Analysis of Latest Experience in Design of Industrial Buildings Reconstruction by Constructing Additional Inter-floor Overlaps

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Abstract. The study relevance is determined by the increasing interest in reconstruction of city historical centers and located in the area of industrial buildings the functional profile of which needs to be changed. The problem of obtaining extra usable spaces in the historical centers of cities is solved by raising the number of storeys in the buildings which can be achieved by the construction of additional built-in inter-floor overlaps. The article is dedicated to the analysis of the recent years’ experience in reconstruction design involving this method in our country and abroad, in the Netherlands, in particular. The article presents the results of the analysis of the experience in reconstruction of the objects by constructing additional inter-floor overlaps and aims to define the optimum construction solution for built-in inter-floor overlapping and to develop non-existing solutions for wide application of this method in the reconstruction of a building with non-unified and unmodulated parameters. It was determined as expedient to apply a monolith reinforced concrete slab with the use of steel profiled flooring as a formwork and reinforcement and steel beams designed as “Built-in Beams” for the construction of built-in inter-floor overlaps in reconstruction. The article will be useful for specialists doing research in the sphere of reconstruction of the buildings and for the practical activity of design engineers.

1. Introduction

In the conditions of transition to the innovative ways of economic development a decrease of investment into new construction is observed. The interests of the construction process participants in Russia and abroad are mainly focused on improvement of historical centers of cities [1-9].

Unsystematic development of urban areas in the past caused the occurrence of industrial buildings inside them, which does not face the requirements of town planning legislation and environmental standards [1,2,10]. That is why nowadays a great number of industrial buildings are in need of functional profile change and will be reconstructed at an early date.

Rising the number of storeys by constructing additional built-in inter-floor overlaps in single-storey buildings in reconstruction of existing industrial objects allows to increase the amount of usable space of the building two or more times with the minimum cost, and satisfy the need of additional spaces in the historical districts of cities [2,10-13].
Despite the relevance of the issue of reconstructing urban areas, nowadays their complex improvement with the reconstruction of industrial objects is restrained by the absence of developed construction solutions for built-in inter-floor overlaps.

2. Formulation of the problem

The information about the effective examples of reconstruction of buildings by constructing additional built-in inter-floor overlaps is given in [9,10,13]. Research on this method of reconstruction of industrial buildings was also described in such works as [10,14]. The issue of improving space-planning and construction solutions for reconstruction of industrial buildings was considered in [14], where the authors offered unified schemes and a nomenclature of prefabricated reinforced concrete and steel constructions of the built-in inter-floor overlaps for reconstruction of buildings with unified dimensions schemes.

However, despite the need of wider application of this reconstruction method, in practice its application is restrained by the absence of developed construction solutions for built-in inter-floor overlaps that could be suitable in reconstruction of any buildings, including the ones with non-unified and unmodulated dimensions.

3. Purpose, objectives and methods of the research

Increasing interest in the issue of reconstruction of historical centers of cities is observed in Russia and abroad. There are examples of successful alteration of single-storey industrial buildings resulting in changing their functional profile and construction schemes. All these lead to the conclusion that it is expedient to improve the construction solutions for built-in inter-floor overlaps and to develop technical solutions for their mass application in reconstruction of buildings with un-unified and unmodulated dimensions.

In order to work out the construction solutions for built-in inter-floor overlaps in reconstruction of industrial buildings, the research was conducted in the following directions:

Firstly, the relevance of the research was proved by considering the recent years projects of reconstruction of industrial buildings in Russia and abroad, in particular in the Netherlands. All the data on the objects of reconstruction, which were found in publications or presented by the project designers, were thoroughly studied from the point of view of unification of the reconstructed objects’ parameters and the dimensions of the newly constructed additional inter-floor overlaps.

Secondly, while studying the experience of designing the reconstruction of buildings with the purpose of finding an optimum one for following developing of technical solutions for built-in inter-floor overlaps in reconstruction of buildings, the authors analyzed the applied on the objects constructive solutions for built-in inter-floor overlaps and identified the most commonly used design solution.

4. Analyses of the experience in reconstruction of industrial buildings by constructing additional inter-floor overlaps

Interest in reconstruction of urban areas and the examples of efficient alterations of single-storey buildings into multi-storey ones with the change of their functional profile and constructive scheme in Russia and abroad prove the expedience of conducting the research aiming to improve the construction solutions and to develop technical solutions for mass reconstruction of industrial buildings with the use of built-in inter-floor overlaps.

4.1. The experience in reconstruction of industrial buildings by constructing additional inter-floor overlaps in Russia

The research included studying the recent experiences of reconstruction of buildings by constructing additional inter-floor overlaps in Russia and abroad.

It is determined that in our country this method was applied in reconstruction of some old industrial buildings having the architectural and historical value for the urban area.
Other industrial ones which were erected in the center parts of cities in the 70-80s of the previous century and their designs are in working order.

In the process of reorganization of single-storey industrial buildings into two- or multi-storey ones, the newly inter-floor overlaps were constructed in different constructive solutions and supported by the existent reinforced-concrete or steel columns or additional columns. The use of monolith reinforced concrete slab on steel beams was reasoned by un-unified and unmodulated parameters of the building. Analysis of the experience in reconstruction of industrial buildings by constructing additional inter-floor overlaps in Russia is presented in Table 1.

| Object | Scheme before reconstruction | Scheme after reconstruction | Reconstruction method/ constructive solution
|------|----------------------------|-----------------------------|--------------------------------------|
| The building of the machine tool shop in Chkalovskiy Prospekt in St.Petersburg | | | Reconstruction of a building into a shopping center by constructing of additional built-in inter-floor overlap/reinforced concrete plate upon steel beams |
| The instrument building in Schorsa str. in Kirov | | | Reorganization of a building into shopping center by constructing of additional built-in inter-floor overlaps in it’s part/reinforced concrete plate upon steel beams |
| The building of flax factory in Zavodskaya str. in Kirov | | | The arrangement of built-in inter-floors allowed to divide the building into several recreation areas of the bar/reinforced concrete plate upon steel beams |
| The building of auto repair plant in Vorovski str. in Kirov | | | The building was reconstructed into a shopping center by constructing of built-in inter-floor overlap/prefabricated reinforced concrete plates upon steel beams |
| The industrial building in Proizvodstvennaya str. in Kirov | | | Construction of the additional overlap for offices allowed to double the total area of the building/reinforced concrete plates upon steel beams |

Thus, in Russia within the recent years the reconstruction of existing industrial buildings by construction of additional inter-floor overlaps resulting in change of their functional profile is quite
often practiced. Various individual construction solutions for built-in inter-floor overlaps are applied in reconstruction of industrial buildings. The most frequently used overlaps are made of monolith reinforced concrete slab on steel beams, which allows to overlap the spans with un-unified and un-modulated dimensions.

4.2. The experience in reconstruction of industrial buildings by constructing additional inter-floor overlaps abroad

Aiming to prove the relevance of the conducted research and to identify the most efficient construction solutions for built-in inter-floor overlaps, foreign experience in reconstruction of industrial buildings was studies. Due to the limited volume of the article, Table 2 presents the data on the representative examples.

| Object | Scheme before reconstruction | Scheme after reconstruction | Reconstruction method/ constructive solution built-in inter-floor overlaps |
|--------|-----------------------------|-----------------------------|-----------------------------------------------------------------------|
| The building of the metallurgical plant in Rotterdam (the Netherlands) | ![Scheme before](image1) | ![Scheme after](image2) | Reorganization into the "IMd" company office center by constructing additional built-in overlaps/reinforced concrete plate upon steel beams |
| The industrial building in Amersfoort (the Netherlands) | ![Scheme before](image3) | ![Scheme after](image4) | The building was reconstructed into a shopping center by constructing built-in overlap at the level of +4,500 m/reinforced concrete plate upon steel beams |
| The building «Graansilo Korthals Altes» in Amsterdam (the Netherlands) | ![Scheme before](image5) | ![Scheme after](image6) | Reconstruction into a multi-storey residential building by constructing additional built-in floor overlaps/monolith reinforced concrete plate |
| The industrial building near the Best (the Netherlands) | ![Scheme before](image7) | ![Scheme after](image8) | Reconstruction of a one-storey building by constructing built-in inter-floor overlap allowed to get 10 thousand square meters/reinforced concrete plate upon steel beams |
| The industrial building in Antverpen (Belgium) | ![Scheme before](image9) | ![Scheme after](image10) | Reconstruction of a one-storey building into the office building by constructing built-in inter-floor overlap/prefabricated sandwich panel upon steel beams |
Reconstruction of buildings by reorganization into two- or multi-storey ones abroad was carried out on many objects, including those having architectural-historical value. Analysis of the designing experience in reconstruction of buildings and facilities of various uses by constructing additional inter-floor overlaps is presented in Table 3.

**Table 3.** Analyses of the experience in designing the reconstruction of buildings and facilities of various uses with the help of additional inter-floor overlaps abroad.

| Object | Scheme before reconstruction | Scheme after reconstruction | Reconstruction method/constructive solution |
|--------|-----------------------------|-----------------------------|------------------------------------------|
| The building of Kerk ‘VERPL.HS.ST.HIERONYMUS’ *in Utrecht* (the Netherlands) | ![Scheme before reconstruction](image1.png) | ![Scheme after reconstruction](image2.png) | Reconstruction of a historical building into a multi-storey residential one by constructing additional built-in overlaps in its part/monolith reinforced concrete plate upon steel beams |
| The ‘De Buffel’ building *in Amsterdam* (the Netherlands) | ![Scheme before reconstruction](image3.png) | ![Scheme after reconstruction](image4.png) | Reconstruction of a historical building into a multi-storey one by constructing additional built-in overlaps in its part/monolith concrete/wood plate upon steel beams |
| The building of ‘Kerk in Bergen op Zoom’ *in Utrecht* (the Netherlands) | ![Scheme before reconstruction](image5.png) | ![Scheme after reconstruction](image6.png) | Reconstruction of a historical building into a theater by constructing additional built-in overlaps in its part/monolith reinforced concrete plate upon steel beams |
| The building of ‘St.Josephkerk’ *in Zwolle* (the Netherlands) | ![Scheme before reconstruction](image7.png) | ![Scheme after reconstruction](image8.png) | Reconstruction of a historical building into a multi-storey residential one by constructing additional built-in overlaps/steel and wood plate |
| The building of ‘De Watertoren aan de Wilhelminasingel te Breda’ *in Breda* (the Netherlands) | ![Scheme before reconstruction](image9.png) | ![Scheme after reconstruction](image10.png) | Reconstruction of a historical building into a multi-storey residential one by constructing additional built-in overlaps/monolith reinforced concrete plate |
| The building of ‘De Watertoren te Utrecht’ *in Utrecht* (the Netherlands) | ![Scheme before reconstruction](image11.png) | ![Scheme after reconstruction](image12.png) | Reconstruction of a historical building into a multi-storey residential one by constructing additional built-in overlaps/monolith reinforced concrete plate |
In the process of analyzing the experience in reconstruction of buildings by constructing additional inter-floor overlaps, it was determined that this method of reconstruction is used not only for industrial buildings, but also for buildings of a different profile, including the objects of cultural heritage.

The built-in inter-floor overlaps are most frequently designed with the use of monolith reinforced concrete on steel profiled plates and, as a rule, on steel beams. Herewith, in the Netherlands effective for inter-floor overlapping complete delivery systems “ComFloor” [15] are widely used, as for the bearing beams, it is common to apply the “Built-in beams” type beams designed according to the technique presented in [16].

5. Conclusions
The analysis of the experience in building reconstruction in Russia and abroad proved the necessity to develop constructive solutions of built-in inter-floor overlaps for reconstruction of single-storey industrial buildings with non-unificated and un-modulated dimensions.

The results of studying the foreign experience in reconstruction design indicated that the monolith reinforced concrete with the steel profiled plate as non-removable framework and external reinforcement on steel built-in beams is the best constructive solution for built-in inter-floor overlaps in reconstruction.

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