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Evaluation of Multiple Twi-hinge Precast Arch Culvert Seismic Capacity Through Elastoplastic Numerical Simulation

〇Budi Luhur DARMANTO, Yasuo SAWAMURA, Kiyoshi KISHIDA, Makoto KIMURA

Introduction

Two-hinge precast arch culvert is a precast concrete product which has the peculiar characteristic of modularity and is suitable for application to roads and railway underpasses, different level crossings, hydraulic structures and other types of structures. The simplest configuration for the culvert is comprised of three segments of precast units, with two hinges at the connections between the precast segments as depicted in Photo 1. As the structure utilizes hinge functions in its main body, conventional design method cannot be applied. Therefore, the seismic capacity evaluation of this type of culvert has become an important issue. In this study, numerical analysis to determine the seismic capacity of three culvert setups: single, double and triple unit under shallow embankment was conducted.

Analysis Outline

Two-dimensional FEM analysis was performed on two-hinged precast arch culvert with 2 m shallow overburden. In these analyses, the effect of water table was neglected. Soil used was Toyoura sand, which modelled as elastic model on self-weight analysis, and nonlinear subloading tij model (Nakai and Hinokio,

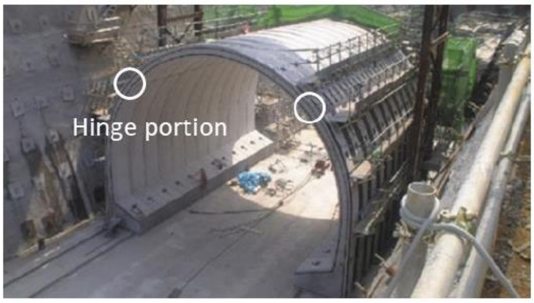

Photo 1. Single unit two-hinge precast arch culvert

2002) on dynamic analysis. Soil parameters are derived from SPT N-value, with N = 15 for the foundation soil and N = 10 for backfill soil. Culvert are modelled as beam elements with behavior following the nonlinear Axial Force Dependency model (Zhang and Kimura, 2002). Fc'40 MPa concrete and SD345 rebar parameters are used to model culvert material. Spring element (arch culvert segment hinge) are set to follow bending test result on hinge model. Soil culvert interaction is modelled as joint element. For dynamic load, level 2-2 1995 Kobe standard input wave from Specification of Highway Bridges were applied.

Result and Discussion

The bending moment diagram of self-weight analysis and earthquake maximum response for precast arch culvert can be observed in Figure 1 (a), (b) and (c). The maximum response is taken when the middle of vault segment on each culvert reached maximum acceleration. It can be observed that for multiple culvert, the maximum working bending moment is slightly bigger compared to the single unit. The middle wall segment also suffered significant increase in bending moment. To discuss the internal stresses and failure condition of culvert member, stress-strain relationship of the culvert reinforcement during the maximum bending moment response are depicted in Figure 2. Red circles represent the location of beam element under consideration, with red lines and blue lines represents outer and inner rebar, respectively. It can be observed that all culvert setups exceed elastic limit during level 2 type 2 earthquake excitation. Strain hardening occurred on the middle and side wall segment of multiple units. However the level of strains was still within 1% range.

Conclusion

In analysis conditions depicted in this study, two-hinge precast arch culvert showed sufficient seismic capacity against Level 2 type 2 earthquake even on multi-unit setup.

【References】

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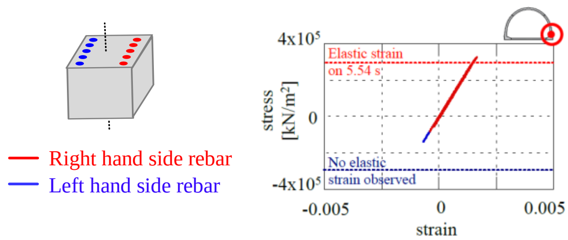
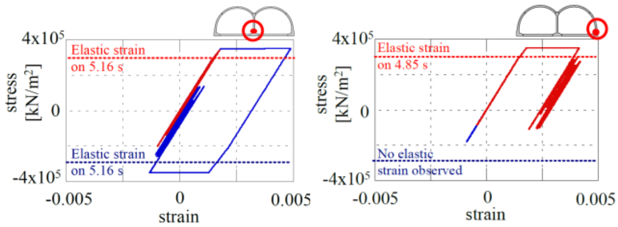
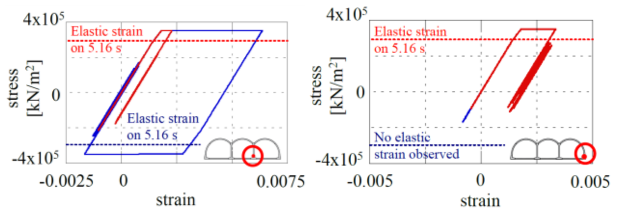
2. Nakai, T. and Hinokio, M. : A Simple Elastoplastic Model for Normally and over Consolidated Soils with Unified Material Parameters, Soils and Foundations, Vol. 44, No. 2,pp. 53-70, 2004.



(a) Single arch side wall

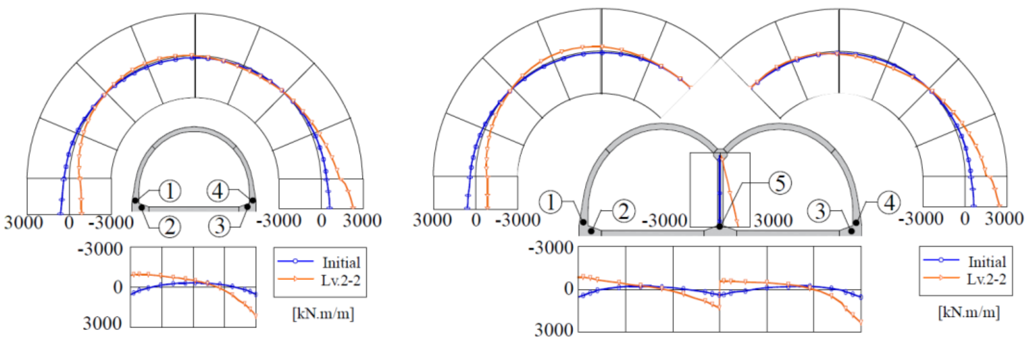


(b) Double arch middle wall (c) Double arch side wall



(d) Triple arch middle wall (e) Triple arch side wall

Figure 2. Rebar stress-strain hysteresis

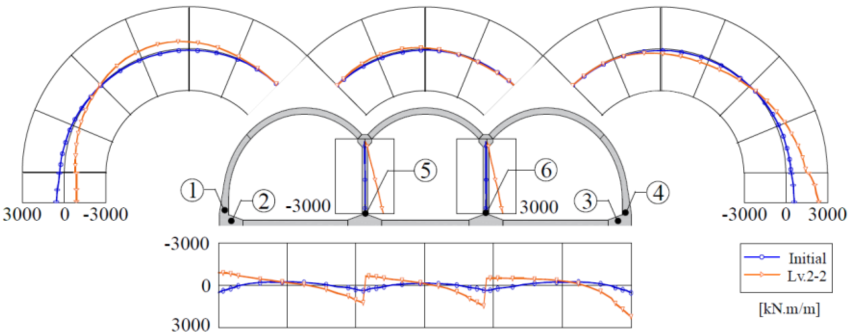


Case	①	②	③	④
Initial	625	563	563	625
Lv.2-2	-871	-900	2200	**2298**

(a) Single unit arch culvert

Case	①	②	③	④	⑤
Initial	625	566	568	626	-6
Lv.2-2	-824	-828	2347	**2448**	1854

(b) Double unit arch culvert



Case	①	②	③	④	⑤	⑥
Initial	608	549	549	608	44	44
Lv.2-2	-858	-858	2259	**2360**	2125	2175

(c) Triple unit arch culvert

Figure 1. Bending moment diagram at rest condition (initial) and during maximum acceleration on vault portion (Lv.2-2)