Nonlinear static analysis of cable-stayed bridge considering semi-rigid connections

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Abstract

Studying the structures under the effect of incremental lateral loads and achieving the capacity curve of structure are defined as nonlinear static analysis. The speed and ease of results interpretation in this method is more than that of the NRHA. Hence, for seismic assessment of cable-stayed bridge with semi-rigid connections, nonlinear static analysis method is employed in this paper. The impact of connection flexibility is investigated in the two separated states (the connection of deck to tower and the supports of tower). The cable-stayed bridge is modeled in the OpenSees software based on the load control. In addition, the maximum base shear and lateral displacement results, calculated in different nodes of bridge tower, are reported. According to responses, the rate of displacement increasing due to decrease of connection flexibility is about 15 percentages less than that of caused by reducing tower supports rigidity.
Keywords: Cable-stayed bridge, nonlinear static analysis, semi-rigid connection, load control method, OpenSees software

1. INTRODUCTION

The nonlinear pushover analysis is a simple way for estimating the capacity of the structure under lateral loads. Furthermore, this technique can also be utilized to determine plastic hinges of the structure. The development and implementation of this method date back to recent decades. Gulkan and Sozen [1] employed the nonlinear static analysis for investigating the behavior of MDOF structure by using equivalent system. During the last years, nonlinear static analysis has played an important role in the development of the earthquake engineering based on the performance of the structure and it has been widely utilized in the regulations and guidelines for evaluating the seismic behavior of structures. Nevertheless, traditional nonlinear static analyses of current guidelines, such as ATC-40 and FEMA-356 [2, 3] are faced with shortcomings; so these analyses are employed based on a constant shape mode and effects of higher modes are not considered. Also, the nonlinear modal pushover analysis suggested by Chopra and Goel [4] employs several nonlinear static analyses with load patterns proportional to elastic first mode shapes and seismic response of the structure is obtained from combining responses of each mode by SRSS method. Also, these researchers [5] offered a modified method of nonlinear modal pushover analysis (MMPA) based on elastic response spectrum in higher modes. An adaptive modal combination (AMC) was introduced by [6], in which constant-ductility inelastic spectra were used to obtain the displacement of target point. Also, an advanced spectra-based multi modal adaptive procedure (MMA) has been presented by [7] to improve the accuracy of nonlinear static analysis with once implementation. Most of these methods have been developed for building structures and their application in other structures, such as cable-stayed bridges is faced with uncertainties.

One of the assumptions in dynamic analysis of frames is the consideration of rigid and hinge connections. These connections include support and nodal connections. Although, the application of this method simplifies the analysis but it doesn't reveal the true behavior of the structure. In the past, so many researches have been done about semi-rigid frame analysis. A numerical solution was presented for linear and non-linear free vibration analysis of the frames with semi- rigid connections by Chan and Ho. They modeled connections with rotational springs and introduced stiffness matrix [۸]. In 1989, the influence of non-linear semi-rigid connections on static and dynamic responses of spatial frames is examined by Shi and Atluri. They analyzed semi-rigid frames by using geometric stiffness matrix of the semi-rigid member [۹]. In 1998, Rodrigues et al. investigated the behavior of steel frames with and without lateral brace, having nodal semi-rigid connections. They employed FEM in the analysis frame [۱۰].