Engineering Structures 32 (2010) 3301–3312

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Parametric study on the dynamic response of cable stayed bridges to the sudden failure of a stay, Part II: Bending moment acting on the pylons and stress on the stays

C.M. Mozos [a,*], A.C. Aparicio [b]

[a] Department of Civil Engineering and Building, UCLM University of Castilla-La Mancha, Av. Camilo Jose Cela s/n 13071, Ciudad Real, Spain

[b] Department of Construction Engineering, UPC Technical University of Catalonia, C. Jordi Girona 1-3, 08034, Barcelona, Spain

ARTICLE INFO

Article history:
Received 15 December 2009
Received in revised form
25 May 2010
Accepted 1 July 2010
Available online 12 August 2010

Keywords:
Cable stayed bridges
Dynamic amplification factor
Loss of a cable

ABSTRACT

The limit state of failure of a stay is one of the accidental events that must be considered in the design of cable stayed bridges. The existing recommendations propose a static analysis with a dynamic amplification factor, D.A.F., of 2.0 for evaluating the response of the bridge to this accidental limit state. This paper is the second part of a companion paper (i.e. Part I) which deals with the response of the cable stayed bridges to the sudden failure of a stay. Its objectives are to quantify the relative importance of the accidental ultimate limit state of failure of a stay in the design of the bridge, and to determine the safety level provided by the simplified procedure of using a static analysis with a D.A.F. of 2.0. For this purpose, a parametric study has been carried out. In this study, ten cable stayed bridges have been analyzed and the effects of characteristics such as the layout of the stays, either fan or harp pattern, the number of planes of stays and the stiffness of the deck have been studied. The Part I companion paper details the geometry and materials of the studied bridges, the numerical models, the basis of the analysis developed and the results related to the deck cross sections. The present paper focuses on the response of the pylons and the stays.

1. Introduction

Recent studies such as [1–5] have demonstrated that the use of a dynamic amplification factor, D.A.F., equal to 2.0, as it is suggested in [6,7], for obtaining the maximum dynamic response of a cable stayed bridge, see [8–12], to the sudden rupture of one of its stays becomes unsafe in some cases.

Thus, the response of four different cable stayed bridges with a length of 403 m, which were obtained combining two concrete decks with a fan or a harp arrangement of the stays, to the sudden failure of a stay was studied in [1]. Simplified 2D numerical models of the bridges were used for obtaining their dynamic responses and self weight and fifteen live load distributions were considered. Results detailed in [1] show that the dynamic amplification factors for bending moments on the deck and bending moments on the pylons can reach values much larger than 2.0 such as 4.18 and 10.61 for deck and pylons, respectively. In the case of the forces acting on the stays, the dynamic amplification factors obtained were around 2.0. Another general result summarized in [1] is that only a D.A.F. smaller than 2.0 was observed at cross sections which were located close to the broken stay.

A five-span cable stayed bridge with a total length of 1140 m, steel deck and concrete pylons was studied in [3–5]. The influence of cable modelling and damping on the dynamic response of the bridge to the loss of a stay was obtained from a 3D numerical model of the bridge under permanent loads and two possible distributions of live loads. In addition, the envelopes of the D.A.F. were obtained from the responses of the undamped system to the loss of each one of the stays under self-weight and without live loads. The authors of these works concluded that a D.A.F. smaller than 2.0 seems possible for bending moments in the stiffening girder, a D.A.F. of 2.0 is necessary for the design of the cables and significantly a larger D.A.F. was observed for the bending moments acting on the pylons. High values of the D.A.F. were observed at locations of the deck placed further away from the ruptured cable, however, the authors concluded that the dynamic responses at locations further away from the broken cable are irrelevant when considering all cable loss load cases, because only responses in the vicinity of the ruptured cable are design governing.

The present paper is the second part of two papers dealing with the response of cable stayed bridges to the sudden rupture of one stay. The objectives are to quantify the relative importance of the accidental ultimate limit state of failure of a stay in the

* Corresponding author. Tel.: +34 926295300; fax: +34 926295391.
E-mail addresses: carlosmanuel.mozos@uclm.es (C.M. Mozos), angel.carlos.aparicio@upc.edu (A.C. Aparicio).

0141-0296/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2010.07.002

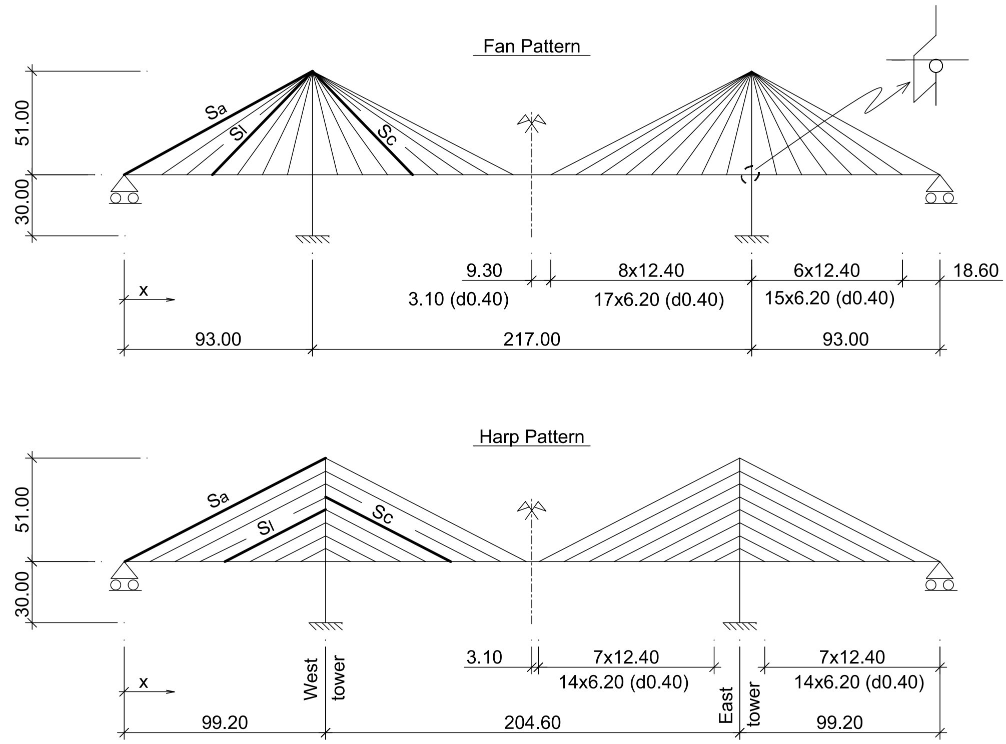

Fig. 1. Longitudinal layout of the bridges and location of the anchor stay studied, *Sa*, lateral span stay studied, *Sl*, and central span stay studied, *Sc*. Dimensions in meters.

design of the bridge, and to determine the safety level provided by the simplified approach proposed in [6,7]. To this purpose, the dynamic and static behavior of ten cable stayed bridges, which are obtained combining three decks with four layouts of the stays, are numerically analyzed. Detailed 3D numerical models of the bridges, which include the corresponding live and variable loads, are developed for obtaining the responses of the bridges. The live loads distributions are determined from the influence lines corresponding to each cross section and bridge studied. Results for the failure of the stay which is critical for the internal force and section studied are obtained in order to quantify and compare the ultimate limit states of permanent and transitory loads with the accidental limit states of failure of a stay. The influence of damping, stiffness of the deck, number of planes of stays and arrangement of the stays, fan or harp, on the response of the bridge to the loss of a stay arises from the parametric study allowing to determine which ones of these characteristics reduce the effects of the loss of a cable and, consequently, avoid that the accidental event governs the design of the bridge. In addition, the error incurred when the approach suggested in [6,7] is used for evaluating the response to the sudden loss of a stay is expressed in terms of the envelope of the ultimate limit states of permanent and transitory loads in order to quantify the relative importance of this error.

Results related to the response of the deck, in terms of bending moments acting on five deck cross sections of the bridges, are discussed in Part I [13]. The main conclusions reached indicate that the simplified approach proposed in [6,7], $AULS_{DAF=2}$, is unsafe in most of the cases of load combination for negative bending moments on the deck, and the incurred error has a magnitude that in some cases overcomes the envelope of the ultimate limit states of permanent and transitory loads, $ULS_{p,t}$. Otherwise, in the cases of load combinations for positive bending moments, it was found that the simplified approach leads to an unnecessary overdimensioned deck.

The present paper focuses on the responses of the pylons and the stays of the bridges analyzed in Part I [13]. Thus, Section 2 describes the parametric study and the pylon cross sections and stays in which the study is focused. In Sections 3 and 4, results related to the response of the pylons and stays, respectively, are presented and discussed. Finally, Section 5 provides some of the conclusions related to the response of the pylons and the stays.

The references in Part I [13] are also relevant to this paper and they will not be repeated here.

Table 1
Decks. Cross section, A, second moment of area, I_y, and torsion constant, J_x.

Deck	Depth (m)	A (m^2)	I_y (m^4)	J_x (m^4)
d0.40	0.40	5.20	0.069	0.277
d1.15	1.15	5.20	0.817	2.334
d2.25	2.25	5.20	3.710	9.755

2. Description of the parametric study

Ten cable stayed bridges with a total length of 403 m spaced out in one principal span and two lateral spans, see Fig. 1, are studied in the parametric study. These bridges are obtained combining three decks, whose main mechanical properties are detailed in Table 1, with two layouts of the stays, either in a fan or in a harp pattern, which can also be arranged in one central plane or in two lateral planes. In all of the cases, both pylons and decks are considered to be made of concrete. Table 2 summarizes the characteristics of the ten bridges studied. Numerical models of the bridges are developed and studied by means of linear static and dynamic analysis using the finite element code SAP2000NL v. 8.0.8. A detailed description of the geometry and materials of the bridges, loads considered, numerical models and analysis developed are included in Part I companion paper [13].

The study in this paper focuses on the bending moments acting on the pylons and the axial stress on the stays. Since the bridges have two symmetry axes, the bending moments on the pylon are studied at four cross sections along one of the pylons of each bridge. Fig. 2 shows the location of the cross sections studied along the North-West and West pylons of bridges with two and one