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Research paper



Concrete Filled Tubular Elements Joints Investigation

Pavlo Semko^{1*}, Serhii Skliarenko², Volodymyr Semko³

¹poltava National Technical Yuri Kondratyuk University, Ukraine
 ²poltava National Technical Yuri Kondratyuk University, Ukraine
 ³poltava National Technical Yuri Kondratyuk University, Ukraine
 *Corresponding Author E-Mail: Syomka7@Gmail.Com

Abstract

The stress-strain state and the bearing capacity of the dismountable joints of concrete filled tubular elements are investigated. The methods of calculation and constructive solutions of concrete filled tubular elements with joints are analyzed. Five new types of dismountable joints are proposed. Experimental studies of concrete filled tubular elements have been carried out. It was determined that the most effective for compression was a joint with a steel coupling and for bending the most effective was a joint with longitudinal ribs. The numerical modeling algorithm is presented; results are verified using experimental tests. A method for constructing N-M boundary dependences for concrete filled tubular structures is proposed. Bearing capacity diagrams for concrete filled tubular elements and their joints have been constructed. The costs of the materials needed to perform the joint as the example of a real construction for similar loads are analyzed.

Keywords: bearing capacity, concrete filled tubular elements, dismountable joints, numerical modeling, stress-strain state

1. Introduction

Concrete filled tube today is one of the most effective composite materials used in construction. Concrete filled tubular constructions are especially relevant as compressed elements of structures, in particular columns, and are widely used throughout the world. However, the most important and difficult task for the design of concrete filled tubular structures is the performing of joints. It is recommended to arrange them in the zone of zero moments and the main load that they perceive is compression. However, often, especially during mounting, large bending moments occur in the joints. Therefore, the definition of tensile forces in the elements of the joints from the effect of external loads is a key issue, which the answer this work gives.

It should also be noted that the use of dismountable joints has a number of significant advantages over their integral analogues. In particular, the installation of the structure accelerates and a number of tasks connected with the dismantling of the building are solved.

The paper is devoted to solving the actual scientific and technical problem of determining the bearing capacity and describing the stress-strain state of concrete-filled tubular element dismountable joints on the basis of experimental, numerical and theoretical studies.

2. Main Body

The performed analysis of scientific literature allows us to conclude that today dismountable joints of concrete filled tubular elements have not been sufficiently investigated, both in Ukraine and in the world [1-10]. There are no recommendations for determining the tensile force arising from external loading for

nonaxial compressed concrete filled tubular columns with joints. Also, there are no data on experimental studies of the dismountable joints of compressed concrete filled tubular elements.

Standard dismountable flange connection has several disadvantages. Such as significant flange size, suboptimal use of the material. Therefore, 5 new types of concrete filled tubular dismountable joints were proposed and patented (Fig. 1). This is a dismountable joint of concrete filled tubular elements with a centering plate, a joint with hidden bolts, a joint with steel inserts, a joint with longitudinal ribs, the joint with a steel coupling. The main feature of the joint (Fig. 1. a) there is the use of a centering plate, which is used to optimize the transfer of loads between the concrete filled tubular elements (CFT). Benefit of joints (Fig. 1. b, c) is that the junction itself is in the body of the CFT element, which makes it possible to apply it in a limited space. Benefit of the joint (Fig. 1. d) is a greater bearing capacity of this connection under the influence of significant nonaxial loads. Advantages of joint (Fig. 1. e) are relatively small sizes, a small amount of component parts and the ease of installation.



Fig. 1: Types of dismountable joints: a) centered plate joint; b) joint with hidden bolts; c) a junction with steel inserts; d) joint with longitudinal ribs; e) joint with steel coupling

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According to the authors, the most promising are joints with longitudinal ribs (TBR series) and steel couplings (TBC series). These joints and the standard flange joint (TBF series) chosen for comparison were studied experimentally, with the help of mathematical modeling and the theoretical method of their calculation was presented. Also, for comparison purposes, CFT elements without joints (TB series) and 1 sample without concrete filling (series T) were investigated. Drawings and photo samples are presented on Fig. 2. The common for all samples was the height of the pipe - 800 mm, the diameter of the pipe (D) - 108 mm, and its thickness is 4 mm, the diameter of the bolts - 12 mm.



Fig. 2: Design of prototype samples. a) TBC series; b) TBR series; c) TB and T series; d) TBF series

To measure the deformation of the samples tension sensors were applied with base 20 and 30 mm and resistance of 100 ohms and 200 respectively. Tension sensors were housed in the most stretched places of structure. Measurement of deformations was carried out with accuracy up to 1×10^{-5} relative units. Also, as gauges for longitudinal deformations, hourglass indicators with a price of 0,01 mm and a base of 300 mm were used, which were used in quantities of 4 pcs. for each of the samples under study. To measure the transverse movement of samples at nonaxial compression applied leverarm deflection indicator with point value of 0.01 mm.

Tests of concrete filled tubular elements were carried out at the age of concrete, more than 28 days. The loading of samples was carried out in degrees by 0,1 from the predicted theoretical calculation of the destructive load N. All load levels were maintained for at least 10 minutes. At all stages of experimental studies, longitudinal and transverse deformations of concrete filled tubular elements were measured. Photos of prototype samples during the test are shown in Figure 3.



Fig. 3: Photo of samples during the test

The purpose of conducting experimental research was to obtain data on the influence of the dismountable joint design on the bearing capacity of the CFT element and the nature of its work.

Experimental samples were tested for the central and nonaxial compression eccentricities of applying a load equal to 0; 0.25D and 0.5D (27 and 54 mm) and for bending load.

Physical and mechanical properties of materials were determined. For a steel pipe shell, the average yield strength in the result of tests of steel strips was 344 MPa, and the average tensile strength 484 MPa. For concrete filling the characteristic value of concrete strength was 23.8 MPa. Bolt average tensile strength and shear strength were the same and amounted to 300 MPa.

During compression test concrete filled tubular elements with dismountable joints, two criteria were selected for the bearing capacity of the CFT element. The first criterion was the state of samples in which the deformation of the steel pipe corresponds to deformations of steel which reached the yield strength (N_I) . The second is a state where a significant deformation development occurs in the CFT element with a constant or insignificant load increase of samples (N_2) . As the criterion of bearing capacity for joints was chosen a moment of steel achievement yield strength for one of its elements.

Table 1 shows the obtained experimental values of the bearing capacity N_1 and N_2 . Also, the table shows the relation N_2/N_1 for the samples under study. Depending on the structure of the joints and the eccentricity of the applied load, it varied from 1.09 to 1.79. For nonaxial compressed concrete filled tubular joints samples this ratio was greater than for centrally loaded, which indicates a decrease in the impact of the concrete core on the bearing capacity with an increase in the eccentricity of the applied load.

 Table 1: Compression tests values of experimental samples bearing capacity

Sample	Eccentricity of	Bearing capacity, kN		NL/NI
code	load, mm	N ₁	N_2	$1N_2/1N_1$
T-1	0	450	580	1,29
TB-1	0	730	950	1,30
TB-2	27	360	465	1,29
TB-3	54	300	326	1,09
TBR-1	0	690	980	1,42
TBR-2	27	410	580	1,41
TBR-3	54	320	440	1,38
TBC-1	0	725	996	1,37
TBC-2	27	400	620	1,55
TBC-3	54	280	500	1,79
TBF-1	0	725	900	1,29
TBF-2	27	400	610	1,53
TBF-3	54	280	440	1,57

Bearing capacity N_1 was approximately equal for all similar experimental samples (the difference was less than 10%). Analyzing the onset of destruction (N_2): on central compression – samples of the TBR and TBC series had a slightly higher bearing capacity (up to 5%). In nonaxial case the difference in bearing capacity has increased significantly and amounted to 35% for samples of the TBF and TBR series and up to 53% for samples of the TBC series when compared with samples without joints.

The highest bearing capacity during the experimental studies of concrete filled tubular elements on central and nonaxial compression were samples of the TBC series (from 5% to central compression up to 53% for non-centered) compared to reference ones and the best coefficients of efficiency (from 4% to 12%), which indicates the rationality of the construction of this type of connection with minor tensile moments in the joint (at eccentricities up to 0.5 D).

 Table 2: Bending tests values of experimental samples bearing capacity

Sample code	Destruction load Q,	Destructive moment M, kNm
	KIN .	
TB	70	13,1
TBC	73	13,9
TBR	168	33,6
TBF	78	15,6

Table 2 shows the results of tests of joints of concrete filled tubular elements on the bend (Fig. 4). In the bending test, the joints with longitudinal ribs proved to be the most effective joint, the bearing capacity of which more than 2 times exceeds the analogues. This is due to the large cross-section and, correspondingly, the higher moment of resistance, compared with other samples.



Fig. 4: The nature of the destruction of samples after bending tests

The deformability of the samples without joints was smaller than the samples with dismountable joints. The bearing capacity of samples without joint (Table 1) was also lower which allows us to conclude that the joint was used for experimental samples not only by a certain stress concentrator but also by amplification.

Figure 5 shows the appearance of experimental samples after the central and nonaxial compression tests. Characteristic features that should be noted were the formation of corrugations in the supporting areas of the samples, the appearance of Luders-Chernoff lines at an angle of approximately 45° in compressed zones and the fact that the destruction was not due to the bursting of the pipe shell but because of the local shell stability loss when the samples reached the boundary state.



Fig. 5: The nature of the destruction of samples after testing on central and nonaxial compression

Analyzing the results of experimental studies, it should be noted the efficiency of dismountable joints with steel ribs (TBR) during bending tests. At the central and nonaxial compression, the highest bearing capacity had samples with a steel couplings (TBC).

In addition to experimental studies numerical simulation of concrete filled tubular elements with dismountable joints was carried out using the finite element method. The purpose of the simulation was to obtain data on the stress-strain state of concrete filled tubular elements under loadings of equivalent N_1 and in comparison with the experimental results for the possibility of substitution in a further part of the experimental research by numerical.





To determine the optimal size of finite elements the test task was solved as an example of the steel pipe with a diameter of 108 mm, a thickness of 4 mm and a height of 800 mm, not filled with concrete (model of sample T-1). The main parameters that were compared, were the accuracy of the stresses determination in the pipe (Fig. 6) and the time required for modeling in different sizes of finite elements (Fig. 7). The following sizes were adopted: 15 mm for concrete and steel simulation, 3 mm for bolt modeling. Steel was modeled as an elastic material, concrete as an elastic plastic one.



Fig. 7: Dependence of modeling time on the size of finite elements

The simulation was performed at an elastic stage, because if any element of the joint reaches the yield point, the connection will be considered to have lost bearing capacity. In order to compare the data obtained with the experimental load values on the models, they were assumed to be equal to the load N_1 for each sample. All geometric sizes and conditions of fastening were taken identically experimentally.

Figure 8 shows the graphic representations of the main stresses for the experimental prototype.



Fig. 8: Graphic representations of the main stresses

In general, the pattern of stress distribution corresponded to the experimental results obtained. In areas of concentration of stresses in the supporting zones of experimental samples corrugations were formed. In the zones of increasing stresses in the middle part of the upper CFT element with joints (Fig. 8), significant

deformations took place which are clearly visible in Figure 5. Also, the simulation confirms the fact of very small stresses and deformations in the elements of the joints (ribs, flanges) and reduction of stresses for the lower CFT element.

For the additional verification of the obtained data, the experimental values of stresses in the compressed and stretched zone of samples were determined (in the middle - for solid samples and in the center of the CFT element and samples with joints) and were compared with the stress values in similar locations obtained by simulation. The coefficient of variation and the mean square deviation varied within 5-7% which confirms the possibility of using finite elements simulation as a partial replacement of experimental tests.

For theoretical calculations an algorithm for determining the bearing capacity of concrete filled tubular elements and their joints was presented by constructing N-M curves. To determine the main characteristics of the stress-strain state in the cross section, the Bernoulli hypothesis was guided (hypothesis of plane cross sections). Namely, the assumption that the deformation within the element will have the same character as on its surface.

The following steps were taken. CFT cross section was divided into 27 segments (Fig. 9). The geometric characteristics of these sites, in particular the area and position of the center of gravity, were determined.



Fig. 9: CFT element presented in the form of 27 parts

The area of the concrete segment was determined by the formula

$$A_{c,seg\,i} = 0.5r^2 \cdot \left(\pi \cdot \alpha / _{180} - Sin(\alpha)\right). \tag{1}$$

where α – angle of the arc of the concrete segment.

r – the radius of the concrete segment.

The area of the steel pipe segment which corresponds to the same concrete segment

$$A_{s,seg i} = 0.5R^2 \cdot \left(\pi \cdot \alpha / 180 - Sin(\alpha)\right) - 0.5r^2 \cdot \left(\pi \cdot \alpha / 180 - Sin(\alpha)\right).$$
(2)

The area of the concrete or steel par

$$A_i = A_{\text{seg } i} - A_{\text{seg } i-1}.$$
(3)

Coordinates of the center of gravity

$$y_{i} = \frac{(2 \cdot r \cdot \operatorname{Sin}(\alpha/2))^{3}}{12A_{c,segi}}.$$
(4)

As the boundary conditions from the central compression to the bend were given deformations for the extreme part (first and twenty seventh) in Table 3. By formula (9) deformations were determined for each part (Fig. 12).

$$\varepsilon_{i} = \frac{(\varepsilon_{1} - \varepsilon_{n})}{x_{n} \cdot x_{i} + \varepsilon_{n}}$$
(5)

After determining the deformations of each part the corresponding values of stresses for the steel and concrete segments were calculated according to formulas (6) - (8).

$$\varepsilon_i \ge \varepsilon_{c3}, \quad \sigma_c = f_{cm},$$
 (6)

$$\varepsilon_i \le \varepsilon_{c3}, \quad \sigma_c = E_{cm} \cdot \varepsilon_i,$$
(7)

$$\sigma_y \le f_y, \quad \sigma_y = E_s \cdot \varepsilon_i. \tag{8}$$

The transition from stresses in the sections to the values of the longitudinal force and moment was carried out by the formulas (9) - (12):

$$N = \sum_{i=0}^{n} \sigma_i \cdot A_i, \tag{9}$$

$$\sigma_{m,i} = \sigma_i - \left(\frac{(\sigma_{i.max} - \sigma_{i.min})}{2} \right), \tag{10}$$

$$N_{m,i} = \sum_{i=0}^{n} \sigma_{m,i} \cdot A_i, \tag{11}$$

$$\mathbf{M} = \sum_{i=0}^{n} \sigma_{m,i} \cdot A_i \cdot y_i. \tag{12}$$

Table 3: Boundary conditions for constructing N-M diagram



By values N and M, the curve of bearing capacity of the CFT element was constructed (Fig. 10) with diameter of 108 mm and a wall thickness of 4 mm (identical to the TB-1 sample). The presented algorithm for automating the calculation was implemented as a program. To check the CFT bearing capacity of an element, it is necessary to determine whether a combination of external loads N, M is within the limits of the obtained curve if it is so – the bearing capacity of the element for this load will be ensured.



Fig. 10: The curve of bearing capacity N-M (1), diagram of the bearing capacity of a steel pipe without concrete filling (2), diagram of the bearing capacity of the CFT element, where the concrete is corrected to the steel by the ratio $\delta = f_{ck}/f_y$ (3) and the diagram where the concrete is corrected to the steel by the ratio $\delta = E_{cm}/E_s$ (4)

In general, it should be noted that the presented methodology, despite some simplifications, has sufficient accuracy and in addition, there is a certain margin (up to 17%) of central compression where the increase of the bearing capacity due to the effect of concrete compression was not taken into account.



Fig. 11: The curve of bearing capacity IN-M (1), curve with allowance for compression of concrete (2), and the diagram obtained from the experimental tests (3)

Concerning the construction of the N-M curves of the studied dismountable joints then the key to this issue is to determine the product of the total longitudinal effort for each stretched section the cross section on the corresponding shoulder from the center of the plot to the position of the boundary line (Fig. 12). It should be noted that for combinations of loads that are to the left of the boundary line 1 (Figure 12), the dimensions of the joints elements from the conditions of tension can be taken constructively, since the total tension moment will be zero.



tensile forces at the joint (1), and the bearing curve of the N-M (2)

To calculate the joint of concrete filled tubular elements from the combinations of forces located to the right of the boundary line, it is necessary to determine the total tension moment. This is a product of tensile strength for each part of the section at an appropriate distance from the boundary line to the center of this site $\sum (N_t \cdot z_t)$. The value of this product will be proportional to the entire line of constant eccentricities action. Therefore, having determined the value $\sum (N_t \cdot z_t)$ for points on the curve N-M, we can calculate it for any

combination of external loads. It should take into account the fact that if combinations of loads are outside the diagram 2 (Fig. 12) than the bearing capacity of the CFT element is insufficient.



Fig. 13: Diagram of the bearing capacity of a dismountable joint of concrete filled tubular elements with longitudinal ribs (TBR series): 1 – diagram of bearing capacity of CFT section taking into account the compressed part of the concrete core by the criterion of reaching the yield strength in the extreme fiber; 2 – bolts shear strength diagram of bearing capacity; 3 – the corrected diagram of the CFT element with the joint bearing capacity; 4 – the bearing capacity diagram of the CFT element which was constructed using experimental data;

The diagram of the joint with the longitudinal ribs bearing capacity presented in Fig. 13 was analyzed. Characteristic difference of this type of connection in comparison with flange or coupling connection is a considerable (more than 2 times) when carrying out bending tests. This growth is due to the presence of 4 pairs of longitudinal steel ribs welded to the upper and lower CFT elements and coupled in pairs with 4 bolts. However, it should be noted that, firstly, on central compression the effect of ribs on the bearing capacity of the design is practically absent. Secondly, on pure bending in the most dangerous case of applying a load in which only one pair of ribs is in a stretched zone two side pairs of ribs have almost no effect, and even in the absence of connecting bolts, the bearing capacity of the connection remained practically unchanged (difference of 2.5%). Figure 14 shows a diagram of the joint with longitudinal ribs bearing capacity, taking into account the tension.



Fig. 14: Diagram of the bearing capacity of a dismountable joint of concrete filled tubular elements with longitudinal ribs: 1 - a diagram of the bearing capacity of a CFT element of 108 mm in diameter and a wall thickness of 4 mm; 2 - diagram of bearing capacity of 16 bolts with a diameter of 12 mm, applied in the joint, the combination of loads N and M above this line satisfies the conditions of the received bolts bearing capacity; 3_- the bearing capacity diagram of longitudinal ribs made of steel with size $200 \times 60 \times 10$ mm.



Fig. 15: Diagram of the bearing capacity of a dismountable flange joint of concrete filled tubular elements with (TBF series): 1 - diagram of bearing capacity of CFT section taking into account the compressed part of the concrete core by the criterion of reaching the yield strength in the extreme fiber; 2 - the diagram of the stretched bolts bearing capacity is constructed

Let's consider in more detail the graphs depicted in Fig. 15. Bearing capacity of CFT cross-section with regard to compressed concrete (curve 1) constructed theoretically, has a lower bearing capacity (up to 10-15%) in comparison with the data obtained with the help of experimental tests which is explained, in addition to the possibility of minor deviations during the experiment, ignoring the effect of concrete compression (the effect of the cartridges), which can increase the bearing capacity to 15%.

Diagram of bearing capacity of 12 mm diameter bolts used in this connection (curve 2) is constructed based on the determined total tensile force N_t and did not take into account the work of bolts that are in a compressed zone but also increase the overall bearing ability of the joint. Taking into account this factor curve 3 was obtained.



Fig. 16: Diagram of the flange joint bearing capacity: 1 - diagram of the bearing capacity of a CFT element of 108 mm in diameter and a wall thickness of 4 mm; 2 - diagram of bearing capacity of stretched bolts with a diameter of 12 mm, the combination of loads N and M above this line satisfy the conditions of the received bolts bearing capacity.

Figure 16 shows the diagram of the flange joint bearing capacity, taking into account the tensile strength. The calculation of the elements of such a joint is carried out in the same way as the previous connection, after determining the total tensile moment $\sum (N_t \cdot z_t)$ from external loads.



Fig. 17: Diagram of bearing capacity of dismountable joints of concrete filled tubular elements with steel couplings: 1 - diagram of the CFT section bearing capacity, taking into account the compressed part of the concrete core according to the criterion of achieving the yield strength in the extreme fiber; 2 - diagram of bearing capacity of samples TBC series obtained by experimental test; 3 - the diagram of the steel coupling bearing capacity is calculated by G. Lame's formula.

Presented in Fig. 17 curves 1 (constructed theoretically) and 2 (with the help of experimental data), similarly to samples with flange connections, have a slight deviation of 10-20% with each other which is due to the ignoring of the effect of compression of concrete by a steel pipe shell.

The diagram of the bearing capacity of the steel coupling obtained theoretically is fully confirmed by experimental data – so for the case of bending the coupling has a lower bearing capacity than the CFT element itself and was destroyed accordingly in this case first. Whereas, for centrally compressed and compressed with eccentricities applying a load of 0.25 and 0.5 of the tube diameter was due to the destruction of the CFT element itself.

Figure 18 shows a diagram of the bearing capacity of a dismountable joint of CFT element with the steel coupling.



Fig. 18: Diagram of the bearing capacity of the dismountable joint with the steel coupling: 1 - a diagram of the bearing capacity of a CFT element of 108 mm in diameter and a wall thickness of 4 mm; 2 - The diagram of the bearing capacity of the steel coupling 2.5 mm thick and an external diameter of 113 mm, the combination of loads N and M, located above this line, satisfy the conditions of the bearing capacity for the given coupling.



Fig. 19: Installation of shopping center carcass in the city Kremenchuk

An example of a shopping and entertainment center in Kremenchuk dismountable joints for concrete filled tubular columns were calculated and designed (Figures 19, 20). In the shopping center were used concrete filled tubular columns made of pipes in diameter of 426 mm and a wall thickness of 8 mm, with concrete filling C20 / 25.



Fig. 20: Joints in concrete filled tubular columns

Based on the above-mentioned algorithm, the bearing capacity was determined and the N-M diagram was constructed (Fig. 21).



Fig. 21: Diagram of bearing capacity of pipe with a diameter of 426 mm and wall thickness of 8 mm, filled with concrete C20 / 25. The curve of the bearing capacity N-M (1), diagram of the bearing capacity of a steel pipe without concrete filling (2), diagram of the bearing capacity of the CFT element, where the concrete is corrected to the steel by the ratio $\delta = f_{ck}/f_y$ (3) and the diagram where the concrete is corrected to the steel by the ratio

$$\delta = E_{cm}/E_s \ (4).$$

For the calculation the following combination of loads was accepted:

N = 1700 kN; M = 345 kNm; Q = 200 kN – boundary loads for calculating the joint from the condition of equilibrium with the CFT element.

 Table 4: The cost of steel for manufacturing 1 joint for CFT element with a diameter of 426 mm

Costs of materials	TBF Joint N=1700 kN M=350 kNm	TBR Joint N=1700 kN M=350 kNm	TBC Joint N=1700 kN M=350 kNm
Steel, kg	81,7	37,7	43,2
Bolts, pc	8Ø24	16Ø16	4Ø12
Weld seams, mm	2670	3470	4040

The least cost of steel was for the joint made with the help of longitudinal ribs, the total costs are given in the Table 4.

3. Conclusions

The important scientific task of studying the stress-strain state and the bearing capacity of dismountable joints of concrete filled tubular elements is solved in the paper. The studies carried out in the work give grounds for making such conclusions:

1. Five new types of dismountable joints of concrete filled tubular elements have been proposed and investigated, namely: the dismountable joint of concrete filled tubular elements with a centering plate, the joint with hidden bolts, the joint with steel inserts, the joint with longitudinal ribs, the joint with a steel coupling and appropriate patents for utility models have been obtained.

2. It has been determined that in the case of experimental tests of samples on central and nonaxial compression, the most effective structure of the joint (which had the highest bearing capacity) was the joint which was made using the steel coupling with bearing capacity of 10-13% higher than other samples. In the study of samples with dismountable joints in bending and with eccentricities of more than 0.5D it was determined that samples with longitudinal ribs are the most effective ones which had more than twice the higher bearing capacity compared with the samples with steel couplings and flange connections.

3. With a purpose to the possible replacement of a part of the experimental tests by numerical studies in this work a detailed step-by-step algorithm for numerical simulation of a CFT element with a dismountable joint is presented. The size of finite elements (FEs) and their influence on the simulation results were analyzed. The following CE dimensions were taken into account: 15 mm for concrete and steel and 3 mm for bolts. Comparison of stresses in the compressed and stretched zone of the CFT element showed that numerical simulation has a high accuracy, the mean square deviation and the coefficient of variation of the data obtained fluctuated within the range of 5-8%, which is permissible and indicates that the modeling results correspond to the experimental data.

4. The non-iterative method of constructing boundary dependences of N-M concrete-filled tubular constructions is presented for the boundary state after reaching the boundary of the pipe-shell flow. Comparison of the results obtained with this technique, with experimental data showed a stock up to 17% for central compression and 2-4% for bending. The program is constructed and implemented in the form of an algorithm for constructing a diagram of the bearing capacity of the CFT section, taking into account the compressed part of the concrete core which

made it possible to determine the tensile forces perceived by the elements of the joint. N-M diagrams of bearing capacity for concrete filled tubular elements and their joints (flanged, with longitudinal ribs and steel couplings) are constructed.

5. The most rational (with conditions of bearing capacity and material consumption) design of a dismountable joint is proposed, based on the calculation results for the building of a shopping and entertainment center in Kremenchuk. It turned out to be a dismountable butt of concrete filled tubular elements with longitudinal ribs, the steel costs were 13% less than for the coupling joint and by 54% - than for the flange joint with the same bearing capacity.

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References

- Zhao X.L. Cold-Formed Tubular Members and Connections / X. L. Zhao, T. Wilkinson, G._J._Hancock // Elsevier Science Pty Ltd, Oxford, UK. – 2005. – 241 p
- [2] Zeghiche J. An experimental behavior of concrete-filled steel tubular columns / J. Zeghiche, K. Chaoui // Journal of Constructional Steel Research. – 2005. – No. 61. – P. 53-66.
- [3] Fan A. Concrete-filled steel tubes subjected to axial compression and lateral cyclic loads/_A._Fan, F. S. Qie, S. Rizkalla // Journal of Structural Engineering, 2004. – 130 (4). – P. 631 – 640.
- [4] Thai H. T. Behavior of bolted endplate composite joints to square and circular CFST columns / H. T. Thai, B. Uy, Yamersi, F. Aslani // Journal of constructional Steel Research. – 2017. – Vol. 131. – P. 68 – 82.
- [5] Morino S. Design and Construction of Concrete-Fillde Steel Tube Column on Japan / S._Morino, K. Tsuda // Earthquake Engineering and Engineering Seismology. – 2002. – Vol. 4. No. 1. – P. 51 – 73.
- [6] Liang Q. Q. Nonlinear analysis of axially loaded circular concrete filled stainless steel tubular short columns / Q. Q. Liang, V. Patel, M. Hadi // Journal of constructional Steel Research. – 2014. – Vol 101. – P. 9 – 18.
- [7] Schneider S.P. The Design and Construction of Concrete-Filled Steel Tube Column Frames / S. P. Schneider, D. R. Kramer, D. L. Sarkinnen // 13th World Conference on Earthquake Engineering. – Vancouver, B.C., Canada. – Paper No. 252. – 2004.
- [8] Xiao Y. Confined Concrete-Filled Tubular Columns / Y. Xiao, W. He, K. Choi. // Journal of Structural Engineering. – 2005. – N3. – P.488– 497.
- [9] Li D. Analysis and Design of demountable steel column baseplate connections / D. Li, B. Uy, F. Aslani, V. Patel // Steel and Composite Structures Vol. 22. – 2016. – N4. – P.753-775.
- [10] Zhao Y. G. System Reliability Assessment by Method of Moments / Y. G. Zhao, A. Ang // Journal of Structural Engineering. – 2003. –N10. – P.1341–1349.
- [11] Gasii G. Estimate of technical and economic benefits of a new space composite structure / G. Gasii, O. Hasii, O. Zabolotskyi // MATEC Web of Conferences. - 2017. - vol. 116. - 02014, doi:10.1051/matecconf/201711602014.
- [12] Storozhenko L.I. Experimental research of strain-stress state of ferrocement slabs of composite reinforced concrete structure elements / L.I. Storozhenko, G.M. Gasii // Metallurgical and Mining Industry. – 2014. – vol. 6. – iss. 6 – P. 40–42.