Dynamic Analysis and Innovative Design of a Kilometer-Long Highway Bridge under Extreme Landslide Generated Wave Loading

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Abstract

This paper focuses on the dynamic analysis and innovative design of a 1042 m long highway bridge under extreme Landslide Generated Wave (LGW) impact loading. The proposed bridge crosses a deep and wide river valley which will become a part of a large reservoir after a hydroelectric dam is constructed. A rare extreme landslide event could occur and generate fast-moving waves in the reservoir impinging large forces on the bridge. To investigate the wave impact loadings on the bridge, three-dimensional Computational Fluid Dynamics (CFD) modeling of wave propagations were completed by hydrotechnical specialists, which were then used to analyze the structural dynamic response and to obtain force and displacement demands for structural design via a time-stepping analysis of the bridge structure. The innovative design included the use of non-uniform single circular-shaped pier columns supported on a hexagon-shaped pile cap with axisymmetrically configured rock-socketed steel pipe piles to address directional uncertainty associated with LGW. The bridge is currently under construction.

Keywords: dynamic analysis; bridge design; landslide generated wave loading; extreme loading

1 Introduction

Past experience has shown that wave impact loading can cause extensive damage or collapse of structures in the event of a hurricane and tsunami-generated waves [1-3]. It is recognized that waves with frequencies similar to that of structures could lead to resonance and increased structural demands [1]. After the catastrophic events of the 2004 India Ocean Tsunami and the 2011 Great East Japan Tsunami, there have been extensive studies to understand wave impact loadings of tsunami on structures [4-7]. Experimental investigations of wave loading on structures were reported in [8-11]. In addition to experimental studies, numerical studies were performed by researchers and practitioners. In general, there are two ways of analyzing structural response under wave loading [12]. The first approach is the fully integrated computational method considering full dynamic interactions between structure and wave propagation. Examples of software having this capability are Abaqus and ANSYS, which incorporate the response of structure impacted by wave and effect of structure on fluid simultaneously [12]. The second approach uses a decoupled