Design of pre-stressed intersecting cable string steel bridge

Povilas Dabrila, Algirdas Juozapaitis

Vilnius Gediminas Technical University, Vilnius, Lithuania

Contact: povilas.dabrila@vilniustech.lt

Abstract

The article presents the methodology for designing an innovative pre-stressed cable-stayed steel bridge structural system using intersecting cables and string. The behavior of this new structural system under the effect of permanent and temporary loads is also taken into account. The article also discusses the design of the components of this new type of structure and presents the calculation methodology of this structural system taking into account geometrical nonlinearity. Installation sequence variants of such a bridge are also considered as well as the influence of string and cable pre-stressing on bridge displacement and component stresses. Equations for calculating bridge string stresses and displacements are presented. The article shows how to design this new steel bridge system which is more effective than the typical cable-stayed bridge structure according to the mass criterion.

Keywords: steel bridge; cable-stayed bridge; pre-stressed string; intersecting stay cables; nonlinear analysis; analytical model; numerical modelling.

1 Introduction

Cable-stayed bridges are exceptional structures due to their form and architectural appeal [1,2]. Bridges of this type of structure not only cover record spans [3,4] but are successfully implemented for shorter spans, too [5,6]. Nevertheless, we have to mention their disadvantages: e.g. sensitivity to asymmetrical or local loads and the relatively big mass of stiffening girder and pylons [7,8]. Additional cables, branched stay cables, pylon connection with stringers, etc. could be used to work around mentioned issues [9,10,11]. Intersecting cable stays could be one of the way to stabilize bridges initial form. They can not only control displacements, but shorten required pylon height as well. Such cable-stayed pedestrian bridges were built in the United Kingdom - Royal Victoria Dock Bridge [12] and the Forthside Footbridge [13], and in France - Passerelle du Grand Large bridge [14].

Stress ribbon bridges are well known for their light weight [6,15]. However, such bridges are also marked by high deformability [16] and certain initial sag [5,6]. Different approaches have been developed to reduce the kinematic-type displacements of this type of bridge [17,18,19]. However, many of them are costly and complex.

To keep the straight deck shape suitable for the usage, additional structures are designed. A pre-stressed string functions as the main supporting element [20]. This supporting element has no kinematic displacements, i. e. they are not sensitive to the effects of asymmetrical loads. Using high strength materials could be one of the solutions confronting high stresses and relatively small cross-sections. [20,21]. The main disadvantage of these systems – they can only cover small spans.

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