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SAFETY ENGINEERING OF ANTHROPOGENIC OBJECTS

COMPUTER SECURITY ANALYSIS OF LARGE-PANEL BUILDINGS RESULTING FROM THE COOPERATION OF THE BUILDING WITH THE ELASTIC HALF-SPACE OF THE SOIL CENTER WITH THE POSSIBLE SCRATCHING OF THE REINFORCED CONCRETE COMPOSITE

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Streszczenie

W pracy poruszono ogólnokrajową problematykę bezpieczeństwa budynków wielkopłytowych z punktu widzenia osiadania budynku na podłożu gruntowym. Przemieszczenia w poziomie posadowienia konstrukcji budynku powodują wtórną dystrybucję naprężeń, co za tym idzie możliwość powstania zarysowania strukturalnego wewnętrznych prefabrykowanych elementów płytowych. Autorski model MES konstrukcji budynku wielkopłytowego systemu Wk-70, który został zbudowany do celów badawczych pozwolił na przybliżenie zjawisk zawartych w tytule niniejszej pracy. Świadomość bezpieczeństwa konstrukcji budynków zrealizowanych w technologii wielkopłytowej jest bardzo ważna i stanowi istotny wydźwięk, nie tylko konstrukcyjny, ale również ogólnospołeczny.
Słowa kluczowe: bezpieczeństwo konstrukcji, budownictwo wielkopłytowe, modelowanie konstrukcji, podłoże sprężyste, zarysowanie

Abstract

The work touches on the national security issues of large-panel buildings from the point of view of settlement of the building on the ground. Displacements of the structure in the level of foundation of the building structure cause the secondary distribution of stresses, thus the possibility of structural scratches of internal prefabricated plate elements. The original model FEM of the construction of the large-panel building system Wk-70, which was built for research purposes, allowed the approximation of the phenomenon contained in the title of this work. Awareness of the safety of the construction of buildings implemented in large-panel technology is very important and constitutes a significant overtone, not only structural, but also general social.
Key words: key words

INTRODUCTION

Currently, housing resources in Poland account for approximately 12 million apartments, of which approximately 2.5 million were implemented in large-panel technology. The share of large-panel construction in Poland is about 20% of the total domestic housing construction [1,2]. The work uses the author's model of the Wk-70 large-panel building developed according to the regional solution by F.D. Iława - for the area of the Warmian-Masurian Voivodeship - Figures 1 a, b and 2 [3,4,5].

The publication provides values of displacements in the x, y, z direction of the building structure, determined for the model taking into account the interaction between the building and the elastic half-space of the soil center. For the layout of two buildings (adjacent solids founded on a common footing - according to the existing architectural and construction design) considered as built on a rigid foundation, the displacement values were zero for all possible types and directions. Displacement analysis results are presented for a foundation model with characteristics corresponding to the work of a structure placed on an elastic Winkler substrate (Fig. 1b). The results of standard stress for a large-panel wall, which is part of a stiffening diaphragm integrally connected to the vertical communication structure, are also presented (Fig. 2). The wall section (Fig. 7) was subjected to stress analysis for the model without a crack (Fig. 7a) as well as a cracked model (Fig. 7b).

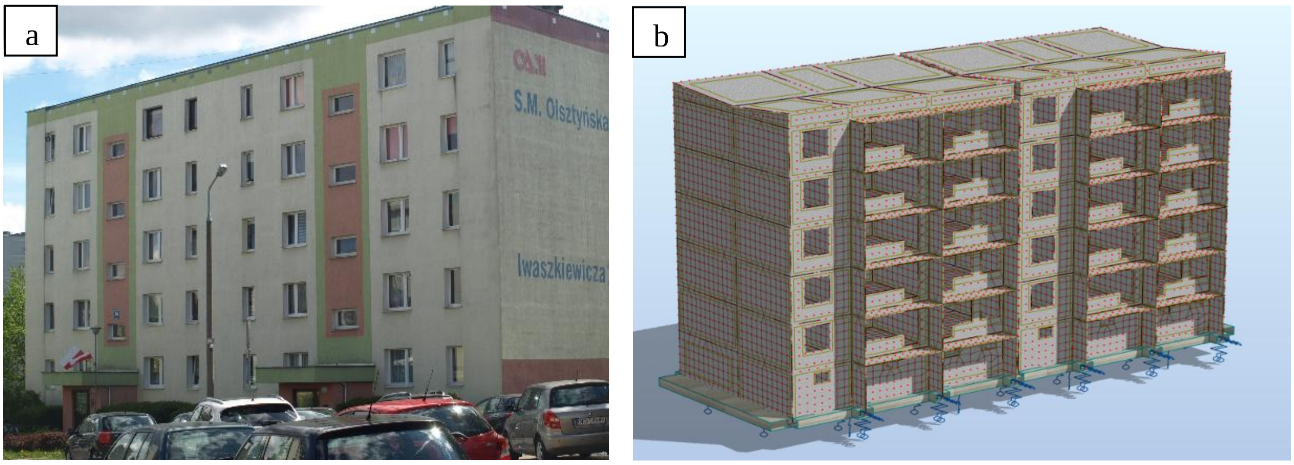


Fig. 1. Residential building of the Wk-70 large-panel system (F.D. Iława) - 5th floor: a) northern facade - photograph; b) southern facade - FEM 3D model of the building structure based on Winkler (Bieranowski P. 2018/19)

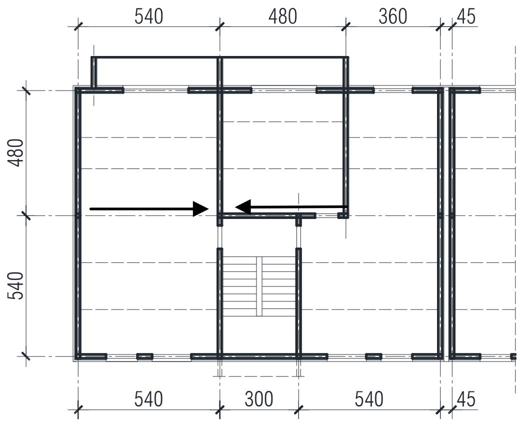


Fig. 2. Floor plan of the repetitive structure of the Wk-70 large-panel building - own work [3,4,5]

LITERATURE REVIEW

Design principles for residential buildings from large-size prefabricated elements are described in detail in two monographs by B. Lewicki [6,7]. Along with the period of use of large-panel buildings, the period of structure testing began, which from the point of view of settlement of the structure resulted in work, unique due to the natural scale of the Z. Ciałowicz model [8]. Many publications have been created in the field of emergency analysis of the wall structure of large-panel buildings. [9,10,11,12]. Instytut Techniki Budowlanej also published a series of monographs on the safety and rational use of buildings erected in large-panel technology [13].

RESEARCH METHODS USED

The Finite Element Method is currently the basic computer design tool, which consists in determining approximate partial differential equations [14]. Displacements and stresses are the basic quantities that should be checked at the stage of designing a large-panel building structure. For each structural element to be designed on the safe side, limit states must be fulfilled, checked in accordance with applicable European standards. There are two basic types of limit states:

ULS (Ultimate Limit State) - which includes calculated stresses occurring in the structure, in relation to the allowable stresses that a given element can carry,

SLS (Serviceability Limit State) - which includes calculated displacements occurring in the structure, in relation to permissible displacements.

A model of interaction between the building and the ground was used, corresponding to the characteristics of the elastic Winkler substrate. Due to the fact that the displacement caused by the building structure subsidence on elastic foundation [19,20,21] and the stress on the edges of scratches [12,13,17] are discussed in the paper, the results are given for the SLS state. The author developed all the results with the help of the Robot Structural Analysis 2019 computer program.

RESEARCH RESULTS AND THEIR DISCUSSION

The model adopted for monitoring displacements in the x, y directions, from the global coordinate axis system of the Autodesk Robot program, whose genesis is included in the cooperation of the building structure with a soil elastic soil center (type of building soil - medium sands), is a multi-panel residential building Wk-70 . Figures 3 a, b and 4 a, b illustrate displacement results for longitudinal and gable walls of the building structure.

When adapting the system designs of large-panel buildings to the ground conditions existing in a given area, no work was carried out when considering geotechnical impacts, work on the Winkler foundation (review of the design projects of large-panel buildings from two housing cooperatives, by the author of the study). The result of abandoning the analysis of the work of the building structure on the Winkler substrate, illustrated in Fig. 3a, horizontal displacements u_x and u_y and vertical w_z do not occur, reaching a value of 0.0 cm. Figures 3b and 4a, b show the results of displacements for the building structure's cooperation with the elastic half-space: 3b) horizontal $u_{x,\ max}$ = + 0.3 ÷ -0.7 cm, 4a) horizontal $u_{y,\ max}$ = + 0.2 ÷ - 0.2 cm, vertical $w_{z,\ max}$ = + 0.2 ÷ -0.7 cm. The signs +/- indicate a compatible / opposite displacement to the system of accepted coordinate axes (global Robot program).

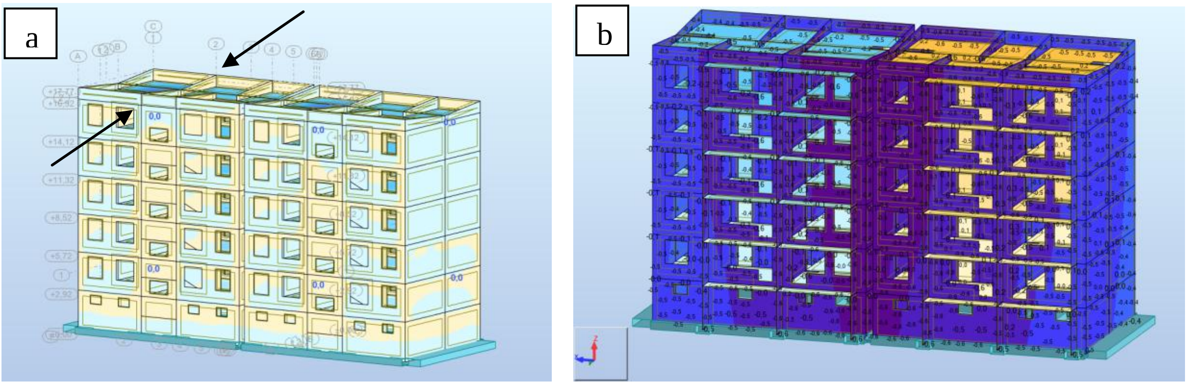


Fig. 3. The values of horizontal displacements towards the global x axis of the Wk-70 building structure: a) FEM model that does not take into account the cooperation of the building structure with the soil center; b) FEM model of the building structure in cooperation with the half-space of the soil center,
horizontal displacement u_x [cm] (Bieranowski. P. 2019)

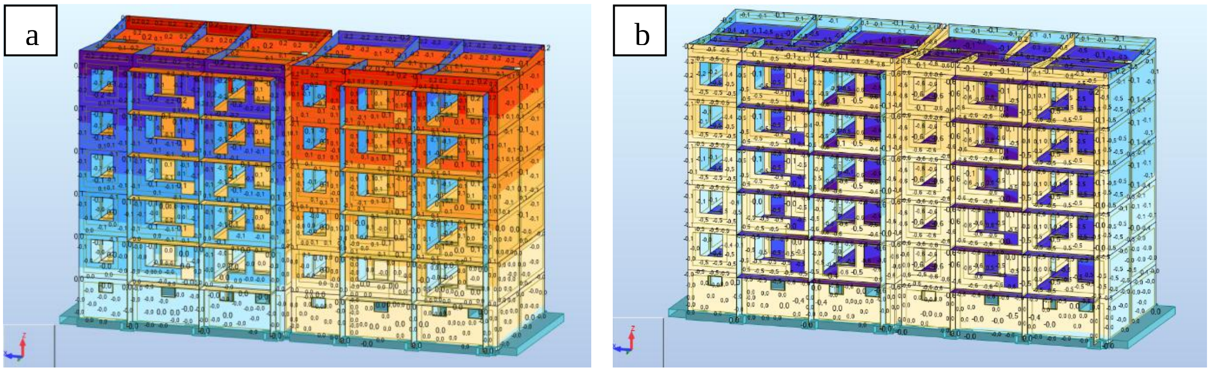


Fig. 4. Displacement values of the Wk-70 building structure: a) horizontal towards the global y axis; b) vertical towards the global z axis,
horizontal displacement u_y [cm], vertical displacement w_z [cm], (Bieranowski. P. 2019)

In the further part of the work, the building was separated from the structural FEM model of the building, the wall - a stiffening diaphragm, integrally connected to the vertical communication structure (shaping the spatial rigidity of large-panel buildings [6,7]) - Fig. 5a. The results of horizontal displacements u_x and u_y [cm] and vertical w_z [cm] are presented, respectively, in the order in Fig. 5 a, 6a and 6b.

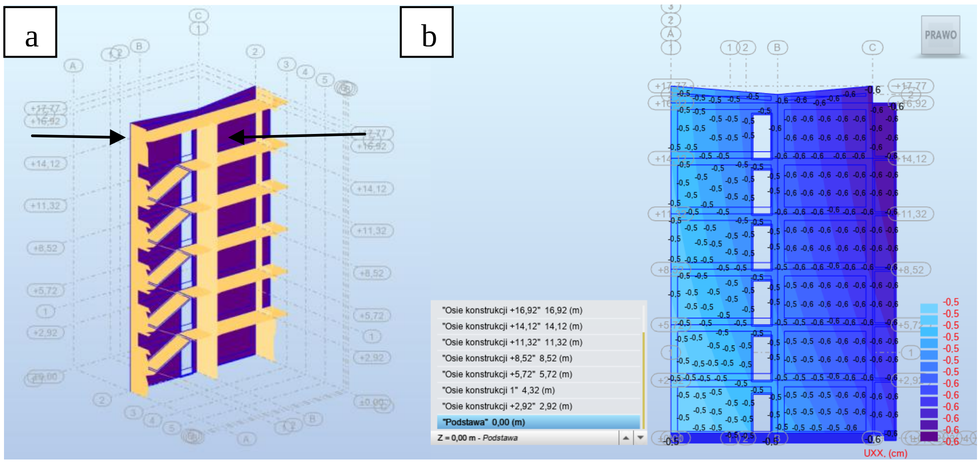


Fig. 5. Diagram stiffened by vertical communication structure: a) 3D diagram with an indication of the wall considered in the analysis; b) horizontal displacement u_x [cm] (Bieranowski P. 2019)

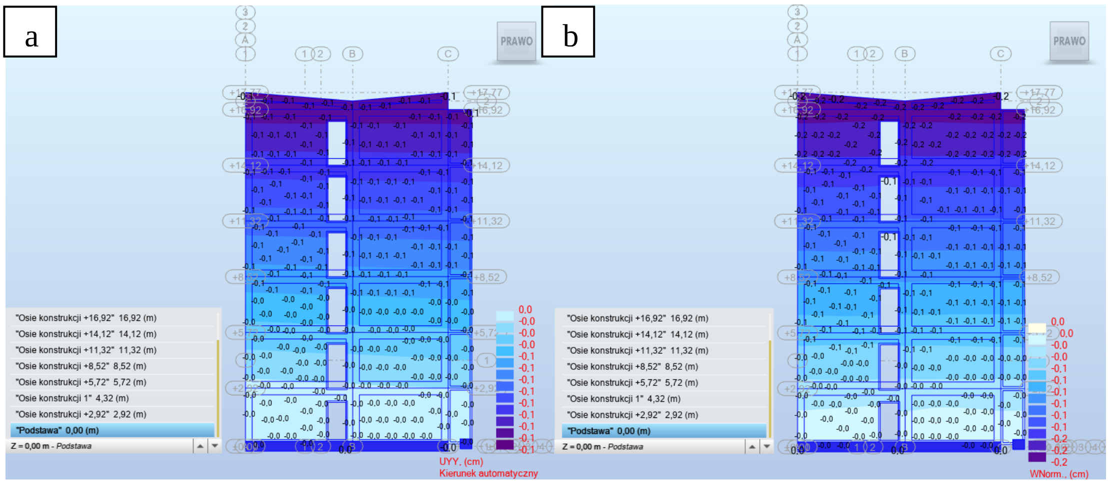


Fig. 6. Diaphragm stiffened by vertical communication structure: a) horizontal displacement u_y [cm]; b) vertical displacements w_z [cm] (Bieranowski P. 2019)

The largest displacements, as well as interaction, take place in the last floor zone. Incomplete cross-sections, i.e. with holes in the wall cross-section, are susceptible to any imperfections. A prefabricated wall panel with a door opening (level of the last floor) was separated from the stiffening structure of the large-panel diaphragm - Fig. 7a and b. Fig. 7a shows a map of compressive and tensile stress σ_x [MPa] for a separated multi-panel wall without scratching, Fig. 7b with crack, the width of the vertical crack in w_k = 3 mm (the crack runs through the entire width of the cross section, 800 mm from the left edge of the panel). In the central part of the FEM grid there are values of normal stresses determined for the EC – SLS [15] standard combination, for which the settlement [16] and cracking [17] of the structure are determined.

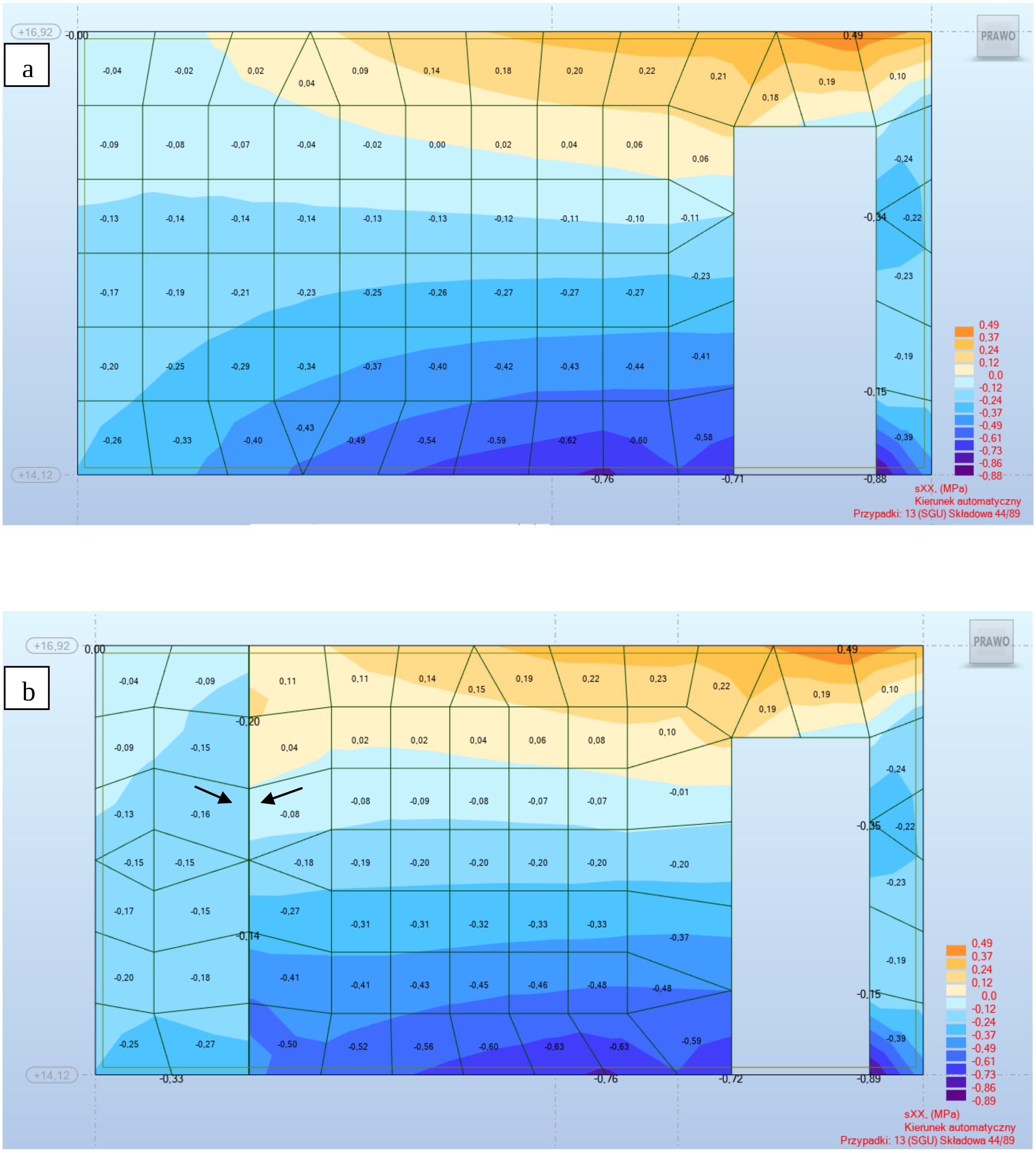
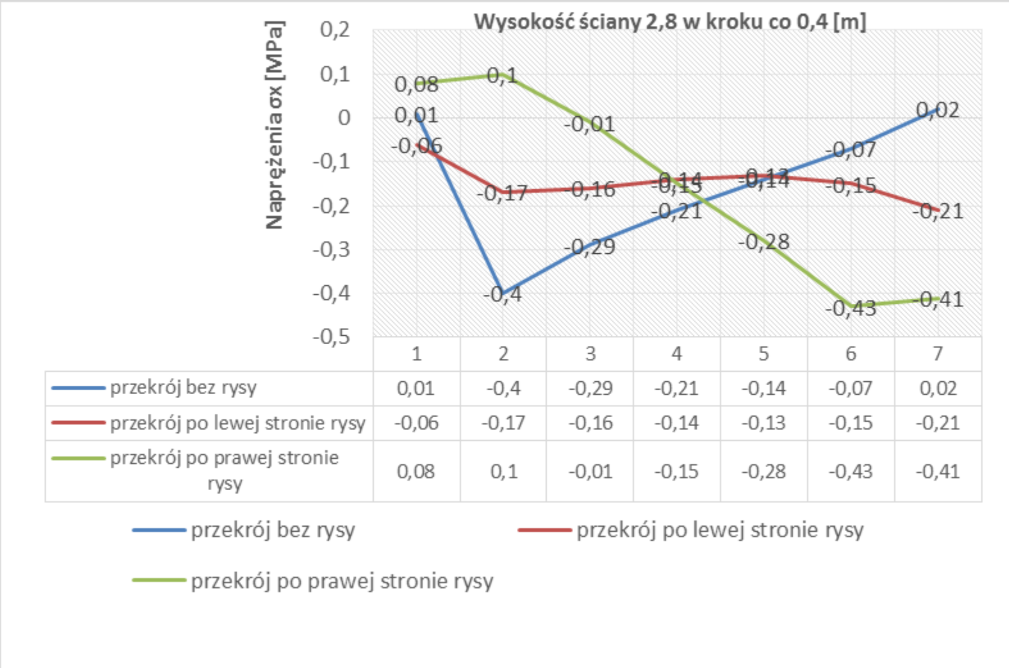


Fig. 7. FEM mesh with results for a separate part of the stiffening diaphragm - load-bearing wall of the last floor of the Wk-70 large-panel building: a) wall without scratching; b) a cracked wall, (Bieranowski P. 2019)

PRESENTATION OF THE ANALYSIS

Due to the panel enabling stress analysis, Robot Structural Analysis can also be used to determine the value of concrete cracking mechanic parameters [18]. On the chart - Fig. 8, the values of normal stress σ_x [MPa] are given for the cross-section of a prefabricated element without (Fig. 7a) and with a crack (Fig. 7b). The stress values for the prefabricated element with a crack were determined for the left and right edges of the crack cross-section - Fig. 8. Scratches / scratches in concrete structures arise as a result of concrete achieving tensile strength in specific cross-sections and zones of elements. One factor is the settlement of supports. When the concrete cross section reaches the crack, the stress distribution changes, dictated by the discontinuity of the structure (Fig. 7a, b). In parts of the section separated by a crack, the stresses not only change their value, but also the stress sign (compression / stretching) in the given zones changes - the values are presented in Fig. 8. This phenomenon may be a genesis for the creation of subsequent scratches, and bearing in mind the scratches structural, which tend to further increase, constitute information on a threat to the safety of structures.



	1	2	3	4	5	6	7
przekrój bez rysy	0,01	-0,4	-0,29	-0,21	-0,14	-0,07	0,02
przekrój po lewej stronie rysy	-0,06	-0,17	-0,16	-0,14	-0,13	-0,15	-0,21
przekrój po prawej stronie rysy	0,08	0,1	-0,01	-0,15	-0,28	-0,43	-0,41

Fig. 8. Diagram of normal stresses in the direction of the local x axis for the cross section of a reinforced concrete panel wall,
normal stress - σ_x [MPa], (Bieranowski P.2019)

CONCLUSIONS

The reason for the appearance of structural scratches are usually uneven ground deformations under the building, very often unanalyzed (the author did not meet with checking the foundation of large-panel building structures on a elastic foundation) while adapting the foundation structure to locally existing soil and water conditions. This is the main reason for the emergence of "dangerous" scratches in the cross section of the wall structure of a large panel building. The development of structural cracks is also affected by design and manufacturing defects, as well as manufacturing - at the stage of production of prefabricated large-panel elements. It should also be noted that there may be a cross overlap of these phenomena.

Considering the use of the structure, scratches will always be a construction defect [17]. In order to determine the degree of security, it should be stated whether they are stable features, i.e. with unchanging propagation time. Surface and local scratches occur mainly in stabilized constructions and can be removed with immediate room renovations without fear of safety. Structural features often of a developmental nature are an obvious premise for a threat to the safety of structures, including local

features with propagating morphology. The intervention of a building expert, then, will determine the corrective procedure necessary to restore the expected safety condition.
Limits of displacements should be set in the structural foundation design, as can be seen from this work, not only for cohesive soils, as recommended by Eurocode 7 [16], but also for cohesive ones, which is dictated by the logic of the theory of structure, especially when the constructor's engineer, commonly software analyzing structures based on FEM [14] is available.

BIBLIOGRAPHY

1) Bernatowicz A., *Analiza parametrów mechaniki pękania betonu z wykorzystaniem nowoczesnych technik komputerowych, Civil and Environmental Engineering*, 8/2017.
2) *Budynki wielkopłytowe – wymagania podstawowe*. Zeszyty 1÷12. Seria: Instrukcje, wytyczne, poradniki. ITB, Warszawa, 2002/2003.
3) Ciałowicz Z., *Praca statyczna budynków wielkopłytowych w warunkach nierównomiernie osiadającego podłoża*. Zeszyty Naukowe Politechniki Śląskiej, 7-8, 1980.
4) Dzierżewicz Z., Starosolski W., *Systemy budownictwa wielkopłytowego w Polsce w latach 1970-1985. Przegląd rozwiązań materiałowych, technologicznych i konstrukcyjnych*. Wolters Kluwer, Warszawa, 2010.
5) *Katalog przykładowych mieszkań dla budynków – system Wk-70 – konstrukcja*, Biuro projektowo-badawcze budownictwa ogólnego „Miastoprojekt", Olsztyn, 1988.
6) Lewicki B. i inni, *Budynki wznoszone metodami uprzemysłowionymi*, Arkady, Warszawa, 1979.
7) Lewicki B., *Bezpieczeństwo konstrukcji istniejących budynków wielkopłytowych, Inżynieria i Budownictwo* 3/2000.
8) Lewicki B., *Budynki mieszkalne z prefabrykatów wielkowymiarowych*, Wydawnictwo Arkady, Warszawa, 1964.
9) Lewicki B., *Rysy w ścianach i stropach budynków wielkopłytowych*, Prace ITB nr 2-3/2000.
10) Ligęza W, Płachecki M., *Analiza uszkodzeń i możliwości wzmacniania konstrukcji budynków wielkopłytowych*. V konferencja „Warsztat pracy rzeczoznawcy budowlanego", Kielce, 1999.
11) Ligęza W, Płachecki M., *Badania efektywności wzmocnienia konstrukcji budynku wielkopłytowego zagrożonego katastrofą*. V konferencja „Warsztat pracy rzeczoznawcy budowlanego", Kielce, 1999.
12) Palacz P, Major M., *Analiza porównawcza przemieszczeń ustroju prętowego z użyciem programów ADINA*, Autodesk Robot oraz RFEM, Zeszyty naukowe Politechniki Częstochowskiej nr 24, Budownictwo, Częstochowa, 2018.
13) Pieczyrak J., *Obliczanie osiadań według zaleceń Eurokodu 7*, Inżynieria Morska i Geotechnika 3/2015.
14) Pietrzak J., Rakowski G., Wrześniowski K., *Macierzowa Analiza Konstrukcji*, PWN, Warszawa-Poznań, 1979.
15) *PN-EN 1990:2004/AC – Eurokod 0 – podstawy projektowania konstrukcji*, PKN, Warszawa, 2008.
16) *Projekt techniczny budynku mieszkalnego nr 48 na osiedlu Mleczna w Olsztynie – architektura i konstrukcja*.

17) Rakowski G, Kacprzyk., *Metoda Elementów Skończonych w mechanice konstrukcji*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 2005.

18) *Roczniki statystyczne GUS – lata 1965 – 1985*.

19) Runkiewicz L., Szudrowicz B., Geryło R., Szulc J., Sieczkowski J., *Diagnostyka i modernizacja budynków wielkopłytowych*, Przegląd Budowlany 7-8/2014 cz. I, 9/2014 cz. II.

20) *System Wk-70 program produkcyjny prefabrykatów dla budownictwa mieszkaniowego realizowany przez F.D. Iława* – opracował Dębski E., Biuro projektowo-badawcze budownictwa ogólnego „Miastoprojekt", Olsztyn, 1988.

21) Zienkiewicz O.C., *Metoda Elementów Skończonych*, Arkady, Warszawa, 1972.