SEISMIC EVALUATION OF MULTIPLE TWO-HINGED PRECAST ARCH CULVERT USING ELASTO-PLASTIC FEM ANALYSES

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1. INTRODUCTION

In the increasing need of optimizing construction work efficiency by utilizing precast structure, it can be expected that the usage of precast arch culvert will be increased. One of the option is the utilization of two-hinged precast arch culvert. Due to the availability of middle wall segment for this type of culvert, the structure can be built as series (multi units), enabled it to function as alternative for elevated bridges. 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.

A numerical analysis of the seismic stability of precast multi-arch culvert (Hwang et al., 2006) have been conducted on this type of structure. However, the modelling of the hinge part is still insufficient, which did not represent the special characteristics of this type of culver. In this study, numerical analyses on the seismic stability of three culvert configurations: single unit, double unit and triple unit were conducted, focusing on the bending moment and stress-strain relationship of the precast segment units.

2. ANALYSIS CONDITIONS

(a) Analysis method and material parameters

Two-dimensional analyses were performed by using numerical analysis program DBLEAVES (Ye et al., 2007). The objects of analyses were two-hinged precast arch culvert under 2 m shallow overburden, with culvert segment setup and boundary condition were shown in **Figure 1**. Self-weight analyses were conducted using construction steps to generate the dynamic analysis initial conditions. Soil used was Toyoura sand, modelled as elastic model on self-weight analysis, and nonlinear subloading t_{ij} model (Nakai and Hinokio, 2002) on dynamic analysis. Soil parameters were derived from SPT N-value, with N = 15 for the foundation soil and N = 10 for backfill soil. The effect of water table was not taken into account.

Culvert elements were modelled as nonlinear AFD beam model (Zhang and Kimura, 2002). The dimensions of culverts and its cross-sections were shown in **Figure 2**. Beam elements were placed in the centerline of the culvert segment. Fc'40 MPa concrete and SD345 rebar parameters were used to model the culvert reinforced concrete material. Spring element (segment hinge) were set to be rigid on x, y translation direction, with free rotation without any breaking point. Interaction between culvert and surrounding soil was modelled as joint parameter with rigidity of 1.55 kN/m^2/m on both shear and normal direction (Sawamura et al., 2015).

b) Input waves

For dynamic analysis, Level 2-2 1995 Kobe EW wave from Specification of Highway Bridges was applied on three culvert setups. The PGA of the wave is 7.65 m/s^2, with waveform shown in **Figure 3**.

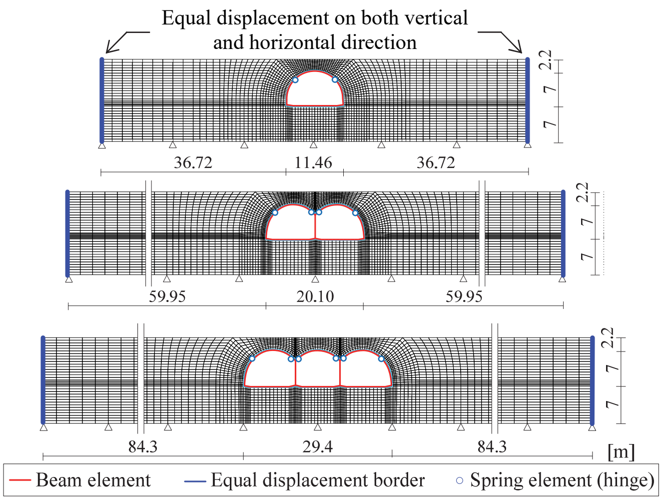

Figure 1. Analysis mesh

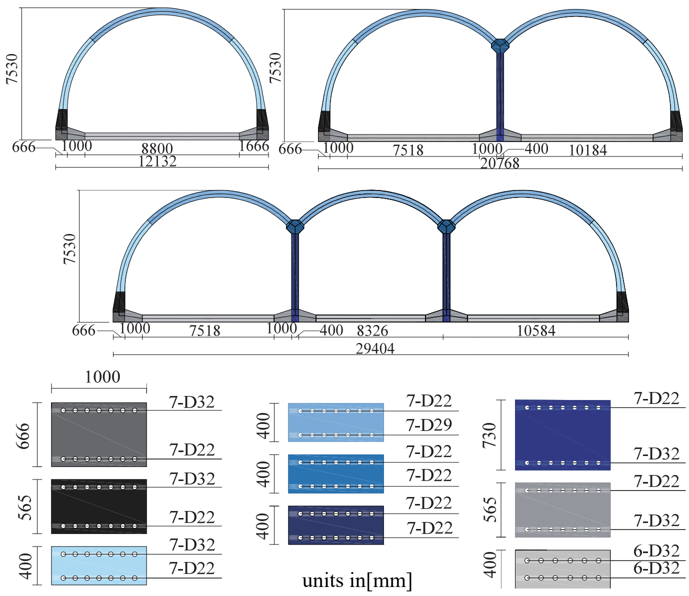

Figure 2. Culvert dimension and section detail

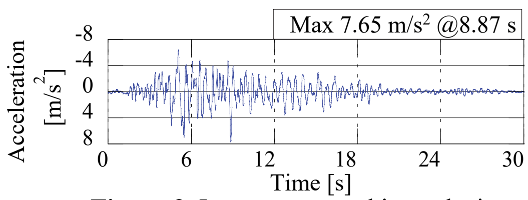

Figure 3. Input wave used in analysis

3. RESULT AND DISCUSSION

The bending moment diagram of self-weight analyses and earthquake maximum responses can be observed in **Figure 4**. The blue line shows bending moment from self-weight analyses (service condition), where the red line shows culvert maximum bending moment responses under Kobe wave. Due

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to the wave, maximum bending moment occurred on the bottom right hand side of the side wall for every setup. It is also worth to be noted that for multiple unit setup, while the base of middle wall segment suffered small bending moment during service condition, very high increase of bending moment occurred due to earthquake excitation.

The stress-strain relationships of the bottom side wall and middle wall of the culvert during the maximum bending moment responses are plotted on **Figure 5**. The stress of the rebar is positive for the tension, with red line represent right-hand side rebar and blue line for the left-hand side rebar. It can be observed that single culvert setup was slightly plasticized, without experiencing strain hardening. On the other hand, for multiple culvert setup, strain hardening occurred on the side wall segment and middle wall segment, with higher strain level on middle wall. The result is reasonable due to smaller rebar and section dimension on the middle wall segment. The strain level however, were still under 0.5% which could be considered to have sufficient seismic stability against Level 2-2 earthquake.

3. CONCLUSION

1. Within the range of conditions described in this study, the multiple two-hinged precast arch culverts has sufficient seismic resistance against strong earthquakes, as the maximum rebar strain occurred is still within range of 1%.
2. Nevertheless, due to the comparatively high magnitude of strain on the middle wall, improvement by increasing the member dimension, or increasing the number and diameter of the rebar might be needed to increase its performance.

Reference

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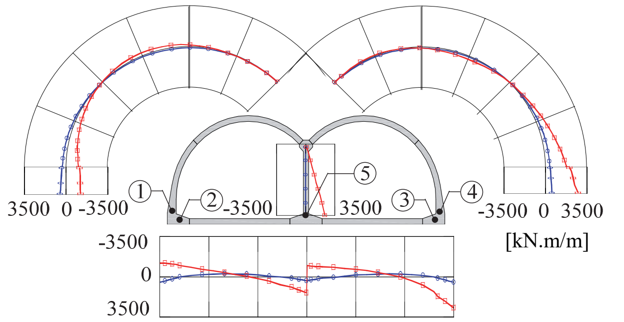
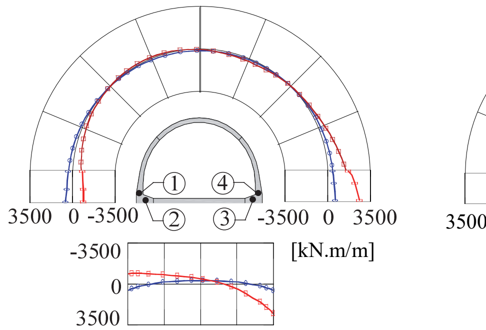


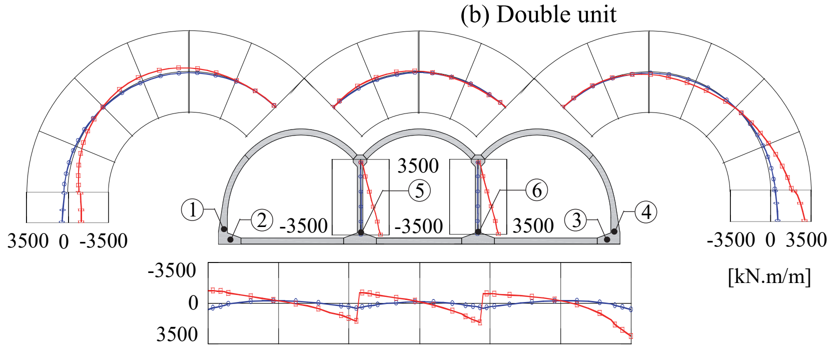
Case	①	②	③	④	⑤
Initial	625	566	566	625	-1
Lv.2-2	-770	-774	2617	2723	1961

(b) Double unit



Case	①	②	③	④
Initial	625	564	564	625
Lv.2-2	-798	-833	2454	2548

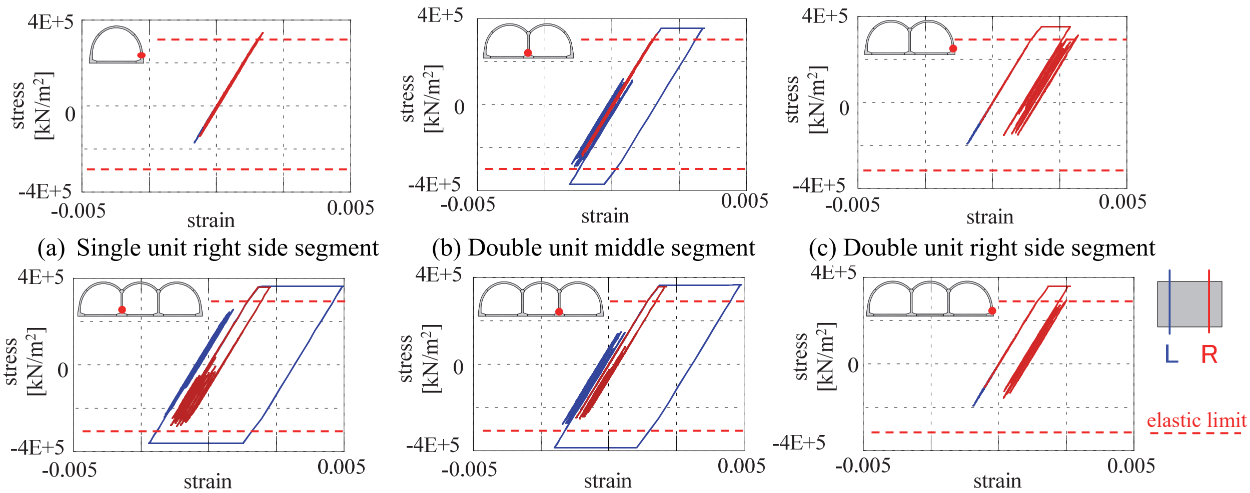
(a) Single unit



Case	①	②	③	④	⑤	⑥
Initial	608	549	549	608	44	-44
Lv.2-2	-844	-843	2582	2694	2125	2175

(c) Triple unit

Figure 4. Bending moment diagram and its magnitude on appointed points of culvert units



(a) Single unit right side segment (b) Double unit middle segment (c) Double unit right side segment

(d) Triple unit left middle segment (e) Triple unit right middle segment (f) Triple unit right side segment

Figure 5. Stress and strain relationship on appointed points of culvert units