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Evaluating the Sensitivity of Dynamic Transient Solution of Concrete Bridge Piers in Contact with Surrounding Water to Time Step Values via ANSYS Finite Element Software

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Abstract

Sensitivity of developed finite element models with respect to time step needs to be investigated for accurate transient analyses. In this paper, sensitivity of the ANSYS finite element software for dynamic analyses of cylindrical concrete bridge piers with surrounding water modeled by SOLID45 and MASS21 elements is investigated for the displacement-control and force-control analyses. Although displacement-control method is more convenient than the force-control method for modeling seismic ground motions in ANSYS environment, it is shown that the displacement-control method is sensitive with respect to time step and its accuracy does not stably increase by decreasing time step. Furthermore, the amplitude-reduction coefficient for parameters of the Newmark time-marching solution can reduce numerical oscillations of the ANSYS displacement-control method. The force-control method is less sensitive to time step reduction and has higher accuracy than the displacement-controlled method for transient analyses such as fluid-structure interaction of bridge piers.

Keywords: Transient finite element modeling, Fluid-structure interaction, Time-step sensitivity analyses, Displacement-control method, Force-controlled method.

1. INTRODUCTION

For seismic evaluation, design, and retrofit of water-crossing bridges, fluid-structure interaction should be properly modeled. Except for critical important bridges where fluid domain is modeled, bridge engineers use added hydrodynamic mass developed by Goyal and Chopra (1989) [1, 2]. Finite element modeling of such fluid-structure interaction problems under transient loads requires verification, sensitivity, and calibration analyses [3, 4, 5, 6]. It is well-known that such analyses are software dependent. In this paper, accuracy and sensitivity of ANSYS software [7] for transient dynamic analyses are investigated.

For transient dynamic analyses, ANSYS uses force-control and displacement control methods. Force-control method is the ANSYS default for applying dynamic loads. This method is efficient for most practical cases as long as the analysis allows. The displacement-control method needs the force-displacement curve for a certain degree of freedom. The displacement-control and force-control methods have been widely used by experts of ANSYS software, as presented in ANSYS web site http://www.ansys.net [8, 9].

The time-step size directly affects the stability, rate of convergence, and accuracy of a transient finite element solution. Issues regarding the time-step size selection are discussed in literature [10, 11]. It is well-known that transient finite element solution becomes more accurate when the time step increases. However such a trend cannot be observed with ANSYS transient analyses especially when the time step becomes very small. At small time steps, the solution becomes instable and wild response numerical oscillations are dominant the response time histories. Such behavior has been investigated in this paper for ANSYS transient finite element analyses of cylindrical concrete bridge piers with surrounding water under constant base acceleration, harmonic loading, and seismic ground motions. Such fluid-structure interaction problems require small time steps due to low periods of the model and high pressure wave velocity affecting solution stability controlled by Courant number [12].

In order to investigate the sensitivity of ANSYS displacement-control and force-control methods, both methods are used with various time step values for the fluid-pier interaction problem. The pier response time