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НОВА КОНСТРУКТИВНА ФОРМА ЖОРСТКОГО З'ЄДНАННЯ МОНОЛІТНОГО ЗАЛІЗОБЕТОННОГО ПЕРЕКРИТТЯ З ТРУБОБЕТОННОЮ КОЛОНОЮ

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Анотація. Мета. Трубобетонні колони мають значно вищу міцність на стиск ніж звичайні залізобетонні колони такої ж форми. Проте, недоліком використання трубобетонних колон є складність влаштування жорсткого з'єднання з монолітним залізобетонним перекриттям. Такий тип з'єднання має меншу товщину, ніж звичайний тип жорсткого з'єднання з використанням сталевих балок, що важливо для висотних будинків. Згідно цього поставлено завдання створення нової конструктивної форми з'єднання трубобетонної колони з монолітним залізобетонним перекриттям, конструктивне виконання якого дозволить забезпечити жорстке з'єднання монолітного залізобетонного перекриття з трубобетонною колоною та зменшити матеріалоємність залізобетонного каркасу. ***Наукова новизна.*** Базуючись на аналізі існуючих досліджень конструктивних форм з'єднання трубобетонної колони з монолітним залізобетонним перекриттям та досліджень в галузі залізобетону, запропонована нова конструктивна форма жорсткого з'єднання трубобетонної колони з монолітним залізобетонним перекриттям, удосконалена використанням сталевого елемента жорсткості, що складається з вертикальних пластин, які перетинають бетонне ядро колони та приварені до сталевої оболонки колони. Для забезпечення жорсткого з'єднання з трубобетонною колоною, конструкція перекриття містить пластини зовнішнього армування, приварені до сталевого елемента жорсткості та до сталевої оболонки трубобетонної колони. ***Методика.*** Порівняльне чисельне моделювання напружено-деформованого стану монолітного залізобетонного перекриття з трубобетонними колонами діаметром 477мм з шарнірним та жорстким з'єднанням перекриття та колони, та з використанням пластин зовнішнього армування у випадку жорсткого з'єднання, зроблене за допомогою розрахункового комплексу Autodesk Robot Structural Analysis. Перша модель включає в себе звичайне залізобетонне перекриття. Друга модель включає в себе залізобетонне перекриття з пластинами зовнішнього армування, змодельованими з допомогою скінченних елементів приведеної жорсткості. ***Результати.*** Порівняльне моделювання довело ефективність запропонованого рішення, за рахунок зменшення згинальних моментів в середині прольоту плити на 40%. ***Практична значимість.*** Нова конструктивна форма забезпечує жорстке з'єднання трубобетонної колони з монолітним залізобетонним перекриттям та дозволяє зменшити товщину перекриття та загальну витрату матеріалів на залізобетонний каркас.

Ключові слова: монолітне залізобетонне перекриття; сталебетонні конструкції; трубобетонні конструкції.

НОВАЯ КОНСТРУКТИВНАЯ ФОРМА ЖЕСТКОГО СОЕДИНЕНИЯ МОНОЛИТНОГО ЖЕЛЕЗОБЕТОННОГО ПЕРЕКРЫТИЯ С ТРУБОБЕТОННОЙ КОЛОННОЙ

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Аннотация. Цель. Трубобетонные колонны имеют значительно более высокую прочность на сжатие чем обычные железобетонные колонны такой же формы. Однако, недостатком использования трубобетонных колонн является сложность устройства жесткого соединения с монолитным железобетонным перекрытием. Такой тип соединения имеет меньшую толщину, чем обычный тип жесткого соединения с использованием стальных балок, что важно для высотных домов. Согласно этому поставлена задача создания новой конструктивной формы соединения трубобетонных колонны с монолитным железобетонным перекрытием, конструктивное исполнение которого позволит обеспечить жесткое соединение монолитного железобетонного перекрытия с трубобетонной колонной и уменьшить материалоемкость железобетонного каркаса. ***Научная новизна.*** Основываясь на анализе существующих исследований конструктивных форм соединения трубобетонных колонны с монолитным железобетонным перекрытием и исследований в области железобетона, предложена новая конструктивная форма жесткого соединения трубобетонных колонны с монолитным железобетонным перекрытием, усовершенствованная использованием стального элемента жесткости, состоящего из вертикальных пластин, которые пересекают бетонное ядро колонны и приварены к стальной оболочке колонны. Для обеспечения жесткого соединения с трубобетонных колонной, конструкция перекрытия содержит пластины внешнего армирования, приваренные к стальному элементу жесткости и к стальной оболочки трубобетонных колонны. ***Методика.*** Сравнительное численное моделирование напряженно-деформированного состояния монолитного железобетонного перекрытия с трубобетонной колоннами диаметром 477мм с шарнирным и жестким соединением перекрытия и колонны, с использованием пластин внешнего армирования в случае жесткого соединения, сделанное с помощью расчетного комплекса Autodesk Robot Structural Analysis. Первая модель включает в себя обычное железобетонное перекрытие. Вторая модель включает в себя железобетонное перекрытие с пластинами внешнего армирования, смоделированными с помощью конечных элементов приведенной жесткости. ***Результаты.*** Сравнительное моделирование показало эффективность предложенного решения, за счет уменьшения изгибающих моментов в середине пролета плиты на 40%. ***Практическая значимость.*** Новая конструктивная форма обеспечивает жесткое соединение трубобетонных колонны с монолитным железобетонным перекрытием и позволяет уменьшить толщину перекрытия и общий расход материалов на железобетонный каркас.

Ключевые слова: монолитное железобетонное перекрытие; сталебетонные конструкции; трубобетонные конструкции.

NEW CONSTRUCTIVE FORM OF RIGID CONNECTION OF SITECAST REINFORCED CONCRETE CEILING TO CONCRETE FILLED TUBE COLUMN

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Abstract. Purpose. Concrete filled tube columns have significantly better compression strength than same shape regular reinforced concrete columns. However, the disadvantage of applying the concrete filled tube columns is the complication of providing the rigid connection to sitecast reinforced concrete ceiling. Such type of joining has less ceiling thickness versus to regular rigid joining, using the steel girders, which is important for high-rise buildings. Regarding to this, the task of creating the new constructive form of connection concrete filled tube to sitecast reinforced concrete ceiling, which constructive fulfilment allowed providing the rigid connection sitecast reinforced concrete ceiling to concrete filled tube and decrease the material consumption of reinforced concrete frame was set. ***Originality.*** Basing on analyzing of existent researches of constructive forms of concrete filled tube to reinforced concrete ceiling joining and investigation in reinforced concrete area, the new constructive form of rigid connection of concrete filled tube to sitecast reinforced concrete ceiling, which is enhanced by using steel rigid element which consists of vertical steel plates, which cross column concrete core, and welded to steel tube was offered. For providing the rigid connection with concrete filled tube column, construction of ceiling includes the stripes of external steel plate reinforcing, welded to steel rigid element and to concrete filled tube column's steel casing. ***Methodology.*** The comparative finite element analysis modelling of tension-strain conditions of sitecast reinforced concrete ceiling construction with 477mm diameter concrete filled tube columns with link and rigid conditions of joining of ceiling and column and using the stripes of external steel plate reinforcement in case of rigid connection, was made using the Autodesk Robot Structural Analysis. The first model included the regular sitecast reinforced concrete ceiling. The second model included the reinforced concrete ceiling with external steel plate reinforcement, modeled by equivalent rigidness finite elements. ***Findings.*** The comparative finite element modelling proved the effectiveness of offered constructive decision by decreasing the bending moments in plate middle area on 40%. ***Practical value.*** New constructive form provides the rigid connection of concrete filled tube column to sitecast reinforced concrete ceiling and allows to decrease ceiling height and overall material consumption of reinforced concrete frame.

Keywords: sitecast reinforced concrete ceiling; steel reinforced concrete constructions; concrete filled tube constructions.

The problem statement in general and its connection with important scientific or practical tasks

Among a huge variety of reinforced concrete and steel reinforced concrete constructions excel a concrete filled tubes. Such type of constructions elements has significantly better compression strength than same shape regular reinforced concrete elements. This is why concrete filled tube columns have one of the best effectiveness for concrete inclusive columns. The disadvantage of applying the concrete filled tube columns is the complication of providing the rigid joint to sitecast reinforced concrete ceiling. Such type of joining has less ceiling thickness versus to regular rigid joining, using the steel girders, which is important for high-rise buildings. The rigid connection of sitecast reinforced ceiling to concrete filled tube requires sufficient amount of steel reinforcement in connection area, so can't be constructed using the regular reinforcement, but the column assuming of bending moments and reducing regular plate reinforcing amount can be provided by using external reinforcement steel plates.

Analysis of recent research and publications, where are laid the foundations for solving this problem, on which the author is based

The fundamental researches in area of concrete filled tubes was made by Luksha L.[1], Storozhenko L.[2] and other scientists. That researches highlighted the concrete filled tubes as one of the most efficiency elements for compression and their advantages for using as columns.

The concrete filled tube consist of steel tube coating and concrete core, which work like one element. Concrete filled tubes have the best efficiency when working under noncentral compression. Therefore, the concrete filled tubes are highly recommended for using as columns in high-rise frames. Unlike the regular reinforced concrete column, the concrete filled tube column require no internal reinforcement. The concrete filled column high efficiency is provided by all direction concrete core compression, which increase bearing capacity by about half. All direction compression of concrete, by steel casing of column, which works like a cage is achieved [1].

All direction compression effect is increasing while the consolidation of concrete mortar because of concrete extension. Because of humidity exchange to environment lack, shrinkage effect is also lessened. Insulated from environment influence concrete is in better condition than uninsulated, because over time, the microfissures and nonlinear creep deformation appears in the uninsulated concrete [2].

Concrete filled tube has better corrosion resistance because concrete protects its inner surface. The concrete filling of steel tube increase overall buckling resistance and particular stability of steel tube. Therefore, the overall construction fire resistance is increasing.

Klymenko F. [3] made fundamental investigation about steel external reinforcement. This investigation includes calculation methods for external reinforcement steel plates, anchoring solutions and practical appliance of such type of construction. Recent investigations in area of concrete filled tubes and steel reinforced concrete were focused in DBN B.2.6-160:2010 [4] and Eurocode 2 [5] norms.

American scientists Alostaz Y. and Schneider S. made the fundamental research of different types of connection steel I-shaped beams to concrete filled tube columns [6]. According to this research, there are few variants of connection concrete filled tube to steel I-shaped beam. The most efficient variants of connection include elements, which cross the column's concrete core and reduce stress concentration in steel tube.

Recent constructive forms [7, 8] of connection concrete filled tube to reinforced concrete ceiling are made like hided in ceiling consoles or capitals, which provides the shear force resistance, but provides no rigid connection of concrete filled tube to reinforced concrete ceiling.

The comparison of different types of connection the ceiling construction to concrete filled tube [9] showed, that the rigid connection concrete filled tube to steel reinforced concrete ceiling has many advantages relatively to other types of connection and creates a promising area for research.

Defining of the unsolved aspects of the problem, which are devoted to this article

The problem of creation the new constructive form wasn't reviewed fully by previous scientists and needs the closer consideration. The main difficulty in providing the rigid connection concrete filled tube to reinforced concrete ceiling is concentration of reinforcement in near column area, which can be solved by using the external reinforcement steel plates, connecting the columns like beams and steel rigid element, which provides the shear resistance of connection.

The purposes formulation of article (problem definition)

The main purpose of investigation is the creation a new constructive form of rigid connection concrete filled tube to reinforced concrete ceiling and verifying its efficiency, comparatively to link connection.

The new constructive form of connection is described in a utility model of rigid connection concrete filled tube to reinforced concrete ceiling [10].

The comparative finite element analysis modelling of tension-strain conditions of sitecast reinforced concrete ceiling construction with concrete filled tube columns with link and rigid conditions of joining of ceiling and column and using the stripes of external steel plate reinforcement in case of rigid connection, was made using the Autodesk Robot Structural Analysis.

Presentation of the main research material with full justification of scientific results

1. Solutions of rigid connection reinforced concrete ceiling constructions to concrete filled tube columns

Concrete filled tube constructions have best efficiency when using in high-rise office and residential buildings. At this condition, with considering the massive loads and small calculation height, concrete filled tube columns have the opportunity to show its best qualities. In such type of multistory buildings, the most important parameter is ceiling thickness, which affects on the material expense of building and overall building height and treads, which can create the problems during the rooms planning.

Applying the rigid joining concrete filled tube columns to reinforced concrete ceiling allow to reduce bending strain at middle area of slab, comparing to link joining. Reducing the strain in slab allow to reduce reinforcement percentage and thickness of slab in general.

For providing the sufficient amount of negative moment concentration in connection with a column, the considerable concentration of stretched reinforcement at near column area of slab is required. For achievement, this purpose, will be beneficial to combine the sitecast reinforced ceiling with steel concrete perfect beam, made by using the external reinforcement steel plates.

For creating such rigid connection reinforced concrete ceiling slab with the concrete filled tube column, we can use the same methods as for steel girders, described in Alostaz Y., Schneider S. Connections to concrete-filled steel tubes [5]. In such case, we can create the rigid connection of reinforced concrete slab with the concrete filled tube column and provide the complete transfer of stresses on column.

Creating the rigid connection concrete filled tube column to reinforced concrete ceiling allows to rich the double effect. In case of negative moment appearance at near column area of slab, the middle area of slab has slightly less moments, and in case of concentration bending moments in external reinforcement steel plates, appear the opportunity of reducing the thickness of ceiling. Also, due to rigid connection concrete filled tube to reinforced concrete ceiling creates the rigid frame, which requires no treads.

2. Comparative modeling of reinforced concrete ceiling constructions

For providing the expediency of the creating a new constructive form, the comparative modeling in Autodesk Robot Structural Analysis is made, using model of beamless ceiling with 3x3 column with 6m step and 2m overhanging, with thickness of 250mm and loaded evenly distributed load 9.0kN/m2. Steel casing of concrete filled tube column diameter is 377mm. The first model includes regular beamless reinforced concrete ceiling with link connection to concrete filled tube columns and the second one include reinforced concrete ceiling with external reinforcement steel plates zones (400mm width), modelled by equivalent ceiling rigidity and rigid connection of ceiling to concrete filled tube columns. The rigid connection is modelled by rigid fixing of outside finite elements. The result bending moments mapping of comparative modelling are in the (Fig. 1) and (Fig. 2).

Modelling showed that version with rigid connection concrete filled tube to reinforced concrete ceiling slab by using the external reinforcements steel plates has the significantly less bending moments in plate by about half. Therefore, the concentration of bending moments in external reinforcement steel plates and the negative moments appear at near column area.

Consequently, the rigid connection of sitecast reinforced ceiling with external reinforcement steel plates to concrete filled tube allows to provide the overall reinforcement and thickness reduction of reinforced concrete slab.

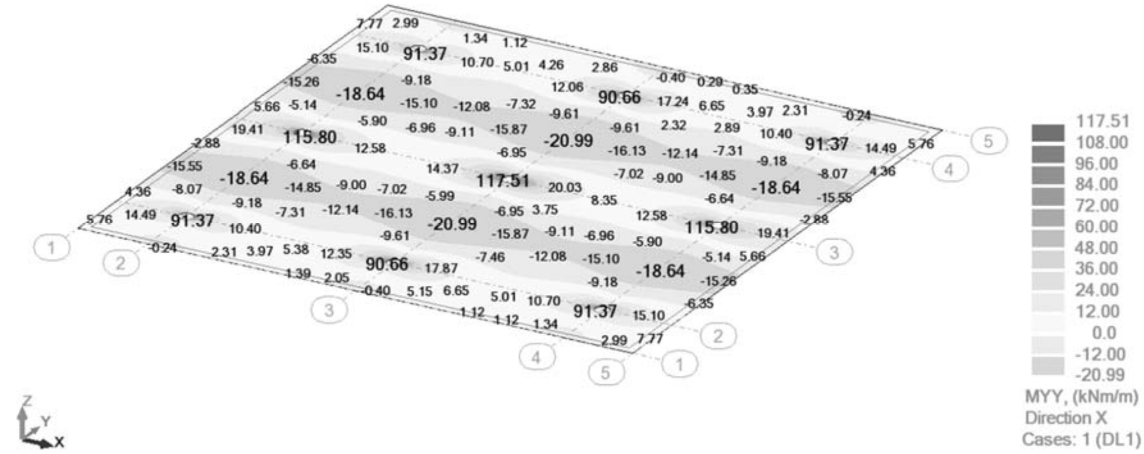

Fig. 1. Bending moments mapping in Y direction in slab with the link connection to concrete filled tube column.

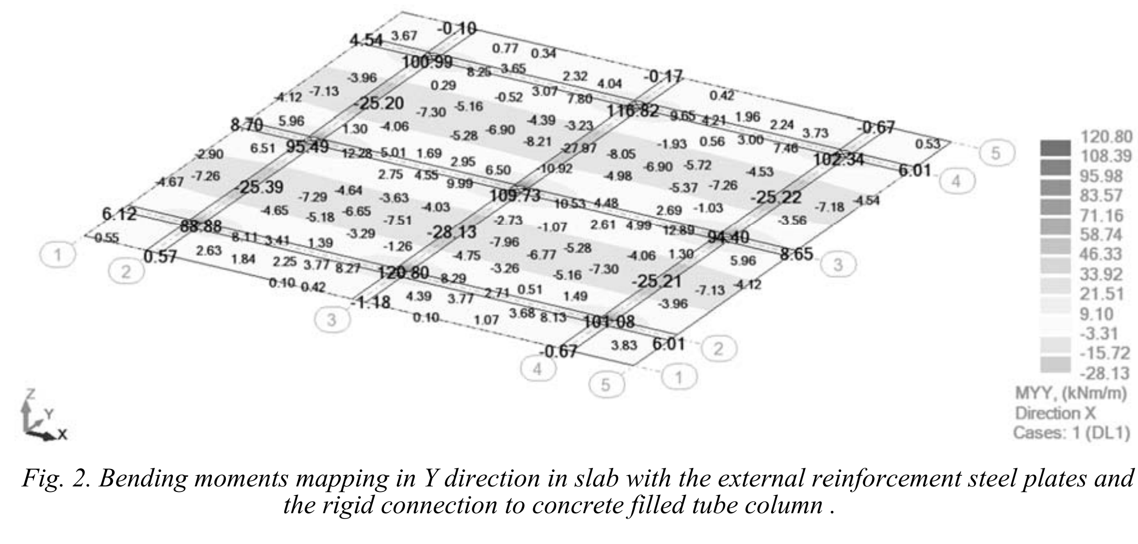

Fig. 2. Bending moments mapping in Y direction in slab with the external reinforcement steel plates and the rigid connection to concrete filled tube column .

3. New constructive form of rigid connection concrete filled tube to reinforced concrete slab.

Based on a utility model of rigid connection concrete filled tube to reinforced concrete ceiling [10], the following description of the arrangement of this type of construction is given.

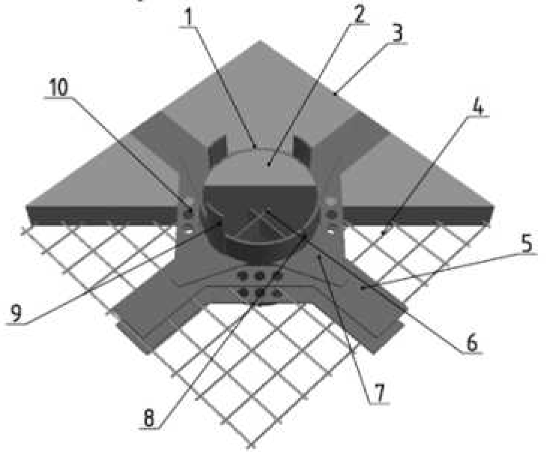

Fig. 3. New construction form of rigid connection concrete filled tube column to reinforced concrete slab. 1 – concrete filled tube steel casing; 2 – concrete filled tube concrete; 3 – sitecast reinforced concrete slab; 4 – slab reinforced frames; 5 – external reinforcement steel plates; 6 – steel rigid element; 7 – steel connection plates; 8 – assembling slots in steel tube; 9 – vertical steel coating plates; 10 – steel tread plates.

Creation of new constructive form is solved by adding to existent variants of connection concrete filled tube to reinforced concrete slab the steel rigid element and external reinforcement plates (Fig. 3). The steel rigid element consists of few welded together vertical plates, which are placed into assembling slots in steel tube of concrete filled tube column and welded to it. The steel rigid element can be made in cruciform or another multibeam shape with any angles between vertical steel plates, according to architectural building project. The external reinforcement steel plates are placed between the columns by analogy to flanges of regular I-beams. The steel rigid element external plates are welded to external reinforcement steel plates. For providing the bending moments transfer from slab to column, the steel external reinforcement steel plates are welded with column casing by using the steel connection plates. The vertical steel coating plates is providing covering the assembling slots in concrete filled column casing and facilitation the assembling of next column casing. Also, the steel thread plates were designed for providing the rigidness of connection.

Assembling of connection sitecast reinforced concrete slab to concrete filled tube consist of the following steps.

Steel casing of concrete filled tube column is placed into project position. Than steel rigid element is placed into assembling slots in steel tube and welded to steel tube by corner-welded seams. The concrete core of concrete filled column is concreted. After this, the ceiling slab formwork is assembled. The bottom external reinforcement steel plates are welded to steel rigid element by corner-welded seams and to bottom steel tread plates by butt-welding. Than slab reinforcement frames are placed into project position. After that, the top external reinforcement steel plates are welded to steel rigid element by corner-welded seams and to top steel tread plates by butt-welding. Connection plates are welded to steel casing of concrete filled tube and to external reinforcement steel plates. Vertical steel coating plates were welded to steel casing of concrete filled tube column and the next steel coating is placed. After that, the steel reinforcement slab is concreted.

The conclusions of this research and the prospects for further development in this direction

The new constructive form allows to provide the rigid connection of concrete filled tube column to reinforced concrete ceiling by using external reinforcement steel plates and steel rigid element. The comparative finite element modelling proved the effectiveness of offered constructive decision by decreasing the bending moments in plate middle area on 40%, which allows to reduce the ceiling height and reduce the overall material consumption.

In such case, this type of connection concrete filled tube with the reinforced concrete ceiling confirms its scientific novelty and efficiency. The creation of new constructive form opens the promising area for research.

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