Numerical modeling of concrete beams strengthened by iron-based shape memory alloys embedded in a shotcrete layer

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ABSTRACT

Shape memory alloys are a group of materials which, due to their unique features such as shape memory effect and pseudo-elasticity, have been widely used in civil engineering applications like active and passive control of structures, sensing and actuating, and strengthening RC structures. Iron-based shape memory alloys have gained extensive attention during recent years. The aim of this paper is to model and analyze the behavior of RC beams strengthened and pre-stressed with a special class of these alloys invented at Empa laboratories in Switzerland. By using this method of pre-stressing, there are no friction losses and no space is required for hydraulic jacks. Finite element analyses have been performed on the 3D beam models in the commercial finite element code ABAQUS, employing the concrete damaged plasticity model to predict the load – displacement response of the beams. Results of the finite element analysis agreed well with the experimental data in terms of the cracking load and the ultimate load capacity of the beams.

Keywords: shape memory alloys, strengthening, finite element

1. INTRODUCTION

Shape memory alloys are a class of materials that are capable of recovering the applied stresses and strains and getting back to their original shape in some circumstances. Like many other metals, shape memory alloys have more than one crystal structure for which they are referred to as poly-crystalline [1]. The dominant phase or structure of a material is determined by the temperature of the metal and the amount of stress applied to it; In shape memory alloys however, the so-called austenite and martensite phases are dominant at high and low temperatures respectively. The temperature at which the phase transformation occurs is a feature unique to each alloy but this feature could be changed by variations in the composition of the alloy according to the intended application [2].

An overview of the phase transformation procedure in shape memory alloys is presented herein. During the cooling process, forward phase transformation initiates as the temperature of the alloy reaches M_s and finishes when it later equals M_f that are defined as the forward martensitic transformation start and finish temperatures respectively. At temperatures lower than M_f the alloy is completely in the martensite phase and pseudo-plastic deformations tend to occur in the alloy if subject to stress. By the same token, reverse transformation from martensite to austenite begins as the alloy is heated to the A_s temperature and completes at A_f that are the reverse martensitic transformation start and finish temperatures respectively. The martensitic and reverse martensitic transformations are schematically illustrated in Figure 1.

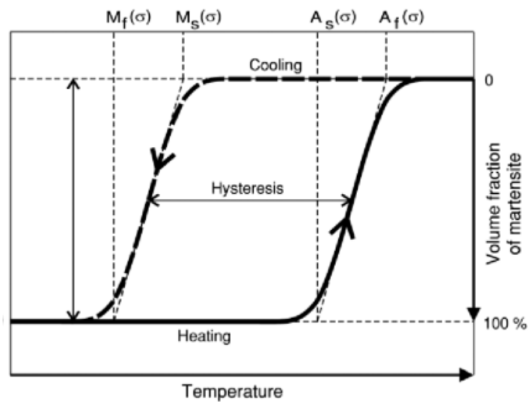

Fig. 1. *Schematic view of forward and reverse martensitic transformations [3]*