УДК 624.016:69.059

FEATURES OF DEFORMATION OF COMPRESSED CONCRETE FILLED TUBULAR ELEMENTS WITH SEPARABLE JOINTS

ОСОБЛИВОСТІ ДЕФОРМУВАННЯ СТИСНУТИХ ТРУБОБЕТОННИХ ЕЛЕМЕНТІВ ІЗ РОЗ'ЄМНИМИ СТИКАМИ

ОСОБЕННОСТИ ДЕФОРМИРОВАНИЯ СЖАТЫХ ТРУБОБЕТОННЫХ ЭЛЕМЕНТОВ С РАЗЪЁМНЫМИ СТЫКАМИ

Semko Pavlo, postgraduate (Poltava National Technical Yuri Kondratyuk University)

Семко П.О., аспірант (Полтавський національний технічний університет імені Юрія Кондратюка, м. Полтава)

Семко П.А., аспирант (Полтавский национальный технический университет имени Юрия Кондратюка, г. Полтава)

Features of deformation of compressed concrete filled tubular elements with separable joints were described. The most effective design of separable joint was found based on experimental research. Also article deals with bearing capacity data and stress-strain state of design.

Описано особливості деформування стиснутих трубобетонних елементів із роз'ємними стиками. На основі експериментальних досліджень було визначено найбільш ефективну конструкцію роз'ємного стику. Також у статті наведено дані про несучу здатність і напружено-деформований стан конструкцій.

Описаны особенности деформирования сжатых трубобетонных элементов с разъёмными стыками. На основании экспериментальных исследований была определена наиболее эффективная конструкция разъёмного стыка. Также в статье приведены данные про несущую способность и напряженно-деформированое состояние конструкций.

Keywords:
Concrete filled tube, separable joints, stress-strain state, deformation.
Трубобетон, роз'ємні стики, напружено-деформований стан, деформування.
Трубобетон, разъёмные стыки, напряженно-деформированое состояние, деформирование.

Introduction. Concrete filled tubular structures have effective combination of steel and concrete that allows to fully implement the features of such materials. Because of that we have saving of metal and cement, reduce the size of cross section of concrete filled tube elements and as a consequence reduce the weight of the strucrure and transportation costs [1, 2].

It should be noted that the joints are an important structure element of concrete filled tubular designs. One of the main features of concrete filled tube elements is thing that during design the joint we should provide the joint operation of a steel pipe-shell and concrete core [4]. It is also worth noting that in our country and abroad in recent years greatly increased interest in the application of concrete filled tubular elements joints, and so this issue requires detailed experimental and theoretical research.

Analysis of recent research publications. Over the past 30 years, interest in concrete filled tubular structures increased significantly, as reflected in works L.I. Storoghenko [1, 9], V.I. Barbarskii [5], O.P. Voskoboynik [6], A.V.Gasenko [7], G.V. Golovko [8], D.A. Yermolenko [2, 3], particularly joints of concrete filled tube elements and methods of their calculation were engaged P.G. Kortushov [10], O.V. Nazarov [11], V.F. Pents [12], V.M. Tymoshenko [13].

In foreign countries the concrete filled tubular structures began to investigate and apply in China, the USA and Europe since 1950 [14, 15]. Over the last 30 years they have intensively studied under the guidance of organizations CIDECT and IIW. A series of guides for the design of tubular structures were issued due CIDECT [16, 17] in order to facilitate the work of practicing engineers.

The problem statement. The purpose of the experimental research was to obtain data on the impact of design of jonts on the nature of work of the junction, deformation and bearing capacity of concrete filled tubular elements. Within the purpose of concrete filled tubular elements separable joints research assumed to solve of the next problems:

– determination of the bearing capacity of concrete filled tubular elements with separable joints;
– research of the nature of work and the features of destruction of concrete filled tubular elements with separable joints;
– research of stress-strain state of experimental samples;
– determination of deformation of concrete filled tubular elements joints at different load levels.

The basic material and results. Considering review of research of concrete filled tubular elements clear that the nature of work of compressed concrete filled tubular elements with separable joints depend on the physical and mechanical properties of materials and design of the sample.

According to experimental program of research test samples of five series were tested, namely:

– concrete filled tubular elements without joints – TB series (Fig. 1, a);

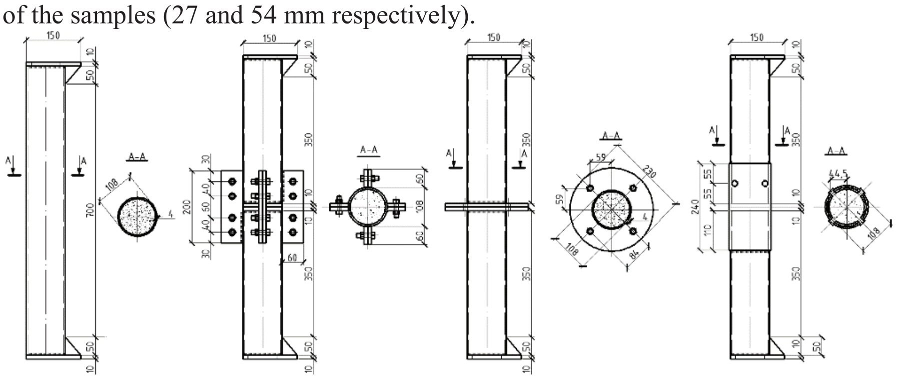
– concrete filled tubular elements with separable joint made with the help of longitudinal ribs - TBR series (Fig. 1,b);

– concrete filled tubular elements with flange separable joints - TBF series (Fig. 1, c);

– concrete filled tubular elements with separable joints made with the help of steel coupling - TBM series (Fig. 1, d).

For the possibility of comparison the sample without joint and filling of concrete was tested - T series.

For obtaining data on the concrete filled tubular elements with joints nature of work under noncentral compression (such working conditions concrete filled tube usually occur in extreme columns of industrial buildings) samples of series TB, TRP, TBF and TBM made to test with various eccentricities application of load - including random eccentricity and eccentricity equal 0.25 and 0.5 of the diameter of the samples (27 and 54 mm respectively).



a) b) c) d)

Fig. 1. Design of concrete filled tubular samples

Common to all experimental samples were design of concrete fillled tubular elements: steel pipe, not reinforced, made of steel grade S345, tube length - 800 mm pipe diameter - 102 mm pipe wall thickness - 4 mm. In samples with bolted connection the bolts used 5N6, made of steel grade 5.8. For the test on noncentral compression the eccentricities of applying loads were 27 and 54 mm, in some samples in support zone was designed console.

The samples TB and T (fig. 2) series were tested first. Deformation had been recorded in the most tense zone of compressed steel elements. For sample T-1 was observed typical as for centrally loaded steel pipe development deformation with elastic work before reaching the yield point and a sharp increase strain after its achievement Lyuders-Chernoff line were observed in the compressed area of sample. Corrugations were noticeable in support zone of the sample. Longitudinal and transverse strain at the time of achieving N_1 accounted for 155 and 28 units of $\varepsilon \times 10^{-5}$ respectively.

Sample TB-1 almost not deformed at the initial stage of work but after reaching $0,5N_1$ was observed similar with T-1 character of strain with the gradual development of deformations in the elastic stage and a sharp increase after its achievement. In the compressed area of sample observed Lyuders-Chernoff line. Corrugations were noticeable in support zone of the sample. Longitudinal and transverse deformation of concrete filled tubular element TB-1 at the time of achievement N_1 accounted for 160 та 44 units of $\varepsilon\times10^{-5}$ respectively.

In contrast to the central compressed concrete filled tubular elements for TB-2 and TB-3 (fig. 2) was observed a sharp increase the strain after achieve N_1. Lyuders-Chernoff line were observed in the compressed area of sample. Corrugations weren`t noticeable in support zone of the sample. Longitudinal and transverse deformation of concrete filled tubular element TБ-2 at the time of achievement N_1 accounted for 130 and 56 units of $\varepsilon\times10^{-5}$; for TБ-3 – 158 and 63 units of $\varepsilon\times10^{-5}$ respectively.

Fig. 2. Samples of TB and T series after test

Samples of TBR (Fig. 3) series had been characterized complicated stress-strain state as noted during experimental research. In the joint zone all cross-section had been worked as compressed element without longitudinal tensile strain, unlike the central section of concrete filled tubular element. Lyuders-Chernoff line were observed in the compressed area of sample. Corrugations were noticeable in support zone of the sample and near longitudinal ribs. Longitudinal and transverse strain at the time of achieving N_1 accounted for 175 and 151 units of $\varepsilon\times10^{-5}$ respectively.

A characteristic feature of samples TBR-2 and 3 deformation was that the longitudinal ribs due to the design of the given connection almost didn`t deformable, including the weld between ribs and tube wasn`t destruction and the connecting bolts weren't cut. Lyuders-Chernoff line were observed in the compressed area of sample. Corrugations weren`t noticeable in support zone of the sample. Longitudinal and transverse strain for TBR-2 at the time of achieving N_1 accounted for 162 and 42 units of $\varepsilon \times 10^{-5}$ for TBR-3 – 151 and 68 units of $\varepsilon \times 10^{-5}$ respectively.

Fig. 3. Samples of TBR series after test

Samples of TBM series (Fig. 4) had similar nature of work and deformation with samples of TB series. They were characterized by a slight deformation of the steel coupling and loss of the bearing capacity not separable joints area, but in the central part of one of the concrete filled tubular elements. Lyuders-Chernoff line were observed in the compressed area of sample. Corrugations were noticeable near steel coupling of the sample TBM-1 and TNB-2. Longitudinal and transverse strain at the time of achieving N_1 accounted for 158 and 129 untis of $\varepsilon \times 10^{-5}$ for TBM-1; 167 and 46 untis of $\varepsilon \times 10^{-5}$ for TБM-2; 157 and 49 untis of $\varepsilon \times 10^{-5}$ for TBM-3.

Fig. 4. Samples of TBM series after test

As noted in the process of experimental research samples of TBF series (Fig. 5) had the biggest strain in the middle part of concrete filled tubular elements. A characteristic feature of deformation samples of this series is that the flanges and bolts by which performed this separable joint after losing bearing capacity were almost undamaged, flanges are not separated and cutting of bolts not happened. Lyuders-Chernoff line were observed in the compressed area of samples. Longitudinal and transverse strain at the time of achieving N_1 accounted for 148 and 129 untis of $\varepsilon\times10^{-5}$ for TBF-1; 158 and 46 untis of $\varepsilon\times10^{-5}$ for TBF-2; 156 and 49 untis of $\varepsilon\times10^{-5}$ for TBF-3.

Fig. 5. Samples of TBF series after test

When tested concrete filled tubular elements with separable joints at compression as the the boundary state for bearing capacity has been chosen two states of concrete filled tubular element. The first was a state of samples in which the longitudinal deformation of steel pipe correspond the deformations of steel which reached the yield strength (N_1). The second state was the state when concrete filled steel tubular sample was destroyed (N_2).

Experimental values the bearing capacity N1 and N2, which correspond to the values in the first and second boundary state for compressed concrete filled tubular elements in Table 1 are presented below. Also, the table shows the ratio of the bearing capacity of the samples. Depending on the design of joints and eccentricity of the applied load it ranged from 1.09 to 1.79.

Conclusions. After conducting experimental researches of compressed concrete filled steel tubular elements with separable joints we did the following conclusions:

1. The samples of TBM (concrete filled tubular structure made of steel coupling) series were the most effective design of concrete filled tubular elements with separable joints.The samples of this series had the highest bearing capacity, the lowest material cost and the biggest ratio of effective work which approved high effectiveness of the such type design. The samples of TBF series had the lowest values of bearing capacity and effectiveness of work compare with other samples. The samples of TBR series were the most material cost design compare with other.

2. The main features of deformation and nature of work of the experimental samples were: the steel pipe-shell did not destroyed during test, Lyuders-Chernoff line were observed in the compressed area of sample, corrugations were noticeable near steel suport area of the most part of samples, also bolts didn`t cutting and samples didn`t destroyed in the joints zone.

Table 1

The bearing capacity of compressed concrete filled steel tubular elements

Sample	Eccentricity, mm	Bearing capacity, kN		N_2/N_1
		N_1	N_2	
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
TBM-1	0	725	996	1,37
TBM-2	27	400	620	1,55
TBM-3	54	280	500	1,79
TBF-1	0	700	900	1,29
TBF-2	27	400	610	1,53
TBF-3	54	280	440	1,57

3. Should be noted concrete core impact on the nature of the work and bearing capacity of concrete filled tubular elements. Comparing samples of T and TB series, we should be noted the presence of a significant effect of the concrete core. So values N1 and N2 for unfilled concrete pipes were lower on average by 40% than concrete filled tubular structure (450 and 580 kN for T series compared to 730 and 950 kN for a TB series) also we should say that blank steel pipe deformed significantly actively. This once again confirms the effectiveness of concrete fill for the structural elements that work in compression.

1. Стороженко Л.И. Трубобетонные конструкции / Л.И. Стороженко. – К.: Будівельник, 1978. – 82 с. **2.** Ермоленко Д.А. Трубобетонные конструкции со стержневым армированием: дис. ... канд. тех. наук: 05.23.01 / Д.А. Ермоленко.

– Полтава, 1998. – 180 с. **3.** Єрмоленко Д.А. Об'ємний напружено-деформований стан трубобетонних елементів [Текст] : автореф. дис. ... д-ра техн. наук : 05.23.01 / Д.А. Ермоленко / Полтав. нац. техн. ун-т ім. Юрія Кондратюка. – Полтава, 2012. – 40 с. **4.** Лопатто А.Э. О свойствах бетона, твердеющего в замкнутой обойме и жесткости трубобетонных элементов / А.Э. Лопатто // Строительные конструкции. – Вып. 11. – К.: Будівельник, 1973. – С. 232 – 234. **5.** Барбарский В.И. Работа и расчет изгибаемых предварительно напряженных трубобетонных элементов: дис. ... канд. техн. наук: 05.23.01 / В.И. Барбарский. – Полтава, 1992. – 326 с. **6.** Воскобійник О.П. Методика експериментальних досліджень мінливості трубобетонних елементів / О.П. Воскобійник // Збірник наукових праць. Сер.: Галузеве машинобудування, будівництво. – Полтава: ПолтНТУ. – 2003. – Вип. 11. – С. 170 – 174. **7.** Гасенко А.В. Надійність сталезалізобетонних стійок, виконаних із швелерів, з урахуванням експлуатаційних пошкоджень : автореф. дис... канд. техн. наук: 05.23.01 / А.В. Гасенко / Полтав. нац. техн. ун-т ім. Ю. Кондратюка. – Полтава, 2008. – 21 с. **8.** Головко Г.В. Напряженно-деформированное состояние центрально сжатых элементов из стальных труб квадратного сечения, заполненных бетоном: дис... канд. тех. наук: 05.23.01 / Г.В. Головко. – Полтава, 1996. – 195 с. **9.** Стороженко Л.І. Сталезалізобетонні конструкції: дослідження, проектування, будівництво, експлуатація / Л.І. Стороженко, В.М. Сурдін, В.І. Ефименко, В.І. Вербицький: Монография. – Кривий ріг: 2007. – 448 с. **10.** Кортушов П.Г. Розрахунок вузлів спряження монолітних залізобетонних конструкцій з трубобетонними стійками / П.Г. Кортушов // Проблеми теорії і практики залізобетону: зб. наук. пр. / Полтав. держ. техн. ун-т ім. Юрія Кондратюка. – Полтава, 1997. – С. 256 – 260. **11.** Назаров О.В. Напружено-деформований стан трубобетонних елементів при місцевих силових впливах [Текст] : автореф. дис... канд. техн. наук: 05.23.01 / Назаров Олександр Вікторович; Державний НДІ будівельних конструкцій. – К., 2004. – 20 с. **12.** Пенц В.Ф. Напряженно-деформированное состояние оголовков трубобетонных стоек: дис. ... канд. техн. наук: 05.23.01 / В.Ф. Пенц. – Полтава, 1995. – 187 с. **13.** Тимошенко В.М. Несуча здатність та деформативність стиснених трубобетонних елементів зі стиками: дис. ... канд. техн. наук: 05.23.01 / В.М. Тимошенко. – Полтава, 2000. – 209 с. **14.** Eurocode 4. Common Unified Rules for Composite Steel and concrete Structures European Committee for Standardization (CEN) ENV. – 1994. – 1-1: 1992. **15.** 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. **16.** CIDECT Design Guide No. 1. Design Guide for Circular Hollow Section (CHS) Joints under Predominantly Static Loading. – 1991. **17.** CIDECT Design Guide No. 8. Design Guide for Circular and Rectangular Hollow Section Welded Joints under Fatique Loading. – 2001.