Earthquake-Resistant Bridges of the Future with Advanced Materials

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Abstract

This paper presents the highlights of several studies on seismic performance of bridges. The results showed that superelastic shape memory alloys, fiber-reinforced grouts, built-in elastomeric pads, concrete-filled fiber-reinforced polymer (FRP) columns, and FRP-wrapped segmental columns successfully resisted earthquake forces while substantially reducing apparent damage. In addition, the seismic performance of innovative connections developed for prefabricated bridge columns was satisfactory and comparable with that of the conventional earthquake-resistant RC bridge columns while the implementation of such details decreased the construction effort considerably.
Keywords: Concrete-filled FRP columns, Elastomeric pads, Pre-fabricated columns, Segmental columns, Shape memory alloys.

1. INTRODUCTION

The driving force behind innovation may be merely curiosity or search for a solution to a known problem. Whereas innovation in science is often is instigated by curiosity, innovation in engineering is linked to potentially practical solutions to problems that are either clearly or vaguely defined. The purpose of this paper is to briefly describe several innovative approaches related to the seismic performance of bridges. The paper presents the highlights of several research projects focused on detailing of highway bridges using novel concepts or advanced materials such as fiber-reinforced polymer (FRP) materials, elastomeric plastic hinges, shape memory alloys, and high-performance fiber-reinforced cementitious materials.

2. SHAPE MEMORY ALLOY (SMA)

Shape memory alloys are able to fully recover deformations even after yielding through application of external heat or removal of stress. The latter group, known as superelastic materials, was the subject of the UNR studies. The focus of the study has been on Nickel-Titanium SMA or Nitinol (NiTi). The yield stress of NiTi can be approximately the same as that of 400 MPa steel, but its modulus of elasticity is approximately one-third of the steel modulus. A typical stress-strain relationship for superelastic NiTi is shown in Figure 1. Upon yielding slight strain hardening is observed. At a strain of six percent major strain hardening occurs.

When the stress is released, the stress-strain curve relationship follows a path that leads to a flag-shaped response. The area within the curve presents the dissipated energy. SMA is hence able to dissipate the earthquake energy, but with no residual strain once the stress is removed. The effectiveness of deformation recovery of SMA bars used as reinforcement in concrete members was investigated. Details of the studies are presented in [1, 2, 3, and 4].