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Multi-face metal columns for urban structures

A. Pustovgar[a], I. Garanzha[b]*, L. Shilova[a], A. Tanasoglo[b], A. Adamtsevich[a], V. Ivanilov[b]

[a]*Moscow State University of Civil Engineering (National Researh University), 26 Yaroslavskoye Shosse, Moscow, 129337, Russia*
[b]*Donbas National Academy of Civil Engineering and Architecture 86123, Makiyivka, Derzhavina Str. 2, Donetsk Region, Ukraine*

Abstract

The article considers national and foreign experience of the use of multi-face bent metal columns (tubes) for the erection of tower structures for the needs of modern cities. The authors present a review of the literature concerned and try to reveal the problem trends in the field for the purpose of the further study of stress-and-strain state (SSS) of the aforesaid structural elements as well as the special features of their work under load. This study may improve the structural shape of the aforesaid multi-face metal structures, improve their design as well as the consideration of the wind load contributing much to their stress-and-strain state. The authors also consider the prospects of production and use of multi-face metal structural elements in modern construction in Russia. The special features of the design methods concerned and a comparative analysis of the SSS parameters of multi-face bent metal columns are considered, too.

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Keywords: multi-face bent metal columns, field of application, stress-and-strain state, design method, metal shell, finite element method, production of multi-face columns, improvement of columns' design parameters.
Introduction

Introduction

The world practice of the use of multi-face metal bent columns (MMBC) lasts for about 40 years. They are mainly used as the posts for aerial power lines (APL). The MMB columns are widely used as power transmission line supporting structures, tangent-suspension and anchor supports, switch-gear portals, electrical equipment posts at power substations. The MMBC may be also used as road signs, exterior lighting posts, TV- and radio broadcast

* Corresponding author.
E-mail address: garigo@mail.ru

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towers, contact-line support structures, etc. There are many post design variants, fixation units and methods of anchoring the posts in the ground [3-8, 17, 33].

The multi-face steel columns are conic tubes with box-shaped multi-face cross-sections; they are produced in the process of bending steel sheets and welding the joints [3, 4, 33]. The post height h may be up to 80 m with the wall thickness of up to 20 mm [3-5]. The post butt diameter d_k varies within the range 250 … 3000 mm, the post upper end diameter is 200 … 500 mm. the MMB structures are shown in Fig.1. (a-f)

The MMBC are still not wildly used CIS-countries. There was some experience of erection of MMBC with section flange joints and guy-ropes for aerial power lines (110 – 330 kV). But such structures had no prospects of their wide use. In Russian Federation, the MMBC have been used since 2006.

Fig.1. General design diagram of MMBC and their structures:
a-c) mobile communication towers; d, e) anchor post VL 420kV; f) railway contact network support

Review of publications in the field

There is no common opinion concerning the design diagram of multi-face bent structures (MBS) and the methodology of their design calculations. In this case, both the MMBC itself and its flange base, that is their joint operation, are of interest.

In the 1970s, a methodology of design calculations for the MBS as the columns with piece-constant cross-sections was suggested [9]. This methodology has been introduced into the normative document “Recommendations on design of steel structures for aerial power line posts and outdoor switch-gears at the substation (with voltage of more than 1kV) (to the CNR II-23-81*)”. The aforesaid methodology was widely used for the design of MBS (in particular, for the APL posts), though it had two serious drawbacks. First, it cannot determine the SSS-parameters in any cross-section (it is possible only at the basement level). Second, the design calculations do not show the work of compressed and stretched post zones, which is very important for compressed-and-bent moments.

If we consider the multi-face bent structures as folded metal shells (folds), their static analysis may be performed in accordance with non-moment and moment theories. The non-moment analysis reduces the solution of three-term equations through the work method or the displacement method [10-14]. The fold analysis through the moment theory (with consideration of transversal moments) is carried out with the use of the work method equations [15] or the mixed method canonical equations [16]. The main contradiction of the application of the fold analysis to the MBS is that the practical construction mostly uses the folds for space reinforced concrete structures made from joint monolith plates (space roofing structures, chute hoppers, water supply channels, etc.).

The theory of non-moment analysis for smooth thin-wall shells is described by V.V. Gorev, E.N. Lessig [17], A.F. Lileeva [17]. Taking into consideration the definition criterion for thin-wall shells ($20 \prec \frac{r}{t} \prec 200$) and the MBS special feature (the shell bend in the cross-section), we can speak of a possible use of this theory for the columns with different number of faces due to their similarity to a round cross-section.

The analysis of flange joints (the most popular joint type in MBS structures for the fixation of columns at the foundation as well as the column sections with each other) is considered in the works by I.A. Birger [21], G.B. Iossilevich [21, 23], S.T. Kovgan [23], Yu.V. Lashtshuk [23]. The aforesaid authors consider loose flanges and the analysis through variable pliability. The main drawback of this methodology is the fact that it is impossible to take