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Sensitivity analysis of pre-stressed concrete sleepers for longitudinal crack prorogation effective factors

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ABSTRACT

B70 mono-block pre-stressed concrete sleepers are one of the most common sleepers in Iran's railways industry. They have been used in many of the country's railway transition lines. The B70 types of sleepers are classified as pre-stressed concrete beams; therefore the value of pre-stressing force is one of the most important parameters in the field of sleepers' structural designing. Selecting high pre-stressing force due to the fact that it increases the steel bars strength, could increase the possibility of longitudinal cracks formation before service loading, especially if the tensile strength is low. Therefore, pre-stressing force and tensile strength are two important factors for investigating the sensitivity of longitudinal crack formation and propagation in sleepers. Sensitivity analysis has been conducted for tensile strength of concrete and the pre-stressing force in the steel bars, by using finite element method. It could be clearly seen in the results that increasing the tensile strength of concrete, increases the cross section capacity. This increase in the capacity does not have a direct relationship with the increase of the tensile strength. Also the numerical model indicates a linear behavior between different pre-stressing forces and maximum tensile stress around the dowels. Applying higher pre-stressing force values can increase the possibility of longitudinal cracks prior to service loading of the sleepers and also long-term sleepers' service life.

1. Introduction

Sleepers are one of the most important components of railways. Their task is to receive the loads imposed by the wheels to the rails and transferring those loads to the lower layers and eventually to the railway substructure. B70 mono-block pre-stressed concrete sleeper is more common in Iran's railway network due to its high strength, lightness, and other benefits [1,2]. Concrete is the main material of B70 sleeper. The 28-days compressive strength for sleeper concrete samples must be equal to 59 MPa. In each concrete sleeper, there are 8 ST-160 reinforcing bars with 7 mm in diameter and 2510 mm length. Steel bars are pre-stressed with a force equal to 44 kN while sleepers are being manufactured [3].

The entire railways of the I.R. Iran's railway network including the main, subsidiary, and maneuver railways, exceeds 12,785 km up to the year 2011 and this value increases every year. Approximately 136,846 sleepers were used to be replaced for maintaining the railways in 2011, which most of them were pre-stressed concrete sleepers [4]. Taking into account the fact that manufacturing, repairing, and maintaining pre-stressed concrete sleepers is extremely expensive, it is crucial to identify the weak points of the sleepers and try to eliminate or reduce them.

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Fig. 1. The longitudinal damage in the concrete sleeper [3].

Since the sleepers are made of concrete, the damages that are common in concrete structures could also occur in the sleepers. The sleepers' damages could be classified in to different types. One of the damages is longitudinal crack which mostly begins near the dowels and gradually develops and destroys the sleeper, even before service load is applied. These damages are formed due to many reasons including the presence of sand within the dowels, the dowels screw is not properly placed, and also water freezing within the dowels which bursts the sleeper by its volume increase [3–5]. The longitudinal damage in the concrete sleeper is shown in Fig. 1.

The B70 types of sleepers are classified as pre-stressed concrete beams; therefore the value of pre-stressing force is one of the most important parameters in the field of sleepers' structural designing. Selecting high pre-stressing force due to the fact that it increases the steel bars strength, could increase the possibility of longitudinal cracks formation before service loading, especially if the tensile strength is low. Therefore, pre-stressing force and tensile strength are two important factors for investigating the sensitivity of longitudinal crack formation and propagation in sleepers.

This paper has tried to study the sensitivity of the tensile stress in the location of the dowel for B70 pre-stressed concrete sleepers against the changes of pre-stressing force and also changes of tensile strength by using the ABAQUS finite element software. This study has assumed that the sleeper is not under the service loads yet (such as train load and etc.). The analysis consists of two separate steps. The first step is called pre-stressing which no other forces are applied except for the pre-stressing force in the steel bars. In the second step, in order to examine the sensitivity of the model to the changes of the tensile strength and pre-stressing force, one conical load is applied within the dowels to model the unwanted stresses mentioned above.

2. Numerical model

2.1. Properties of concrete

ABAQUS presents two types of different composition for analyzing concrete while under an applied confining pressure [6]:

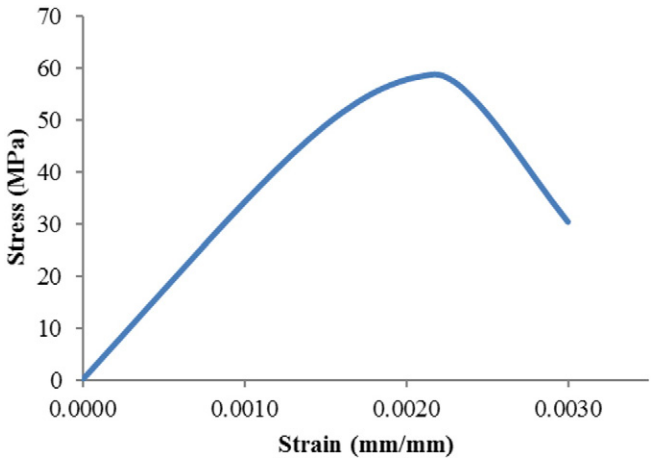

Fig. 2. The compressive stress-strain diagram of concrete $f_c' = 60$ MPa [11].