SEISMIC FAILURE MECHANISMS OF SMALL-RADIUS CURVED BRIDGES WITH VARIABLE PIER HEIGHTS

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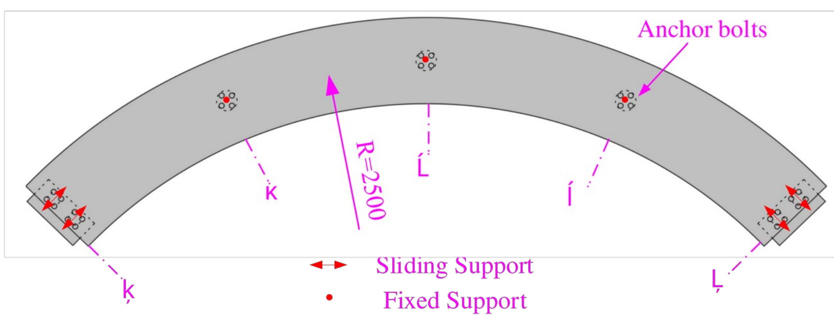
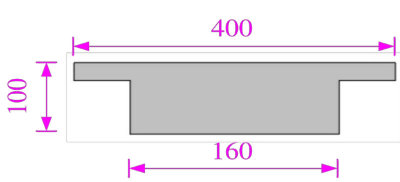
Extended Abstract

Small-radius curved bridges with variable pier heights are widely used in mountainous highways and urban interchanges due to their terrain adaptability, but their irregular configuration leads to complex seismic responses and increased vulnerability. This paper presents a systematic experimental and numerical investigation of three typical pier arrangements: gradient, concave-island, and convex-island types. A 1/20-scale shaking table model of a four-span curved continuous girder bridge with 50 m radius was designed and tested under multiple ground motions, including near-fault pulse-type records, far-field records, and seismic rotational components, with PGA ranging from 0.05g to 1.2g. The convex-island type, characterized by a tall middle pier and gradually shorter side piers, was examined in detail for its most unfavorable input angle, near-fault effects, pulse effects, and nonlinear failure mechanisms using Pushover analysis.

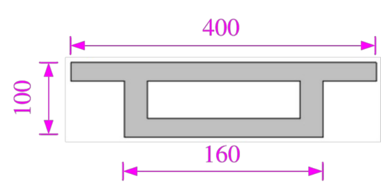
Test results reveal that the seismic response is radial-dominant with strong bending-torsion coupling; the radial-to-tangential ratios of displacement and strain range from 0.9 to 1.35 and increase with PGA. Due to irregular stiffness distribution caused by pier height differences, short piers carry 2.5 to 2.8 times the shear force and 1.5 to 1.6 times the bending moment of tall piers, while tall piers exhibit approximately twice the displacement of short piers. The convex-island type shows significant displacement amplification, severe strain concentration, and rapid damage evolution owing to abrupt stiffness mutation at the middle tall pier. Near-fault pulse-type ground motions amplify pier-top displacement differences by more than 1.6 times and intensify structural irregularity, with multi-pulse excitations increasing displacement by up to 283% and shear force difference by 250%. The rocking component of ground motion increases tall pier displacement by up to 63%, and the torsion component notably enlarges strain at short pier bottoms. Nonlinear amplification becomes notable when PGA exceeds 0.4g, with damage evolving from initial radial cracking at 0.15g to tangential damage at 0.2g, stiffness degradation beyond 0.3g, and plastic hinge formation at pier bottoms beyond 1.0g. Among the three configurations, the concave-island type exhibits the most uniform internal force distribution and best seismic performance, the gradient type is intermediate, and the convex-island type is the poorest. Pushover analysis confirms that modal Pushover analysis (MPA) provides higher accuracy than uniform lateral force distribution for such irregular structures.



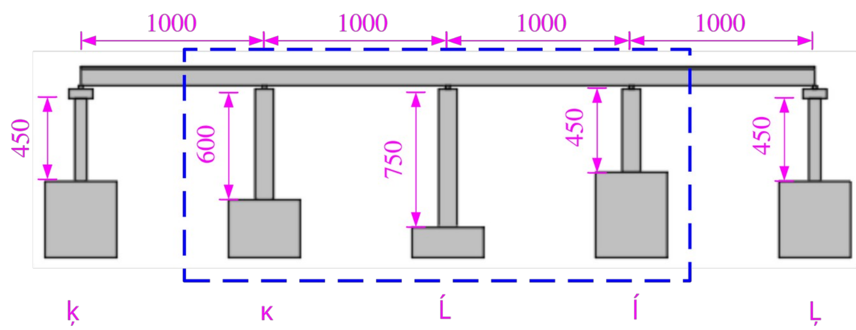
a. Main beam plane



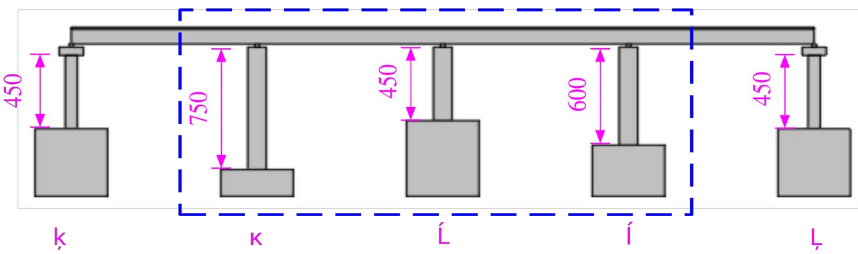
b. Beam end section



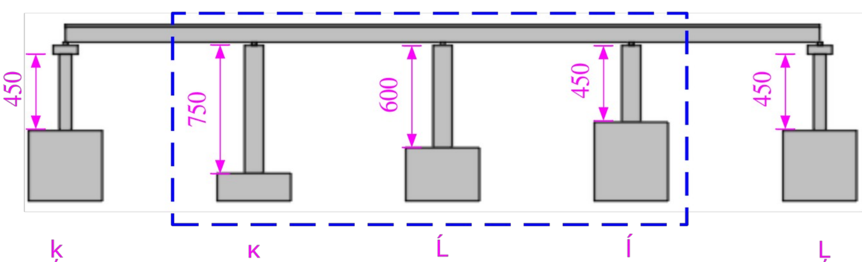
c. Main beam mid-span section



d.Convex island



e.Concave island



f.Gradient

Figure 1-Illustration of three pier arrangements: a gradient type, b concave-island type, c convex-island type (adapted from the shaking table model).

The study concludes that seismic design of small-radius curved bridges with variable pier heights must consider radial-dominant response, avoid convex-island configurations where possible, account for near-fault pulse effects and rotational components, and perform multi-directional seismic input checking rather than single-direction analysis.

Keywords: *Small-radius curved bridge, variable pier height, shaking table test, seismic performance, radial-dominant,*