TECHNICAL SPECIFICATIONS OF ‘CROSSAFE’ CULVERT-END PROTECTION SYSTEM

Culvert end protector

CROSSAFE

TABLE OF CONTENTS

TECHNICAL SPECIFICATION OF CULVERT-END PROTECTION SYSTEM 'CROSSAFE'

1. Definition

The Culvert-end protection system is a patented safety device, which is designed with the aim of protecting vehicles in case of a run-off-road crash against a culvert-end or other drainage elements or auxiliary elements that may be inside the ditches, central reservations and surroundings. Due to its modularity, the device can be adapted to the geometry of any roadside and central reservation ditch, which can be present in different types of roads, without requiring any excavation.

The Culvert-end protection system is composed by a set of structural elements which are positioned longitudinally with regard to the ditch (these elements are described in detail in chapter 2). These structural elements are designed to withstand the dynamic loads caused by the impact of a vehicle road-off and also sustained by a structural support which is installed independently of the ditch characteristics.

The effectiveness of the system has been validated by different crash tests with vehicles of 1500kg mass and a speed of 100 km/h, in two ditch configurations, respectively 2.7 and 4 m width and different depths.

The system supports and the longitudinal elements anchored to the ditch base are preferentially made through the drive of metallic supports inside the ditch. Their installation is independent from the resistant characteristic of the obstacle to protect, although it is possible to install them making use of the existing concrete structure, if deemed necessary[1].

Figure 1.- System installation on standard ditch

Figure 2.- System installation on a concrete culvert-end

[1] This aspect might be of convenience in some precast culvert embouchure that present huge dimension of lateral walls and heavy foundations or in complex ditch with concrete coated.

The Crossafe protection system is designed to be installed independent of the structural characteristics of the elements to protect, given that it is composed by modular elements, with an individual mass of less than 250 kg, which can be joined together to cover the entire ditch width and are held up on an independent structure support, creating a previous protection surface which is independent from the obstacle and adapted to the ground geometry.

2. Elements constituting the protection device

The culvert-end protection system has a modular conception, so that it is possible to join together different units in order to protect different widths ditches. Every unit is formed by the following elements:

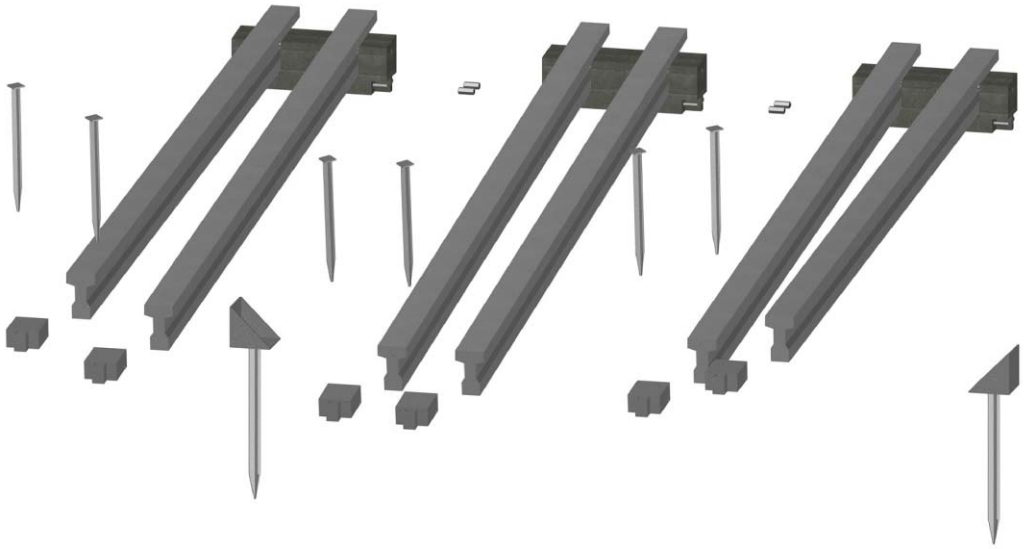


Figure 3.- Explode view of a protection device composed by three units

2.1. Transverse support element

Every module is constituted by one reinforced concrete support element with a width of 600 mm, designated transverse support, which is used to sustain two longitudinal elements, connected with the transverse support by a galvanized steel join pin which guarantees that the elements will not move during an impact.

Figure 4.- Transverse support

Figure 5.- Joint pin

2.2. Longitudinal elements

Longitudinal elements, made by reinforced concrete, might be of different lengths, from 2.5 m up to 6.6 m, to guarantee that the maximum slope of each longitudinal element is less than 16% (6:1 slope) independently of the depth of the culvert-end to protect.

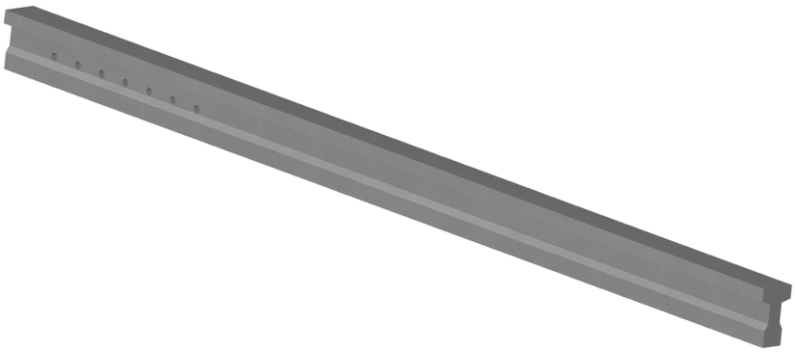


Figure 6.- Longitudinal element

These longitudinal elements present holes on their sides to allow for modifications of the join pin installation position and allow the covering of complex installations that present an irregular geometry of concrete, as shown in figure 2.

2.3. Joint and support elements

In case it would be necessary to join two or more units, this process is performed by connecting the transverse support through galvanized steel bolt sleeve which guarantees the efforts transmission in case of a vehicle impact.

Figure 7.- Units connection

The extreme parts of the union between the different transverse supports, used to cover the ditch width, are sustained resting on lateral supports. These lateral supports are driven into the ditch soil to maintain the protection system at a sufficient height to ensure that the obstacle does not represent a risk and to transmit to the ground the efforts generated by an impact.

Figure 8.- Lateral supports

The lower end of each longitudinal element is driven and fixed inside the ground ditch through a lower anchor, which restrict the longitudinal displacement as well as transversal shifting of longitudinal elements. Finally, the lower ends are buried, being completely covered.

Figure 9.- Anchoring of lower end of longitudinal elements

Figure 10.- Final state detail of lower end of longitudinal elements

3. Characteristics of Culvert-end protection system

3.1. H:V slope ratio

The set of structural longitudinal elements create a surface which protects the obstacle with an individual maximum slope of less than 16% (slope ratio 6:1). This surface is adaptable to any ditch geometry using its modular design and allows the installation of as many longitudinal elements as necessary to cover different widths ditches.

Figure 11.- Ditch configuration of 2,7 metres width (System made by three units)

Figure 12.- Ditch configuration of 4 metres width (System made with by five units)

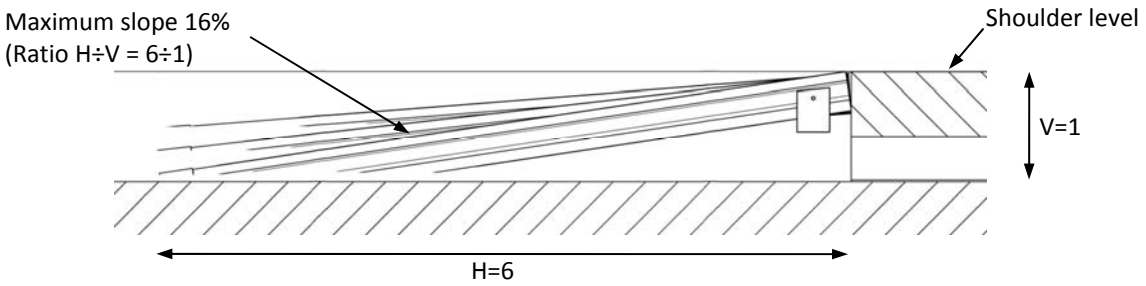


Figure 13.- Section view of Culvert-end protection system

3.2. Crash performance

3.2.1 Car crash tests

The culvert-end protection system has been tested in real conditions where there is an impact with a vehicle of a mass of 1.500 kg based on the standard "Road restraint system" EN 1317:2010, with a speed of 100 km/h, on different ditch typologies and with different impact angles (0° and 6°), demonstrating its effectiveness by avoiding the direct impact of the vehicle against the culvert end structure, and causing only small deformations of front and rear bumpers and wheels. However, in case of an impact under these conditions but without any protection system, heavy deformations of the cockpit would appear as a consequence, which could produce serious or mortal injuries for the car passengers. In fact, real accidents against a culvert-end usually produce a 70% between serious injuries and death[2].

Below the characteristics and the consequences of two tests conducted in the same conditions are shown, with a vehicle mass of 1500 kg with a speed of 100 km/h and an angle of 0°, one of them against a culvert-end without any protection system and the other one against a culvert-end with the Crossafe protection system.

[2] Data available inside the in depth analysis accident database "DIANA".

Without CROSSAFE	With CROSSAFE

Figure 14.- Car crash test with a mass of 1500 kg, a speed of 100 and an angle of 0º, without and with culvert-end protection system Crossafe

The damages produced on the system as a consequence of the impact tests are limited only to the longitudinal elements of the protection system, which are easily replaced to guarantee a prompt and effective protection of the obstacle.

Regarding the impact tests severity with the culvert-end protection system, analysed according to the acceptance criteria of the EN 1317:2010 standard, the result has been an A severity index that corresponds to an ASI (Acceleration Severity Index) value of less than 1 and a THIV (Theoretical Head Impact Velocity) value of less than 33 km/h. These results indicated a reduced risk of injuries for the car occupants. In the vehicles tested with the Crossafe system there were not any deformations or intrusions that could produce any safety damage to the car occupants.

One particularity of the protective device of culvert-end Crossafe is that during its interaction with the vehicle, thanks to its resistant characteristics and the placement of the longitudinal elements, is capable of correcting the trajectory, achieving, in addition to avoid the direct impact against the obstacle, aligning this exit trajectory with the ditch, reducing the likelihood of impacts against other obstacles located beyond the culvert end (buildings, trees, support structures, etc).

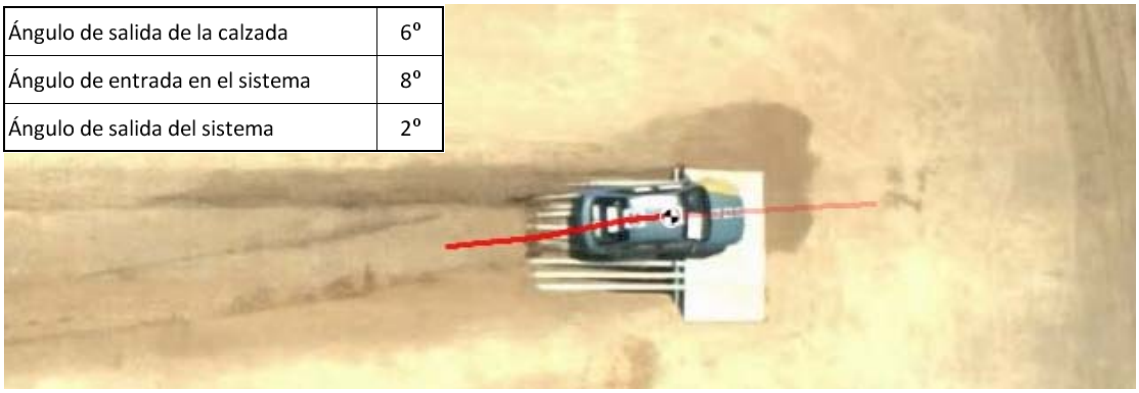


Figure 15.- Vehicle trajectory redirection during the impact test of a passenger car against the culvert-end protection device (1500 kg, 100 km/h)

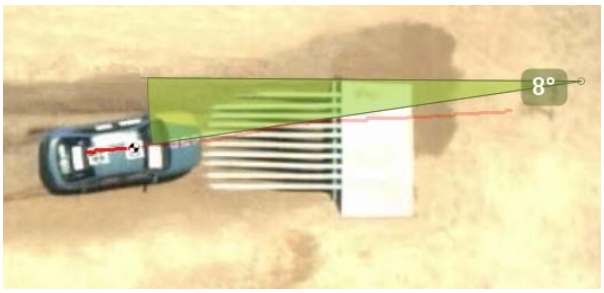


Figure 16.- Entrance angle 8°

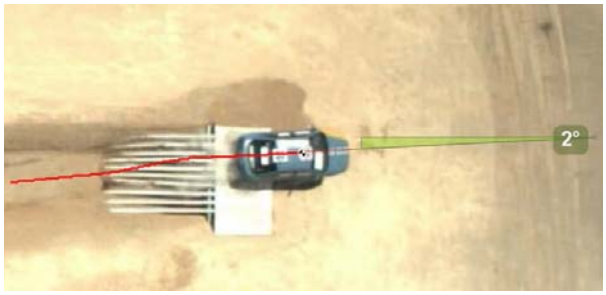


Figure 17.- Exit angle 2°

3.2.2 Motorcyclists Tests

Likewise the protective device of culvert-end Crossafe has been tested with passenger cars, its effectiveness has been validated in the event of a motorcyclist's impact against the culvert-end. The tests carried out, based on the standard *"TS 1317-8 (Road restraint systems – Motorcycle road restraint systems)*, has consisted of the impact, at 60 km/h speed, of a dummy against a protective device of culvert-end, with different configurations of trajectories and approach angles.

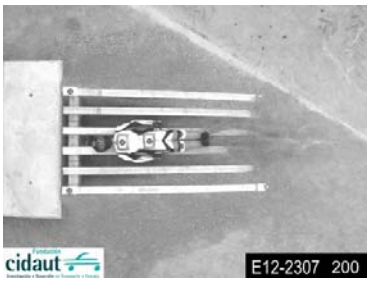


Figure 18.- Test sequence

Test at 60 km/h speed where the longitudinal axis of the Dummy and the approach trajectory coincides with the medium point of the clearing space between two adjacent longitudinal elements and trajectory and position angle of 0°

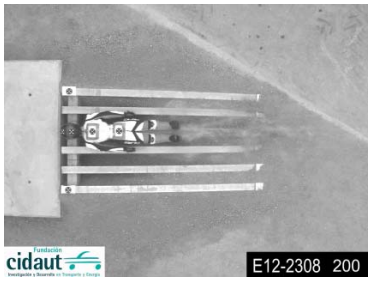


Figure 19.- Test sequence

Test at 60 km/h speed where the longitudinal axis of the dummy and the approach trajectory coincides with one of the longitudinal element

Figure 20.- Test sequence

Test at 60 km/h Speedy where the Dummy centre of gravity and the approach trajectory coincides with the medium point of the clearing space between two adjacent longitudinal elements with angles of trajectory and position of 0° and 30°.

Taking into account severity evaluation of the impact in the tests carried out and analyzed according to acceptance criterion gathered in standard TS 1317-8 CROSSAFE obtain a severity impact level of "I", which is the minimum considered in this standard. Therefore, CROSSAFE reduces the risk of causing a motorcyclist severe injuries during an impact against a culvert-end protective device. In the same way, none of tests had intrusions, protruding rearwards, elements of detachment and lacerations in the dummy against this system.

3.3. Flexibility

Structural elements are designed in such a way that allow the system to be completely adapted to all different kind of ditches, minimizing installation time and avoiding traffic disruptions, because it is not necessary to make the concrete, digging or additional heavy machinery apart from the vehicle chosen to transport the protective device.

Each element has a maximum weight of approximately 250 kg in total allowing its manipulation with light machinery and just with a tow truck for its transport and installation. Likewise, resistant properties of each unit and its connecting elements are allowed to be carried and handle as a whole making easier the protection of the approaches in short periods.

Figure 21.- Manipulation of CROSSAFE device composed of two modules

3.4. Cleaning

The space between the longitudinal elements that contributes to correct the vehicle trajectory in case of impact, allows in turn enough space to do cleaning and maintenance of the drainage elements existed in culvert-ends.

3.5. Reparability

In case of accident of a vehicle against the protective device, due to the characteristics of each unit and connecting elements, it is possible to replace damaged elements without replacing all the system, therefore maximizing the cost-benefit ratio of the installation of these devices.

4. Durability

All the components are manufactured with materials that guarantee durability as a whole above 25 years, being made up of prefabricated concrete and using connecting elements and galvanized steel support.

Hot dip galvanizing by immersion according to UNE-EN ISO 1461 of metallic pieces, including utilization of a high-quality concrete and the using of additives anticipated by "Instruction of Structural Concrete" EHE-08 of the pieces of reinforced concrete give the protective device culvert-end Crossafe the capability to resist satisfactory normal and predictable environmental actions, allowing to guarantee a useful life to the protective device.

4.1. Treatment to Protect against Corrosion

4.1.1 Galvanized

The surface of all metallic components of the system that are not totally covered of concrete are hot dip galvanized according to the standard UNE-EN ISO 1461. In this standard the average mass of galvanized steel in the surfaces (Equivalent to a minimum average thickness of galvanizing in microns) is defined taking into account the thickness of upper base steel used.

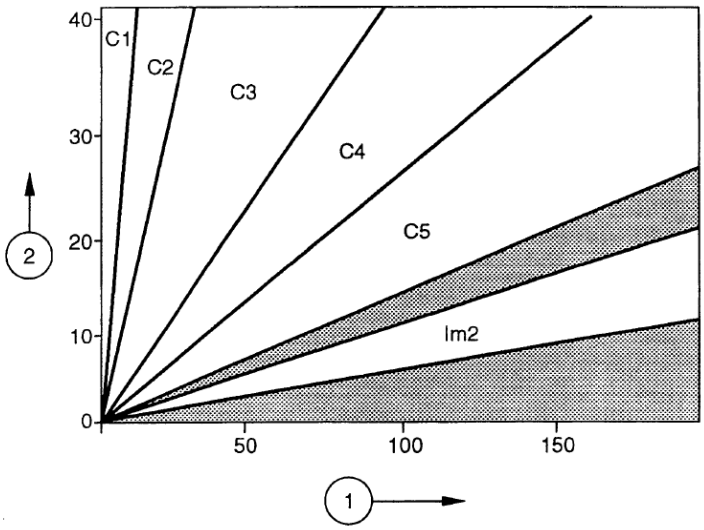
4.1.2 Reinforced Concrete

The minimum covering of the frameworks has been considered according to the kind of environmental exposure, and as a result of the kind of concrete used, the dosage as well as its resistance against frosts and sulphate attacks according to "Instruction of Structural Concrete" EHE-08.

4.2. Useful Life

To evaluate the durability in terms of average life economically reasonable, referred to normal and predictable conditions of use, applies to Instruction EHE-08 for pieces of reinforced concrete and for metallic pieces the European standard "Protection against corrosion of steel and iron structures. Coverings of zinc and aluminium. Guidelines" UNE-EN ISO 14713.

The next graph of thickness (µm)-life (years), extracted of the European standard UNE-EN ISO 14713, allows to estimate typical life (in years) until the first maintenance of the coverings of zinc in different categories of environment, according to typical corrosion speed . The minimum average thickness of the components in a protective device culvert-end according to the European standard UNE-EN ISO 1461, varies between 70 µm and 85 µm, depending on the thickness of the piece, that guarantees a useful life higher than 25 years in most of the environments.



Graph 1 –Diagram of covering thickness- covering life

Where: 1 = Thickness of the covering of Zinc, in micron (µm).

2 = Life of the covering until the first maintenance, in years.

And the kinds of climates are:

C1 = Interior: Dry.

C2 = Exterior: Rural exposure in the interior of the country.

C3 = Exterior: Urban in the interior of the country or soft coastal.

C4 = Exterior: Industrial in the interior of the country or urban coastal.

C5 = Exterior: Industrial quite humid or coastal with high salinity.

Im2 = Seawater in temperate regions.

5. Installation

To speed up installation operations of the protective device culvert-end Crossafe as well as minimizing traffic disruptions is convenient to make a previous measurement of the characteristics dimensions of a ditch, in order to determine the number of necessary elements and its minimum length of the longitudinal elements to guarantee a maximum slope of 6:1, the possibility of transporting the different units pre-installed to the installation place.

Once determined the number of units and removed vegetation existed in the surface of the ditch where it will be installed the system to guarantee its completely integration in the ditch, it proceed to the installation of the lateral supports of the structure and the arrangement of the necessary units to cover all the ditch over the supports.

The union between units is carried out with elements of union that allow connecting two or even more units, so that the whole system protects the complete obstacle.

Finally an insertion of fastening elements is made in the lower extremes of longitudinal elements that avoid its movement during an impact.

In case of concreted ditch, it may require the partial retreat of concrete necessary to facilitate the insertion of lateral supports on the ground.

For complex situations in which lateral concrete walls are present, these could be used for positioning the lateral supports. In the same way longitudinal elements can be moved for covering completely the hole available.

Figure 22.- Installation for culvert-end locations with lateral walls

5.1. Manipulation and transport

The protective device of culvert-end is stored and transported in units of 2 longitudinal elements with appropriate lateral supports. In order to avoid damages and facilitate operations of manipulation in installation are available a separator element that restrict the movement of the longitudinal elements that will be removed after the installation. (Figure 21)

6. Maintenance and Conservation

The protective device of culvert-end Crossafe does not need maintenance or conservation in normal conditions and predictable during his useful life.

In case of impacts with vehicles, the damaged elements should be repaired by replacing only the elements fractured, deformed or cracked.