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On the Issue of Determining the Design Lengths of Elements in Structural Constructions of the Kislovodsk Type

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Abstract.
Introduction. The article looks at the issue of determining the design lengths of rods of the structural construction of the Kislovodsk type. While examining the existing structure of the coating of the shopping center, in the design documentation for the object, the authors found that the design length coefficient equal to 0.8 was used in the calculations of the rod structure. The value of 0.8 is due to the results of the tests performed at Kucherenko Central Research Institute in 1987. However, according to the current regulations, a coefficient of design length equal to one is to be used. The aim of the article is to justify the value of the design length coefficient in calculations of such structures.
Materials and Methods. A standard unit of attaching rods to a nodal connector is considered. It was decided to study the work of both a separate structural unit and rods together by modeling in the Femap with Nastran software package. The paper considers the effect of a nodal joint on the stability of an individual rod. To this end, a nodal structural element with a support at the contact connection of a compressed rod and a calculation of a separate rod for stability was modelled. A system of rods is then considered in order to determine the critical force, taking into account the influence of adjoining elements. The scheme consists of four rods of the lower belt and four rods of the braces connected in one node and loaded with a compressive or tensile load.
Research Results. The considered separate joint of the rod with the connector, where compressive forces are transmitted through a tight contact, is very close to rigid fastening by the nature of the work when checking the stability of the rod. The design length coefficient for compressed elements ranges from 0.77 to 0.88, depending on the force values in the elements and their cross sections. Based on this, it can be unambiguously concluded that the application of a coefficient of 0.8 for all compressed rods cannot be theoretically justified.
Discussion and Conclusion. The coating studies show that the requirements of SP 16.13330.2011 "Steel Structures" are correctly applied in terms of determining the design length of a compressed rod equal to 1, and the use of a coefficient equal to 0.8 cannot be theoretically justified. Reducing the metal consumption while using reduced design length coefficients in calculations does not lead to significant savings for the overall structure and is not feasible.

Keywords*:* spatial lattice system, structural design, design length, stability

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Оригинальное эмпирическое исследование

К вопросу определения расчетных длин элементов в структурных конструкциях типа «Кисловодск»

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Аннотация
Введение. В статье рассмотрен вопрос определения расчетных длин стержней структурной конструкции типа «Кисловодск». При обследовании существующей конструкции покрытия торгового центра в проектной документации на объект авторами статьи выявлено, что в расчетах конструкции для стержней применяется коэффициент расчетной длины, равный 0,8. Значение 0,8 обусловлено результатами проведенных испытаний в ЦНИИСК им. Кучеренко в 1987 г. Однако действующие нормативные документы предписывают использовать коэффициент расчетной длины, равный 1. Целью данной статьи является обоснование значения коэффициента расчетной длины в расчетах подобных конструкций.
Материалы и методы. Рассмотрен стандартный узел крепления стержней к узловому коннектору. Принято решение об изучении работы как отдельного узла структурной конструкции, так и стержней совместно при помощи моделирования в программном комплексе Femap with Nastran. В работе рассматривается влияние узлового соединения на устойчивость отдельного стержня. Для этого выполнено моделирование узлового элемента конструкции с опиранием при контактном соединении сжатого стержня и расчет отдельного стержня на устойчивость. Затем рассматривается система стержней для определения критической силы с учетом влияния соседних элементов. Схема представляет собой четыре стержня нижнего пояса и четыре стержня раскосов, соединенных в одном узле и загруженных сжимающей или растягивающей нагрузкой.
Результаты исследования. Рассмотренный отдельный узел стыка стержня с коннектором, в котором сжимающие усилия передаются через плотный контакт, по характеру работы при проверке устойчивости стержня весьма близок к жесткому закреплению.
Коэффициент расчетной длины для сжатых элементов находится в пределах от 0,77 до 0,88 в зависимости от значений усилий в элементах и их сечений. Из чего можно сделать однозначный вывод о том, что применение коэффициента 0,8 для всех сжатых стержней не может быть теоретически обоснованно.
Обсуждение и заключение. Проведенные исследования покрытия показывают правильность применения требований СП 16.13330.2011 «Стальные конструкции» в части определения расчетной длины сжатого стержня равной 1, а использование коэффициента равного 0,8 не может быть теоретически обосновано. Снижение металлоемкости при использовании в расчетах пониженных коэффициентов расчетной длины не приводит к значимой экономии для конструкции в целом и не является целесообразной.

Ключевые слова: пространственная решетчатая система, структурная конструкция, расчетная длина, устойчивость

Для цитирования. Щуцкий С.В., Лиманцев А.А. К вопросу определения расчетных длин элементов в структурных конструкциях типа «Кисловодск». *Современные тенденции в строительстве, градостроительстве и планировке территорий*. 2026;5(2):41–48. https://doi.org/10.23947/2949-1835-2026-5-2-41-48

Introduction. Spatial lattice systems have been actively developed since the second half of the 20th century, and it was during this time that lots of different buildings and structures were designed that were covered with structural constructions[1] [1–3]. One of the most common lattice structures of pipe coating in Russia is the Kislovodsk type structure [4–5] developed as part of a state program and designed to solve the problems of organizing production and complete supply of light metal structures of industrial buildings.

The main property of both planar and spatial rod systems is that all elements are subject to a uniaxial stress-strain state (compression or stretching). Stretched elements are calculated for strength, and compressed elements are calculated for stability. In turn, the stability of an element directly depends on its calculated or reduced length. According to the regulatory documents, both in the current version and those in force in the past, while calculating the elements of spatial structural structures, the full geometric length of the rod is to be taken as the design length, or, in other words, a coefficient of

[1] Dykhovichny YuA, Zhukovsky EZ *Modern Spatial Structures (Reinforced Concrete, Metal, Wood, Plastics).* Moscow: Higher School; 1991. 543 p.

the design length equal to 1 should be applied (except in cases when the elements are welded in the nodes adjacent to spherical or cylindrical nodal elements; in this case the coefficient is assumed to be 0.85).

Throughout the course of the study of the mall coating designed in 2004, while analyzing the initial documentation and collecting initial data for a verification calculation of the structural construction, it was found that while designing it for rods with pipe cross-sections of 48×2.8, 57×3.2 and 76×3, the design length coefficient of 0.8 was used. This coefficient value was adopted by the developers of the design documentation as a result of tests conducted at the Kucherenko Central Research Institute in 1987. The aim of the article is to model the operation of a nodal element of a Kislovodsk-type structural construction and to substantiate the value of the design length coefficient in calculations of similar structures.

Materials and Methods. Let us consider the design of the attachment point of the elements to the nodal connector. The connecting element is a nodal connector that is a steel polyhedron with threaded holes (Fig. 1). All rods of the system have the same nominal length and consist of electro-welded or hot-rolled pipes with washers welded to the end. The rods of high-strength bolts with hexagon couplings attached to them are passed through the holes of the washers (Fig. 2). The threaded holes are directed towards the belts and braces converging at the node. The faces of the nodal element are normal to the axes of the holes and are equally spaced from the center of the node. Thus, in the case of stretched rods, the force is transmitted through high-strength bolts, and with a compressed rod, the force is transmitted through the contact of the coupling with the connector face[2].

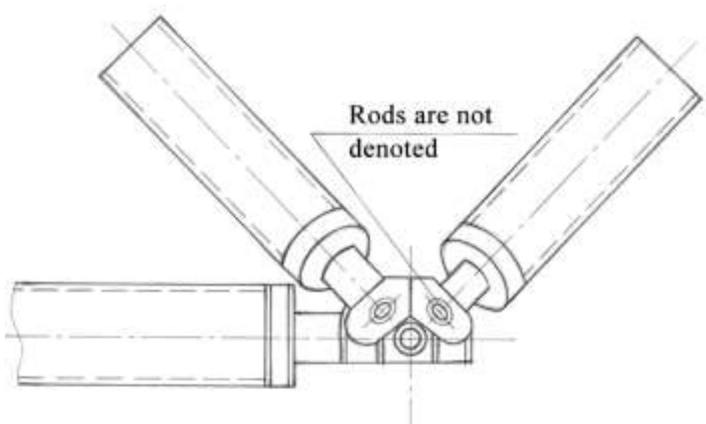


Fig. 1. Rod attachment unit of the Kislovodsk system.
URL: https://meganorm.ru/Index2/1/4293830/4293830102.htm (accessed: 17.04.2026)

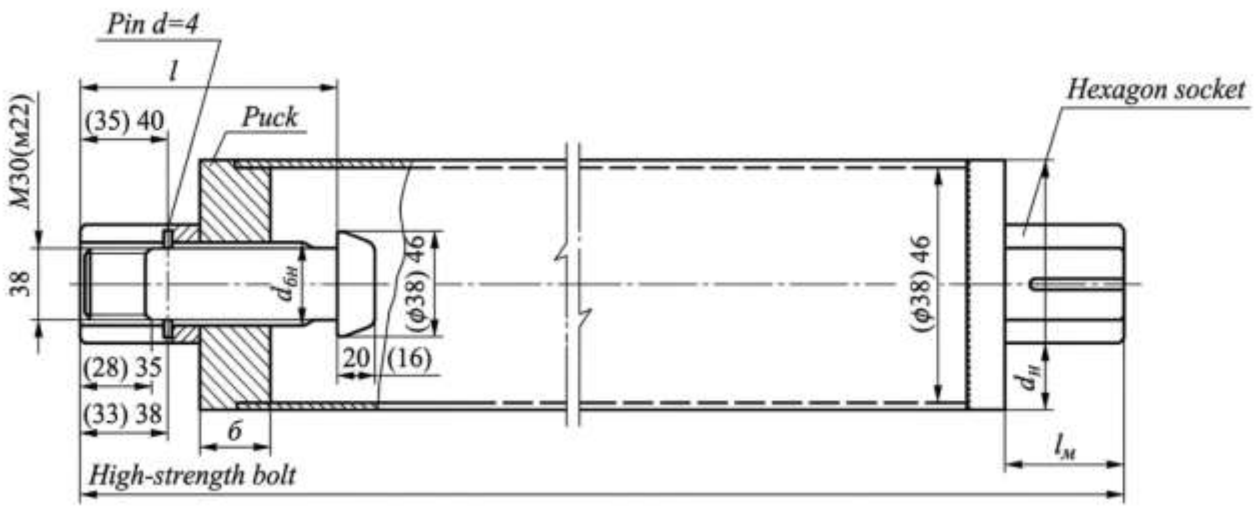


Fig. 2. Rod element of the Kislovodsk system.
URL: https://meganorm.ru/Index2/1/4293830/4293830102.htm (accessed: 17.04.2026)

[2] *Spatial Lattice Structures Made of Pipes of the Kislovodsk Type. Working Drawings.* 1.466-2 Series. Gipromontazhindustry; 1973. URL: https://meganorm.ru/Index2/1/4293830/4293830102.htm (accessed: 16.03.2026).

At a quick glance, such a joint seems to be more "hinged" than "rigid". However, a coefficient less than 1 can be obtained only with a "rigid" connection of the rods. Therefore, in order to verify the validity of applying a coefficient equal to 0.8, two questions need to be answered: what is the coefficient of stability of the rods of the lattice elements with a rigid connection and to what extent the accepted junction node can be considered close to rigid in terms of the stability of the rods.

As part of the study, it was decided to investigate the operation of structural construction elements using computer modeling. Modern engineering analysis systems (or automation systems for engineering calculations) — CAE (computer-aided engineering) — provide solutions to a large number of diverse problems of linear and nonlinear static analysis with a high degree of accuracy [6–10].

In order to perform calculations within the framework of this work, the Femap with Nastran software package was chosen as a powerful and flexible tool for solving a wide range of task types.

Research Results. The research part is divided into two separate tasks. First, the influence of the nodal connection described above on the stability of one rod is considered. Secondly, a system of rods is considered in order to determine the critical force, taking into account the influence of neighboring elements.

Task 1. Femap with Nastran provides the ability to connect two bodies of three-dimensional finite elements that touch each other, but do not have common nodes, using a "contact" and "glued" type connection. A "glued" joint restricts the movement of nodes in all directions over the entire joint area, and in fact the two bodies become one. The "contact" type connection prohibits the mutual penetration of bodies and allows one to model the free support of one body on another with no connection.

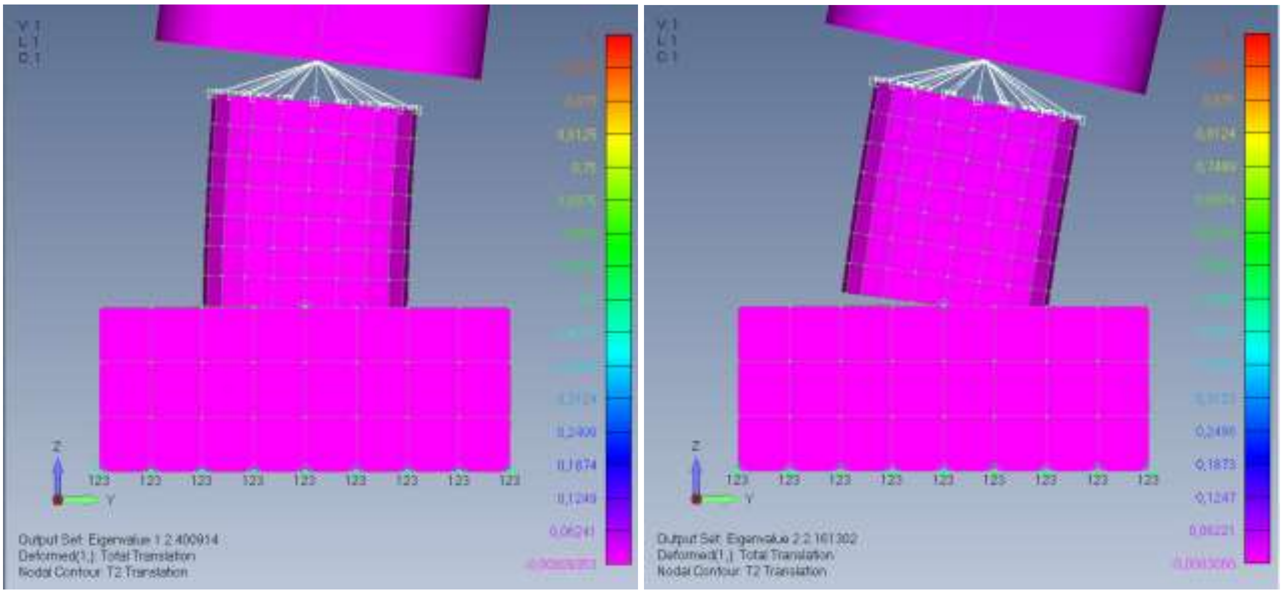
Let us model a node connection in the Femap with Nastran system. The connector is conventionally represented as a parallelepiped, the hexagonal coupling is replaced by a cylinder. The main rod is represented as a rod element and is connected to the coupling by means of a rigid coupling. The coupling and connector in the model is made as a "contact", which is closest to the actual design of the node. To compare, a stability calculation was also performed for the "glued" joint, which corresponds to a rigid joint (Fig. 3).

The main rod in the structural design has a cross-section in the form of a round tube of 80×3 and a total length of 300 cm. The Euler force for such a rod is

$$P_{\text{E}} = \frac{\pi^2 E I_x}{l^2} = \frac{\pi^2 \cdot 20600 \cdot 53{,}87}{300^2} = 121{,}7 \text{ kN}.$$

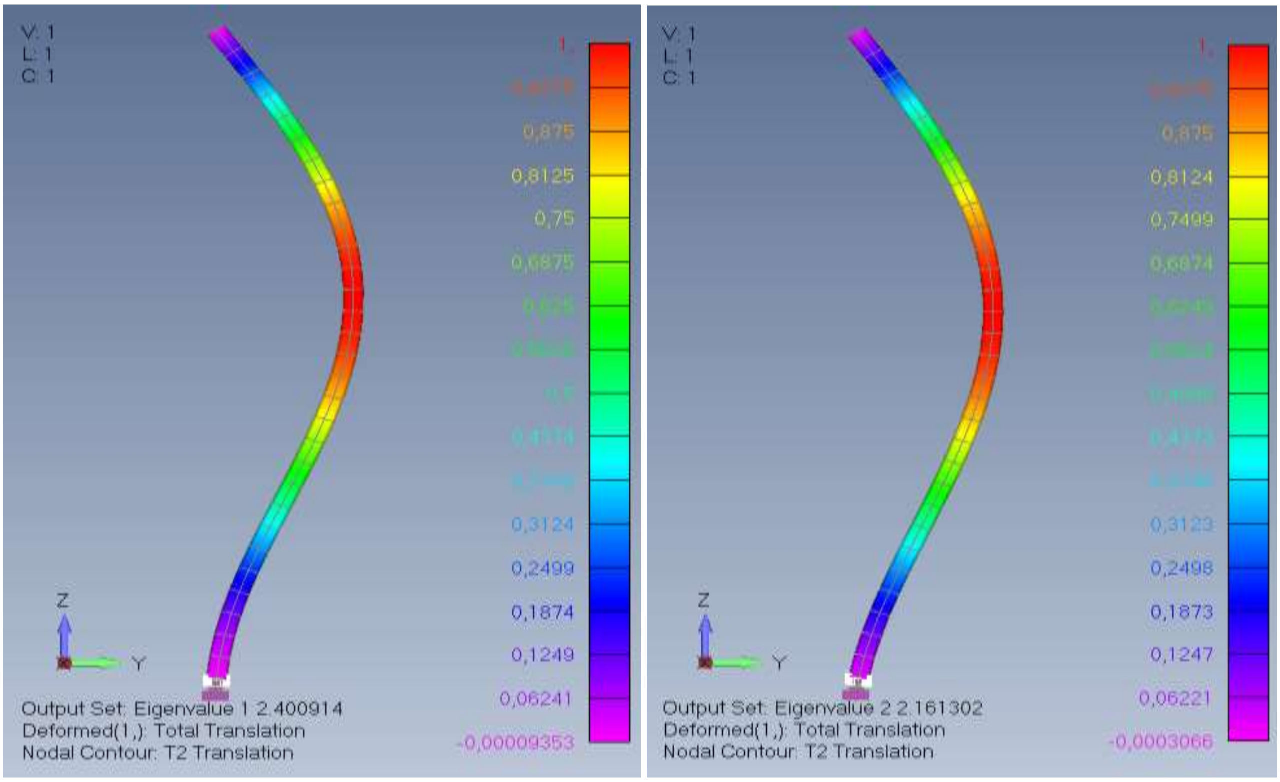
The values of the forces where the stability of such a rod was lost were 240.1 kN at the "glued" type connection, 216.1 kN at the "contact" type connection (Fig. 4). In this case, the design length coefficients are 0.712 and 0.75, respectively.

Comparing the results clearly shows that the actual operation of the node in terms of stability is very close to the rigid connection of the rod to the connector. The value of the longitudinal bending coefficient increases by 5%.



a) *b)*

Fig. 3. Options for modeling a nodal connection: *a* — "glued" type connection; b — "contact" type connection



a) *b)*

Fig. 4. Loss of stability while connecting: *a* — "glued"; *b* — "contact" type

Task 2. In order to identify the critical force for compressed elements, the following calculation scheme was chosen: four elements of the lower belt and four lattice elements connected in one node are considered [11–14]. The opposite end of each of the circuit elements has a hinge attachment. The length of all of the rods is 3 meters. It should be noted that while adding elements of the upper belt to the calculation model, the bevel rod will have two ends with varying degrees of pinching from loss of stability. However, it is assumed that the elements of the upper belt are predominantly in a compressed state, therefore they have a lower fixing effect, which is commonly neglected.

For starters, let us provide as an example an idealized loading variant of the design scheme, where all the elements of the lower belt are stretched by a single force, and the elements of the braces are stretched and compressed in pairs by a single force (Fig. 5). The cross-section of all the elements is a 60×3 tube.

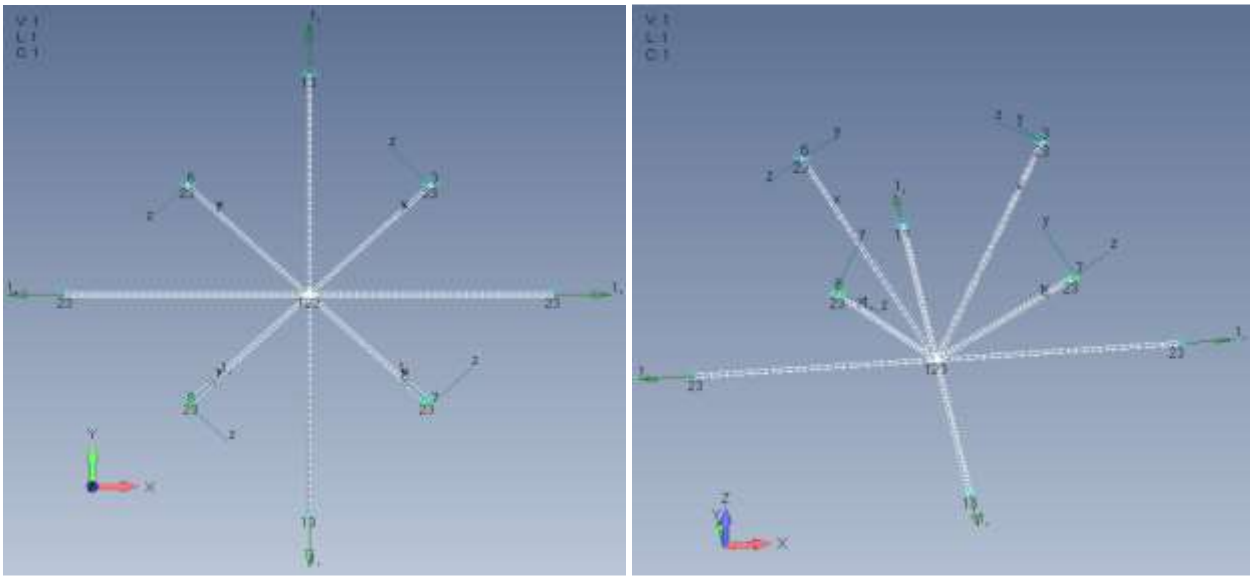


Fig. 5. Calculation scheme

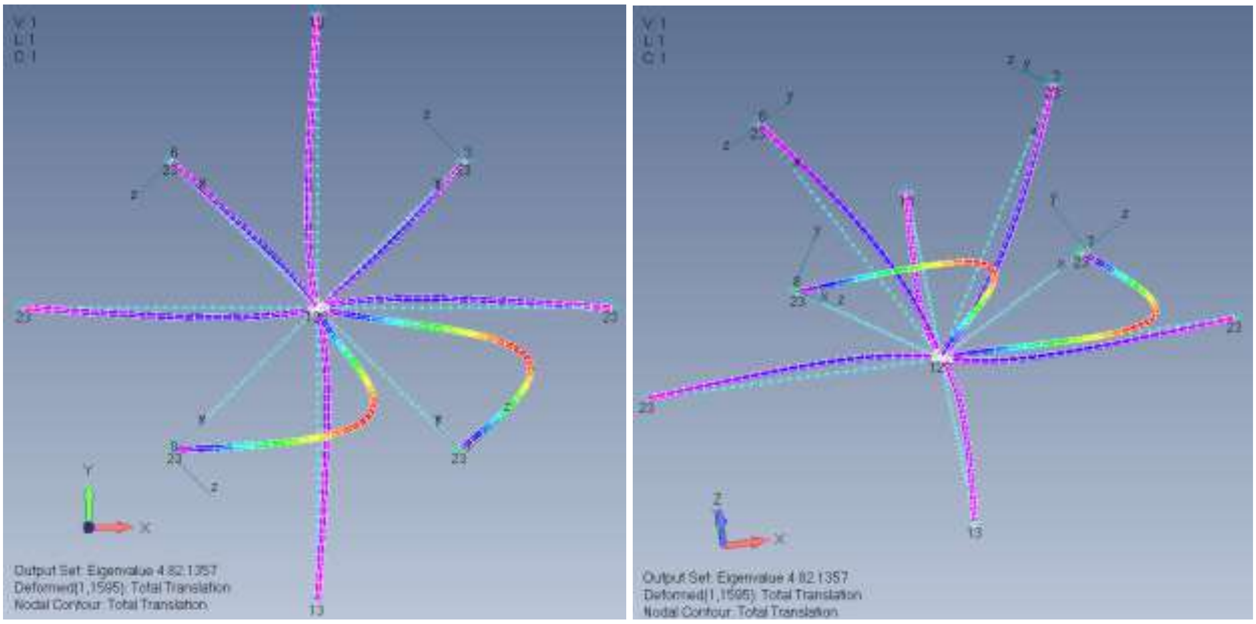


Fig. 6. Deformed circuit with loss of stability option 1

The compressed rods lost their stability at a force of 82.14 kN (Fig. 6), which yields a stability coefficient of 0.776.

The following is an example with a calculation for force ratios taken from an actual design. The loss of stability of the compressed rod occurs at a force value of 143.88 kN (Fig. 7), which yields a stability coefficient of 0.849. Some other combinations of forces and cross-sections of elements that were calculated as this study was being performed resulted in a design length coefficient ranging from 0.77 to 0.88.

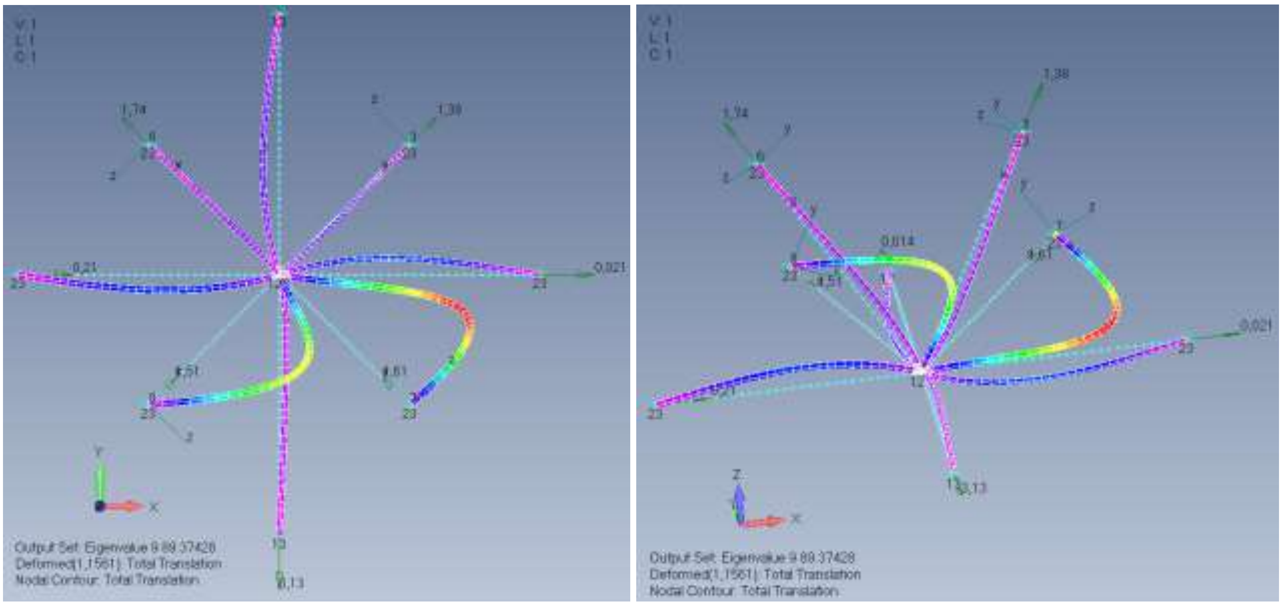


Fig. 7. Deformed circuit with the loss of stability option 2

As a result of the calculations, the following conclusions can be made:

1. The joint of the rod with the connector, where the compressive forces are transmitted through a tight contact, is very close to rigid fastening by the nature of the work while testing the stability of the rod.

2. The design length coefficient for compressed elements ranges from 0.77 to 0.88, depending on the force values in the elements and their cross sections. Based on this, it can be unambiguously concluded that the application of a coefficient of 0.8 for all the compressed rods cannot be theoretically justified.

Discussion and Conclusion. The studies of the coating in the form of a structural constructions of the Kislovodsk type show the correctness of the application of the requirements of SP 16.13330.2011 "Steel Structures" in terms of determining the design length of a compressed rod equal to 1, and the use of a coefficient equal to 0.8 cannot be theoretically justified. On top of that, while calculating and designing such structures, the fact that in a system of this type there are a large number of rods with different forces should be taken into account and considering all possible combinations is a complex task. At the same time, the increase in metal consumption while considering a single element and taking into account only the pipe section is 20–30%, however, if the metal consumption and cost of manufacturing the entire structure is taken into consideration, these savings are significantly offset and are not feasible.

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Claimed contributorship:

SV Shchutsky: formation of the basic concept, aims of the study, revision of the manuscript, correction of the conclusions.

AA Limantsev: preparation of the manuscript, calculations, formation of the conclusions.

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А.А. Лиманцев: подготовка текста, расчеты, формирование выводов.

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