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INFLUENCE OF THE CONNECTION METHOD OF FLOOR-BY-FLOOR SUPPORTED MASONRY WALLS WITH THE SUPPORTING FLOOR ON THE CRACK RESISTANCE

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Abstract

The purpose of this article is to analyze the influence of deflections of supporting floors on the crack resistance of floor-by-floor supported masonry walls, depending on the method of their connec-tion with the reinforced concrete floor. This article shows that the deflection of the floor causes the appearance of main tensile stresses in the wall with the doorway, the maximum values of which are concentrated in the corner areas of the opening. To reduce the risk of cracks in the wall filling between the masonry and the supporting floor, it is recommended to install a separating layer of one or two layers of film material. In case of deflection of the supporting floor the separating layer allows to exclude the transfer of load to the walls, which may be caused by the adhesion of the leveling layer of mortar to the floor. It has been established that an increase of the coefficient of friction between the wall and the supporting floor leads to a decrease in the main tensile stresses in the corner area of the doorway. Therefore, when constructing a separating layer, it is not recommended to perform it at the end sections of the filling. Based on numerical studies, the dependence of the main tensile stresses in a partition with a doorway on the value of the coefficient of friction between the surfaces of the masonry and the supporting floor.

Keywords: masonry, floor-by-floor supported walls, deflection, supporting floor.

ВЛИЯНИЕ НА ТРЕЩИНОСТОЙКОСТЬ ПОЭТАЖНО ОПЕРТЫХ КАМЕННЫХ СТЕН СПОСОБА ИХ СОПРЯЖЕНИЯ С ПОДДЕРЖИВАЮЩИМ ПЕРЕКРЫТИЕМ

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Реферат

Целью данной статьи является анализ влияния прогибов поддерживающих перекрытий каменной кладки на трещиностойкость каменных стен поэтажно опертых стен в зависимости от способа их сопряжения с железобетонным перекрытием. В данной статье показано, что прогиб перекрытия вызывает в стене с дверным проемом появление главных растягивающих напряжений, максимальные значения которых концентрируются в угловых зонах проема. Для снижения риска возникновения трещин в стеновом заполнении между каменной кладкой и опорным перекрытием рекомендуется устраивать разделительный слой из одного-двух слоев пленочного материала. Разделительный слой позволяет при прогибе перекрытия исключить передачу на стены нагрузки, которая может быть обусловлена сцеплением выравнивающего слоя раствора с перекрытием. Установлено, что увеличение коэффициента трения между стеной и поддерживающим перекрытием приводит к снижению главных растягивающие напряжения в угловой зоне дверного проема. Поэтому при устройстве разделительного слоя его не рекомендуется выполнять на концевых участках заполнения. На основании численных исследований построена зависимость главных растягивающих напряжений в перегородке с дверным проемом от величины коэффициента трения между поверхностями каменной кладки и поддерживающим перекрытием.

Ключевые слова: каменная кладка, поэтажно опертые стены, прогиб, поддерживающее перекрытие.

Introduction

Modern frame buildings are erected in a short time. For this reason, floor-supported wall filling of frames in the form of internal and external walls is carried out in conditions where significant rheological deformations of reinforced concrete frame elements and uneven settlements of the foundations are possible. The wall filling of frames, as a rule, is erected on thin-layer mortar joints with a thickness of 0.5–3 mm. In terms of their homogeneity, masonry with thin-layer joints approaches monolithic unreinforced walls, which, from the point of view of crack formation, are very sensitive to uneven temperature and shrinkage deformations, local loads, uneven settlements of foundations, dynamic and other influences. As for floor-supported walls of frame buildings, practice shows that their cracking is predetermined by the deflections of the reinforced concrete floor. At the same time, technical solutions for connecting floor-by-floor supported walls with supporting floors have a significant impact on the stress-strain state of masonry and its crack resistance.

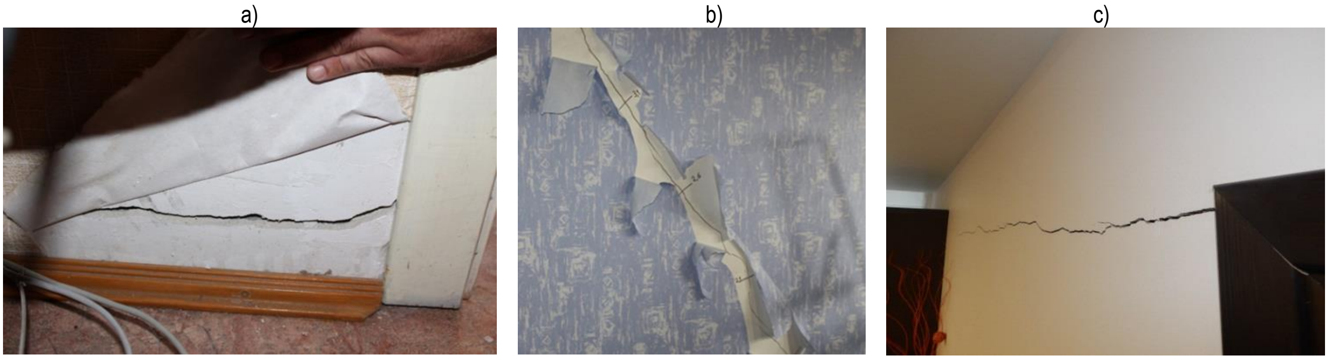
The nature of cracking in floor-by-floor supported walls during floor deflection

According to standard technical solutions [1–2], floor-by-floor supported walls and partitions should rest on the floors through a layer of M100 leveling cement mortar, and sometimes be fixed to them using tie elements in the form of reinforcing bars embedded in the masonry and supporting floor. This constructive solution for connecting the wall fence with the floor is incorrect, because it limits the deformation of the masonry in the plane of the wall caused by temperature and humidity influences, and leads to the transfer of a vertical load to the filling when the supporting floor deflects. It should be noted that there is a lack of special research concerning the nature of the load transfer from masonry walls to floors during their deflection, which led to incorrect decisions in typical albums of floor-by-floor supported walls [1–2].

After the erection of the wall filling, layers of acoustic insulation and finished floor screeds are laid on the floor, and the walls are finished. The increment of constant and variable load, after completing the specified works, will be approximately 20–25 % of its full value (80–75 % of the total value of constant and variable long-term load is the own weight of the floor and wall filling). Taking into account the creep of concrete, it can be assumed that the deflection of the floor after the erection of the walls will reach 40–50 % of the total deflection caused by the action of constant and variable long-term load, including the own weight of the floor. The increment of deflection of hollow floor slabs with a span of more than 6 m can be about 15 mm. For flat beamless slabs of frame buildings, the flexural rigidity of which is not great, this amount of deflection can be achieved with slab spans of 4.5–6 m.

When the floor deflects, the maximum values of the main tensile stresses “σ1” in masonry walls arise, as a rule, along the border of the contact zone of the masonry with the floor, and their trajectories are directed at an angle of ≈ 20º to the horizontal mortar joints [3–5]. This is explained by the fact that the flexural rigidity of the wall in its plane is significantly higher than the rigidity of the supporting floor and when the supporting floor deflects, a redistribution of contact pressure occurs between the wall and the floor, as a result, tangential and tensile stresses appear in the masonry, which can lead to the formation of cracks (Figure 1).

a) b) c)



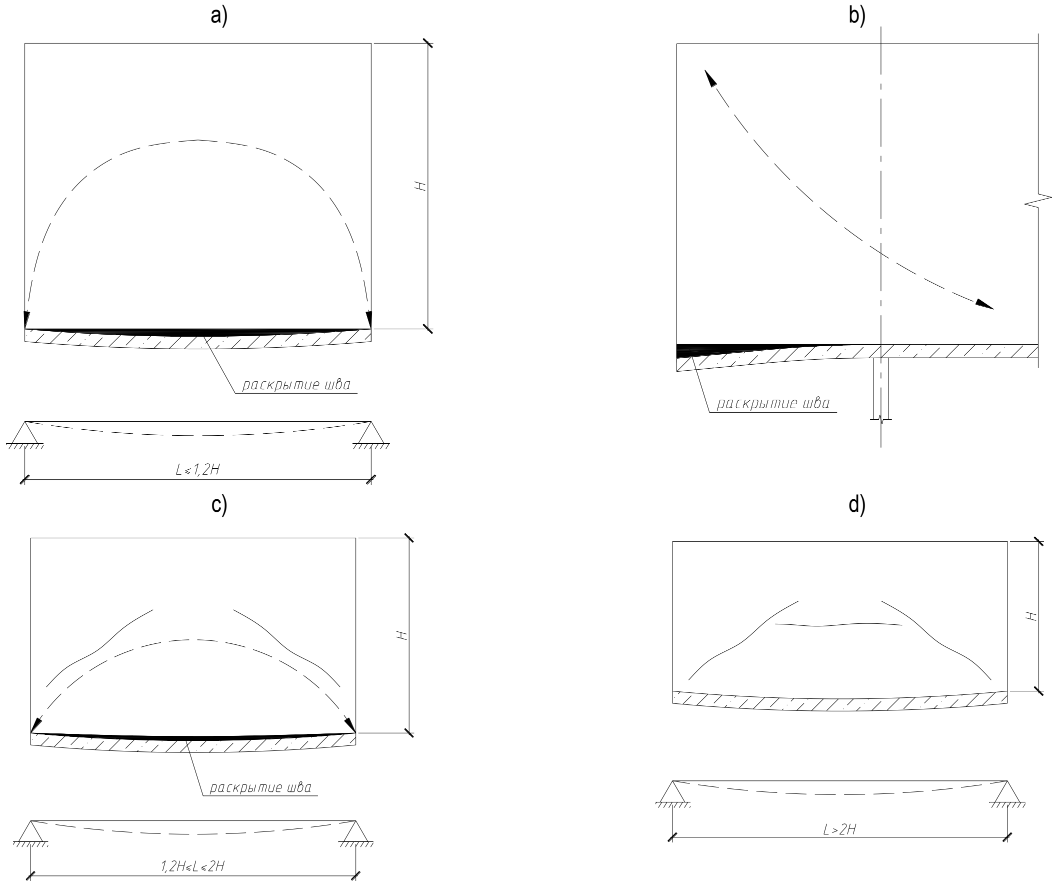
a) – longitudinal crack along the bottom of the wall; b) – an inclined crack along the body of the wall; c) − crack in the wall with a doorway
Figure 1 − The nature of the formation of cracks in the walls of a frame-monolithic building

The cracks shown in Figure 1 arose in the cellular concrete filling wall of the monolithic reinforced concrete frame of a residential building, six years after its commissioning.

Field examinations of wall filling and experimental and theoretical studies show that in case of deflection of the supporting floor various mechanisms for the formation of cracks in masonry walls can be realized [6–8].

For solid walls, the length L of which is commensurate with their height H (L/H ≤ 1.2), the opening of the joint between the wall and the supporting floor or the formation of a crack along the bottom of the wall, developing along the body of the masonry, is characteristic (Figures 2a, 2b). An analysis of the distribution of the main stresses along the plane of the wall indicates that in this case it works according to the arch principle.

As the length of the wall increases, the stresses that arise in it when the floor deflects increase. In this case, in the support zone of walls with 1.2 ≤ L/H ≤ 2.0, inclined cracks may appear, rising either directly along the masonry unit or along horizontal and vertical joints of the masonry (Figure 2c). After the occurrence of inclined cracks, the middle zone of the wall can still work according to the arched pattern. If L/H > 2.0, then in addition to inclined cracks, the formation of horizontal and vertical cracks in the middle zone of the wall is possible (Figure 2d).

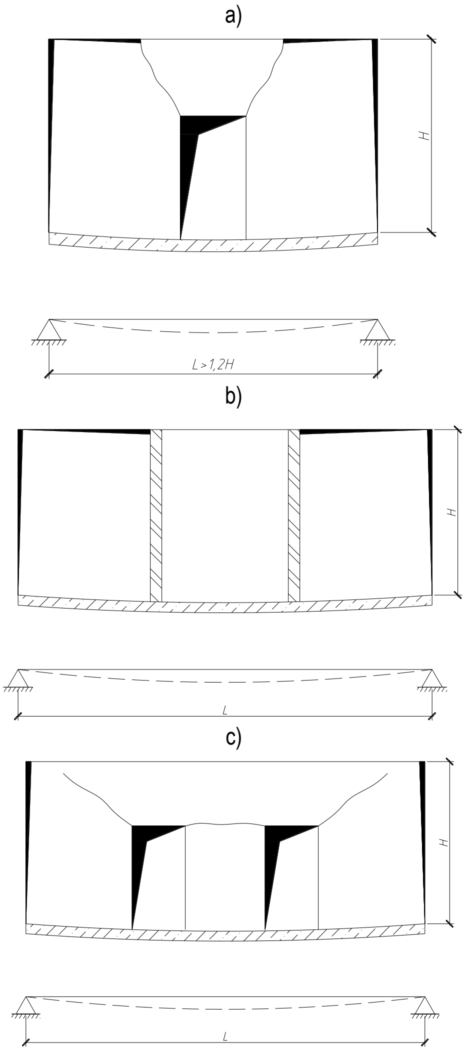


a) at L/H ≤ 1.2; b) with cantilever slabs; c) at 1.2 ≤L/H≤ 2.0, d) at L/H>2.0
Figure 2 − Nature of crack formation in solid walls [7]

It should be noted that in addition to deflections of the floors, the appearance of main tensile stresses in the wall enclosure, the trajectories of which match with the direction of the horizontal mortar joints, is also caused by shrinkage of the masonry walls and partitions.

If there is a doorway or corridor in the middle zone of the wall, in case of deflection of the supporting floor, the wall is divided into two parts, the rotation of which leads to the appearance of cracks shown in Figures 3a, 3b. In walls with a doorway, the maximum principal tensile stresses are concentrated in the upper corners of the opening, and their trajectories are directed at an angle of approximately 45º to the horizontal mortar joints [9]. Calculation analysis shows that when the ratio of the length of the wall to its height is greater than 1,2 times, the main tensile stresses acting near the corners of the doorway exceed the tensile strength of the masonry in the corresponding direction [10]. This leads to the appearance of cracks in the corners of the opening, which subsequently develop along the trajectory of the main compressive stresses. The main tensile stresses near the corners of the doorway reach the tensile strength of the masonry almost immediately after breaking the contact between the wall and the floor, which is confirmed by the results of experimental studies [9, 11]. High values of the main tensile stresses in the direction of horizontal mortar joints arise in the lower zone of the above-opening section of the masonry. Tensile stresses also occur in the contact areas between the wall and the floor, but their values are significantly lower than in the corner areas of the openings. It should be noted that the presence of a doorway leads to a decrease in the main tensile stresses arising in the contact zones compared to a solid wall. The value of the maximum principal tensile stresses in the contact zone in the wall with the opening is about 5–6 % of the maximum value of contact compressive stresses.

In walls in which the opening is shifted to the edge, the maximum principal tensile stresses are localized near the corner adjacent to the long section of the wall. With two doorways, the highest values of the main tensile stresses occur in the corner zones formed by the sides of the middle pier and the horizontal edges of the openings. In such walls, cracks may appear in the middle wall between the openings, developing along the horizontal joints of the masonry (Figure 3c).



a) − with one doorway; b) − with an opening to the full height; c) − with two openings

Figure 3 − Nature of crack formation in walls with openings [7]

When designing, it is recommended to avoid placing doorways in the central zone of the walls. If this cannot be avoided, it is recommended to arrange openings for the entire height of the wall, followed by filling the above-opening belt with masonry in such a way that independent deformation of the wall masonry and the above-opening belt is ensured.

Conjugation of floor-by-floor supported walls with a supporting floor

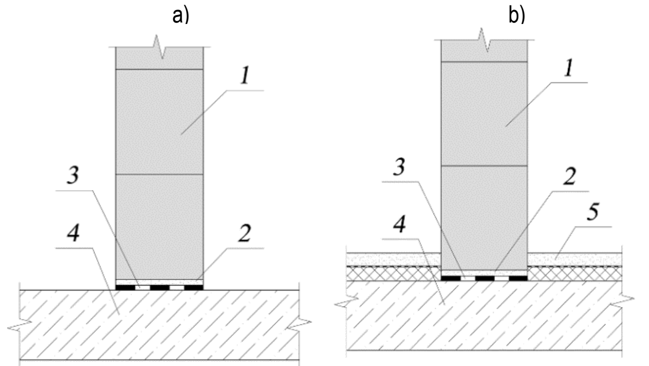
In foreign construction practice, a separating layer of film material is usually constructed between the floor and the filling [12–13]. The separating layer allows you to reduce the friction forces between the masonry and the floor (Table 1), and in case of deflection of the supporting floor, it eliminates the transfer of load to the filling, which may be caused by the adhesion of the leveling mortar layer to the floor.

Table 1 – Friction coefficient «*tga*» [14–15]

Value of «*tga*»	Contact between masonry and supporting structure
0,4–0,6	Two separating layers close to each other (for example, polyethylene film)
0,6–0,8	One separation layer
0,8–1,0	Without separating layer, masonry mortar

His technical solution reduces the tensile stresses that arise in the filling under temperature and humidity influences and deflections of the supporting floor, which has a beneficial effect on the crack resistance of masonry [16–17].

The first row of infill masonry is erected on a leveling layer of cement mortar 10–15 mm thick, laid along the separating layer. Due to the fact that the support of the filling on the supporting floor is carried out through the separating layer, the lower edge of the filling is considered as free supported in the vertical direction and having the ability to move in the horizontal direction, provided that there is no rigid floor screed on the supporting floor (Figure 4a). The floor screed, after gaining strength, limits horizontal movements and rotation of the lower edge of the filling out of the plane, creating conditions for its rigid pinching. This design solution is typical for internal filling, when the screed is adjacent to the masonry on both sides (Figure 4b).



1 – masonry filling, 2 – cement-sand mortar 1:3 (10 mm thick), 3 – separating layer of polyethylene film, 4 – reinforced concrete floor, 5 – cement-sand screed

Figure 4 − Example of pairing an internal wall with a monolithic supporting floor

In domestic construction practice, when constructing the walls of frame buildings, the installation of separating layers between the lower edge of the wall and the supporting floor is ignored. According to the requirements of SN 1.03.01 [18], the first row of masonry walls made of small blocks must be laid on a belt made of reinforced concrete lintels or ceramic bricks. This technical solution of connecting the walls with the supporting floor creates conditions for the formation of cracks in the masonry. Cracks not only worsen the aesthetic appearance of the walls, but also have a negative impact on their sound insulation and thermal characteristics, as well as fire resistance and durability [19–22].

To prevent the formation of cracks during the operation of a building for masonry walls with openings, you can also use local reinforcement of masonry with meshes made of composite materials in areas of expected cracking (areas of masonry near the contact zone of the wall with the floor, corners of door and window openings). Reinforcing meshes should be placed so that their fiber guides, if possible, match with the trajectory of the main tensile stresses, which are established by calculation. In addition to composite meshes, steel meshes that comply with the STB EN 845-3 standard [23] can be used to reinforce walls with openings.

In addition to the reinforcement of masonry, additional measures should be taken that reduce the risk of cracks in the walls of the building:

– erection of masonry as late as possible after the construction of the building frame;

– proper storage conditions for masonry products before the erection of masonry (with protection from weathering by film materials);

– wetting masonry products before erecting masonry.

The influence of the separating layer on the stress-strain state of walls

Numerical studies show that the magnitude of the friction coefficient *tga* between the surfaces of the masonry and the floor significantly affects the magnitude of the main tensile stresses σ_1 arising in walls with a doorway. In this case, the maximum values of σ_1 are concentrated in the corner areas of the doorway.

Figure 5 shows the dependence «$\sigma_1/\sigma_{1(0)}$ – *tga*» at a constant value of the curvature of the axis of a single-span floor and the ratio of the dimensions of the brick partition L/H=2 ($\sigma_{1(0)}$ – the main tensile stresses in the corner zone of the doorway at *tga* = 0).

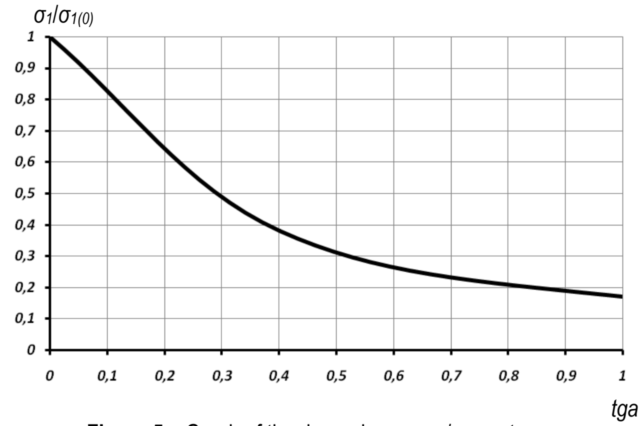


Figure 5 – Graph of the dependence «$\sigma_1/\sigma_{1(0)}$ – tga»

From Figure 5 it follows that an increase in the friction coefficient *tga* from 0 (frictionless contact) to ∞ (hard contact) leads to a decrease in the main tensile stresses σ_1 in the corner zone of the doorway. When *tga* changed from 0 to 1, the values of σ_1 decreased by approximately 6 times. At the same time, there was a drop in the main tensile stresses acting in the contact zone. Therefore, when constructing a separating layer, it is not recommended to perform it at the end sections of the filling.

Conclusion

Based on the above, we can draw the following conclusion:

1. The nature of cracking in floor-supported walls and partitions during deflection of supporting floors depends on the ratio of the overall dimensions of walls and partitions, the presence of openings, their location, conditions of contact with adjacent structures, strength and deformation characteristics of masonry. Walls with doorways made of autoclaved cellular concrete blocks are at greatest risk of cracks forming when in case of deflection of the supporting floor.

2. The building code SN 1.03.01 should include requirements regarding the installation of a separating layer of film material between floor-by-floor supported masonry walls with the supporting floor. The separating layer allows you to reduce the friction forces between the masonry and the floor, and in case of deflection of the supporting floor, to eliminate the transfer of load to the walls, which may be due to the adhesion of the leveling mortar layer to the floor.

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