0.6 m band on the left	-0,04	-0,09	-0,13	-0,15	-0,17	-0,2	-0,3
change %	0%	0%	0%	-12%	-15%	-23%	3%

Fig. 13. Trend analysis for MES1 and 2 models - consider combining with **Fig. 12** (Bieranowski P. 2019)

Trend analysis MES1 and 2 - compensation zone

Normal stresses σx [MPa] / Measurement step / Stress trend analysis [%]

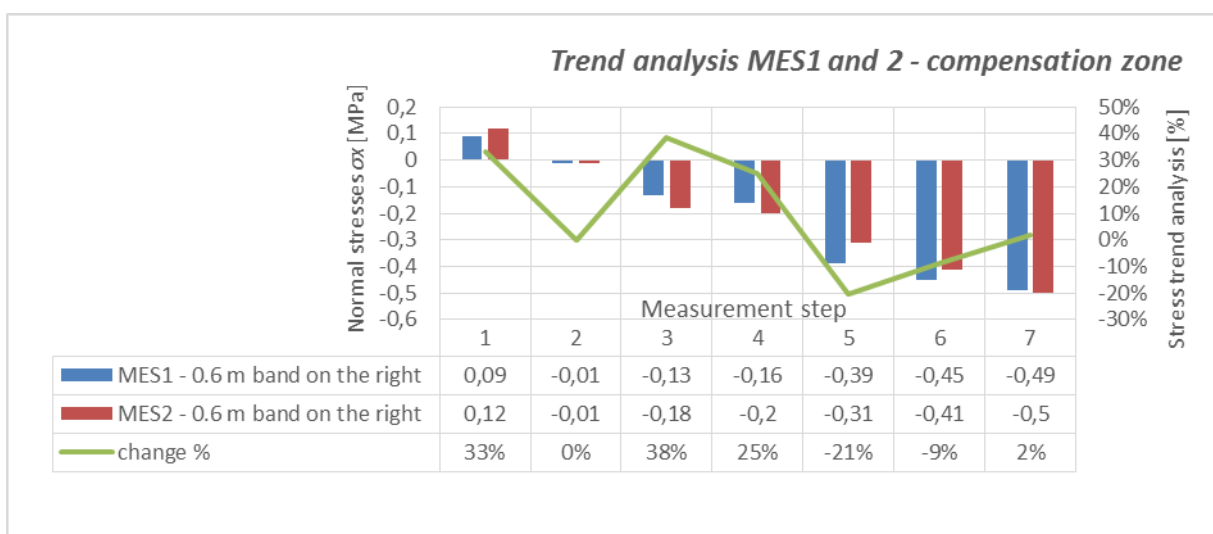|	1	2	3	4	5	6	7
MES1 - 0.6 m band on the right	0,09	-0,01	-0,13	-0,16	-0,39	-0,45	-0,49
MES2 - 0.6 m band on the right	0,12	-0,01	-0,18	-0,2	-0,31	-0,41	-0,5
change %	33%	0%	38%	25%	-21%	-9%	2%

2.   **Fig. 14.** Trend analysis for MES1 and 2 models - consider combining with **Fig. 12** (Bieranowski P. 2019)

CONLUSION

The use of the FEM shell model for a rigid-spatial structure of a large-panel building allows for obtaining real working conditions, which allows to monitor the results necessary to determine the condition and level of security of the building structure. From the point of view of using the structure, scratching will always be a malfunction. The author's method of assessing the safety of building structures in terms of scratching can be helpful in the work of a building expert [14,15,16,17], whose intervention becomes necessary in this type of frequent and problematic phenomena of breaking the reinforced concrete composite structure. Works on the development of the author's method of assessing the state of security - Continuum States methods are ongoing. The actual picture of the state of stress in the structure of a large-panel building becomes more accurate using the FEM shell model. It should be emphasized that the developed results were reflected for the stiffening diaphragm, which together with the vertical communication structure [8,9], constitutes the stiffening core

of the building structure. According to the works [3,4], in the structural system of such a wall, flexible joints are not used, which often occur in prefabricated buildings, and then their elastic nature is a non-linear graph M - φ (bending moment - angle of rotation of the deformed axis of the ceiling disk, resulting from the differential equation of the ceiling deflection line). The rigidity of vertical joints is constituted by the structural system constituting their solution, systems without dowel joints and not containing reinforcement inserts are the most susceptible [3,4]. To sum up, large-panel building structures should be considered holistically - building FEM shell models, remembering where the joint can be identified as elastic or continuous.

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