Soil-Structure-Pipe Interaction Analysis and Inelastic Design of the Port Mann Water Supply Tunnel Shaft and Pipe – Case Study

John Sherstobitoff, Derek Zimmerman

Ausenco, Vancouver, BC, Canada

Upul Atukorala

Golder, Vancouver, BC, Canada

Allen Mitchell

Metro Vancouver, Burnaby, BC, Canada

Contact: john.sherstobitoff@ausenco.com

Abstract

The new Port Mann Water Supply Tunnel in Metro Vancouver, BC, Canada is a 1km long, 60m deep, 2.1m diameter water main constructed under the Fraser River through liquefiable soil. The tunnel, shafts and pipe are designed to withstand ground motions with a 10,000 year return period and continue to deliver water. Non-linear time history analysis of the soils predicts approximately 6m of lateral movement for the design seismic event. Soil-structure interaction analyses indicated conventional design was ineffective for both the shaft and the 60m free-standing steel water pipe within one shaft. A unique hybrid inelastic design was used to enable the steel pipe to realize very high inelastic strains and the concrete shaft to yield to accommodate the soil induced demand. The design required special grades of high ductility steel and innovative details to de-couple the concrete shaft from concrete shoring walls to limit demands on the shaft.

Keywords: seismic, liquefaction, tunnel shaft, inelastic design, soil-structure interaction, steel pipe, concrete hinge, self-consolidating concrete, shear friction.

1 Introduction

Metro Vancouver, the water utility for Greater Vancouver, replaced an existing potable water supply pipeline crossing beneath the Fraser River from Coquitlam to Surrey (suburbs of Vancouver, BC, Canada) in part to improve the seismic performance of this critical part of their water transmission network.

After extensive planning, site investigations, design, and construction that commenced in 2011, the Port Mann Water Supply Tunnel was placed into service in early 2017.

The design involved the use of SAP2000 and ABAQUS finite element non-linear modelling and iterative analysis of the concrete shaft and the steel water main pipe respectively, combined with FLAC soil-structure interaction non-linear analysis for 6 different earthquakes for 2 separate soil models.

This paper focuses on the 65m deep, concrete shaft (integral with a valve chamber) at the north end of the tunnel, and the free standing steel water carrier pipe within.

2 Analysis and Design

2.1 Earthquake Input Motions

The input motions used comprised earthquake time histories that were spectrally-matched (Abrahamson 2006 [1]) to the firm-ground (Vs = 620 m/s) ground motions developed for this project (Abrahamson, 2006). The ground motions correspond to a return period of 10,000 years. These earthquake time-histories were first transferred to firm-ground at depth (Elev. -75m) using the computer code ProShake and then used as input base motions at the bottom boundary of the two-dimensional (2-D) numerical model

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