Calculation model of typical panel building conjugation with large-span frame constructions

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Abstract. The calculation question of a large-panel building conjugation with large-span constructions of lower non-residential floors is considered. A design model of the joint is proposed, which takes into account its actual work, and an analysis of panel walls and large-span structures work in the zone of their interface is made. The main problems that arise in the process of the constructions conjugation simulating are indicated, and general recommendations for their calculation are given.

1. Review of the problem
The rational use issue of the residential buildings’ first floors becomes particularly relevant in connection with the increase in the storeys number and the density of buildings, the strengthening of traffic on city highways, greatly reducing the comfort of living in them. Accommodation of public premises on the first floors allows to solve these problems, as well as to provide the population with trade and service facilities: shops, cafes, pharmacies, etc.

For the placement of these objects in residential buildings, it is required to change the volume-planning decisions of the first floors: increase both the height of the floors and the width of the openings. For this reason, the modified series of panel houses with lower prefabricated and monolithic floors were developed based on walled or frame-walled structural systems that provide flexibility in planning solutions by placing large-span structures under the transverse walls of a typical panel building.

The benefit of this constructive solution is obvious, but in the design process, there are difficulties associated with the interface of a typical panel building part with the lower floors’ large-span structures. A sharp change in the structural and planning solutions of the building's floors in height leads to the fact, that there is a complex stress-strain state in the area of the interface junction between structures and adjacent elements, which evaluation, it is necessary to take into account the actual work of the joint material for. The neglect of these features by the designer leads to errors in the calculation and design of structures.

2. Current and proposed models
At present, perfect and universal design scheme of panel buildings is the spatial system of plate and rod finite elements, based on the equivalent columns method [1]. Bearing elements (poles) are sections of walls, limited in terms of apertures or vertical butt joints. The connecting elements connecting the
poles are disks of overlapping, overheating bridges and prefabricated elements connections in vertical joints.

This constructing method calculated model of a panel building is suitable for buildings, structural and planning solutions, which did not vary in height or vary insignificantly. In the case of calculating the buildings of a combined structural system with skeleton lower floors, this design scheme is suitable only for modelling a typical panel building part. In the process of the lower frame floors and their interface with the panel part of the building modelling, it is necessary to solve the problem of the design model [2].

In the course of the calculations number of apartment houses with a combined structural system implementation, according to the method of equivalent posts by Moscow research Institute of topology and experimental design (MNIITEP) employees, it was revealed that vertical stretching stresses, characteristic for them, did not appear in the supporting section of the second-floor wall panels and the mortar joint. At the same time, the obtained stresses exceeded the resistance of the solution weld to tension.

Analysis of calculation results showed that this stress distribution is caused by incorrect simulation of monolithic conjugation and prefabricated structures of the two lower floors, namely crossbars of monolithic frames and wall panels. The small height of the frame deadbolt and, as a consequence, its small bending stiffness leads to the fact that the deadbolt is "pendant" on the overlying wall panel, only causing its own weight, causing tensile stresses in it. Actually, in the conjugation zone of the frames crossbars and wall panels there must be a separation, because the resulting tensile stresses exceed the resistance of the solution weld to the stretching.

To solve this discrepancy, a calculation model with coupling elements describing the operation of the contact junction is considered (Figure 1). The principle of these finite elements operation (connections) was that when the specified limiting forces (compression and / or stretching) are reached, the end element of the contact joint stops perceiving the additional load and is switched off from further work (Figure 2). In this case, the final elements, where the ultimate effort has been reached, continue to deform like elements from an ideally elastic-plastic material until ultimate strains are reached.

![Diagram of building structures conjugation.](image)

Figure 1. Diagram of building structures conjugation.

3. Experimental research

Based on the accepted design model, numerical simulation of large-scale reinforced concrete models tested in 1977-1979 was carried out, in the laboratory of strength research of MNIITEP. In this work, experimental and theoretical studies were performed to determine the stress-strain state of prefabricated wall panels of large-panel buildings’ first non-residential floors under the guidance of Ph.D. Korovkina V.S. [3]. The studies were carried out on wall fragments at a models scale of 1: 2. Fragments consisted of a first-floor wall panel with a large opening, floor elements and a second-floor
wall panel. The main task of the research was to find out the mechanism of these structures destruction.

![Stress-strain diagram](image)

**Figure 2.** The stress-strain diagram for the joint elements.

The test results showed that the characteristic mechanisms of these structures destruction were those which either a joint destruction of the bridge over a large opening occurred in and a platform joint over the pier walls of the lower panel or the destruction of only the platform joint (Figure 3, a, b) occurred.

![Structures destruction](image)

**Figure 3.** Scheme of structures destruction along the bridge and the platform joint (a); on the platform joint(b); in the area above the posts (c). Lines of plastic deformations are shown.

Simultaneously with the tests, the bearing capacity of wall fragments was also determined theoretically: by the method of limiting equilibrium in the kinematic formulation. The analysis of structures by this method proved to be convenient, since the presence of seams and bridges determined the structural destruction mechanism. All the proposed mechanisms were formed because of plastic deformations in the crosspieces and seams and were calculated to within a few parameters obtained during the tests. The limiting conditions (equilibrium conditions) along the lines of plastic deformations were determined using the existing normative documents. The method of limiting equilibrium made it possible to evaluate the "contribution" of each structural element to the structure overall strength, which made it possible to optimize the structures.

The load-carrying capacity of the structures calculated by the kinematic method of limiting equilibrium turned out to be close to the experimental one, and as a result, the authors of the study concluded this method was effective in calculating the wall panels for strength. However, later in the study of wall panels with arched openings with more flexible bridges, the method of limiting equilibrium turned out to be inapplicable.
A similar approach was used by Kano I.L. in the course of the first non-residential floors designs studies, made in frame construction [4]. Supporting reactions that arise when the wall panel of a typical floor are supported on the frame racks were considered in the form of a local pressing load (stamp). It was assumed that when the ultimate pressing load is reached, the yield zones in the wall panel would be concentrated along some lines (Figure 3, c). Taking as the plastic deformations lines of circles arc and using the ultimate condition for the strength of concrete under pure shear, the author of the study determined the bearing capacity of the wall panels. Nevertheless, despite the good agreement with the experimental data, the method in question had its limitations, primarily related to the ratio of the dimensions of the stakes (dies) to the dimensions of the wall panel.

4. Conclusions
The conducted full-scale tests and the availability of experimental data made it possible to compare the numerical simulation results of the tested wall fragments using the above-described joint model, with the results of field tests shown in Figure 2. It was found that the calculation of panel buildings with lower span floors can be carried out using the given joint model, which takes into account the physical properties of materials, subject to certain restrictions [5]. These restrictions are primarily related to the configuration of the first non-residential floor’s frame: the ratio of the frame crossbar height to the span and the dimensions of the columns’ cross section. The low height of the deadbolt of the frame can lead to an increase in the flexibility of the frame deadbolt and cause the opening of the contact joint in the central part of the frame span. Further redistribution of stresses along the joint length can lead to a significant increase in the compressive stresses at the end sections of the joint and its destruction. The received cross-section of the columns also influences the transfer zone of compressive stresses under the wall panel, the small area that can cause the contact joint destruction at the end sections.

It should also be noted that there is no single approach to the calculation and design of these structures. The design practice shows that the calculation of the panel buildings with the lower frame floors is introduced either separately (frame structures are considered separately from the wall structures and vice versa) or the structures conjugation is adopted rigid. The analysis shows that this approach is inadmissible, as it noted in the set of rules "Large-Scale Design Systems" [6]. This document reflects the requirement to take into account the actual work of the buildings joints in the design of structural systems with structures irregular arrangement in height.

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