THEORETICAL STUDY ON THE MECHANICAL BEHAVIOR OF DUAL TUNNELS SUBJECTED TO VERTICAL OSCILLATIONS

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This study addresses the mechanical characteristics of dual tunnels that are impinged upon by body waves generated due to nearby earthquakes or blasting. A two-dimensional model analysis shows that not only the distance between each tunnel but also the overburden can control the dynamic behavior of this type of underground structures. It is confirmed that the conventional assessment criteria for the static stability of dual tunnels are valid also for the dynamic stability related to the incidence of vertical oscillations.

1. Introduction

The 1995 Hyogo-ken Nanbu (Kobe) and the 2004 Niigata-ken Chuetsu, Japan earthquakes both caused similar (and previously unrecognized) damage patterns in the tunnels in the mountainous and urban regions, which were possibly induced by the direct interaction of longitudinal (*P*-) body waves with the underground structures (Uenishi and Sakurai, 2000; Sakurai and Uenishi, 2005). Since the number of dual tunnels is increasing, especially in urban areas, it may be important at this moment to investigate the effect of such body waves on the mechanical behavior of dual tunnels.

2. Two-dimensional wave analysis

Assume two circular tunnels (radius a), under plane strain conditions, are located in a semi-infinitely extending linear elastic body that is free from initial stresses. The overburden is H and the distance between the centers of the two tunnels is B, and a plane harmonic *P*-wave impinges on and interacts with the tunnels (Fig. 1). The stresses and displacements in the surrounding medium can be analytically obtained by using the scalar and vector displacement potentials, and the effect of the overburden H and the distance B can be evaluated quantitatively from those stress and displacement distributions. For example, Fig. 2 indicates that, at shallow depth ($H/a = 1$), the normal stresses induced on the sidewall at points C and D are sensitive to the change of distance B when B/a is smaller, but when $B/a > 4$, the values of the stresses become nearly constant, clearly showing the effect of distance B. A similar tendency can be observed also for a dual tunnel at depth. Given the same B, Fig. 3 indicates there is a certain depth ($H/a \sim 75$) where the stress amplification on the sidewall becomes maximum, implying a shallow tunnel is not always more stressed than a tunnel at depth.

3. Conclusions

Conventional assessment criteria recommend that the distance should be at least $B/a > 4$ for the static stability of a dual tunnel. The present study also may render the same result, but for the dynamic stability of a dual tunnel. More detailed and quantitative discussion can be found in Uenishi and Tsuji (2007).

References

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Keywords: Wave-induced damage, dynamic stress concentration, dual tunnel, overburden.

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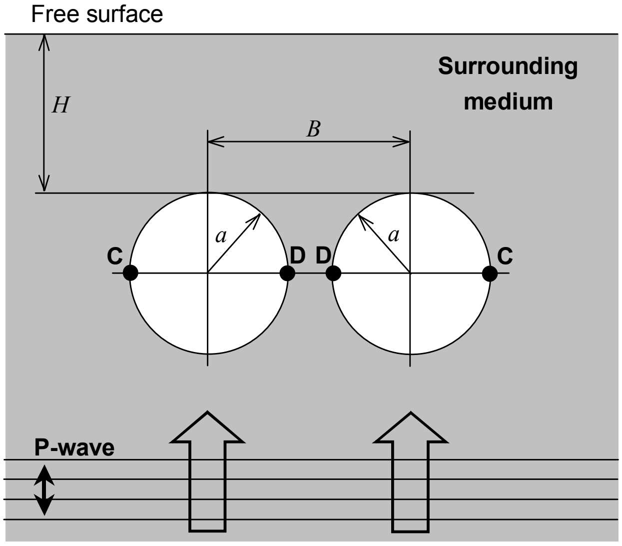

Figure 1. The model employed in the analysis.

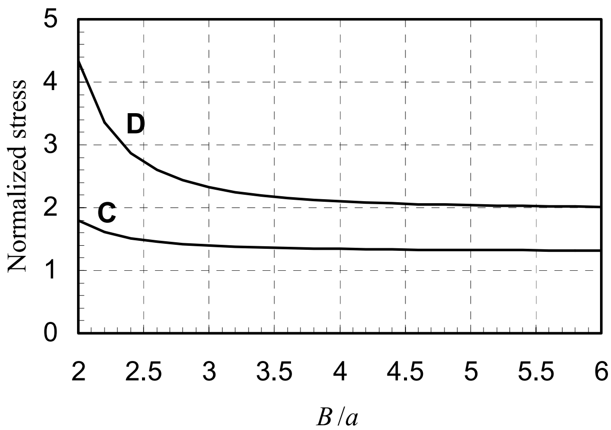

Figure 2. The relation between the maximum circumferential stresses induced on the sidewall (at points C, D) and the distance B/a between the centers of the tunnels (overburden $H/a = 1$, incident wavelength $\lambda/a = 400$, Poisson's ratio 0.25). The stresses are normalized with respect to the stress amplitude of the incident wave.

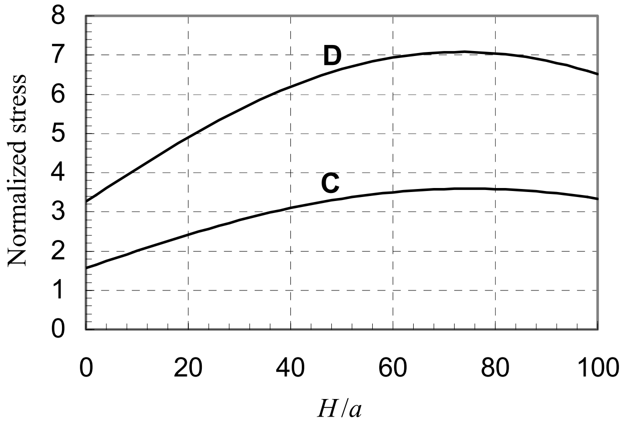

Figure 3. The relationship between the maximum circumferential stresses induced on the sidewall (at points C, D) and the overburden H/a (distance between the centers of the tunnels $B/a = 2.2$, incident wavelength $\lambda/a = 400$, Poisson's ratio 0.25). As before, the stresses are normalized with respect to the stress amplitude of the incident wave.