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Influence of degradation at the base of a support post in a collapse of an old guardrail: A forensic analysis

Luca Sgambi *

Department of Civil and Environmental Engineering, Politecnico di Milano, Milan, Italy

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ABSTRACT

After a violent crash that took place at the entrance of the road on a bridge, the guardrail installed as protection collapsed and the vehicle left the roadway. As at the base of a number of guardrail posts, a situation of severe corrosion was found evident, its influence on the resistance and on the mode of collapse of the guardrail was explored. To this purpose, the information about the state of the place collected immediately after the accident and the plastic deformations observed on the deformed guardrail contributed decisively to reconstructing the dynamics of the impact. Later, using the same assumptions and the same methods of calculation used to assess the strength of the guardrail in a condition of degradation, the impact of a similar guardrail in perfect structural conditions was simulated. The comparison between the two analyses indicated the limited influence of corrosion on the guardrail in question and on the dynamics of the accident that had occurred.

1. Introduction

Following a violent impact caused by a car, the guardrail installed as protection for a narrow curve in entrance of a bridge collapsed, causing the vehicle to veer off the road. Later, the vehicle continued its trajectory through the air, falling from the bridge, crashing down a slope and stopping in the bed of the stream below. The accident caused the death of the driver and the serious injury of a passenger. Given the presence of severe corrosion at the base of a number of support guardrail posts, in the forensic analysis it was necessary to study the influence of structural degradation on the mechanical behaviour and on the guardrail collapse.

The guardrail is a protective element that is placed at the sides of roads to ensure the safety of persons in case of loss of control of the vehicle. Today the design and the placement of guardrails on the roads are carried out taking into account several factors such as the potential crash severities, traffic exposure, and costs of treatment [19,35].

The method of designing a guardrail, as the design of any structural system, underwent significant changes over time, being updated according to experience and to the developments of new research. From a design based solely on the structural strength, a design was slowly developed based on the evaluation of further performance of structure and energy dissipation. Today, the performance-based design is accepted as current methodology of design and is continuously updated according to new needs originated from the society [7,9,25,6,8].

The innovation of the design methods is particularly important with regard to the design of structures subjected to dynamic loads, such as seismic action. From a design based on the concepts of resistance, we moved to a design based on

* Tel.: +39 0223994212.
E-mail address: luca.sgambi@polimi.it

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the concept of energy dissipation [36]. A very similar notion is applied to the design of the guardrail. The first design methods were based on the unique concept of strength of the barrier and tried to prevent the vehicle from veering off the road. To obtain this result the horizontal guardrail beams were sized such as to be able to deform in the field of large displacements, braking and holding with a "rope effect" the running of the vehicle. With the increasing speed of vehicles and the increase of heavy traffic on the road, this mode of design showed a number of limits since, increasing the strength of the barrier, a similar increase in the probability of survival of the occupants of the impacting vehicle was not obtained. In fact, exceeding a certain threshold of resistance it is possible to ensure the remaining of the vehicle on the road but there is a decrease in the probability of survival due to the severity of the impact [14,21]. Therefore, the design of the guardrail was changed, also on the basis of considerable experimental and numerical research that has taken place over recent decades [3,4,38,17,30,23,5]. From a concept of strength we passed, in a similar manner to seismic engineering, to a concept of energy dissipation [11] and to a performance-based design in which, in addition to the strength of the guardrail, we had also to take into account the safety of the persons involved and the diversity of possible impacting vehicles [18,12,22]. These concepts led to a change in the geometry of guardrails, of which the most evident are: the section of the horizontal beam evolves from one to three waves, support posts are today much closer to each other and equipped with devices capable of dissipating energy, etc.

The subject of the correct design of a guardrail was therefore extremely contemporary and concerned research programs in many universities [29,26,27,28,37] as well as regulatory committees [1,15,16].

Most of the studies present in the literature, both experimental and numerical, analyse the guardrail in its design conditions. However, a guardrail must have a very long life cycle and must maintain its characteristics unchanged over time. The atmosphere and the salt used on the roads during the winter can trigger corrosion phenomena on the structure of the guardrail, putting at risk its functionality [20]. And in fact it has been shown that, in certain structures, the presence of corrosion can not only reduce the strength capacity of the structure but can also lead to a change in the behaviour of collapse [32–34]. Corrosion may also lead to a decrease in structural strength, causing a progressive collapse of the structure similar to that which can occur in a suspension bridge after the collapse of a suspension cable [13,24].

The case analysed in this paper relates to an incident involving a guardrail with strong signs of structural deterioration (Fig. 1). The guardrail was installed in 1970 for the protection of road traffic on a bridge located in a mountainous area. To access the bridge the road makes a sharp bend where a speed limit of 30 km/h was imposed to prevent the loss of control of the vehicle on a curve.

Probably because of the anti-freeze salts used in winter to prevent the formation of ice on the roadway and the lack of an adequate system of collection and distribution of rainwater, the base of certain guardrail posts had heavily corroded over the years.

On one night in 2008 a vehicle, moving at high speed, lost control at the entrance curve to the bridge and violently impacted against the guardrail causing it to collapse. In this manner the vehicle broke down the safety barrier, falling from the bridge and subsequently impacting on the slope of the mountain below, until it ended its run in the river bed 30 m below the roadway. The accident caused the death of the driver and the serious wounding of a second passenger.

The purpose of the forensic engineering analysis was to determine the influence of the state of deterioration of the support posts on the dynamics of the accident and whether any maintenance might have prevented the vehicle from veering off from the road, thus saving a human life.

The precise assessment of the state of deterioration of posts seemed immediately to be very difficult and uncertain. In fact, if it is evident that the posts have deteriorated significantly over time, with the posts involved in the accident it is not clear how much the lack of material was due to the corrosive process or to the impact with the vehicle that violently sheared two of them at their base. Therefore, in order to thoroughly examine the failure occurred, we started to analyse the following points:

– The qualitative reconstruction of the dynamics of the impact with identification of the mechanism of collapse.
– The quantitative assessment of the dynamics of the impact, assuming a conventional state of strong deterioration.
– The quantitative assessment of the dynamics of the impact, assuming an absence of deterioration.
– The quantitative assessment of the resistance that the guardrail was supposed to have had to stop the vehicle.
– A comparison between the results obtained.

In the following pages the points listed above will be developed, starting from the qualitative reconstruction of the impact. Throughout the process of analysis, the qualitative analysis is the most important part because it will serve as a guide in the quantitative assessment of the dynamics. The reconstruction of the impact will have to be able to explain the final position of the vehicle, the noticeable plastic deformations observed on the guardrail after the accident, the traces of braking on asphalt, the collapse mechanism and the ultimate strength of the guardrail.

2. Descriptions of the characteristics of the guardrail

The guardrail subject of this work belongs to those designed with the criterion of strength and in Fig. 2 its geometry is reported. The guardrail is formed by a W-beam about 20 cm high and by a secondary beam, 6 cm high, having the function of handrail. The two beams are supported by a series of support posts having a C-section and positioned every 2.4 m. The