Theory and Building Practice

Vol. 6, No. 1, 2024

https://doi.org/10.23939/jtbp2024.01.130

Vitalii Deineka, Pavlo Vegera, Zinovii Blikharskyi

SIMULATION INFLUENCE OF UNEVEN DAMAGE OF REINFORCED CONCRETE BEAM IN LIRA-FEM

Department of Building Construction and Bridges,
Lviv Polytechnic National University,
pavlo.i.vehera@lpnu.ua

This article divulges the outcomes of theoretical investigations into non-uniformly damaged reinforced concrete beams, employing the LIRA-FEM software suite. The manifestation of defects and damages poses operational risks for buildings and structures. The objective of this study is to scrutinize the consequences of irregular damage occurrence in reinforced concrete beams, holding significant practical relevance for the determination of the stress-strain condition in reinforced concrete elements. To facilitate these theoretical inquiries, finite element modeling within the LIRA-FEM software suite is employed. Through the modeling results, stress levels were juxtaposed against ultimate stress thresholds, elucidating the deformability of unevenly damaged reinforced concrete beams. The study's significance lies in its potential to enhance the safety of building structures, mitigating risks during operational phases.

Key words: uneven damage; reinforced concrete beam; LIRA; FEM; nonlinearity; modeling.

Introduction

The determination of residual load-carrying capacity in reinforced concrete beams subjected to various damages is a pressing concern within the construction industry, holding paramount importance for design engineers. Concrete damage can manifest due to diverse factors, including chemical attacks, mechanical injuries, improper operation, and other types of damages as classified in (Voskobiinyk, 2010). Such occurrences may lead to a decline in the load-bearing capacity of beams, escalating the risk of accidents and giving rise to intricate deformations in reinforced concrete elements that defy predictability in the initial design (Voskobiinyk et al., 2011).

Ongoing research in this field focuses on comprehending the mechanisms of damage and its ramifications on the load-bearing capacity of reinforced concrete beams. The outcomes of these investigations can serve as a basis for establishing safety codes and formulating recommendations. Consequently, evaluating the technical condition of reinforced concrete structures becomes the primary diagnostic tool during operation, necessitating the determination of load-bearing capacity and the selection of optimal reconstruction methods. This is crucial for ensuring the safety and longevity of structures in practical application.

The focus of this article revolves around stress analysis and deformability assessments in reinforced concrete beams exhibiting non-uniform damage. These investigations are conducted through the utilization of the LIRA SAPR software package.

Researchers face the challenge of assessing the residual load-bearing capacity of elements exhibiting uneven damage, aiming to identify the most optimal calculation approach and select materials for optimization, ensuring strength and durability. Additionally, the study delves into the examination of the influence of damage and defects, leading to stress-deformed states that elude predictability through conventional calculations. The article (Mykhalevskyi et al., 2023) explores methods for determining the residual load-bearing capacity of reinforced concrete elements afflicted by diverse types of damage.

Furthermore, it conducts a thorough analysis of prevalent defects and damages found in reinforced concrete structures, including various types of corrosion.

The paper (Lobodanov at el., 2021) discusses both the experimental and theoretical findings from research conducted on reinforced concrete beams featuring damaged concrete in a compressed zone under load.

In the article (Klymenko & Polianskyi, 2019), the researchers presented experimental findings focused on determining the stress-strain state of damaged reinforced concrete beams with a rectangular cross-section. The study yielded data on ultimate forces and corresponding deformations of both concrete and transverse reinforcement within the samples. The experimental results revealed that a reduction in the shear span contributed to a decrease in ultimate deformations of concrete. Additionally, the formation of damage resulted in reduced deformations of both concrete and reinforcement. The incurred damage also led to a tilt of the neutral axis. The stress-strain state data obtained from these experiments shed light on the actual behavior of damaged reinforced concrete beams, particularly their collapse along inclined sections.

The paper (Blikharskyy et al., 2021) focuses on an experimental study that aimed to identify the strength and strain parameters of reinforced concrete beams with damage in the load-bearing stretched reinforcement. The damage occurred due to the action of bending moments, resulting in the exhaustion of the bearing capacity of the beams.

A research group (Klymenko et al., 2021) conducted experimental studies to determine the residual load-bearing capacity of inclined sections in damaged reinforced concrete beams with a rectangular cross-section. The calculations were executed using the LIRA-SAPR software complex, enabling accurate predictions of the element behavior and the determination of load-bearing capacity. However, when compared with real-world data, some disparities in the nature of destruction were observed.

In research (Pavlikov et al., 2019), a numerical model of a reinforced concrete beam operating under biaxial bending conditions was examined. The model is relatively straightforward, enabling the study of the stress-strain state at various reinforcement ratios and different angles (β) of the inclination of the external load plane. The authors utilized a computer program to simulate the stress-strain state of a standard cross-section of a beam in biaxial bending conditions, enabling the observation of changes in the position of the neutral axis during loading. The study found that computer modeling not only facilitates the examination of the stress-strain state but also aids in planning experimental studies. It allows for the optimization of the number and size of samples for testing and helps identify specific locations in the samples that require special attention during experiments. The research concluded that finite element modeling on a computer is effective in accounting for the unique characteristics of load-bearing capacity loss in biaxially bent beams.

In the conducted numerical experiment outlined in (Klymenko et al., 2019), which involved modeling the behavior of damaged reinforced concrete beams and determining their stress-deformed state and bearing capacity using the LIRA-FEM software environment, the analysis revealed the capability to scrutinize all processes occurring in the beam under gradually increasing static loads. The modeling results demonstrated a noteworthy convergence of the residual bearing capacity when compared to the full-scale experiment, with differences ranging from 3.23 % to 21.46 %. The calculated coefficient of variation (v) was found to be 14.81 %. The indicators of the stress-strain state showed that the deformation characteristics of concrete and reinforcing bars generally aligned with laboratory studies. However, deformations in the transverse bars did not reach the limit flow, in contrast to the findings in laboratory samples. The failure pattern in samples with the smallest shear span suggested concrete failure at the support, deviating from the actual failure nature. Concrete deformation in the span under load corroborated laboratory study data about the inclination of the neutral axis towards the damage, nearly paralleling the damage front.

In the article (Mykhalevskyi et al., 2023), a theoretical investigation into unevenly damaged reinforced concrete beams was conducted using the FEMAP software environment. The study emphasizes the ability to comprehensively examine stresses in both concrete and reinforcement under various damage scenarios and analyze displacements based on damage parameters. The results highlight the influence of the compressed zone on reinforced concrete beams, indicating that each centimeter of damage reduces the effective working height of the concrete, its bearing capacity, and alters the inclination of the neutral axis. The modeling approach enables an assessment of the repercussions of damage and defects occurring in existing building elements under load, offering insights into the impact on elements and their structural behavior.

In the paper (Kos et al., 2022), the study involved modeling the intricate stress-strain state of experimental structures through non-linear finite element calculations using the "LIRA-FEM" software package. The comprehensive experimental and theoretical investigations addressed the challenge of calculating the bearing capacity near the support sections for punching continuous reinforced concrete beams and high grillages. According to the authors, the utilization of LIRA-FEM enabled the tracking of all stages of reinforced concrete beam behavior under load. The software effectively replicated the results of the conducted experiments, allowing for a reliable prediction of the structures' strength and the nature of their failure.

The design of a reinforced concrete beam, reinforced using the PC LIRA-SAPR software, has been explored in (Shakhmov & Amir, 2022). The model employed for calculation in PC LIRA-SAPR preserves the geometrical characteristics of the beam and also considers the bends in the working reinforcement. The stress-strain state of the reinforced concrete element undergoes three distinct stages as the bending moment M increases: from the absence of cracks in the tensile part of the concrete to the formation of cracks in the tensile zone of the concrete. Crack formation leads to stress redistribution in the cross-section, gradually disconnecting the concrete in the tensile zone from the workload. Consequently, it is essential to consider the physical non-linearity of the deformation of reinforced concrete beams.

The studies discussed in (Barabash, 2018) focus on calculations that account for the actual properties of materials. This primarily pertains to reinforced concrete, where operational loads, in conjunction with the emergence of cracks and plastic deformations in the concrete, result in a notable reduction in the stiffness of elements. This, in turn, leads to an increase in displacements when compared to calculations made in a linear setting. The inherent nonlinear behavior of reinforced concrete under operational loads necessitates a more nuanced and realistic approach to modeling and analysis. The paper addresses specific aspects of modeling structural behavior, including the "engineering nonlinearity" method and determining stresses based on nonlinear stress-strain relationships.

Modern calculation complexes allow you to take into account several types of nonlinearity during the calculation and analysis of building structures. In particular, (Gorodetsky & Romashkina, 2023) describes the main capabilities of the calculation complex LIRA-SAPR.

In (Gorodetskyi & Barabash, 2022), the iterative method "engineering nonlinearity" is considered. The proposed method allows you to determine the real stiffness characteristics of the section, which may be reduced due to the appearance of cracks, plastic deformations of concrete and reinforcement. The main dependences of the non-linear operation of the materials of reinforced concrete elements are also given.

Materials and methods

For the theoretical research and modeling, a normally reinforced concrete beam was conceptualized, with the intention of utilizing it for experimental testing and subsequent comparison of the results with theoretical data.

The geometric dimensions of the reinforced concrete beam are as follows:

- length (l) = 2100 mm;
- height (h) = 200 mm;
- width (b) = 100 mm;
- distance between supports (l1) = 1900 mm.

The working reinforcement in the tensile zone of the beam is designed using rolled steel Ø16A500S, featuring a Young's modulus (E) of 209200 and a Poisson's ratio of 0.29. Additionally, upper reinforcement consists of 2Ø6A240C. The concrete used is of class C30/35, possessing a Young's modulus (*E*) of 34500 and a Poisson's ratio of 0.21. The transverse reinforcement is implemented in the form of U-shaped clamps Ø6A240C with a pitch of 75 mm (Fig. 1).

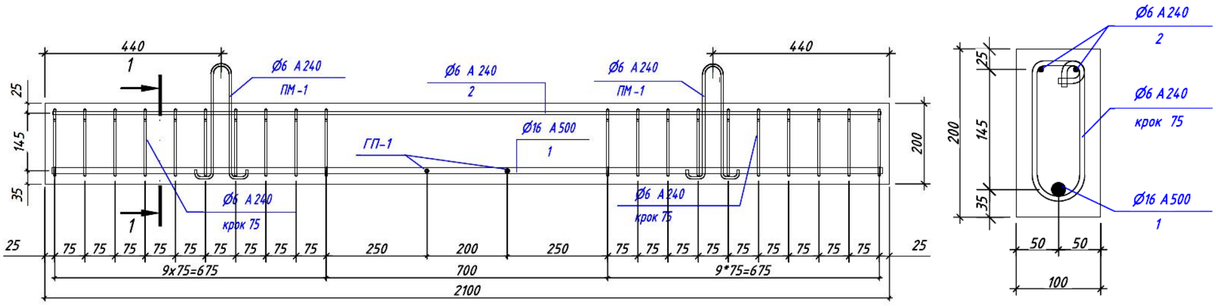
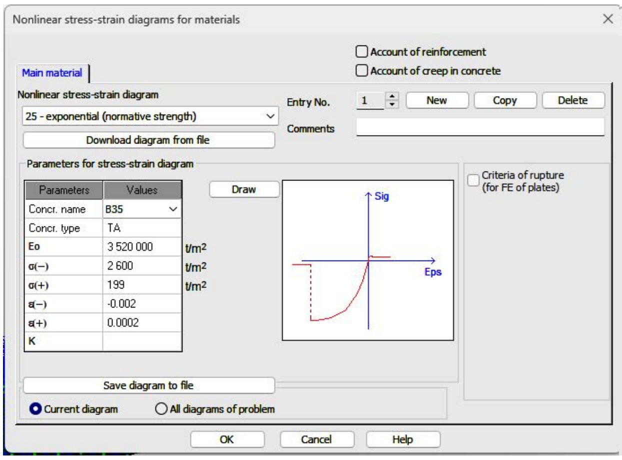


Fig. 1. General view of reinforcement of beam

The calculation was performed in the LIRA-FEM software complex. Volumetric finite elements No. 236, which simulates the non-linear operation of the material, were made for the construction of the finite element model. The 25 exponential law of deformation was used to model the non-linear operation of concrete (Fig. 2). Finite elements No. 210 – physically-nonlinear universal spatial FE – were used to simulate the operation of the reinforcement frame. The 14-th piecewise linear function of deformation was used to specify the physical nonlinearity of the material of reinforcement (Fig. 3).

The cross-section of the beam is divided into finite elements with dimensions according to Fig. 4. In the longitudinal direction, the beam is divided into SE with a step of 25 mm. This division of the beam into cubes is related to the placement of the longitudinal reinforcement and the step of the transverse reinforcement.

Supports are created along the entire width of the beam at a distance of 100 mm from its edge. On the one hand, there is a hinged fixed support, on the other – a hinged support. A load of *F* (kN) is applied in 1/3 of the span (Fig. 5) to ensure a clean bending zone. Applied load *F* = 35.3 kN.


Nonlinear stress-strain diagrams for materials

☐ Account of reinforcement
☐ Account of creep in concrete

Main material

Nonlinear stress-strain diagram: 25 - exponential (normative strength)
Entry No.: 1
Comments:

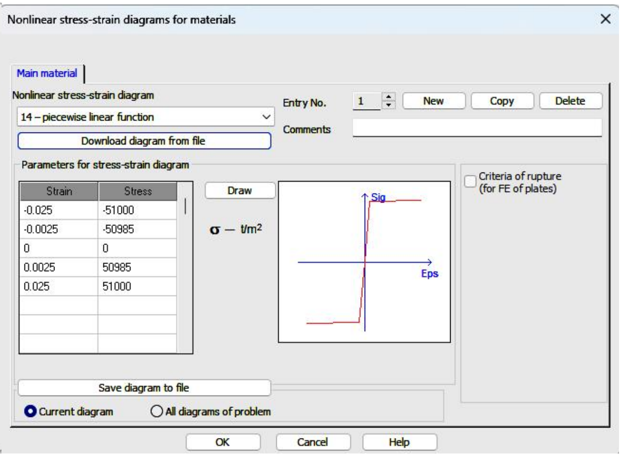
Parameters for stress-strain diagram

Parameters	Values	
Concr. name	B35	
Concr. type	TA	
Eo	3 520 000	t/m2
σ(–)	2 600	t/m2
σ(+)	199	t/m2
ε(–)	-0.002	
ε(+)	0.0002	
K		

☐ Criteria of rupture (for FE of plates)

● Current diagram ○ All diagrams of problem

Fig. 2. Nonlinearity of the concrete


Nonlinear stress-strain diagrams for materials

Main material

Nonlinear stress-strain diagram: 14 – piecewise linear function
Entry No.: 1
Comments:

Parameters for stress-strain diagram

Strain	Stress
-0.025	-51000
-0.0025	-50985
0	0
0.0025	50985
0.025	51000

σ – t/m2

☐ Criteria of rupture (for FE of plates)

● Current diagram ○ All diagrams of problem

Fig. 3. Nonlinearity of the reinforcement

In order to facilitate further study and analysis of a reinforced concrete beam with uneven damage, 5 variations of damage with variable values were selected and subsequently modeled. These variations encompass a range of different damage scenarios, allowing for a comprehensive examination of the beam's behavior under diverse conditions. The modeling of these variations will provide valuable insights into the impact of different types and extents of damage on the structural response and performance of the reinforced concrete beam (Fig. 6).

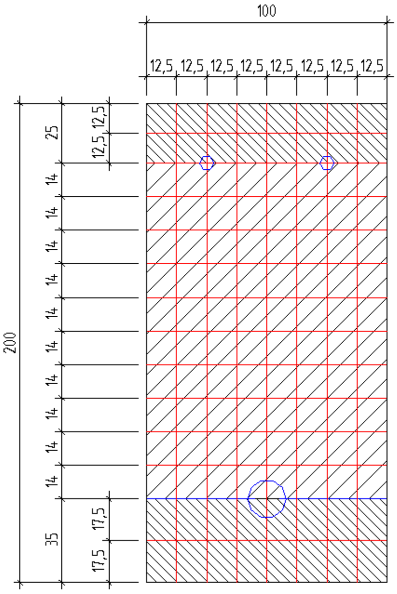


Fig. 4. Finite element mesh

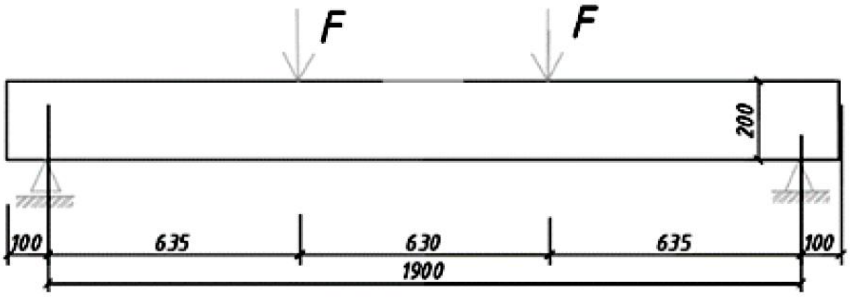


Fig. 5. Load application scheme

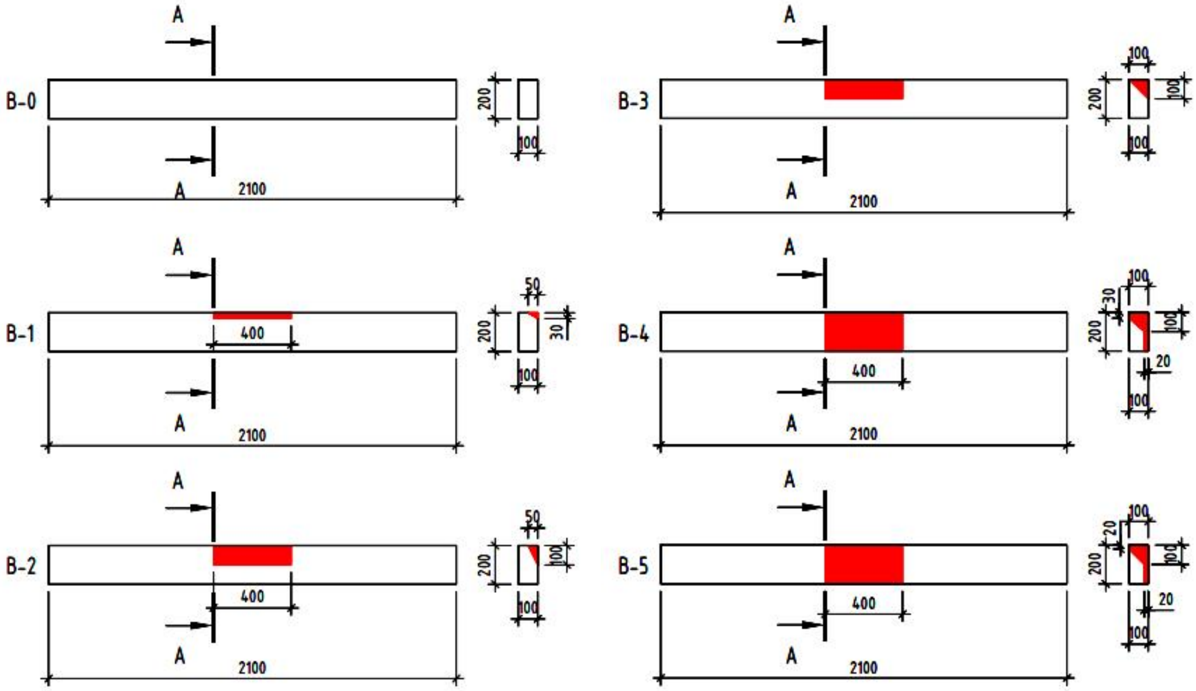


Fig. 6. Damage scheme of reinforced concrete beams under investigation

Results and discussion

The destruction of the computational model in the LIRA-FEM program is created by removing the mesh elements of the reinforced concrete beam. After removal, the Pack Model command was used to prevent errors. It is assumed that this damage can cause a change in the stress-strain state of the reinforced concrete element. As a result of modeling and static calculation using the LIRA-FEM program, models and isofields of reinforced concrete beams with damage were obtained. For example, a general model of a control beam with stresses mosaic plot (Fig. 7) and forces in the reinforcing frame (Fig. 8), movements along the *Z* axis (Fig. 9) and along the *Y* axis (Fig. 10) is shown.

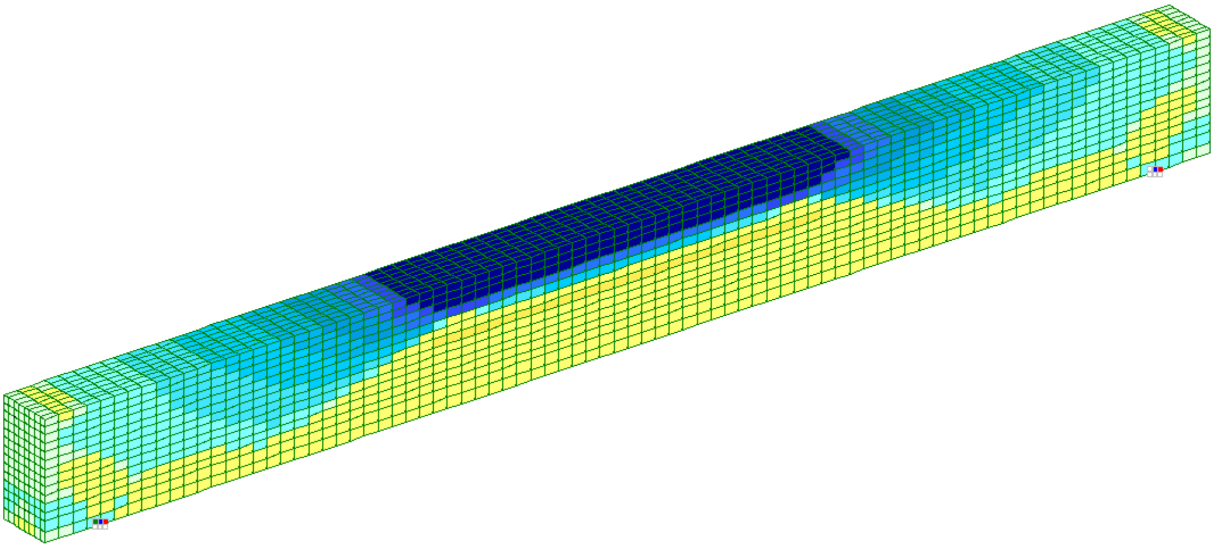


Fig. 7. The general view of the calculation scheme in LIRA-FEM, setting of rigidity for CE and stress mosaic plot

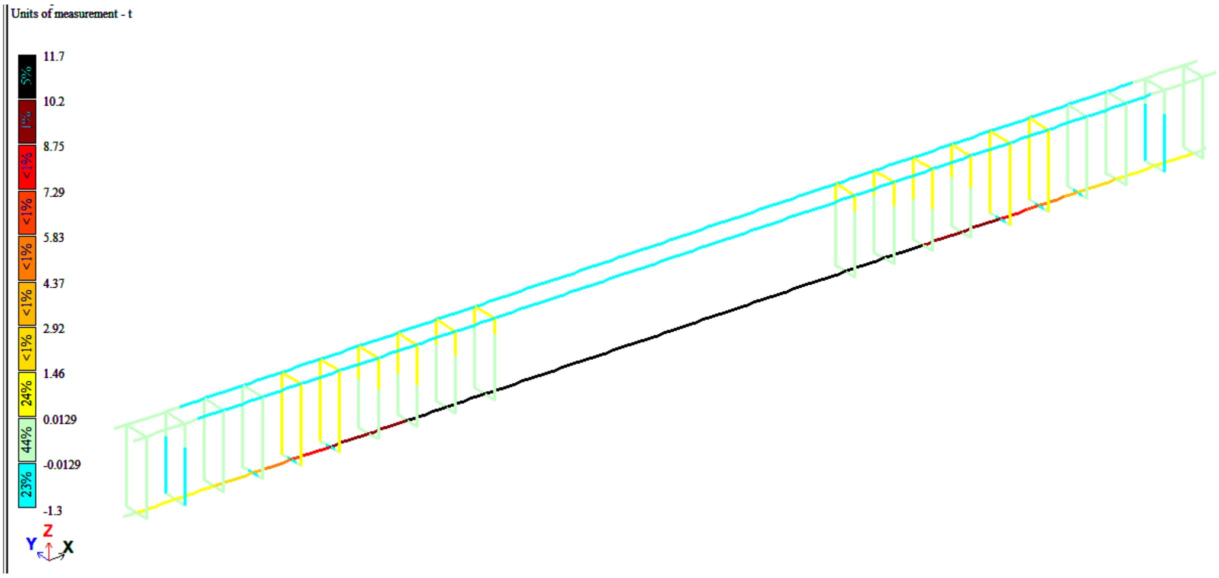


Fig. 8. The general view forces in the reinforcing frame

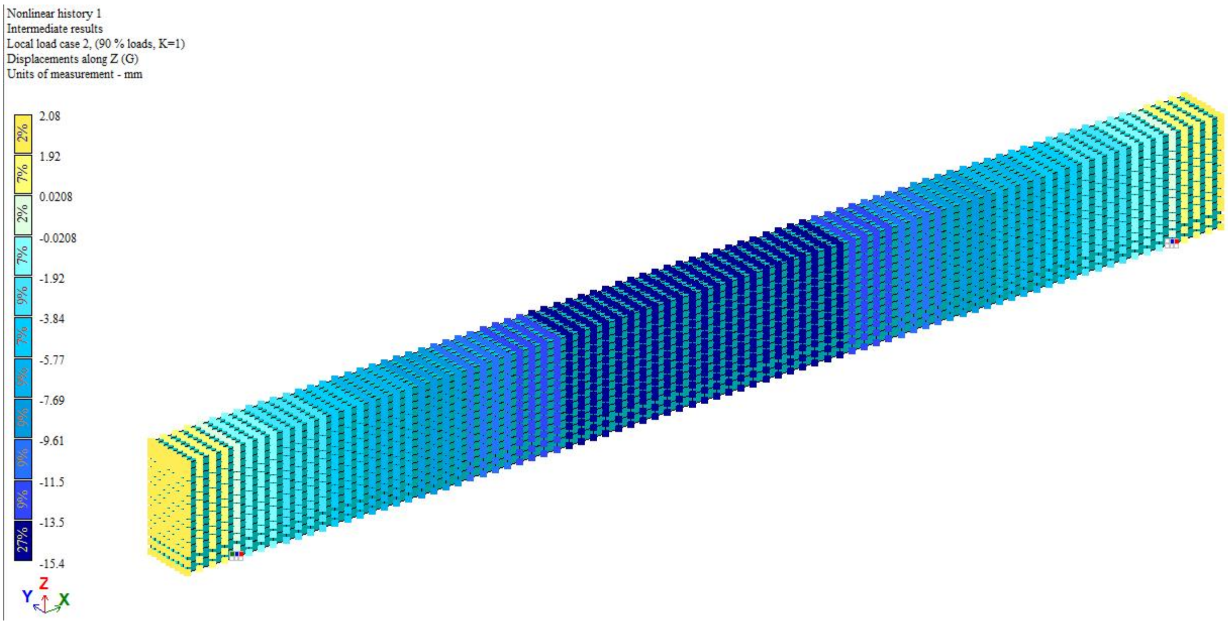


Fig. 9. Movements along the Z axis

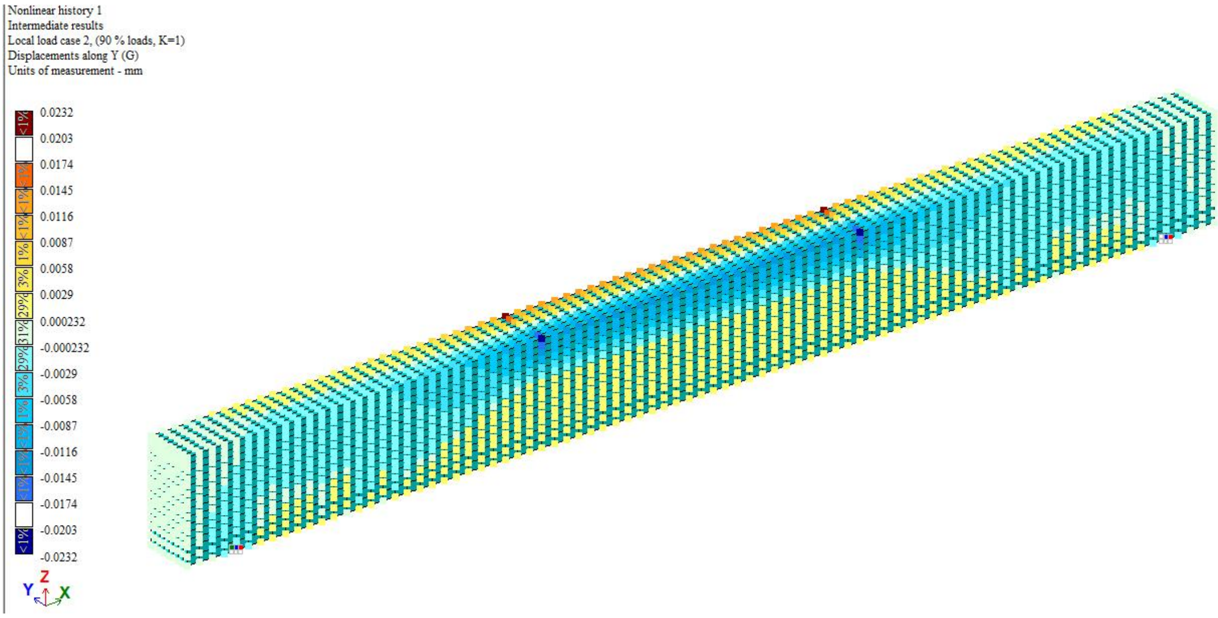
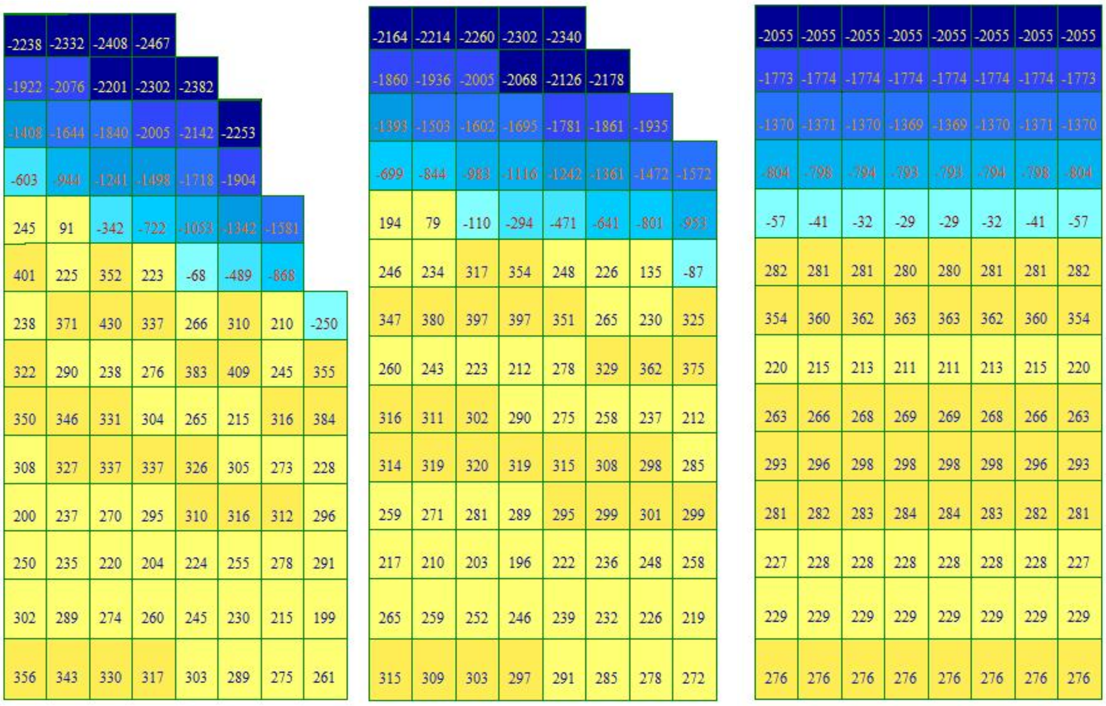


Fig. 10. Movements along the Y axis

Theoretical results for unevenly damaged reinforced concrete beams are presented in Table. Analyzing these data provides insights into the influence of various damage parameters on the increase in deformation under load. By examining the outcomes, it becomes possible to identify and understand the specific factors among the damage parameters that contribute to heightened deformations in the reinforced concrete beams. The movement of damaged reinforced concrete beams was also compared with the control one.

Based on the data presented in Table, it can be established that lateral cracking strongly affects the load-bearing capacity and deformability (deflection) of the test samples. It is worth noting that depending on the depth of the damage, the maximum deflection increases from 6.0 mm (control beam B-0) to 957 mm – for the damaged sample B-4 (Fig. 11). It is also worth noting that samples B-4 and B-5 exhaust their serviceability already by 50 % of the load-bearing capacity of the control samples. It is also worth noting that, depending on the depth of the one-sided damage, the beams may deviate from the plane. According to the data obtained from the models, specimens B-0, B-1, and B-2 did not actually deviate from their design positions. While specimens with more severe damage (B-3, B-4 and B-5) already showed significant lateral bending data: the maximum value was reached for specimen B-4 – 109.2 mm. A similar situation is observed with the stresses – depending on the damage, the stresses were redistributed along the section with the maximum concentration in the damage zone.



Beam B-0

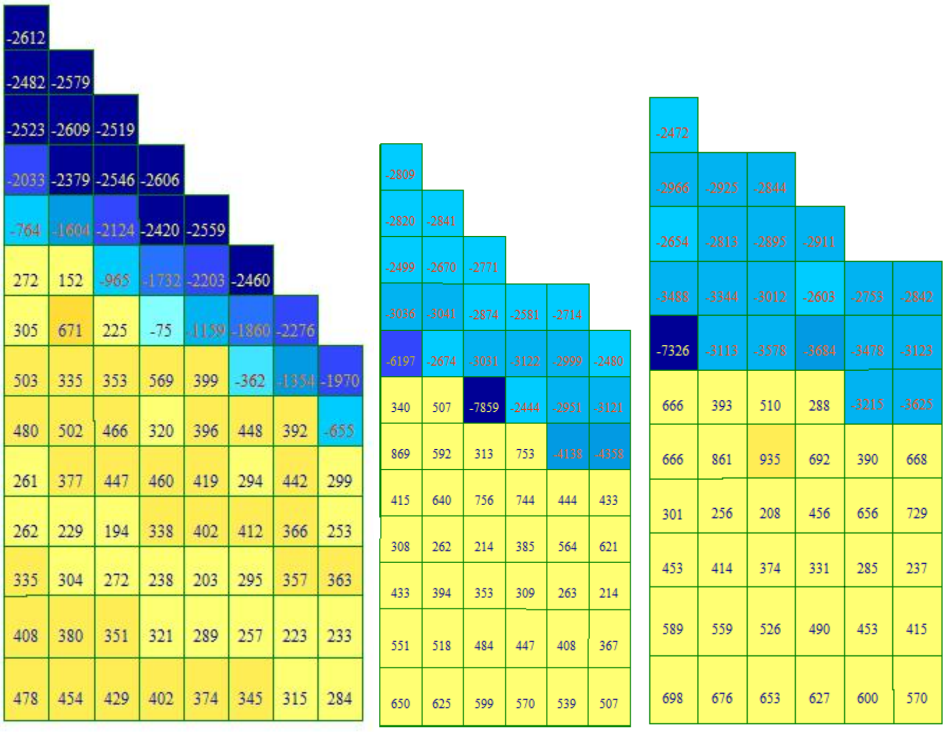
-2238	-2332	-2408	-2467				
-1922	-2076	-2201	-2302	-2382			
-1408	-1644	-1840	-2005	-2142	-2253		
-603	-944	-1241	-1498	-1718	-1904		
245	91	-342	-722	-1053	-1342	-1581	
401	225	352	223	-68	-489	-868	
238	371	430	337	266	310	210	-250
322	290	238	276	383	409	245	355
350	346	331	304	265	215	316	384
308	327	337	337	326	305	273	228
200	237	270	295	310	316	312	296
250	235	220	204	224	255	278	291
302	289	274	260	245	230	215	199
356	343	330	317	303	289	275	261

Beam B-1

-2164	-2214	-2260	-2302	-2340			
-1860	-1936	-2005	-2068	-2126	-2178		
-1393	-1503	-1602	-1695	-1781	-1861	-1935	
-699	-844	-983	-1116	-1242	-1361	-1472	-1572
194	79	-110	-294	-471	-641	-801	-953
246	234	317	354	248	226	135	-87
347	380	397	397	351	265	230	325
260	243	223	212	278	329	362	375
316	311	302	290	275	258	237	212
314	319	320	319	315	308	298	285
259	271	281	289	295	299	301	299
217	210	203	196	222	236	248	258
265	259	252	246	239	232	226	219
315	309	303	297	291	285	278	272

Beam B-2

-2055	-2055	-2055	-2055	-2055	-2055	-2055	-2055
-1773	-1774	-1774	-1774	-1774	-1774	-1774	-1773
-1370	-1371	-1370	-1369	-1369	-1370	-1371	-1370
-804	-798	-794	-793	-793	-794	-798	-804
-57	-41	-32	-29	-29	-32	-41	-57
282	281	281	280	280	281	281	282
354	360	362	363	363	362	360	354
220	215	213	211	211	213	215	220
263	266	268	269	269	268	266	263
293	296	298	298	298	298	296	293
281	282	283	284	284	283	282	281
227	228	228	228	228	228	228	227
229	229	229	229	229	229	229	229
276	276	276	276	276	276	276	276



Beam B-3

-2612							
-2482	-2579						
-2523	-2609	-2519					
-2033	-2379	-2546	-2606				
-764	-1604	-2124	-2420	-2559			
272	152	-965	-1732	-2203	-2460		
305	671	225	-75	-1159	-1860	-2276	
503	335	353	569	399	-362	-1354	-1970
480	502	466	320	396	448	392	-655
261	377	447	460	419	294	442	299
262	229	194	338	402	412	366	253
335	304	272	238	203	295	357	363
408	380	351	321	289	257	223	233
478	454	429	402	374	345	315	284

Beam B-4

-2809					
-2820	-2841				
-2499	-2670	-2771			
-3036	-3041	-2874	-2581	-2714	
-6197	-2674	-3031	-3122	-2999	-2480
340	507	-7859	-2444	-2951	-3121
869	592	313	753	-4138	-4358
415	640	756	744	444	433
308	262	214	385	564	621
433	394	353	309	263	214
551	518	484	447	408	367
650	625	599	570	539	507

Beam B-5

-2472					
-2966	-2925	-2844			
-2654	-2813	-2895	-2911		
-3488	-3344	-3012	-2603	-2753	-2842
-7326	-3113	-3578	-3684	-3478	-3123
666	393	510	288	-3215	-3625
666	861	935	692	390	668
301	256	208	456	656	729
453	414	374	331	285	237
589	559	526	490	453	415
698	676	653	627	600	570

Fig. 11. The stress mosaic plot of beams B-0–B-5

Results of mathematical modeling and analysis of reinforced concrete beams

Title	Displacement along the Z-axis, mm			Displacement along the Y-axis, mm			Min stress in concrete, t/m^2			Max stress in concrete, t/m^2		
	30 %	50 %	70 %	30 %	50 %	70 %	30 %	50 %	70 %	30 %	50 %	70 %
B-0	2.45	6	10.2	0.0043	0.0081	0.0113	1273.6	2057.5	2447.1	363	363	363.1
B-1	2.6	6.5	11.2	0.3	0.6	0.9	1543	2341.9	2540.1	397.5	397.5	397.5
B-2	2.8	7	12.2	0.6	1.4	2.3	1722.8	2469.3	2553.7	430.1	430.2	430.2
B-3	4.1	11.1	33.1	1.7	5.4	10.8	2286.9	2614.7	4397.9	671.3	671.3	671.4
B-4	9.76	957	–	2.7	109.2	134	2965.8	7333	7750.8	935.2	936.2	1504.8
B-5	7.75	137.00	–	2.62	52.32	399.17	2843.2	7866.7	8030.8	869.9	870	992.8

Conclusions

1. Utilizing finite element modeling for existing reinforced concrete elements yields more accurate results compared to analytical methods.

2. The theoretical study of unevenly damaged reinforced concrete beams in the FEMAP software environment provides a detailed understanding of stresses in concrete and reinforcement under various damage scenarios. It enables the analysis of displacements based on damage parameters, revealing the impact of the compressed zone on the reinforced concrete beam. Each centimeter of damage is found to reduce the effective working height of the concrete, and its bearing capacity, and alter the inclination of the neutral axis.

3. Modeling proves effective in assessing the impact of damage and defects on elements within existing building structures under load.

4. It is emphasized that this study is not exhaustive and requires further refinement, including the comparison of theoretical results with experimental data, to enhance its completeness and reliability.

Prospects for further research

The efficacy of the FEM method, coupled with these findings, introduces fresh possibilities for engineers and researchers and forms a foundation for advancing techniques in calculating loaded reinforced concrete elements using cutting-edge finite element modeling technologies.

References

Voskobiinyk, O. P. (2010). Typological comparison of defects and damage of reinforced concrete, metal and steel-reinforced concrete beam structures. *Theory and building practice*, 662, 97–103. https://ena.lpnu.ua/handle/ntb/6747

Voskobiinyk, O. P, Kitaiev O. O., Makarenko Ya. V., & Buhaienko Ye. S. (2011). Experimental investigation of reinforced concrete beams with defects and damages that cause the skew bending. *Industrial Machine Building, Civil Engineering: academic journal*, 1(29), 87–92. http://reposit.pntu.edu.ua/handle/PoltNTU/8074

Mykhalevskyi N. A., Vegera P. I., & Blikharskyi Z. Y. (2023). The influence of damage to reinforced concrete beams on strength and deformability: the review. *Theory and Building Practice*, 5(1), 112–119. https://doi.org/10.23939/jtbp2023.01.112

Lobodanov, M., Vegera, P., & Blikharskyy, Z. (2021). Determination of the bearing capacity of reinforced concrete beams with damage under load. *Science & Construction*, 26(4):26–32 https://doi.org/10.33644/scienceandconstruction.v26i4.3

Klymenko Ye. V., & Polianskyi K. V. (2019). Experimental investigation of the stress-strain state of damaged reinforced concrete beams. *Bulletin of the Odessa State Academy of Civil Engineering and Architecture*, 76, 24–30. https://doi.org/10.31650/2415-377X-2019-76-24-30

Blikharskyy, Y., Vashkevych, R., Kopiika, N., Bobalo, T., & Blikharskyy, Z. (2021). Calculation residual strength of reinforced concrete beams with damages, which occurred during loading. IOP Conf. Ser.: Mater. Sci. Eng. 1021, 012012. http://dx.doi.org/10.1088/1757-899X/1021/1/012012

Klymenko Y., Kos Z., Grynyova I., and Polianskyi K. (2021). Investigation of Residual Bearing Capacity of Inclined Sections of Damaged Reinforced Concrete Beams. *Croatian Regional Development Journal*, 1 (1), 14–26. https://doi.org/10.2478/crdj-2021-0002

Pavlikov A. M., Harkava O. V., Hasenko A. V., & Andriiets K. I. (2019). Comparative analysis of numerical simulation results of work of biaxially bended reinforced concrete beams with experimental data. Building construction: *Bulletin of the Odessa State Academy of Civil Engineering and Architecture*, 77, 84–92. https://doi.org/10.31650/2415-377X-2019-77-84-92

Klymenko Ye. V., Antoniuk N. R., & Polianskyi K. V. (2019). Modeling the work of damaged reinforced concrete beams in the SC “LIRA-SAPR”. *Bulletin of the Odessa State Academy of Construction and Architecture*, 77, 58–65. http://dx.doi.org/10.31650/2415-377X-2019-77-58-65

Mykhalevskyi N. A., Vegera P. I., & Blikharskyy Z. Y. (2023). Analysis of the effect of uneven damage of reinforced concrete beam using the FEMAP software package. *Modern construction and architecture*, 6, 54–61. http://visnyk-odaba.org.ua/2023-06/6-6.pdf

Kos, Z., Klymenko, Y., Karpiuk, I., & Grynyova, I. (2022). Bearing Capacity near Support Areas of Continuous Reinforced Concrete Beams and High Grillages. *Appl. Sci.*, 12, 685. https://doi.org/10.3390/app12020685

Shakhmov, Zh., Amir, S. (2022). Nonlinear calculation of beam reinforcement using the finite element method. *Technobius*, 2(1), 0011. https://doi.org/10.54355/tbus/2.1.2022.0011

Barabash, M. (2018). Some aspects of modelling nonlinear behaviour of reinforced concrete. *Strength of Materials and Theory of Structures*, 100, 164–171. http://nbuv.gov.ua/UJRN/omts_2018_100_15

Gorodetsky, D., & Romashkina, M. (2023). Nonlinearity in LIRA-CAD. Retrieved from https://help.liraland.com/uk-ua/high-technology-innovations/nonlinearity-in-lira-sapr.html?sphrase_id=22531

Gorodetskyi A., & Barabash M. (2022). Taking into account the non-linear operation of reinforced concrete in PC LIRA-CAD. “Engineering nonlinearity” method. Retrieved from https://help.liraland.com/uk-ua/high-technology-innovations/method-engineering-nonlinearity.html?sphrase_id=22531

В. М. Дейнека, П. І. Вегера, З. Я. Бліхарський
Національний університет “Львівська політехніка”,
кафедра будівельних конструкцій і мостів,

МОДЕЛЮВАННЯ ТА АНАЛІЗ ВПЛИВУ НЕРІВНОМІРНОГО ПОШКОДЖЕННЯ ЗАЛІЗОБЕТОННОЇ БАЛКИ В “ЛІРА-САПР”

У багатьох конструкціях і будівлях залізобетонні елементи під час експлуатації зазнають різноманітних пошкоджень і дефектів. У статті висвітлено результати теоретичних досліджень нерівномірно пошкоджених залізобетонних балок із використанням програмного комплексу “ЛІРА-САПР”. Причини виникнення дефектів і пошкоджень різноманітні, вони пов’язані із зовнішніми факторами навколишнього середовища, механічними впливами, агресивним середовищем і навіть вибухонебезпечними явищами. Мета цього дослідження – детальне вивчення наслідків виникнення нерегулярних пошкоджень у залізобетонних балках, що має важливе практичне значення для майбутніх оцінок залишкової несучої здатності та визначення напружено-деформованого стану в залізобетонних елементах. Для полегшення виконання цих теоретичних запитів використано моделювання кінцевих елементів у програмному комплексі “ЛІРА-САПР”. Моделювання охоплювало різні типи пошкоджень з аналізом напружень бетону та арматури за допомогою методу скінченних елементів (МСЕ), надійного числового підходу для вирішення інженерних проблем. За допомогою результатів моделювання ми зіставили рівні напружень із граничними значеннями напружень, з’ясувавши деформативність нерівномірно пошкоджених залізобетонних балок. Теоретичні висновки, безцінні для перспективних практичних експериментів, мають практичне значення для вибору оптимальних методик розрахунку залишкової несучої здатності залізобетонних елементів. Важливість дослідження полягає в його потенціалі для підвищення безпеки будівельних конструкцій, зниження ризиків на етапі експлуатації. Ефективність методу МСЕ у поєднанні з цими висновками відкриває нові можливості для інженерів і дослідників і формує основу для вдосконалення методів розрахунку навантажених залізобетонних елементів із використанням передових технологій моделювання кінцевих елементів.

Ключові слова: нерівномірне пошкодження; залізобетонна балка; ЛІРА-САПР; МСЕ; нелінійність; деформативність.