

INFLUENCE STIFFNESS OF SHEAR BONDS ON THE STRESS-STRAIN STATE OF MULTISTOREY BUILDINGS

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Abstract. The paper considers issues the nonlinear behavior of shear bonds affecting the changes in the distribution of stresses and strains in vertical structures, as well as to compare these stresses and strains with the linear statement of the problem solution in which the compliance of the bonds is constant.

In a complex multiconnected system of the multistory building, the new redistribution of stresses arises, which does not coincide with the original distribution of stresses. To correct the stiffness value for the bonds, the experimental data were used. A secant module was used to determine the stiffness for vertical joints. Loading was performed by the step method. At the extreme stage of loading, the redistribution of stresses in the load-bearing elements of the building showed their significant leveling. The issue of ultimate deformations of shear bonds limiting the process of redistribution of stresses and deformations requires discussion.

Keywords: multistory building, shear bonds, stiffness, nonlinear deformation, bearing system

ВЛИЯНИЕ ЖЕСТКОСТИ СВЯЗЕЙ СДВИГА НА НАПРЯЖЕННО-ДЕФОРМИРОВАННОЕ СОСТОЯНИЕ МНОГОЭТАЖНЫХ ЗДАНИЙ

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Аннотация: В работе рассмотрены вопросы нелинейного поведения сдвиговых связей, влияющих на изменение распределения напряжений и деформаций в вертикальных конструкциях, а также сопоставление этих напряжений и деформаций с линейной постановкой решения задачи, в которой податливость связей постоянна.

В сложной многосвязной системе многоэтажного здания возникает новое перераспределение напряжений, не совпадающее с первоначальным распределением напряжений. Для корректировки значения жесткости связей использовались экспериментальные данные. Модуль секущей использовался для определения жесткости вертикальных швов. Загрузка производилась ступенчатым методом. На предельной стадии нагружения перераспределение напряжений в несущих элементах здания показало их значительное нивелирование. Требуется обсуждения вопрос о предельных деформациях связей сдвига, ограничивающих процесс перераспределения напряжений и деформаций.

Ключевые слова: многоэтажные здания, связи сдвига, жесткость, нелинейная деформация, несущая система

INTRODUCTION

The bearing system of a multi-story buildings consists of vertical structures united into a spatial system by floors slabs and vertical connections with certain stiffness. Vertical shear

bonds (lintels, welded joints, floor areas) can be used as connections in a multi-story building.

Existing mathematics models of load-bearing systems of multistory buildings, in most cases, are guided by the elastic work of load-bearing elements and their connections [1-3]. In the

classical calculation models of a building the relationships between stresses and strains are specified by the Hooke elastic-linear law. However, they do not allow sufficient use of the safety margins of the entire load-bearing system or can distort the assessment of the real state of this load-bearing system of the building. The important feature of the real work of materials is the nonlinear nature of the relationship between stress and deformation of

both vertical load-bearing structures and the elements connecting them.

Deformation diagrams are used to consider the nonlinear properties of structural materials.

Proposals for concrete deformation diagrams are contained in a number of works [4-7]. Description of the diagrams of concrete deformation in compression is contained in the design standards [8,9]. Various studies are devoted to the analysis of the work of shear bonds [10-12], welded butts, vertical concrete joints [13-14].

The aim of this work is to conduct a comparative analysis of the stress-strain state multistorey building with linear and nonlinear deformation of shear bonds. The main task of the work is to establish changes in the stress-strain state of the multistorey building taking into account the experimental data work shear bonds as lintels.

METHOD

In this work, the object of the study was a 30-storey residential building made of monolithic concrete. A multistorey building with the building system is shown in Figure 1. The diagram shows 16 walls W and 14 shear bonds Shb . The building consists of 30 floors and basement and attic premises. Type B25 concrete was used, the walls 30 cm thick were connected by lintels with a cross-sectional size of 20 by 40 cm and a length of 2 m, the columns were taken as 40 by 40 cm and 40 by 6 cm.

The building was subjected to permanent, temporary and wind loads. The calculation was carried out using the ETABS software package

based on the finite element method [15-17]. For walls, a finite element of the shell type was adopted, for shear bonds - an elastic element, the stiffness of which was refined at each stage of the calculation. The maximum size of the wall finite element was 85 x 85 cm. The base of the building was assumed to be non-deformable. To correct the value of the shear modulus, the experimental deformation diagram « shear force Q - displacement Δ » [13,18] was used. A secant module was used to determine the stiffness K for shear bonds. The loading was carried out by the stepwise method (Fig. 2.).

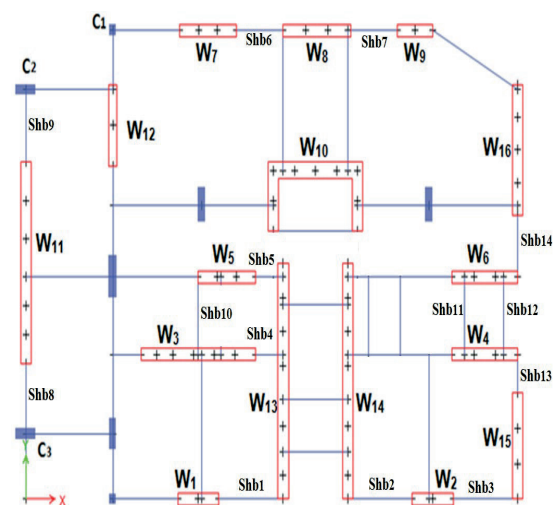


Figure 1. The design scheme of the building (communication)

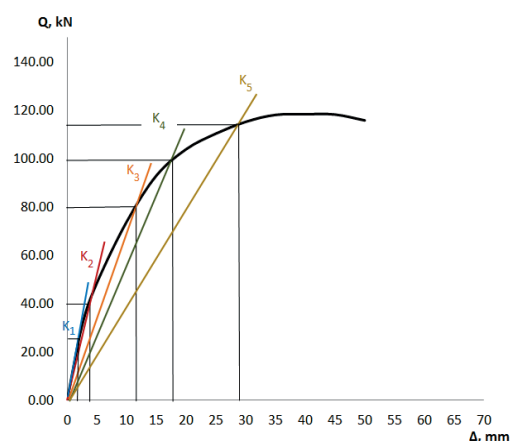


Figure 2. Experimental strain diagram deformation "Q- Δ " for shear joints

The loading was carried until hinged joint is formed in one of the shear bonds. During

loading, shear forces and corresponding deformations were recorded.

RESULTS

The initial calculation of the bearing system multistorey building with constant stiffness of

shear bonds is designated K0. The subsequent steps of changing the stiffness of the shear bonds and the corresponding recalculations of the bearing system multistorey building are designated K1 – K5.

As an example, the stress-strain state of wall W7, wall W2 and the adjacent shear bonds are shown.

Table 1. Change in maximum stresses and percentage of reinforcement in wall W7

	K0	K1	K2	K3	K4	K5
σ (kN/m²)	8881.46	9769.61	10480.13	11013.01	11457.09	11634.72
$\Delta\sigma\%$		-10.0	-7.3	-5.1	-4.0	-1.6
$\mu\%$	0.48	1.03	1.47	1.80	2.08	2.19
$\Delta\mu\%$		0.55	0.44	0.33	0.28	0.11

Table 2. Change in maximum stresses and percentage of reinforcement in wall W2

	K0	K1	K2	K3	K4	K5
σ (kN/m²)	16980.82	14773.32	13414.85	12396.00	11716.77	11207.34
$\Delta\sigma\%$		13.0	9.2	7.6	5.5	4.3
$\mu\%$	2.72	1.70	1.08	0.62	0.31	0.07
$\Delta\mu\%$		-1.01	-0.62	-0.47	-0.31	-0.23

Determination of the actual stress-strain state of structural elements of the bearing system was evaluated on the basis of comparing the results of linear and nonlinear calculations.

The maximum change in normal stresses occurred in the wall W2, W7, W10, W11, W12, W13, W14, W15. For wall W7 (Fig 3, Table 1), the difference was 33.2%, in the first case the value was 8881.46 kN / m², in the second case it was 11827.25 kN / m². For wall W2 (Fig. 4, Table 2), the difference between the calculations was -37.6%, in the first case the value is 16980.82 kN / m², in the second - 10601.57 kN / m².

For wall W8 the difference was 21.5%, in the first case the value was 9758.06 kN / m², in the second case it was 11852.45 kN / m². for wall W9 the difference was -8%, in the first case the value is 12803.33 kN / m², in the second 11774.36 kN / m². Bending moments have changed in almost all walls. For the W7 wall (Fig.5), the difference between the calculations was 37.3%, in the first case the value was 77.88 kN. m, in the second it was 106.9 kN. m, for the W8 wall the

difference was 27.1%, in the first case the value was 180.45 kN. m, in the second 229.3 kN. m, for the W9 wall the difference was 131.1%, in the first case the value was 50.27 kN. m, in the second 116.3 kN. m.

The shear forces in the shear bonds have changed. In a number of connections, efforts increased (Shb6, Shb7), in some (Shb2) – decreased.

Reinforcement of vertical construction s of the bearing system was also calculated based on a comparison of the results of linear and non-linear calculations. Of course, the maximum change in reinforcement occurred in the walls with the largest change in normal stresses, in the wall W2, W7, W10, W11, W12, W13, W14, W15, where in the first case the percentage of reinforcement in the walls W2, W12 was close to the maximum allowable percentage of reinforcement, in the second case, the minimum percentage of reinforcement 1% became less, where it changed by -2.9% and -2.16%.

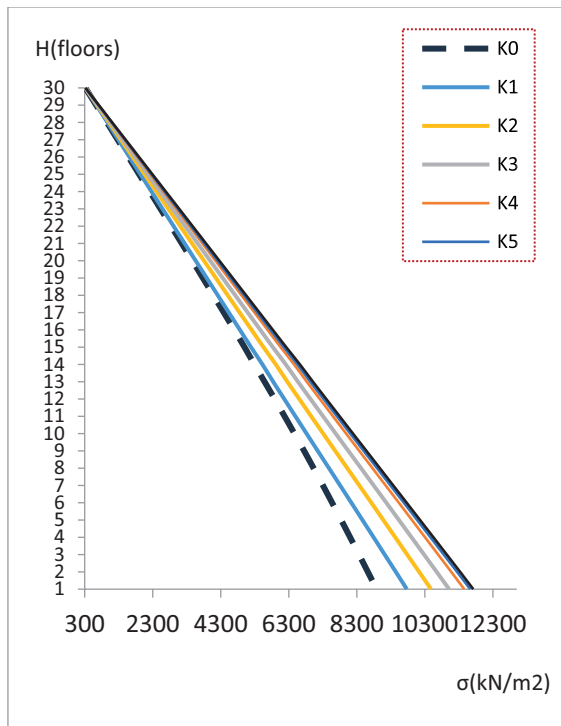


Figure 3. Changes vertical stresses in the wall (W7) depending on changes in the stiffness of shear bonds (K)

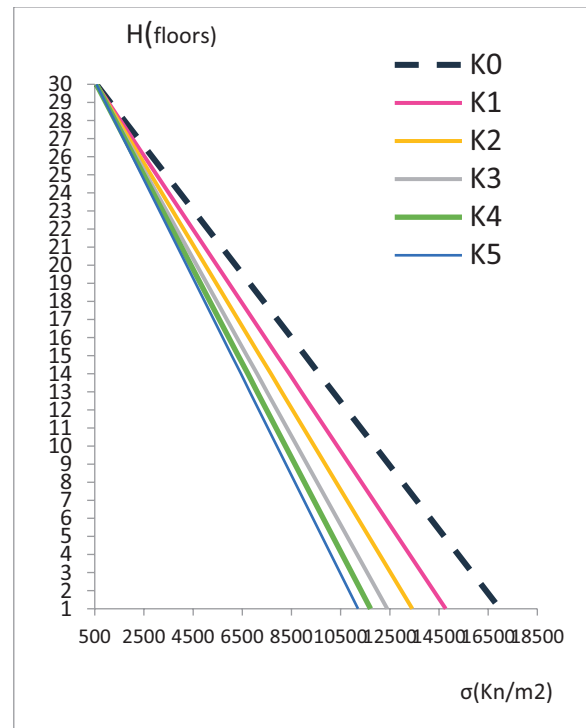


Figure 4. Changes vertical stresses in the wall (W2) depending on changes in the stiffness of shear bonds (K)

For wall W7 the difference in calculations was 1.8%, for wall W8 the difference in calculations was 1.32%, for wall W9 the difference in calculations was -0.6%, for wall W13 the difference in calculations was 2.32%, for wall W14 the difference in calculations amounted to 2.7%. This was due to a redistribution of stresses. In the process of redistribution of stresses and deformation during the nonlinear operation of shear bonds, changes occur in all load-bearing elements of a multistorey building. There is a relative equalization of stress levels in all vertical bearing structures (Fig. 6). Redistribution of stresses from more loaded elements to less loaded ones took place. To the extent that the stiffness parameters of the shear bonds allowed it. Further redistribution stresses is impossible. Shear bonds gradually reach ultimate deformations (Fig. 6). Due to the decrease in the stiffness of the shear bonds, the bending moment in the walls of the bearing system increases. There is an increase in the deflection of the bearing system the multistorey building.

CONCLUSIONS

The bearing system of multistorey buildings is experiencing a turn in the plan and a flat bend in two directions. Stress-strain state multistorey buildings are determined by position of vertical constructions in the building plan and by the stiffness characteristics walls and shear bonds.

In the bearing system, all walls and shear bonds are in a spatial interaction. They cannot be deformed and destroyed independently of other elements, their deformations are constrained by neighboring shear bonds, walls and overlaps.

When the bearing capacity of one or several elements of the bearing system is reached, the bearing capacity of the system as a whole is not exhausted. The numerical experiments carried out have shown that with an increase in the load, the stresses are redistributed in all elements of the bearing system.

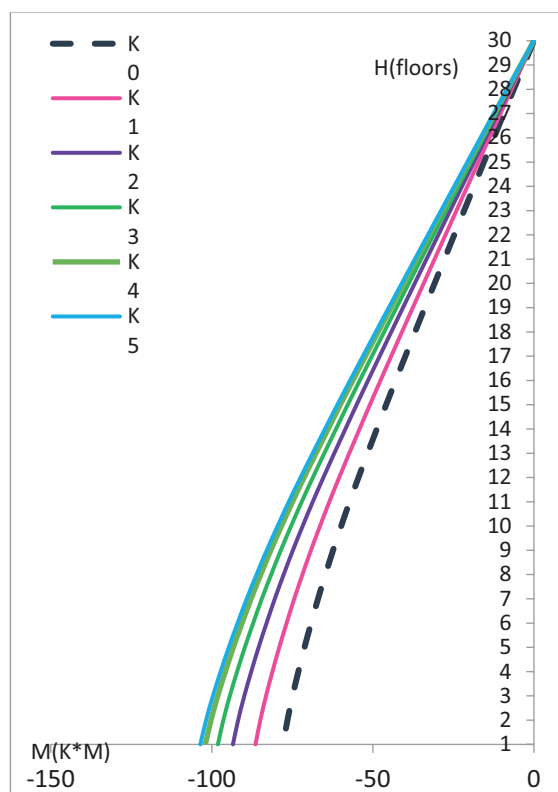


Figure 5. Changes bending moment in the wall (W7) depending on changes in the stiffness of shear bonds (K)

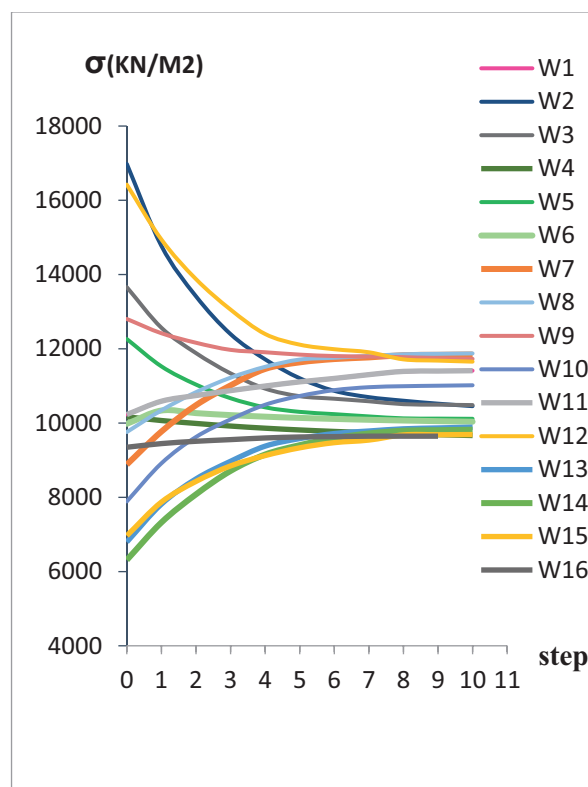


Figure 6. Changing the normal stresses in the walls W1- W16 in accordance with the change in the stiffness of the shear bonds at each step K_i

The maximum value of change in normal stresses -10% occurred in wall W7. The percentage of reinforcement increases significantly in wall W14 - 2.33%.

The spatial work of shear bonds is a mechanism for the spatial redistribution of stresses in vertical structures. The stiffness shear bonds are important for the determination of deformations and stresses in vertical bearing structures.

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