IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL ATAKOY HOTEL

Paper ID:1556

# A Nielsen Arch Rail Bridge Designed to Survive an Extreme Earthquake Event

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## ABSTRACT

The following paper provides insight into the design of a structural steel 118 m span Nielsen arch rail bridge. The critical aspect of the design was the need for the structure to survive extreme earthquake events. A performance based seismic design framework was developed where the bridge remained serviceable at one level and sustained acceptable damage at the extreme level. Although the response of the concrete substructure elements governed the design, the associated modal response of the arch generated significant load effects. The short timeframes for the project delivery meant that the development of site-specific seismic ground motion time histories was not practical. In their absence this paper outlines how an elastic response spectrum analysis was used to calculate the associated load effects in the arch

**Keywords:** Nielsen arch, rail, structural steel, and seismic design.

## 1 INTRODUCTION

Bridges that are part of critical transportation links must often be designed to survive extreme earthquake events as well as the daily rigours of their environment. This paper tells the story of one such bridge, a structural steel 118 m span Nielsen arch rail bridge. The basket handle arch form might be described as conventional, but its seismic design presented several technical challenges. This was because the project's rapid delivery schedule meant that the development of site-specific seismic ground motion time histories was not practical. In their absence the paper provides insight into how an appropriate alternative analysis method was developed to quantify the response of an arch structure supported on concrete piers that plastically hinge under the applied seismic loading. The natural period of the arch structure in the transverse direction was also carefully considered to limit the risk of derailment.

## 2 DESIGN FOR SEISMIC EFFECTS

As is common practice in areas with high seismicity a performance based seismic design framework was used. Practically this that meant the performance requirements for the bridge varied depending on the intensity of the earthquake. Within the framework two levels of earthquake were considered.

A Level 1 earthquake was defined as a seismic hazard with a high probability of occurrence during the set service life of the bridge. For the locality of the bridge moderate earthquakes with peak ground accelerations of 0.12g had to be allowed for. The performance requirement for a Level 1 earthquake was that the bridge must remain serviceable to ensure the continued operation of trains. This meant the structural response of the superstructure and substructure had to be within the



https://doi.org/10.2749/istanbul.2023.0141