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The constructive nonlinearity of a self-stressing steel-reinforced concrete overlapping during uneven deformations of adjacent columns basis

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Constructive nonlinearity during building structures' calculation takes into account the change in the free body diagram of their operation. One of the cases of structurally nonlinear work of steel-reinforced concrete overlapping structures is possible uneven deformation of building transverse frame adjacent columns basis. In the course of setting research objectives, was formulated eight conditions of structurally nonlinear operation of steel-reinforced-concrete overlapping beams, distinguished by uneven subsidence of the building's transverse frame outermost or middle columns and rigid or hinged junctions connecting the overlapping beams to the columns. Also, for each of the mentioned combinations of column subsidence and types of beam-to-column connection nodes, the effect of installing braces under the main overlapping beams, deformed by their weight, was investigated. The calculation of two or more nonlinear systems with specified boundary conditions is performed using numerical methods of finite element modelling, implemented in the Software Package Femap 2020.2 with NX Nastran

Keywords: steel-reinforced concrete overlapping, uneven base deformations, constructive nonlinearity

Конструктивна нелінійність самонапруженого сталезалізобетонного перекриття при нерівномірних деформаціях основ суміжних колон

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Врахування зміни розрахункових схем роботи сталезалізобетонних конструкцій під час їх експлуатації при зміні навантаження на них дозволяє виявляти фактичні резерви несучої здатності та забезпечувати конструктивну безпеку будівлі. Зміну розрахункової схеми роботи будівельних конструкцій серед широкого кола розв'язків задач в нелінійній постановці враховує конструктивна нелінійність. Одним із випадків конструктивно нелінійної роботи експлуатованих сталезалізобетонних конструкцій перекриття є можливі нерівномірні деформації основ суміжних колон поперечної рами будівлі. Цей випадок може виникати при нерівномірному (фрагментальному) корисному навантаженні на перекриття багатоповерхових виробничих будівель і, як наслідок, різних опорних реакцій, що передаються з балок перекриттів на колону і далі на фундамент та основу. У ході постановки задач досліджень сформульовано вісім умов конструктивно нелінійної роботи балок сталезалізобетонного перекриття, що відрізнялися нерівномірним просіданням крайньої чи середньої колон поперечної рами будівлі та жорсткими чи шарнірними вузлами примикання балок перекриття до колон. Також для кожної із зазначених комбінацій просідань колон та типів вузлів примикання балок до колон досліджено вплив встановлення підкосів під деформовані від власної ваги головні балки перекриття. Граничні значення деформацій основ прийняті з таблиці А.1 ДБН В.2.1-10:2018. Розрахунок дво- та більше нелінійних систем із заданими граничними умовами виконані за допомогою чисельних методів скінченно-елементного моделювання, реалізованих в програмному комплексі Software Package Femap 2020.2 with NX Nastran. Під час аналізу конструктивно нелінійної роботи сталезалізобетонного перекриття при нерівномірних просіданнях основ суміжних колон встановлено, що неврахування зазору між підкосами підсилення та сталевими балками перекриття, влаштованими по розрізній схемі завищують розрахункові значення згинаючого моменту до 56%, а при нерозрізній схемі балок – до 54%. Відповідно величину стріли прогину таке неврахування завищує у 2,14 рази при розрізній схемі балок та до 38% при нерозрізній схемі

Ключові слова: сталезалізобетонне перекриття, нерівномірні деформації основ, конструктивна нелінійність

Introduction

Considering the change in the calculation schemes of steel-reinforced concrete structures work during their construction and operation when the load on them changes makes it possible to identify the actual reserves of bearing capacity and ensure the structural safety of the building [6]. Structural nonlinearity takes into account the change in the calculation scheme of building structures work among a wide range of solutions to problems in a nonlinear formulation [2]. One of the cases of structurally nonlinear work of steel-reinforced concrete overlapping structures is possible uneven deformation of building transverse frame adjacent columns basis [14, 15]. This case can occur with an uneven (fragmentary) payload on the multi-story industrial buildings overlapping and, as a result, various support reactions transmitted from the overlapping beams to the column and further to the foundations and basis [5].

Review of the research sources and publications

Structurally nonlinear problems are often encountered during the calculation of building structures interacting with the soil massif. The nonlinear system "structure - soil massif" occurs due to possible violations of the contact between the structure and the soil massif in the deformation process (especially for flexible structures) [3]. Nonlinear calculations performed during the analysis of changes in the stress-strain state of the "deformed building - pile foundation - basis" system showed [13], that the creation (as a strengthening works result) of the slab-pile foundation largely removes the uneven nature of the stress distribution and brings it closer to the design state. In work [10], the behavior of the concrete structure of the foundation with the basis considered. The performed nonlinear analysis made it possible to record the change in the concrete foundation stiffness after cracks formation and simulate its destruction.

The described nonlinear problems can be solved performing numerical analysis of finite element models implemented using computer programs [9; 11]. A detailed consideration of such finite element models creating features is presented in [1] using the example of the "base – vibro-reinforced soil-cement pile" system.

Definition of unsolved aspects of the problem

In analyzed works a structurally nonlinear calculation of building structures (foundations) that are in direct contact with the basis performed. At the same time, no attention paid to how the structurally nonlinear foundations' work affects the supporting structures of building frame located above.

Problem statement

The purpose of the work is to study the constructively nonlinear work of self-stressed steel-reinforced concrete overlapping steel beams with uneven deformations of the building frame adjacent columns' foundations. For a graphic justification of the purpose of the work, it is first necessary to formulate the conditions of structurally nonlinear work of steel-reinforced concrete overlapping beams by depicting the change in the calculation scheme of their work and then model these calculation schemes by creating their finite element models in the software complex.

Basic material and results

A general description of the building's architectural and structural solutions. Figure 1 schematically shows a cross-section of the analyzed three-span three-story industrial building. The building has a steel load-bearing frame of frame-ligature type. The spans of the building are equal to 6 m. Steel columns and beams of the building frame are made of rolled I-beams. Interfloor overlapping consists of a monolithic reinforced concrete slab 120 mm thick, arranged on the construction site on a fixed formwork of profiled flooring. Steel beams of the building frame serve as overlapping load-bearing structures.

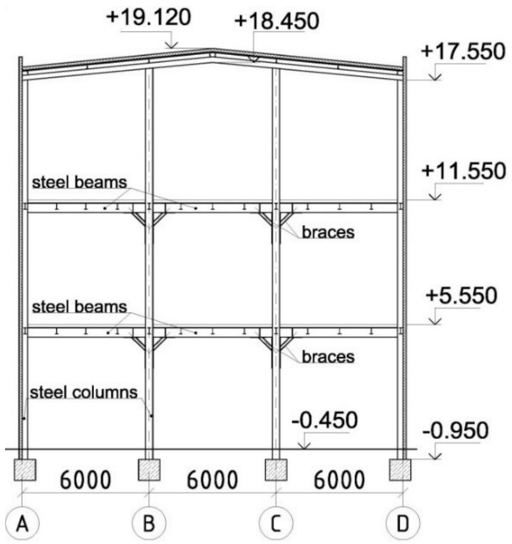
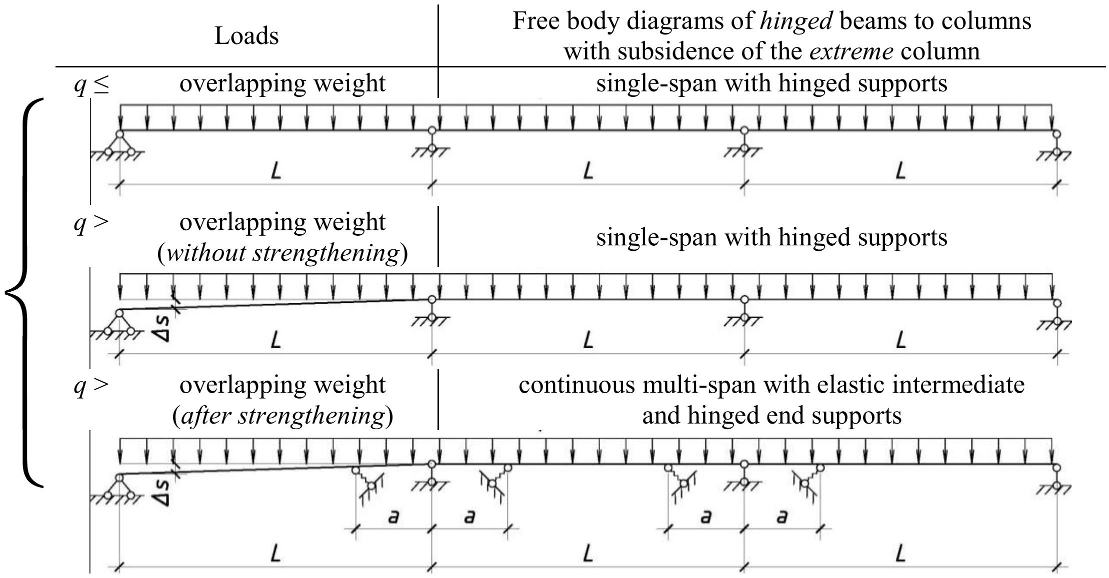


Figure 1 – Schematic cross-section of a three-span three-story building

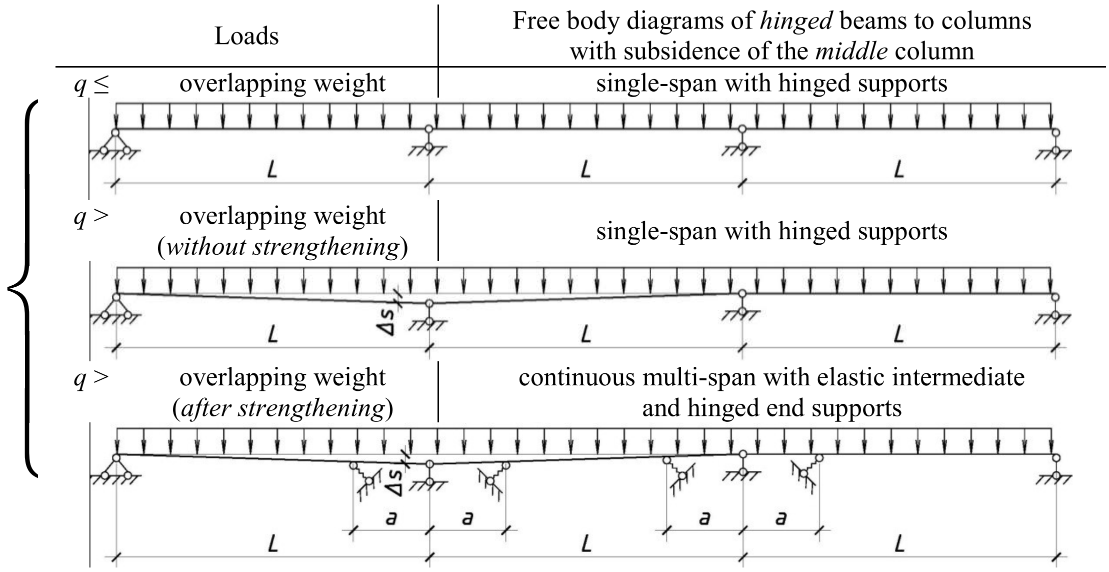
During the installation of a monolithic steel-reinforced concrete overlapping, measures provided for its self-stressing [8; 12]. These measures included either the installation of temporary stands under the overlapping steel beams during the concreting of the monolithic overlapping shelf or the installation of braces under the steel beams deformed by the self-weight of the steel-reinforced concrete overlapping. The last specified measure of overlapping self-stressing causes structurally nonlinear work of overlapping steel beams, which will be taken into account below when drawing up the boundary conditions of their work.

The conditions of structurally nonlinear work of steel-reinforced concrete overlapping steel beams formulation. We will write down the specified conditions for cases of uneven subsidence of the extreme or middle columns of the building transverse frame and rigid or hinged junctions of beams to columns. Also, for each of indicated combinations of column subsidence and types of nodes connecting beams to columns, we will investigate the effect of installing braces under the main overlapping beams deformed by their weight to increase its bearing capacity.

Let's depict a three-span scheme of beams according to the accepted cross-section of the building in Figure 1. With the hinged scheme of connecting the overlapping beams to the columns prior to the installation of braces under the beams, the uneven columns subsidence will not affect the change in internal forces in the overlapping beams, since the latter work according to the one-span split scheme (see the second scheme of conditions 1 and 2). After the arrangement of braces to strengthen the overlapping beams and increase the payload, the beams will work according to two or three span schemes, respectively, for the extreme or middle spans with one support shifted (see the third scheme of conditions 1 and 2). In this case, uneven deformations of adjacent columns bases will affect both the change in the calculation scheme of the beams work and the change in the internal forces in it.



(1)



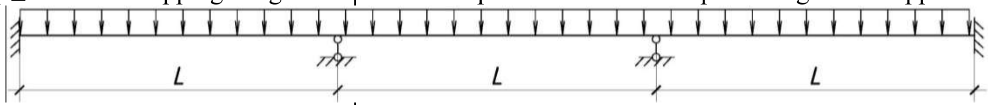
(2)

With rigid junctions connecting beams to columns, the beams will work according to an inseparable multi-span scheme. Uneven column subsidence will affect the stressed-deformed state of the beams in any case (without and with reinforcement braces). However, in the case of installed reinforcement braces, the beam will have a greater number of spans with reduced length, which will likely reduce the calculated values of internal forces in the beams. For the specified conditions, the stages of overlapping steel beams work when the load increases depicted by the systems of boundary conditions 3 and 4. In these conditions, the extreme supports should be considered yieldingly stiff, since for the accuracy of the calculations it is necessary to consider the actual bending stiffness of the columns.

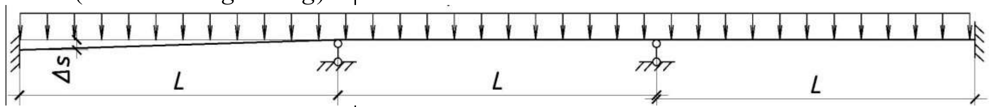
Table 1 provides a complete list of the accepted numbering of the performed calculations considering the uneven subsidence of adjacent columns. The evenly distributed load applied to the beams is equal to the sum of the overlapping structures' weight and the payload.

Limit values of deformations of the bases of adjacent columns in the industrial multi-story building with a steel frame and monolithic reinforced concrete overlapping according to Table A.1 of Appendix A of the State Standards B.2.1-10:2018 [4] are equal to $(\Delta s)_u = 0.005 \cdot L = 0.005 \cdot 6000 = 30$ mm.

Loads		Free body diagrams of *rigidly* beams to columns with subsidence of the *extreme* column
$q \leq$	overlapping weight	three-span continuous with pliable rigid end supports

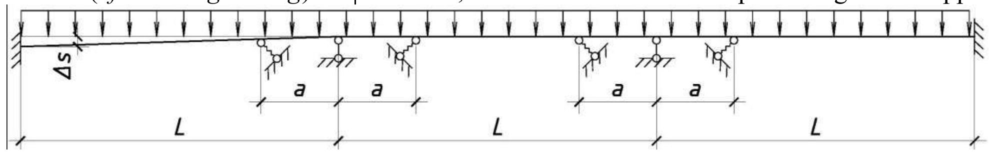


$q >$	overlapping weight (*without strengthening*)	three-span continuous with pliable rigid end supports

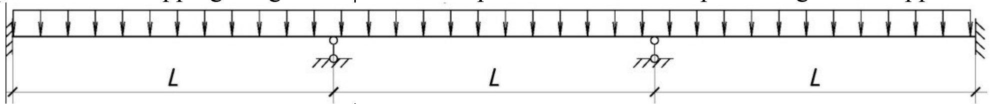


(3)

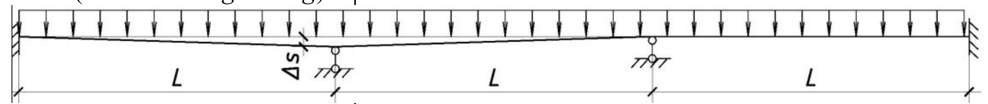
$q >$	overlapping weight (*after strengthening*)	multi-span continuous with hinged supports on the middle columns, elastic on the braces and pliable rigid end supports



Loads		Free body diagrams of *rigidly* beams to columns with subsidence of the *middle* column
$q \leq$	overlapping weight	three-span continuous with pliable rigid end supports



$q >$	overlapping weight (*without strengthening*)	three-span continuous with pliable rigid end supports



(4)

$q >$	overlapping weight (*after strengthening*)	multi-span continuous with hinged supports on the middle columns, elastic on the braces and pliable rigid end supports

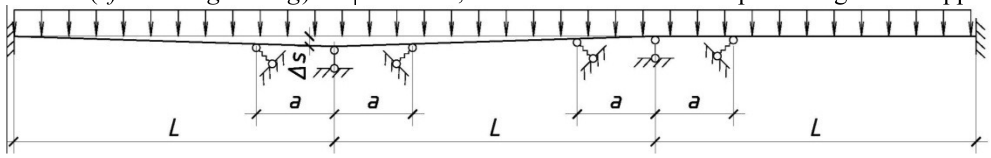


Table 1 – Numbering of the performed calculations considering the structurally nonlinear work of the steel-reinforced concrete overlapping beams with uneven subsidence of adjacent columns foundations

The type of nodes connecting beams to columns	Settlement of one column in the three-span calculation scheme (see Fig. 1):		
	without strengthening the main overlapping beams	with reinforcement of the main floor beams by installing braces	
		without considering the deformed state of the beams	considering the deformed state of the main beams – setting the initial gap between the braces and beams, which is equal to the deflections of the steel beams due to the overlapping weight
settlement of the middle column by Δs = 30 mm			
hinged	C.2.1	C.2.2.1	C.2.2.2
rigid	D.2.1	D.2.2.1	D.2.2.2
settlement of the extreme column by Δs = 30 mm			
hinged	E.2.1	E.2.2.1	E.2.2.2
rigid	F.2.1	F.2.2.1	F.2.2.2

Description of the numerical method used for solving nonlinear systems. Calculation of two or more nonlinear systems with given boundary conditions (1) ... (4) is a more difficult task compared to solving equations in a linear formulation. In this case, it is necessary to consider the deformed state of the beams to "timely" switch to the next calculation scheme of their operation. It also leads to the rejection of the forces' independence principle. It is necessary to use special methods of finding and analyzing solutions, which are specific to the solution of constructively nonlinear problems. As a rule, it is not possible to obtain an analytical solution to the problem under such described initial conditions. Therefore, the calculations were performed using the numerical method of finite element modeling, realized in Software Package Femap 2020.2 with NX Nastran (was used Trial Version Siemens Digital Industries Software with a personal activation code 2827301401535961). This method uses the procedure of successive approximations based on the linearization of nonlinear equations. That is, the search for a solution to two or more nonlinear equations is carried out by solving a recurrent sequence (a certain number in a given sequence) of linear equations. The enlarged algorithm for creating and analyzing finite element calculation models in the Software Package Femap 2020.2, considering structural nonlinearity, is shown in Figure 2.

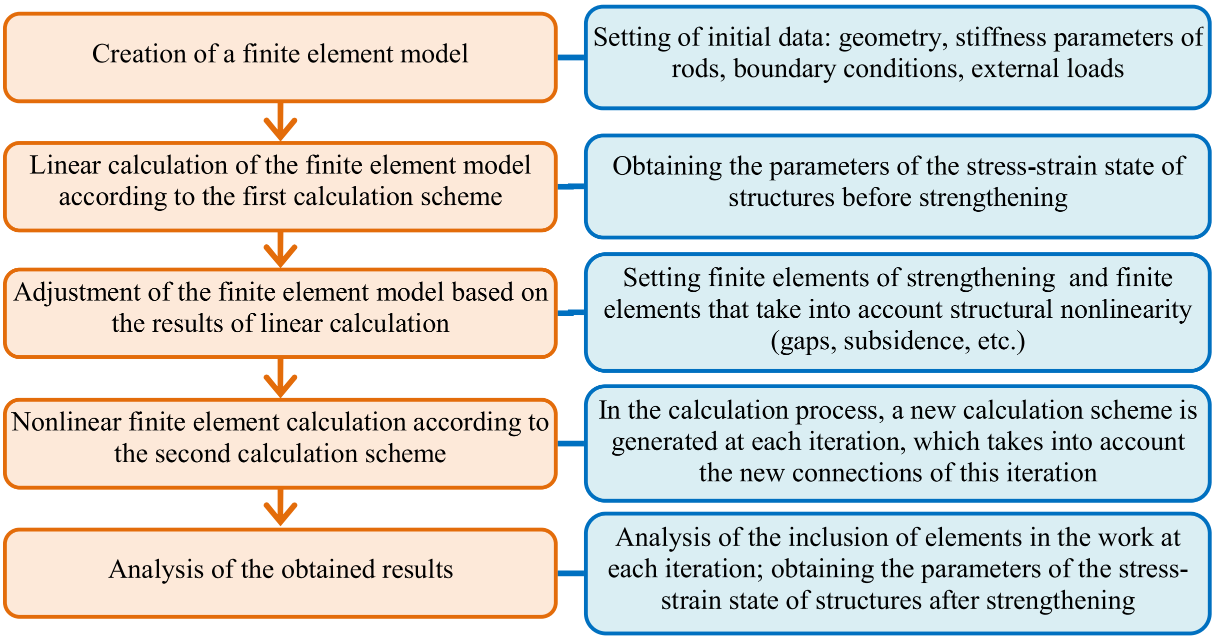


Figure 2 – Enlarged algorithm for creating and analysing finite element calculation models in the Software Package Femap 2020.2, considering structural nonlinearity

The basis of the nonlinear calculation apparatus of the used finite element modeling software complex is the step-iterative Newton-Raphson method. When solving problems by this method, at each step of the calculation, an iterative correction is determined based on the deviation of nodal internal forces with an adjustment of the linearized stiffness matrix at each iteration. At the same time, in the settings of the calculation characteristics, it is possible to set both the desired number of steps (iterations) and the desired accuracy of the solution. The basic equation of the calculation apparatus of this method has the form:

$$\left[K(u)\right]\{u\}=\{F\}, \tag{5}$$

where $\left[K(u)\right]$ – the stiffness matrix, which is recalculated at each step, taking into account physical, geometric and structural nonlinearities;

$\{u\}$ – matrix of nodal movements;

$\{F\}$ – matrix of nodal internal forces.

On the graphic interpretations of the course of the used step-iterative Newton-Raphson calculation method, automatically built by the calculation block of the program, a nonlinear increase in the load on steel beams during the settlement of individual columns and the inclusion of reinforcement braces in the work of the transverse frame traced.

Calculation results. Figures 3 and 4 show diagrams of bending moments along the length of steel reinforced beams of a steel-reinforced concrete overlapping with uneven subsidence of the middle or extreme columns and hinged or rigid junctions of the overlapping beams to the columns. In Tables 2 and 3, for ease of comparison, all the calculations results, considering structural nonlinearity, for the various analyzed settlement schemes of adjacent columns are collected (maximum values of internal forces - bending moment - in the extreme and middle spans, including over the supports, and deflection arrows in the extreme and medium spans).

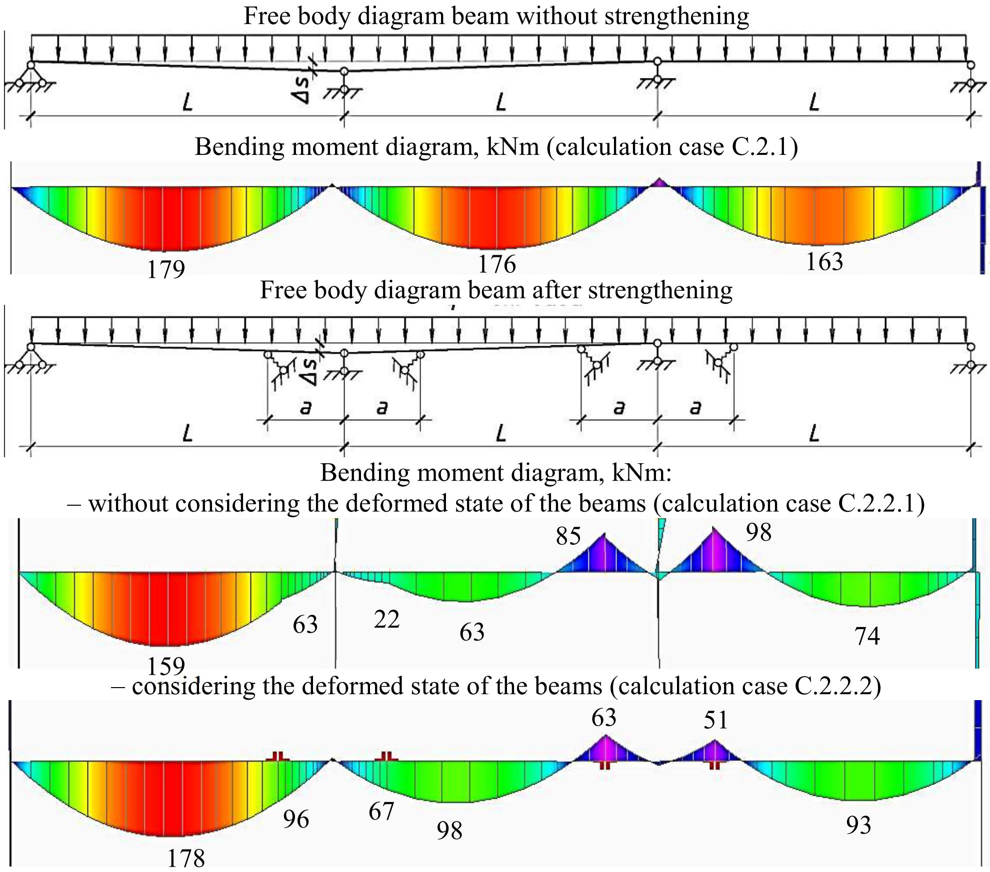


Figure 3 – The results of constructively nonlinear calculation of hinged beams

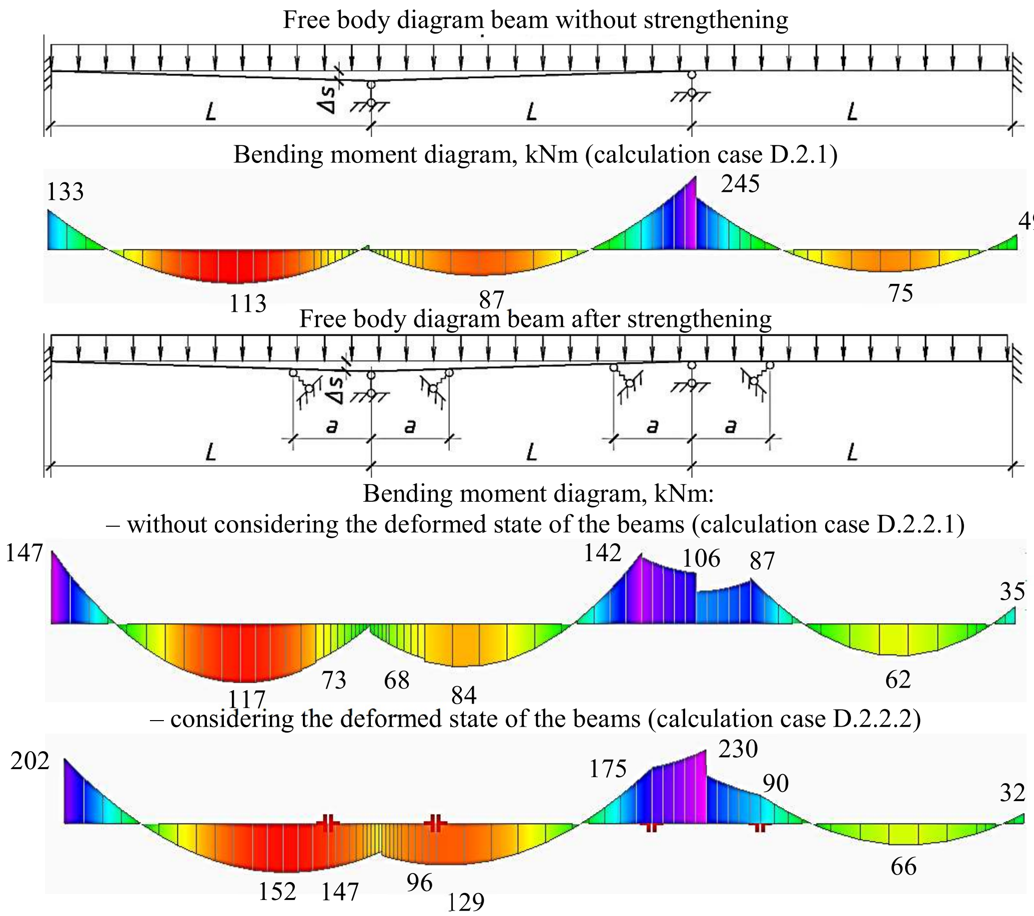


Figure 4 – The results of constructively nonlinear calculation of rigidly fixed beams

Table 2 – Maximum internal forces and deflections of steel-reinforced concrete overlapping beams cross-sections *at the hinged nodes* of beams to columns

Calculation case (see adopted numbering)	Bending moment M, kNm				Maximum deflection, mm	
	extreme span		middle span		extreme span	middle span
	span	above the brace	span	above the brace		
Settlement of the middle column by Δs = 30 mm						
C.2.1	179	97	176	94	35,2	34,8
C.2.2.1	159	63	63	22	33,5	23,3
C.2.2.2	178	96	98	67	32,0	23,2
Comparison of changes in internal forces and deflections						
a type of comparison	the ratio of the analyzed factors					
$\Delta_{C.2.2.2 / C.2.1}$	**0,99**	0,99	**0,56**	0,71	0,91	0,67
$\Delta_{C.2.2.2 / C.2.2.1}$	**1,12**	1,52	**1,56**	3,05	0,96	1,00
Settlement of the extreme column by Δs = 30 mm						
D.2.1	179	97	176	94	34,8	11,5
D.2.2.1	67	-178	44	-110	20,1	2,5
D.2.2.2	97	-61	95	-20	27,8	6,1
Comparison of changes in internal forces and deflections						
a type of comparison	the ratio of the analyzed factors					
$\Delta_{D.2.2.2 / D.2.1}$	**0,54**		**0,54**		0,80	0,53
$\Delta_{D.2.2.2 / D.2.2.1}$	**1,45**		**2,16**		1,38	2,44

Table 3 – Maximum internal forces and deflections of steel-reinforced concrete overlapping beams cross-sections *at the rigid nodes* of beams to columns

Calculation case (see adopted numbering)	Bending moment M, kNm				Maximum deflection, mm	
	extreme span		middle span		extreme span	middle span
	span	above the brace	span	above the brace		
Settlement of the middle column by Δs = 30 mm						
E.2.1	113	92	87	69	31,5	26,8
E.2.2.1	117	73	84	68	31,5	22,4
E.2.2.2	152	147	129	129	29,8	22,6
Comparison of changes in internal forces and deflections						
a type of comparison	the ratio of the analyzed factors					
$\Delta_{E.2.2.2 / E.2.1}$	**1,35**	1,60	**1,48**	1,87	0,95	0,84
$\Delta_{E.2.2.2 / E.2.2.1}$	**1,30**	2,01	**1,54**	1,90	0,95	1,01
Settlement of the extreme column by Δs = 30 mm						
F.2.1	84	88	55	67	25,0	3,6
F.2.2.1	73	125	38	91	24,5	2,1
F.2.2.2	79	145	52	99	20,5	2,9
Comparison of changes in internal forces and deflections						
a type of comparison	the ratio of the analyzed factors					
$\Delta_{F.2.2.2 / F.2.1}$	**0,94**	1,65	**0,95**	1,48	0,82	0,81
$\Delta_{F.2.2.2 / F.2.2.1}$	**1,08**	1,16	**1,37**	1,09	0,84	1,38

Conclusions

During the analysis of structurally nonlinear work of a reinforced concrete overlapping with uneven subsidence of the foundations of adjacent columns, it was established that the failure to consider the gap between the braces and the overlapping hinged single-span beams overestimates the calculated values of the bending moment up to 56%, and continuous beams – up to 54%. Accordingly, this disregard increases the value of the maximum deflection by 2.14 times in the case of a hinged single-span beam and up to 38% in the case of continuous beams.

References

1. Гасенко А.В., Новицький О.П., Рожко В.Н. (2017). Особливості створення скінченно-елементної моделі системи «основа – віброармована ґрунто-цементна паля». *Зб. наук. пр. УкрДУЗТ, 167,* 34-41
2. Гуслиста Г.Е. (2011). Дослідження нелінійної поведінки системи «споруда–ґрунтовий масив» при розрахунку залізобетонних конструкцій, що взаємодіють з ґрунтом. *Зб. наук. пр. НДІБК: Будівельні конструкції*
3. Гуслиста Г.Е., Банніков Д.О. (2011) Оцінка важливості врахування нелінійних властивостей системи «Споруда–ґрунтовий масив» при визначенні її напружено-деформованого стану. *Вісник ДНУЗТ*, 155-160
4. ДБН В.2.1-10:2018 (2018). *Основи і фундаменти будівель та споруд. Основні положення.* Київ: Мінрегіонального розвитку, будівництва та житлово-комунального господарства України
5. Кушнер С.Г. (2008). *Розрахунок деформацій основ будівель та споруд.* Запоріжжя: «ВПО Запоріжжя»
6. Стороженко Л.І., Сурдін В.М., Єфіменко,В.І., Вербицький В.І. (2007). *Сталезалізобетонні конструкції: дослідження, проектування, будівництво, експлуатація.* Кривий Ріг
7. EN 1990:2002/A1:2005/AC (2010). *Eurocode: Basis of Structural Design.* The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC
8. Hasenko A.V. (2021). Deformability of bends continuous three-span preliminary self-stressed steel concrete slabs. *Industrial Machine Building, Civil Eng.*, *1* (56), 135-141 https://doi.org/10.26906/znp.2021.56.2518
9. Hasenko A.V. & Novytskyi O.P. (2018). Numerical experiment for the determination of the stress-strain condition of the system "Basis – Vibroreinforced soil-cement pile". *Intern. Journal of Engineering & Technology, 7*(4.8), 41-47 https://doi.org/10.14419/ijet.v7i4.8.27211
10. Hrubesova E., Mohyla M., Lahuta H., Bui T.Q. & Nguyen P.D. (2018). Experimental analysis of stresses in subsoil below a rectangular fiber concrete slab. *Sustainability, 10,* 7, art. no. 2216
11. Kozielova M., Marcalikova Z., Mateckova P. & Sucharda O. (2020). Numerical analysis of reinforced concrete slab with subsoil. *Civil and Environmental Engineering*, *16*(1), 107-118 https://doi.org/10.2478/cee-2020-0011
12. Semko O.V. & Hasenko A.V. (2021). Self-stressed steel-reinforced concrete floor slab stress-strain state numerical analysis taking into account the concreting stages. *IOP Conf. Series: Materials Science and Engineering, 1141*, 7 https://doi.org/10.1088/1757-899X/1141/1/012043
13. Vynnykov Yu.L., Kharchenko M.O. & Manzhalii S. (2020). Stress strained state change in the «deformed building – pile foundation – base» system resulting from supplying the slab under the grilles. *Industrial Machine Building, Civil Eng.*, *1 (54)*, 61-72 https://doi.org/10.26906/znp.2020.54.2271
14. Zotsenko M.L. & Vynnykov Yu.L. (2016). Long-term settlement of buildings erected on driven cast-in-situ piles in loess soil. *Soil Mechanics and Foundation Engineering, 53(3)*, 189-195 https://doi.org/10.1007/s11204-016-9384-6
15. Zotsenko M.L., Vynnykov Yu.L., Lartseva I.I. & Sivitska S.P. (2018). Ground base deformation by circular plate peculiarities *Paper presented at the MATEC Web of Conferences,* 230 https://doi.org/10.1051/matecconf/201823002040

1. Hasenko A.V., Novytskyi O.P. & Rozhko V.N. (2017). Features of creation finite-element model of the system "basis – vibroreinforced soil-cement pile". *Coll. of science works of UkrDUZT, 167,* 34-41
2. Guslysta A.E. (2011). Study of the nonlinear behavior of the "building–soil massif" system in the calculation of reinforced concrete structures interacting with the soil. *Coll. of science works NDIBK: Building structures*
3. Guslista A.E. & Bannikov D.O. (2011) Assessment of the importance of taking into account the nonlinear properties of the "Building–soil massif" system when determining its stress-strain state. *Bulletin of the DNUZT*, 155-160
4. DBN B.2.1-10:2018 (2018). *Basis and foundations of buildings and structures. Main principles.* Kyiv: Ministry of Regional Development, Construction, and Housing of Ukraine
5. Kushner S.G. (2008). *Calculation of buildings and structures foundations deformations*. IPO Zaporizhzhya
6. Storozhenko L.I., Surdin V.M., Yefimenko V.I. & Verbytskyi V.I. (2007). *Steel-reinforced concrete structures: research, design, construction, exploitation*. Kryvyi Rih

7. EN 1990:2002/A1:2005/AC (2010). *Eurocode: Basis of Structural Design.* The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC
8. Hasenko A.V. (2021). Deformability of bends continuous three-span preliminary self-stressed steel concrete slabs. *Industrial Machine Building, Civil Eng.*, *1* (56), 135-141 https://doi.org/10.26906/znp.2021.56.2518
9. Hasenko A.V. & Novytskyi O.P. (2018). Numerical experiment for the determination of the stress-strain condition of the system "Basis – Vibroreinforced soil-cement pile". *Intern. Journal of Engineering & Technology, 7*(4.8), 41-47 https://doi.org/10.14419/ijet.v7i4.8.27211
10. Hrubesova E., Mohyla M., Lahuta H., Bui T.Q. & Nguyen P.D. (2018). Experimental analysis of stresses in subsoil below a rectangular fiber concrete slab. *Sustainability, 10,* 7, art. no. 2216
11. Kozielova M., Marcalikova Z., Mateckova P. & Sucharda O. (2020). Numerical analysis of reinforced concrete slab with subsoil. *Civil and Environmental Engineering*, *16*(1), 107-118 https://doi.org/10.2478/cee-2020-0011
12. Semko O.V. & Hasenko A.V. (2021). Self-stressed steel-reinforced concrete floor slab stress-strain state numerical analysis taking into account the concreting stages. *IOP Conf. Series: Materials Science and Engineering, 1141*, 7 https://doi.org/10.1088/1757-899X/1141/1/012043
13. Vynnykov Yu.L., Kharchenko M.O. & Manzhalii S. (2020). Stress strained state change in the «deformed building – pile foundation – base» system resulting from supplying the slab under the grilles. *Industrial Machine Building, Civil Eng.*, *1 (54)*, 61-72 https://doi.org/10.26906/znp.2020.54.2271
14. Zotsenko M.L. & Vynnykov Yu.L. (2016). Long-term settlement of buildings erected on driven cast-in-situ piles in loess soil. *Soil Mechanics and Foundation Engineering, 53(3)*, 189-195 https://doi.org/10.1007/s11204-016-9384-6
15. Zotsenko M.L., Vynnykov Yu.L., Lartseva I.I. & Sivitska S.P. (2018). Ground base deformation by circular plate peculiarities *Paper presented at the MATEC Web of Conferences,* 230 https://doi.org/10.1051/matecconf/201823002040