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Influence of the size and depth of a circumferential notch on the impact behavior of streetlights. A passive-safety concept

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ABSTRACT

Impact tests on weakened streetlights were carried out using a high energy pendulum. The weakening mechanism consists of a circumferential notch at the base of the streetlight. The objective is twofold: firstly to reduce the maximum acceleration values during an impact which will lessen the potential injuries of the occupants of the vehicle and secondly to help avoid the installation of protective barriers, necessary when the supporting structure has no mechanical fuse, thus helping the failure with low energy absorption values. The machining of the notch is possible in streetlights already installed in the road, due to the fact that the actual values of the structural stiffness and strength of these structures are much higher than those values typically required by the external loadings (mainly wind actions). These preliminary tests have shown a significant decrease in the two parameters under analysis, maximum acceleration and absorbed energy, when using the circumferential notch. These results suggest it would be beneficial to perform a crash test following EN12767 in order to certify the streetlight.

1. Introduction

Streetlights, as well as other support structures on the road (e.g. traffic lights) are potential obstacles for a vehicle impact. Understanding their energy absorption behavior is of major importance to determine possible injury levels of the vehicle occupants.

In impacts where the incident velocity is low and where the streetlight stops the vehicle, secondary injuries caused by the uncontrolled path of the vehicle after the impact could be avoided. On the contrary, in impacts where the incident velocity is high (typically in intercity roads), a sudden stop at the streetlight could originate high deceleration values giving rise to potential human injuries. In this latter case, passive safety, understood as low energy absorption values at the streetlights, may be considered to be desirable. The residual vehicle speed would be, of course higher, but no potential harm to pedestrians is expected in these intercity roads.

It must also be taken into account that in some national regulations, see for example [1], using support structures which do not generate deceleration values over a certain threshold in an impact, means that the associated protective barrier is not required to be installed, with the corresponding cost saving. In order to reduce the vehicle incident speed in an efficient way (high energy absorption capability without peak acceleration values), there are specific geometries and structure configurations available (see for example [2], the classical work [3] or the more recent developments with filled structures [4]).

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Vehicles can also be designed to absorb energy in an efficient way using composite materials [5]. Nevertheless, streetlights are not specifically designed to act as energy absorbers and that is the reason why, in the aforementioned regulations, a protective barrier has to be installed to protect the vehicle from excessive impact loads.

The structural stiffness and strength of most streetlight columns is much higher than those required in the standards dictated by the typical loads definitions (e.g. EN 1991-1-4 "Wind Actions" [6]), giving rise to the presence of dangerous obstacles in the road. One way to reduce the potential injuries to occupants in the event of an impact with a streetlight already installed in the road is to weaken, in some way, the area where the vehicle will make impact. In this study, a circumferential notch was made in the streetlight base. Different radii and depths were used and the impact behavior was studied experimentally.

There are specific standards concerning passive safety of support structures (e.g. EN 12767 [7]) in which the impact test requirements are defined and described in detail. Nevertheless, the cost of such tests, requiring standardized vehicles, high-speed recordings and many additional technical specifications, are quite high for performing a preliminary study like this one.

Therefore, a high-energy pendulum is used first to assess the impact behavior of streetlights. Although the weight and incident velocity chosen is similar to that used in the EN 12767 test (900 kg and 30 km/h), the pendulum (stiff steel block) does not behave in a similar way to a vehicle (designed to deform and absorb energy). Thus, the results and conclusions must only be taken as an initial assessment of the real impact behavior of the streetlight.

With all previous comments in mind, the objective of the present study is to analyze the influence of a notch on the impact behavior of a streetlight.

2. Definition and machining of the circumferential notch on the streetlight base

Streetlight columns are weakened by making a circumferential notch along the whole perimeter of their base. This weakening procedure is, of course, directed at streetlights already installed on the road and currently has its patent pending.

The streetlight chosen for the present study is a straight column, made of galvanized steel, with a height of six meters and 3 mm thickness, supplied by JOVIR [8]. The diameter at the bottom part is 135 mm, and 60 mm at the top. Due to the fact that only the local behavior at the notch section was of interest, only the bottom part of the streetlight (at a height of 1.5 m) was tested with the high energy pendulum. A dead mass of 80 kg was fixed to the top part to reproduce the total mass and inertia of the complete streetlight.

Three notch radii and three notch depths were used to weaken the streetlight base. The selected radii were: $r = 0.5$, 1.5 and 4.0 mm. Taking into account that the thickness of the streetlight is 3 mm, the selected depths were: $d = 1.0$, 1.5 and 2.0 mm. The notch was machined along the perimeter, 200 mm above the bottom part of the streetlight. A view of the base of the streetlight, where the circumferential notch was made, is shown in Fig. 1.

Six streetlights were prepared with the combination of radii and depths shown in Table 1. The order shown in Table 1 corresponds to the order in which the streetlights were tested. Test specimens 2, 3 and 5 (in Table 1) have a constant depth (1.5 mm) and three different radii (0.5, 1.5 and 4.0 mm respectively). Test specimens 1, 3 and 4 (in Table 1) have a constant radius (1.5 mm) and three different depths (2.0, 1.5 and 1.0 mm respectively). These parameter combinations, keeping one of them constant, allow the influence on the impact behavior of the variable parameters to be seen more clearly. The reason for choosing these values is linked to the fact that the hollow streetlight's wall thickness is 3 mm. 1.5 mm (one half of the wall thickness) was chosen as a reference value for depth and radius, and then, one value was chosen higher and one lower, both for the thickness and for the depth.

Due to the fact that the streetlights are manufactured by means of welding a curved steel plate along the longitudinal direction, the geometry of the transversal plane does not have a constant radius value. This means that direct machining

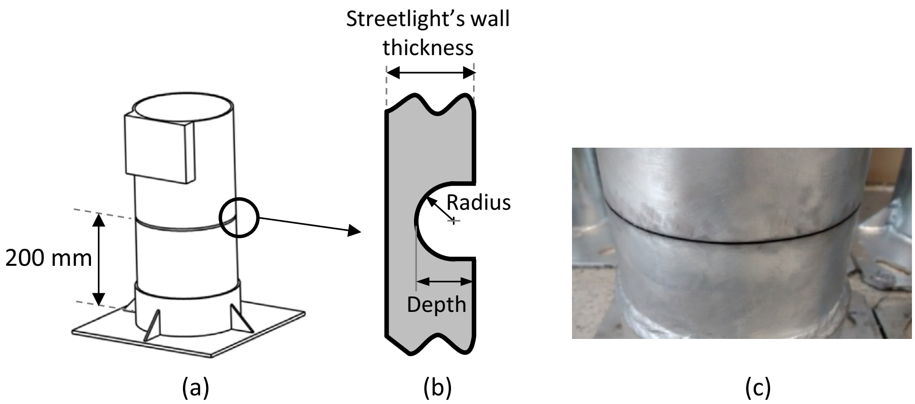

Fig. 1. Detail of the notch (a) notch section detail view, (b) detail of hollow streetlight's wall, and (c) picture of a real notch machined at the streetlight base.