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Mechanical Analysis on Secondary Lining Damaged by Local Load under Earthquake

Yuanyuan Yu[1, a], Xun Guo[1, b], Ningwei Wang[1, 2, c] and Hongbiao Liu[1, d]

[1]Institute of Engineering Mechanics, China Earthquake Administration, Harbin 150080, P.R. China

[2]Shenyang Jianzhu University, Shenyang 110168, P.R. China

[a]yyxuyu82@hotmail.com, [b]guoxun@iem.ac.cn, [c]sy_wnw@163.com, [d]liuhbhit@yahoo.com.cn

Keywords: Mountain Tunnel; Wenchuan Earthquake; Secondary Lining; Local Load; Seismic Damage Mechanism

Abstract. Secondary lining of Longxi mountain tunnel damaged seriously during Wenchuan earthquake. To interpret the seismic failure reasons about secondary lining, the analysis adopts mechanical calculation and numerical simulation method. As a result, it was found that the bearing condition of secondary lining has an obvious spatial effect when the local loads act on the tunnel. Due to the inertial force of local load exerted by vertical seismic action, the secondary lining tends to be cracking, spalling, or even collapse.

Introduction

As mountain tunnels are surrounded by rock mass, they are highly resistant to earthquakes as long as the mountain is stable. Therefore, it is generally said that mountain tunnels do not require a seismic design. Nevertheless, in recent years, investigations of mountain tunnels after strong earthquake revealed that many tunnels suffered significant damage to various extents. The 1999 Chi-Chi Earthquake incurred much damage on mountain tunnels in central Taiwan, such as cracking, spalling of concrete lining and deformation of steel reinforcement [1]. The 2004 Chuetsu earthquakes of Niigata (Japan) triggered invert arch processes, lining shedding and other large disasters in Uonuma tunnel and Myoken tunnel. Both tunnels were not found traversing the active fault. Judging by lining cracks, there was great pressure on tunnel axis or strong impact on local areas [2]. The 2008 Wenchuan earthquake that measured at 8.0 Ms occurred at 14:28 on May 12, 2008 in Sichuan province of China. The rupture time lasted close to 120 sec, and the focal depth was deeper than 10 km [3]. Many tunnels on the highway from Dujiangyan to Wenchuan were damaged severely. Zipingpu tunnel, longdongzi tunnel, longxi tunnel and shaohuoping tunnel which located near the epicenter suffered most.

There are many unknown influence factors of tunnel seismic damages. According to references [4,5], the factors include large magnitude, epicenter, wave propagation direction, waveform superimposition, fault and rupture of rock mass, discontinuous bedrock-cover, strong in-situ stress and tunnel structure problem. However, no techniques have yet been established to quantitatively explain mountain tunnel damage mechanism under earthquake, and tunnel earthquake-resistant design methods are lacking. Taking Longxi tunnel as investigated subject, we summarize the seismic failure patterns of mountain tunnel and discuss the geological and structural negative influence factors. Quantitative analysis is given to evaluate ultimate bearing capacity of secondary lining vault which damaged by local load under earthquake. Hope to provide some reference for the seismic design and construction of mountain tunnels.

Geological Condition and Seismic Damage of Longxi Tunnel

Pre-earthquake Project Summary. Longxi tunnel is located in the Yingxiu-Dujiangyan expressway which terrain flexible and cut by Minjiang River (Sichuan). The tunnel axis is northwest, but mountain ridge which intersects the tunnel axis at large-angle is northeast. The tunnel lengths (right&