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Improving the crashworthiness of reinforced wooden road safety barrier using simulations of pre-stressed bolt connections with failure

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ABSTRACT

During the development process of a new type of steel reinforced wooden road safety barrier parametric computational simulations were used to simulate the experimental vehicle impact certification tests as prescribed by the standard EN 1317. First a detailed study of pre-stressed bolt connection behavior between the guardrail and the guardrail connector was performed using parametric computational simulations of which results were later used in a large scale vehicle impact simulations. A novel, simplified approach to the modeling of barrier wooden parts was introduced to achieve reasonable simulation times in parametric study of the barrier behavior under vehicle impact. The wooden parts of the road safety barrier were modeled indirectly through a modified contact definition. The developed safety barrier design was later successfully experimentally certified in a full scale crash test according to the standard EN 1317. Experimental results were in a good agreement with the results of the full scale crash test simulations, which validates the proposed computational safety barrier model and thus justifies the use of the simplified modeling approach of the wooden safety barrier parts.

1. Introduction

The road safety barriers are used to increase the passive safety on public roads. The installation, performance classes, impact test acceptance criteria and test methods for safety barriers are covered in detail in standard EN 1317-2 [1]. According to the standard, each safety barrier has to be tested with a full scale crash test and at the same time fulfill the requirements given by the standard.

Usually, the barriers are made of steel or concrete to withstand the loads of the vehicle impact without failure. But in some countries and regions, additional requirements for the safety barriers are given in respect to their appearances. In national parks, for example, the barriers should be similar to their environment and look natural, i.e. they shall be made of wood. Because wooden barriers would not successfully withstand vehicle impact at higher containment levels, such barriers are usually reinforced by load carrying steel core, which is on the outside concealed with wooden elements [2], as shown in Fig. 1.

The load carrying parts are joined with bolt connections, which have a very important role during the vehicle impact [3–6]. The barrier has to be designed in such a way that some bolt connections, such as bolt connections between the post and the guardrail, must fail during the car impact to prevent the lowering of the guardrail due to post deformation. However, most bolt connections, such as bolt connections between the wooden elements and steel core of the barrier guardrail, should

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Fig. 1. Steel reinforced wooden road safety barrier.

not fail in the event of vehicle impact. They have to retain the longitudinal load carrying capability of the barrier and to prevent release of large and heavy guardrail wooden elements, which might increase the severity of the impact.

Parametric computational simulations were used in the development process of a new class of steel reinforced wooden road safety barrier, with particular attention to optimize the behavior of pre-stressed bolt connections, since failure of the bolt connections is vital for the behavior of the barrier during vehicle impact. The results of parametric simulations of bolt connections were later used in full scale vehicle impact simulation.

Special attention was also focused on proper simulation of the wooden parts of safety barrier. The wooden parts are not designed to carry the longitudinal load during vehicle impact. However they do influence the behavior of the safety barrier during the vehicle impact. Some researchers have tried to characterize the wooden components for structural applications [7,8], but only a couple of authors used computational simulations to evaluate the behavior of wooden road safety barrier parts [9–13]. They applied the finite element method for the evaluation of separate specific wooden barrier parts, but they did not attempt to model the complete composition of the safety barrier, neither its full length. In this paper we present the results of full scale crash test simulations which are based on a novel and simplified model of steel reinforced wooden safety barrier, which were used to improve the crashworthiness of the safety barrier.

With such approach, the number of experimental full scale certification tests was considerably reduced [14–17]. After the design and development phase using computational simulations the full scale crash tests were carried out and the results of simulations and experiments are presented and discussed.

2. Road safety barrier design

The load carrying parts of the developed wooden barrier are made of steel. These parts are assembled together using different bolt connections to achieve the transfer of the load from one part of the barrier to the other. The wooden cover elements are mounted on the barrier after assembling the steel load carrying parts. The steel subassembly of the steel reinforced wooden road barrier comprises of the following elements (Fig. 2):

- Guardrail – longitudinally placed elements which are connected by bolts to a guardrail connector element; they are deformable and reduce the severity of an impact but should be strong enough not to rupture during vehicle impact.
- Guardrail connector – an element for the connection of the neighboring guardrails using bolt connections.
- Distance spacer – decreases the impact severity and connects the guardrail with the post.
- Post – assures the guardrail position at a certain distance from and above the road.

The load carrying parts of the steel reinforced wooden road safety barrier are made of construction steel S235. Guardrails are C shaped with the dimensions of 120 × 40 mm and are 4000 mm long. The guardrail connectors are of the same shape