Road Safety Barriers with Short Elements of Lightweight Concrete

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Abstract: *Concrete road safety barriers have been employed broadly in Italy, beginning from the 1980s, particularly on the highways and freeways.*

The safety barrier homologation and design standards, have not precisely determined, in particular for concrete barriers, specific fields of application or modality of installation. Sometimes such barriers have been judged too much rigid and, therefore, inadequate to pass the crash tests conducted with the lightweight vehicle.

There wasn’t any change or new design (cross section shape and size) in the last 20 years, so, for all these reasons it is interesting to investigate the possibility to achieve, with concrete barriers, better overall performances (containment of the heavy vehicles and lower accelerations on the occupants of the lightweight vehicles).

In this sense, a proposal regarding the design of these modular systems is to use lightweight concrete and make the element shorter than the one usually adopted in Italy. In such way, the higher lateral deformability of this barrier could lead to a greater dissipation of energy, with the resulting decrease of the dynamic effects for the users, maintaining a good containment capability in the high energy crash tests.

In this paper this new design is evaluated with “virtual” crash tests, carried out with a finite element code, LS-DYNA. The model has been previously validated by comparing the result of a real crash test (using the existing Italian concrete barrier design) with the “virtual” crash test performed in the same conditions.

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INTRODUCTION

Passive road safety devices can effectively concur to lower the risk of severe crash consequences, if correctly designed, properly installed and supervised during the normal service.
Currently, all over the world, these devices are a particular component of the infrastructure that require a special design, whose final confirmation is based on the performance of a full scale crash test (well described by the acceptance standard), that is essentially the capability to contain a heavy vehicle and the impact severity measured on a light vehicle.
The device homologation requires, for that reason, two tests, one with a light vehicle and one with a heavy vehicle; these tests are needed to evaluate in a conventional way the minimum safety requirements of the devices using performance based criteria.

Figure 1 - The lack of adequate roadside protection can lead to serious accidents

The quality of a road restraint system with respect to vehicle occupant's safety is essentially based, according to the current standards, on an index of risk that gives a quantitative evaluation of the probability of having serious injuries produced by the high acceleration measured in the short duration of the crash event.
In general it is possible to say that a limitation of the acceleration on the vehicle, and in particular the lateral component, during all the crash, corresponds to a lower risk for the vehicle occupant
With regard to this requirement, the two major categories of longitudinal safety barriers (concrete and steel guardrails) have a different behavior during crashes. With the steel guardrails, the accelerations reduction is obtained using the deformability of the material itself, with the concrete barriers it is important the shape of the barriers, that helps to control the vehicle trajectory while dissipating the energy using the high mass of the barrier elements and friction with the road pavement.
In the last thirty years, in particularly in Italy, the steel barriers improved more than the concrete barriers.
In the past years some analyses performed in the US shown that the safety shaped profiles (basically New Jersey and F-Shape, all with double slope) can lead to the rollover problems, in particular with small vehicles. Not to reduce the strength of this evidence it is important to say that the usual US design is different in some aspects, however.
Apart from the differences in cross section dimensions and details, the actual Italian design is basically a double slope (see Figure 2) concrete barrier with precast elements; the elements are not restrained to the ground (apart from bridge installations), like many US temporary concrete barrier designs.

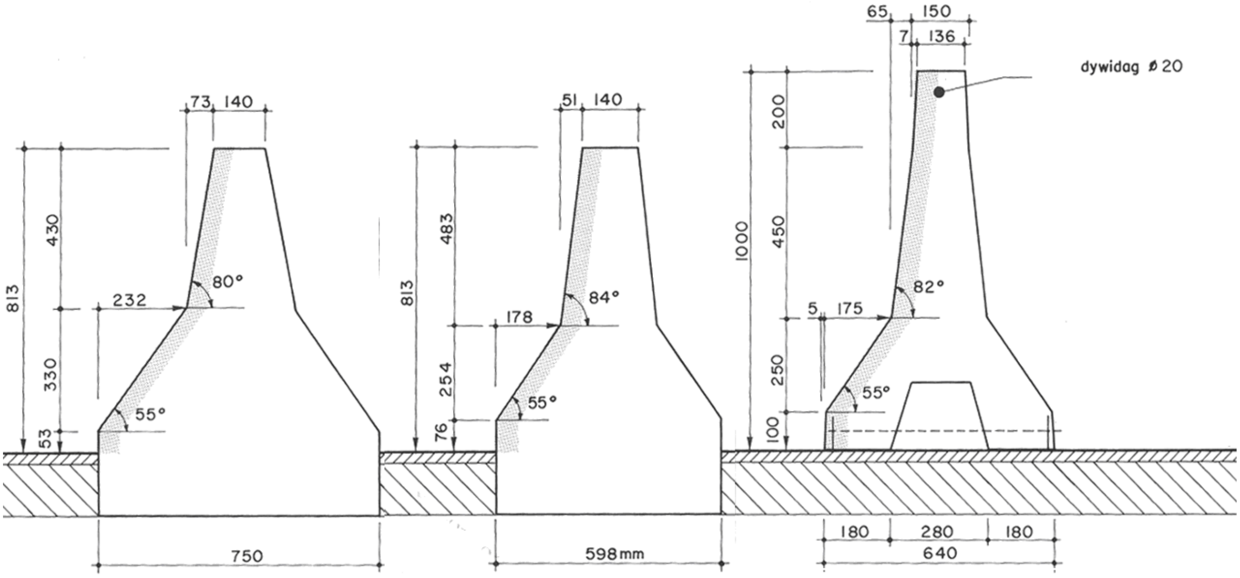

Figure 2 – Original New Jersey concrete barrier (left), F-Shape profile concrete barrier (center) and actual 1000mm Italian PCB design (right); all the dimensions in mm

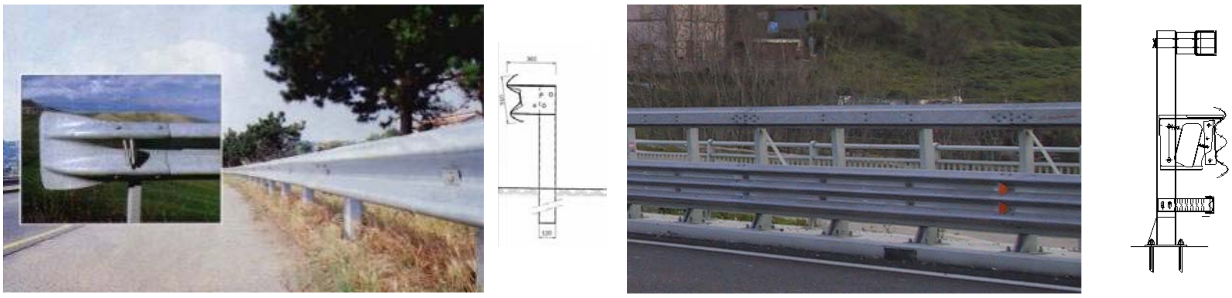

Figure 3 – Two samples showing the evolution of steel barriers in the last 20 years: the common two beam profile used since the 70s (left) and one of the heavy containment bridge guardrails (right)

The design of the actual Italian concrete barrier (Figure 2) did not change at all from the 80s, while the steel barrier had a huge development (Figure 3), in particular starting from the late 90s.
In this paper, starting and maintaining the common Italian 1200 mm height portable concrete barrier design, will be evaluated the effect of some modification (element length and the use of lightweight concrete); no modification will be made to the cross section or to the element connections.

CONCRETE BARRIERS

Starting from the 80s the concrete barriers have had used extensively in Italy and today, in the major highway network, they are still the most common type, either as a median or as a bridge parapet.
These kind of barriers were adopted in the 80s to assure an adequate containment for the heavy vehicle in the narrow median roads, very common in the Italian highway network. Starting from the median version profile and general design it was created a bridge concrete barrier; the main differences were the addition of a steel tube on the top of the barrier and the full restraint to the bridge deck.
The standard barrier is based on precast concrete element 6 m long, 1.0 m or 1.2 m tall (Figure 4 – Cross section (left) and typical reinforcement (right) of the analyzed barrierFigure 4), weighting about 5 ton; the element are reinforced and are connected head to head with a high resistance steel bar (Dywidag®) on the top and with two transversal steel beams and steel plates on the bottom (Figure 5).
Before the experimentation with full scale crash tests, only for the bridge parapets, a research-design phase was carried on (Autostrade – University of Rome, 1986).

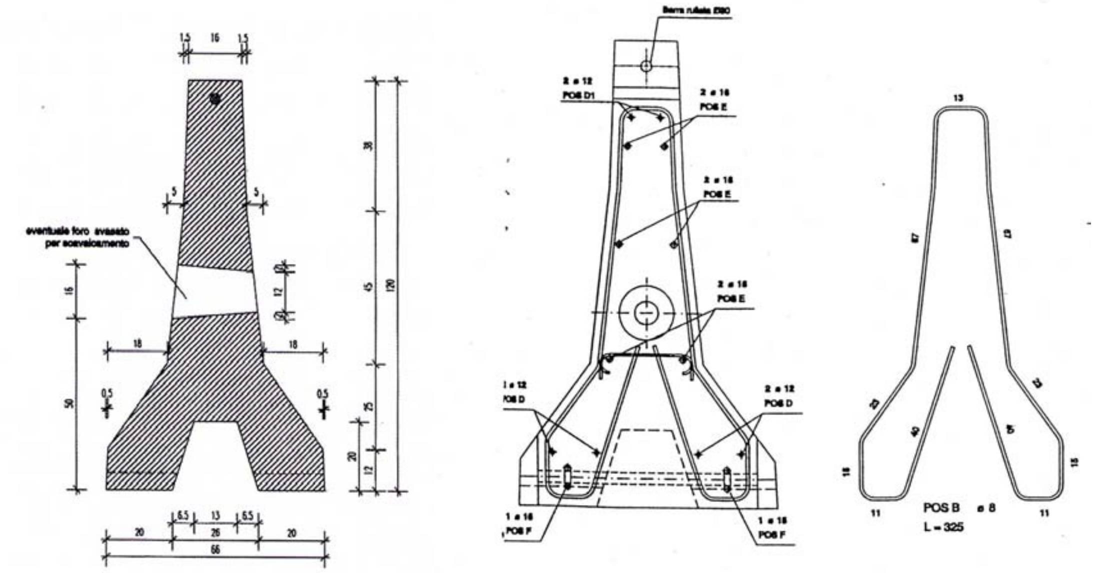

Figure 4 – Cross section (left) and typical reinforcement (right) of the analyzed barrier

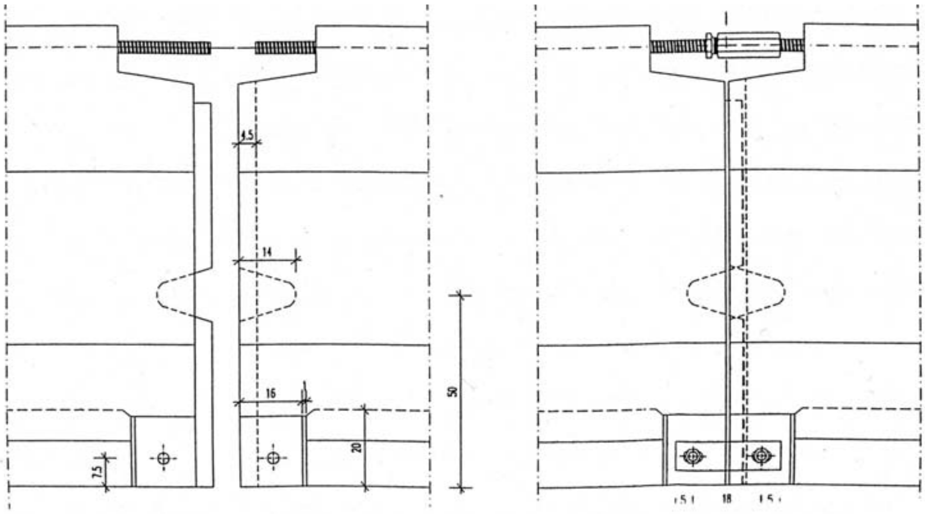

Figure 5 - Element to element connections

The actual design, after 20 years of service, shown good performance about the containment and redirection of heavy vehicles, while the impact results with the light vehicle is severe, resulting in accelerations that can cause injuries to the motorists.

It is important to note that, according to the current Italian road safety device standard (DM June 3rd, 1998) and European EN1317 part2, the ASI value should be under the value 1 (1.4 is accepted for particularly dangerous sites); in some laboratory crash tests and also in the computational mechanics models the ASI value is higher than 1.4. It is necessary to say that the ASI index is not the only evaluation index used and it is not able to give a comprehensive evaluation of the complex interactions that happen in a vehicle crash, but there are many data available from the crash tests performed and it is a synthetic index that (considering also the other evaluation parameters included in the standards and the overall test behaviour) is able to quantify the impact severity to the motorists.

The initial design of these concrete barriers was not enhanced, while the steel manufacturers did a lot of tests to redesign and improve their products, getting very good results.

Regarding the concrete barriers, it is necessary to analyze some of the aspects that can be enhanced:

- Shape and size of the cross section;
- Class and quality of the concrete (e.g. light concrete);
- Reinforcement layout, possibility to introduce some structural ductility by using controlled failure;
- Length of the element;
- Element to element connection;
- Restraints design and ductility for the fixed barriers (e.g. bridge parapet);
- Contact surface characteristics in the movable barrier (Portable Concrete Barriers or PCB).

In particular, the most promising factors seems to be the material properties (use of lightweight concrete to reduce the element mass), the shape of the cross section and the size of the elements. It is necessary to clarify that it is very hard to perform a comprehensive analysis of all the possible design modifications: for example, studying the effect of a cross section (shape) change and varying the barrier connection to the ground together can be misleading because the vehicle-barrier interaction is influenced by the deformation of the barrier.

In this paper it was decided to maintain fixed the element cross section and change only the element size and weight; the cross section change is a very important factor to analyze and the roadside research community (Sicking, 2004) is beginning to seriously to consider the need for a deep analysis.

Regarding the element mass, using a simplified theoretical model it is possible to study the barrier behaviour and forecast a good reduction of the impact severity. The concrete barrier is modelled as a simple 2D articulated mechanical system: the elements are connected with joints that reproduce the real possible degrees of freedom and move on a flat surface with an adequate friction coefficient.

This model was used to calculate the force needed to reach the imposed deformation with the hypothesis that, raising the displacement *S*, the number of reacting elements vary from the initial minimum of 2 only when the relative angle between two adjacent elements is equal to B_0 (Figure 6).

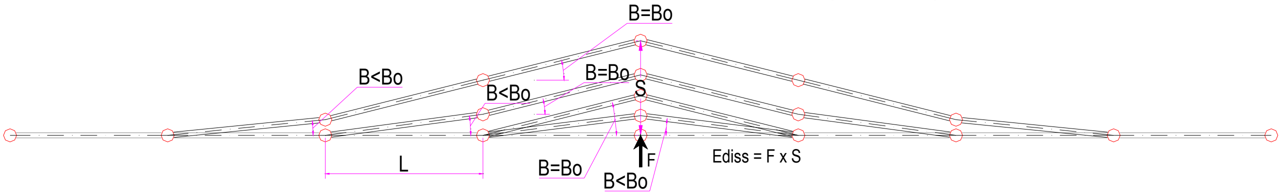

Figure 6 – Number of elements involved by an imposed displacement

Regarding the value to be assigned to the angle B_0, in Figure 7 it is possible to see that, with reference to the relative deformation of two adjacent elements observed on real or simulated tests, in this kind of devices the maximum value is about 15 degrees, but it is very common to have values of about 5 degrees.

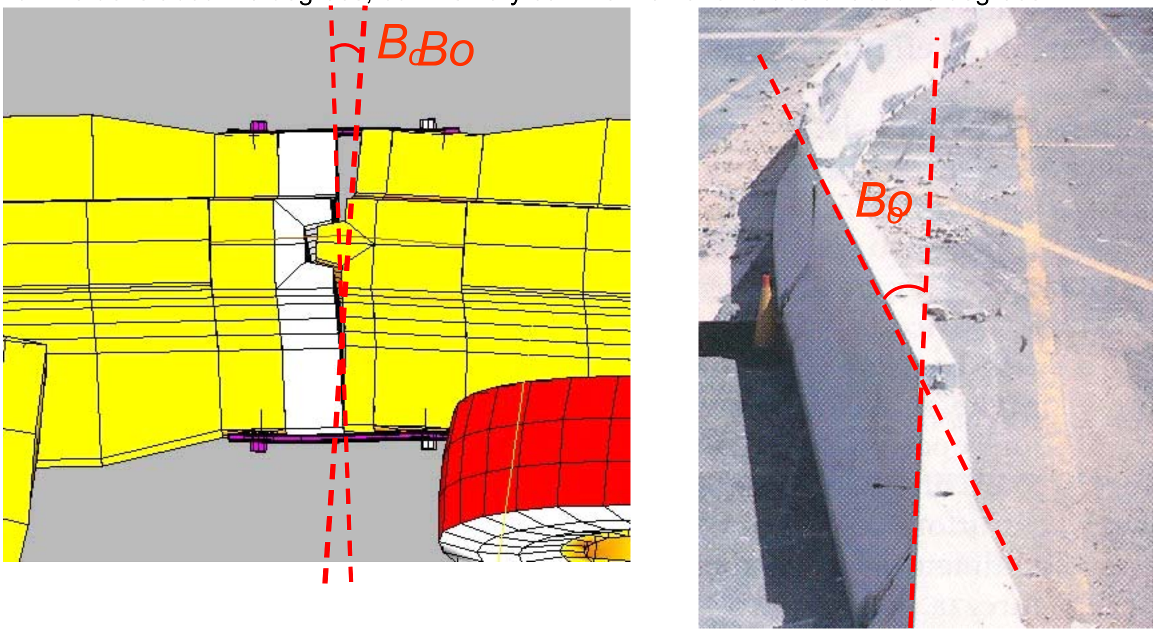

Figure 7 – The value of B0 measured in simulated and in real crash tests

In this simple model, the force *F* that produces the displacement *S*, using the energy equilibrium equation, it is equal to the energy dissipated by the friction forces of the entire system divided the same displacement *S*. With reference to Figure 8 (for a contribution of 4 elements) it is:

$$F = \frac{E_{diss}}{S} = \frac{E_{tra} + E_{rot}}{S} = \frac{\left[2 \cdot \rho \cdot g \cdot L \cdot \mu \cdot L \cdot \tan(B)\right] + \left[2 \cdot \rho \cdot g \cdot B \cdot \mu \cdot L^2 + 2 \cdot \rho \cdot Bo \cdot \mu \cdot L^2\right]}{L \cdot \left[\tan(B) + \tan(Bo)\right]} \tag{1}$$

- ρ is the mass per unit length of the device elements [kg/m];
- *g* is the gravity acceleration [m/s^2];
- *L* is the length of the collaborating device [m];
- μ is the friction coefficient between barrier and pavement;
- *Bo* is the threshold angle [radiant];
- *B* is the relative rotation angle between two adjacent elements [radiant].

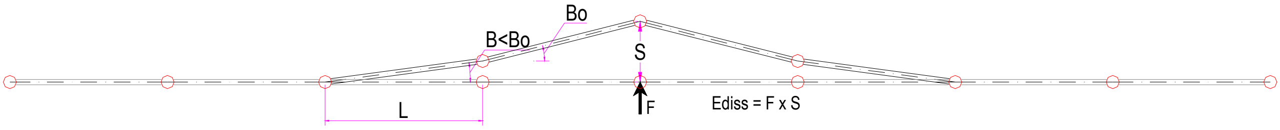

Figure 8 – Rigid element model of the barrier kinematics used to evaluate Force/displacement curve

To understand the behavior of safety devices varying the mass density and the length of the element, in Figure 9 are shown the 3x3=9 curves of the dissolved energy *E* vs. displacement *S* (given by the equation (1)), for 3 cases of length L (included the standard actual 6 m length) and 3 cases of density of mass *ρ* (included the actual design value of 828 kg/m). The curves show that, with the same dissolved energy, reducing the density of mass (e.g. using lightweight concrete), the displacement is higher, as projected. It is possible to expect an attenuation of the accelerations on the vehicle occupants.

Simplifying the phenomenon, it is possible to suppose that all the impact energy is used to produce the barrier displacement, therefore the deceleration of the vehicle (and of the vehicle occupants) is inversely proportional to the displacement. In fact, if we suppose that an impacting body (the vehicle, n. 1) loses all the initial energy ($E_{1,0}$) displacing a second body (the barrier, n. 2), the average force opposed by the second body ($F_{2,\mathrm{av}}$) multiplied the total displacement at the end of the impact ($d_{2,\mathrm{f}}$) is equal to the kinetic energy of the first body ($E_{1,0}$), therefore it is:

$$E_{1,0} = {}^{1}\!/_{2}\, m_1 v_{1,0}^2$$

$$m_2 a_{2,av} = F_{2,av} d_{2,f} = E_{1,0}$$

$$a_{2,av} = \frac{E_{1,0}}{m_2}$$

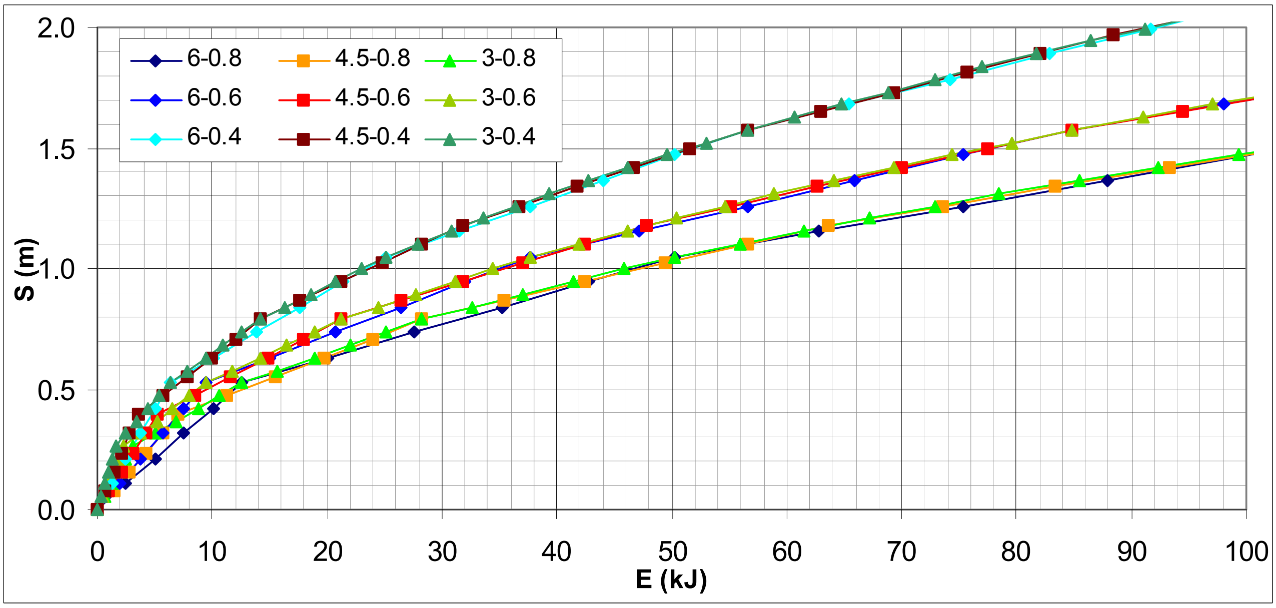

Figure 9 – Energy vs. displacement using different element length-material density combinations

Using the Energies shown in Figure 9 and with an impacting mass m_2=1000 kg travelling at a speed of 100 km/h, thus with a lateral velocity of 9.5 m/s (100 Sin(20)/3.6=9.5 m/s) it is possible to plot the diagram in Figure 10, that is useful to explain theoretically, the advantage of using the new design (short elements and lightweight concrete) compared to the actual design.

In fact, according to this simplified theoretical model, with the same energy and reducing the element mass, it is possible to get a lower lateral acceleration in the vehicle using the higher system deformability.

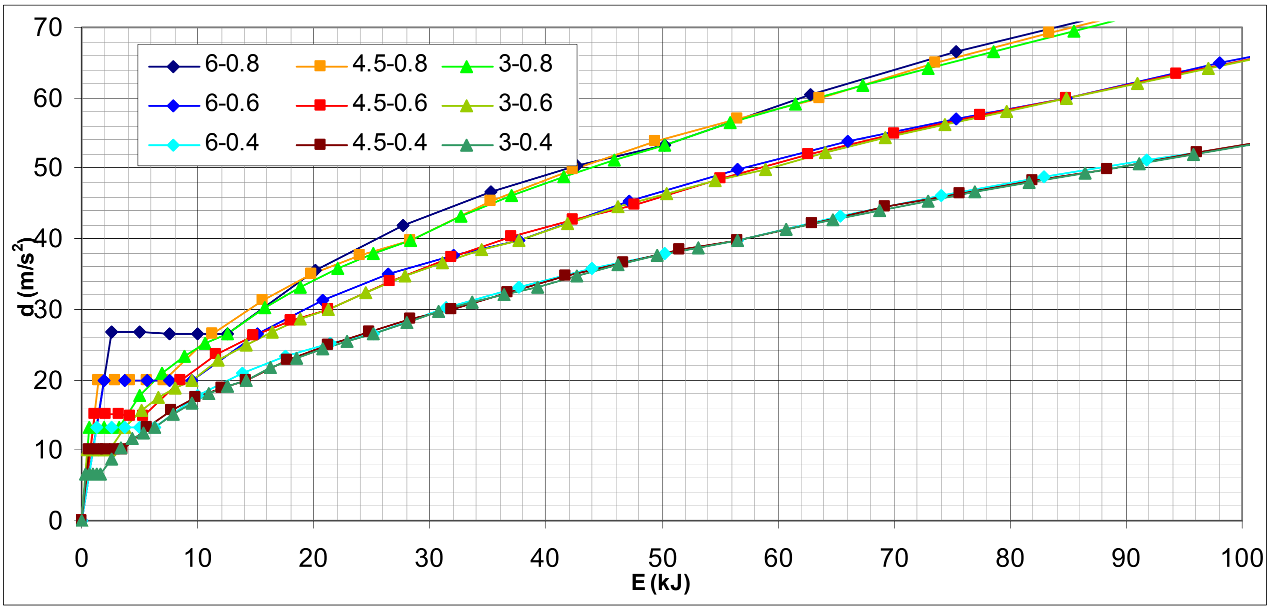

Figure 10 – Energy vs. decelerations using different element length-material density combinations

Regarding the second feature, the length of the elements, using the theoretical model it seems that this has no clear advantages (the curves with the same density of mass overlap, except a small initial part corresponding to the initial loading).

However the possibility to reduce the severity of an impact can be explained because it is possible (using shorter elements) to increase the dissolved energy, either looking at the deformed configuration shown in Figure 11, or considering that the higher number of involved elements means also higher number of plastic hinges (metal connections) and therefore more dissolved energy.

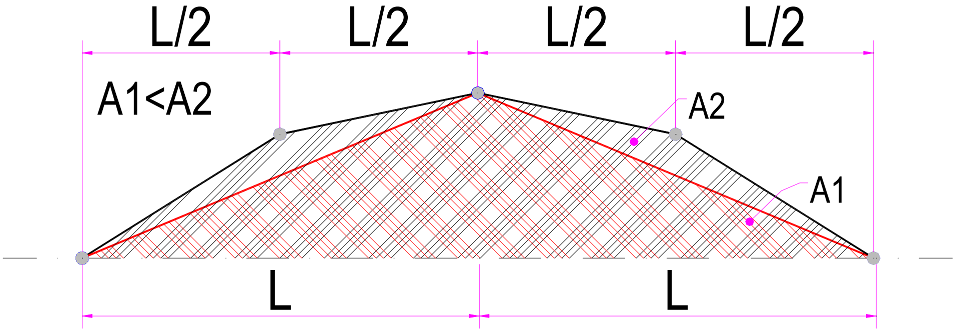

Figure 11 – Comparison of the energy dissolved by friction, long and short elements design

Taking into consideration the evidences of this preliminary theoretical study, it was started the analysis of a new design with short elements and lighter concrete, with the aim to increase the global deformation of the system and maintaining the same cross section.

It is necessary to say that the “global deformations of the system” should not be reached by a higher lateral displacement, but with a “relocation” of the element displacement producing something similar to what shown in Figure 11. This is important to control the working width (W) of the device, that affects directly the road cross section dimensions.

However, it is important to notice that the larger lateral deformation reached using the new design needs to be carefully evaluated, either in terms of larger working width, either as a request of a longer minimum length of installation (the larger deformation involves a longer section of barrier).

The next step in the analysis is possible only using computational mechanics and FE models, that is the central part of this research.

COMPUTATIONAL MECHANICS MODELS

To evaluate the possible enhancements given by the implementation of a short and lightweight element design for the concrete barriers was used the computational mechanics, performing the simulated crash test on two different Finite Element models. All the analyses were performed using LS DYNA explicit Finite Element code.

For each model two set of simulations were performed: one with the heavy vehicle, to verify the barrier containment capability, and one with the light vehicle, to calculate the severity of the impact on the vehicle.

In the following paragraphs these models are described and the results are compared.

Finite Element models of the vehicles used in the simulations

The development of a FE model for the simulation of a crash test can be also subdivided in the development of many component model that are “modules” of the final complete model. It is important, however, that the component models share the same units of measurement, have a correct mutual position and that they can interact during the simulations by means of the contact surfaces.

One of the most important component models is the vehicle. Since it is common, particularly for the high containment barriers, that the acceptance standard request two different tests, also for the simulations it is necessary to use the FE models of two different vehicles.

Regarding the light vehicle there are several validated light vehicles, that are downloadable for free at the National Crash Analysis Center (NCAC) website (http://www.ncac.gwu.edu/); among these models the General Motors GeoMetro model is very useful to perform the TB11 test (according to the European EN 1317 standard). The model downloaded from the website was adjusted to match the mass and Center of Gravity position requirements of the EN1317 standard.

Figure 12 – Lightweight vehicle used for the TB11 test (GM Geo Metro) – National Crash Analysis Center

This model has 16652 finite elements divided into 216 parts (88% shell elements, 5% solid elements, 7% spotwelds elements, 4 damper and 4 spring to model the suspensions), with a total mass of 865 kg+75 kg (concentrated mass simulating the dummy).

Regarding the heavy vehicle, in the preliminary phase was used a bogie vehicle, to reduce the calculation time; this bogie vehicle is very similar to a rounded box, reproducing only the mass and C.O.G. position and global deformability of a real heavy vehicle (Figure 13). In this phase was important only to foresee roughly if the barrier was able to contain a vehicle with the energy of the test vehicle.

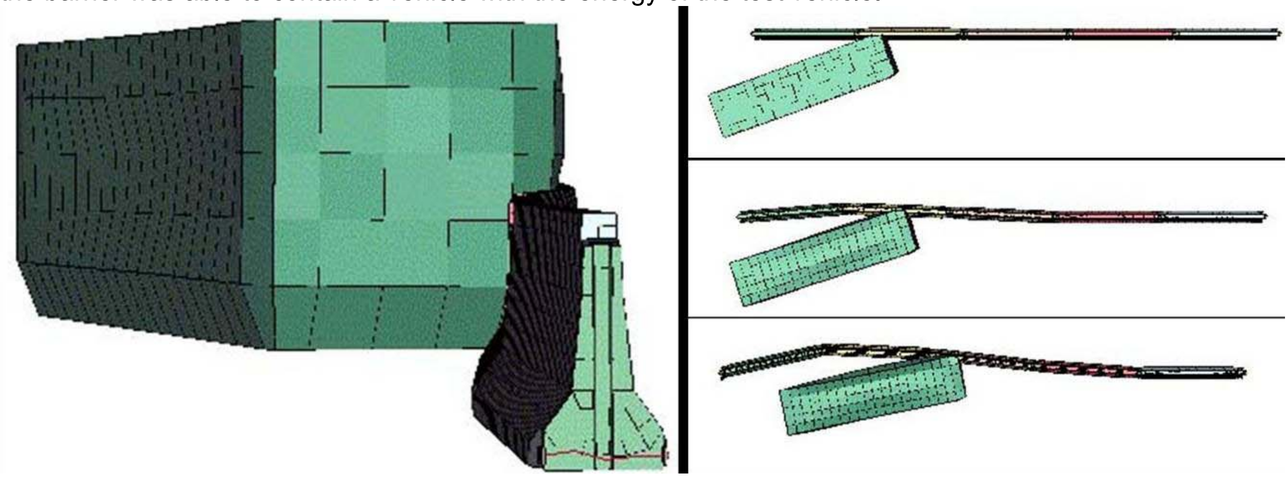

Figure 13 – Bogie heavy vehicle used in the preliminary phases.

In these models without wheels, the vehicle-pavement interaction is a Coulomb friction contact with very low coefficient, to simulate the rolling tires low resistance. With this assumption, the behaviour of the vehicle is different from reality, in particular in the post impact phase: the vehicle “bounces” away from the barrier too quickly.

For this and also for other reasons, the researchers of the "Area Strade" of the University of Rome "La Sapienza" began the development of a new finite element model of a heavy vehicle (Figure 14), to be used in the simulations of crash test with roadside safety devices.

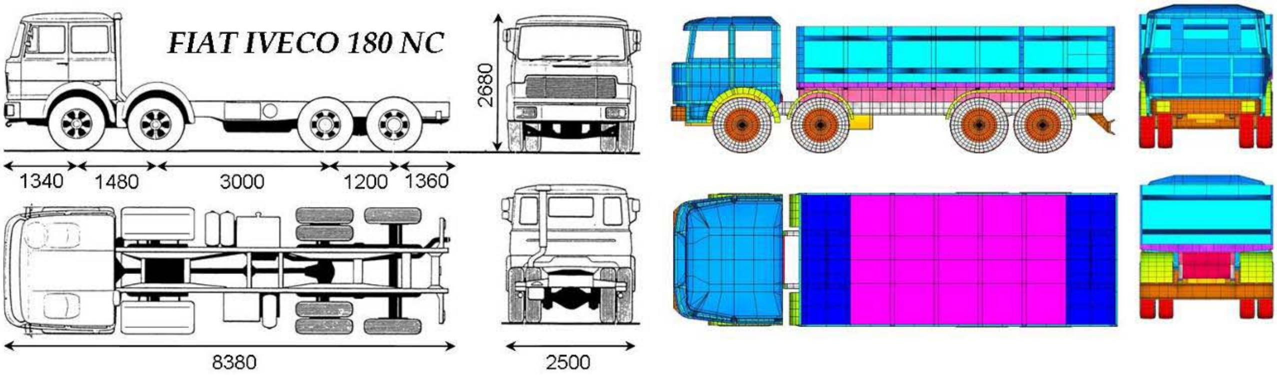

Figure 14 – Finite Element model of the heavy vehicle

It is a FE model with 24311 elements (54% shell elements, 44% solid elements, 2% beam elements, 8 damper and 8 spring for the suspensions) that reproduces a 4 axles vehicle (FIAT IVECO 180 NC) with a total mass of 30'000 kg (net mass 10'500 kg). This model can be used to perform the TB71 test (according to EN 1317) for the acceptance test of the H4a level safety barriers.
For the details on the modeling of this heavy vehicle refer "*Development of a HGV FEM: analysis and calculation of road restraints system*" (Bonin, Cantisani, Loprencipe, 2004).

Finite Element model of the actual Portable Concrete Barrier

It was chosen to build first the model of the actual design of the concrete barrier (standard reinforced concrete elements 6 m long) to evaluate by comparison the enhancements of the new proposed device, using the same test conditions by changing only something (mass and length of elements) in the barrier design.
The basic module of the median barrier is 1.2 m tall and has a mass per unit of length of about 800 kg/m; it was divided in parts: the central body, the two extremities, the upper connection bar, the lower connection bars and plates.
The main part of the barrier is made of 8 nodes solid elements, while the connecting beams are made with beam elements and the plates are shell elements. A single element is made of 1125 elements (95% solid elements, 3% shell elements, 2% beam elements).
The two ends of each elements are modeled with special care, since in this region there is the major stress concentration.

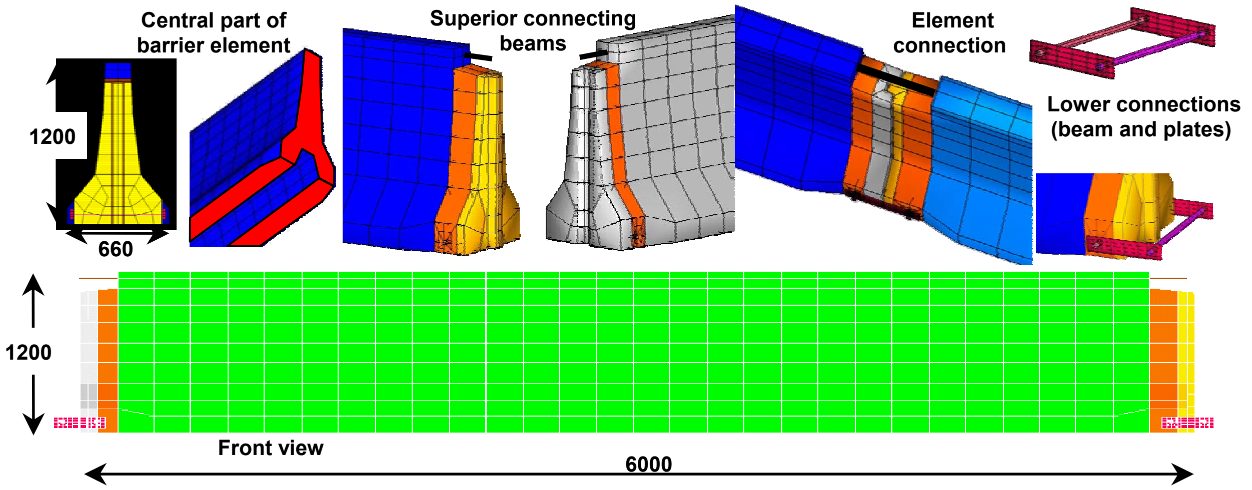

Figure 15 – Concrete barrier element layout

To verify the properties of the material model used in the simulation and to choose the correct finite element size and formulations, some particular models have been developed. In these models was reproduced the standard laboratory tension test for the steel material (Figure 16) and the compression test for the concrete (Figure 17).

The results obtained with the steel (modeled with an elastic plastic material with failure) are very good and it is also possible to fine tune the model to the particular quality of steel used, having the real laboratory test results.

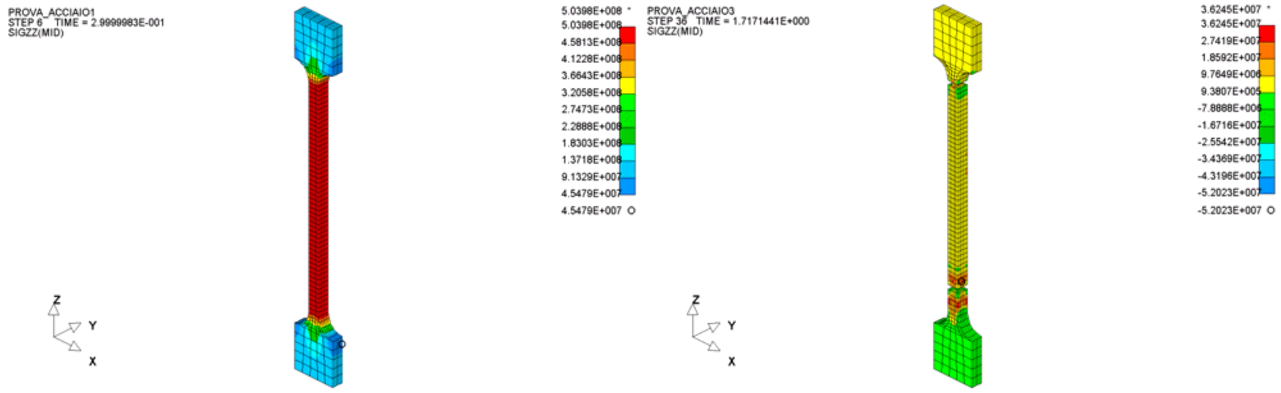

Figure 16 – Computational Mechanics FE model of a steel tension test.

The test performed on the cylindrical specimen made of concrete was a compression test. For this analysis several material models were used, but none of them gave good results in all the conditions, in particular near the failure.

A new material model for concrete (specifically designed for roadside applications) will be included in the next version of the LS DYNA code.

However, since the failure in these precast reinforced concrete barriers is usually localized near the edges, but usually it is not important for the whole barrier performance, for our simulation models was used a standard elastic plastic material with failure. This material is simpler, but is more manageable and it is always possible to monitor the stresses in the elements during the test, in order to put particular attention to possible critical regions.

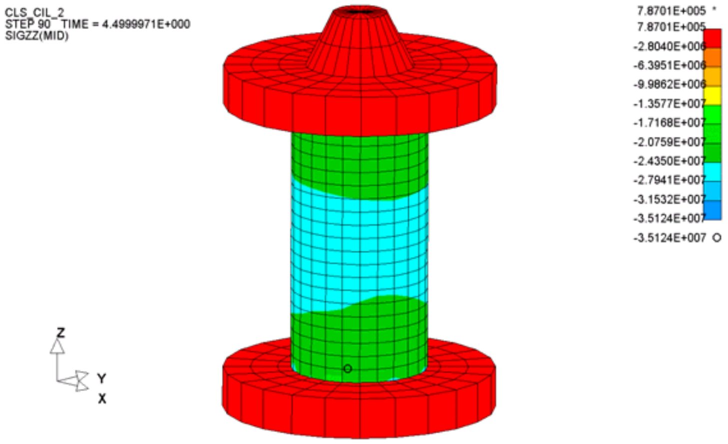

Figure 17 – Cylindrical specimen for the concrete material compression test

The material model definition was performed together with the geometric definition of the model, that took most of the time spent in the model building. The barrier model and the vehicle model were prepared as two separate model, that interact together, in the simulation, using contact surfaces. The last action before staring the calculation is defining the boundary conditions (restraints, initial velocity and gravity acceleration).

In the following pictures there is a comparison between a laboratory crash test and the simulation performed in the same conditions.

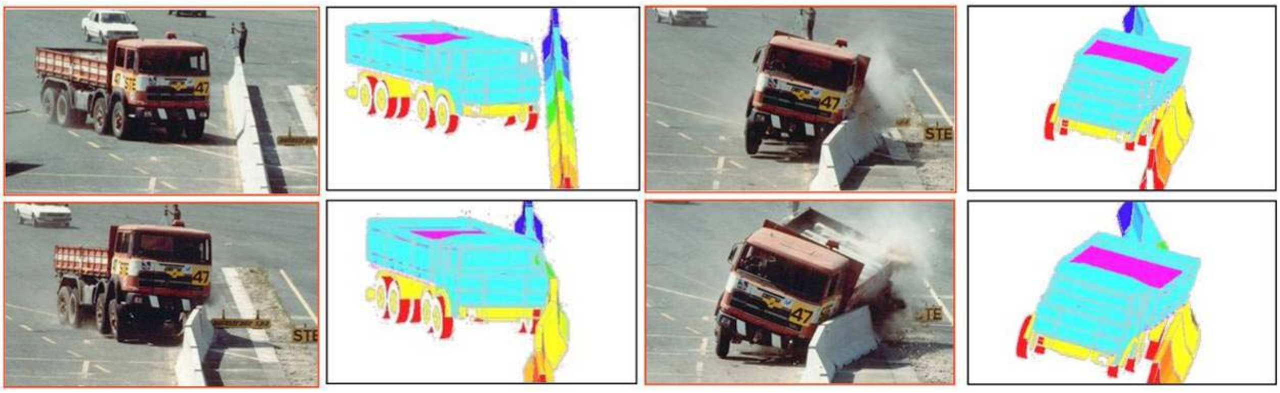

Figure 18 – Comparison between laboratory crash test for the heavy vehicle (TB71) test

The results are very good, in particular for the heavy vehicle, because the vehicle is very similar to the real one; in the light vehicle test the simulation was able to reproduce all the most important dynamic and kinematic aspects, but there is some small discrepancy because of the structural differences between the real vehicle and the model.

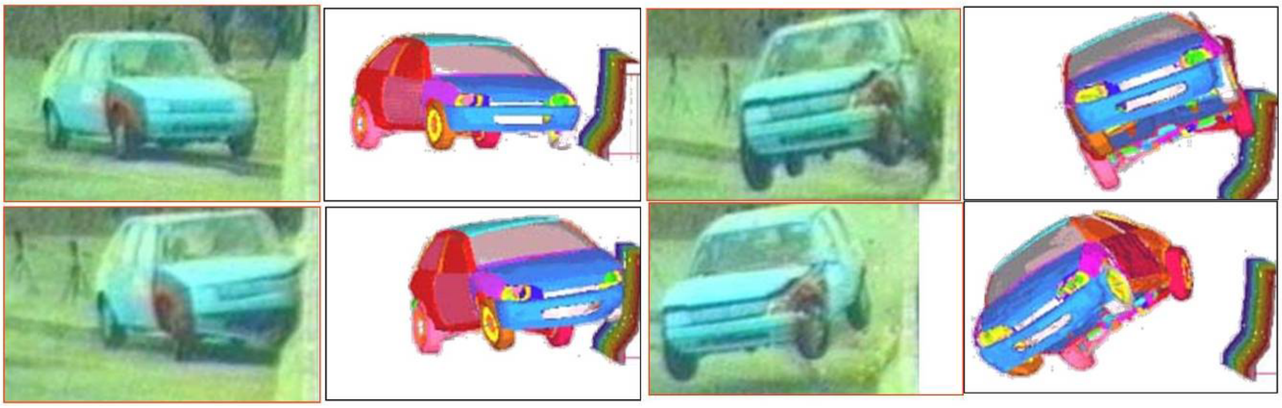

Figure 19 – Comparison between laboratory crash test for the light vehicle (TB11) test

Finite Element model of the short elements Portable Concrete Barrier

The results of the theoretical model previously considered, shown the need to limit the accelerations during the crash to reduce the impact severity on the vehicle occupants. To realize this goal could be good to have a barrier that is able to have higher displacements.

The initial idea is that, by increasing the number of joints, there is a better capability of the whole barrier to move.

The new design maintains the same cross section shape, material model and connection type, but the central part of each element has been shortened, to reduce the total length of the single element from 6.00 m to 2.00 m. In a further analysis the barrier was modeled using the lightweight concrete, using two different mass per unit of volume: 1900 kg/m³ and 1500 kg/m³. The weight of the single 2.00 m element decreased as shown on the following Table 1.

Code	Length of element	Concrete mass per unit of volume	Weight of an element	Weight per unit of length
1	6.00 m	2400 kg/m³	4970 kg	828 kg
2	2.00 m	2400 kg/m³	1655 kg	828 kg
3	2.00 m	1900 kg/m³	1258 kg	629 kg
4	2.00 m	1500 kg/m³	930 kg	465 kg

Table 1 - Weight of the elements in the actual and proposed design

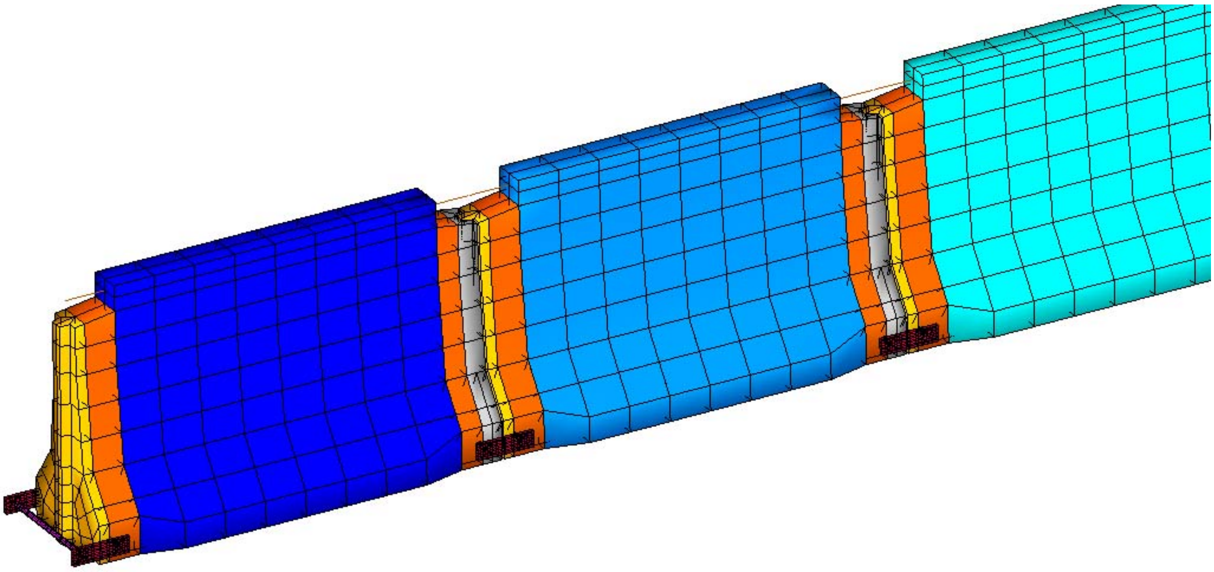

Figure 20 – Model of the 2.00 m concrete barrier (detail)

With each of these models a set of crash test was performed, with the heavy and with the light vehicle.

PERFORMANCE COMPARISON OF THE SYSTEMS MODELED

In the previous paragraphs it was shown that is possible to improve the performance of a safety barrier (in terms of reduction to the lateral acceleration) also increasing the lateral displacement of the device.
This result was achieved with the light and short element devices, as it is possible to see in Figure 21, that shows the comparison between the actual design (reference) and two modified designs.

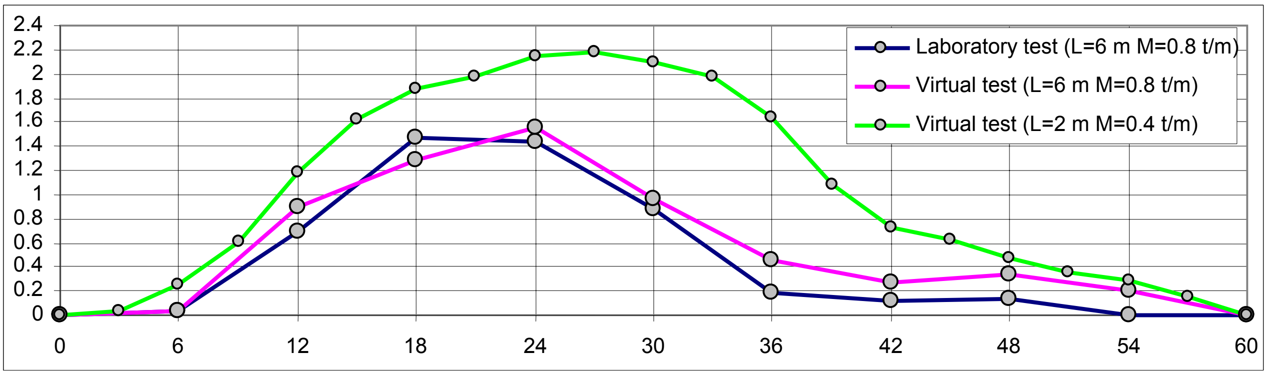

Figure 21 – Comparison of the displacements in the real and in the simulated crash test

This preliminary result is obtained in real (reference barrier design) and virtual crash test (modified barrier design) with a 30’000 kg heavy vehicle traveling at about 70 km/h (TB71 test level); in this case the displacements are bigger, but the result is appropriate also in the case of the light vehicle.
In the case of the light vehicle, to confirm the reliability of this achievement, it is important to consider the accelerations measured during the test. The three component acceleration diagrams are shown in Figure 22 for actual concrete barrier and in Figure 23 for short element lightweight concrete barrier. In this diagrams, the curve in blue is relative to the signal obtained from Computational Mechanics Simulation and the red curve is the moving average of the signal with a frequency at 20 Hz.

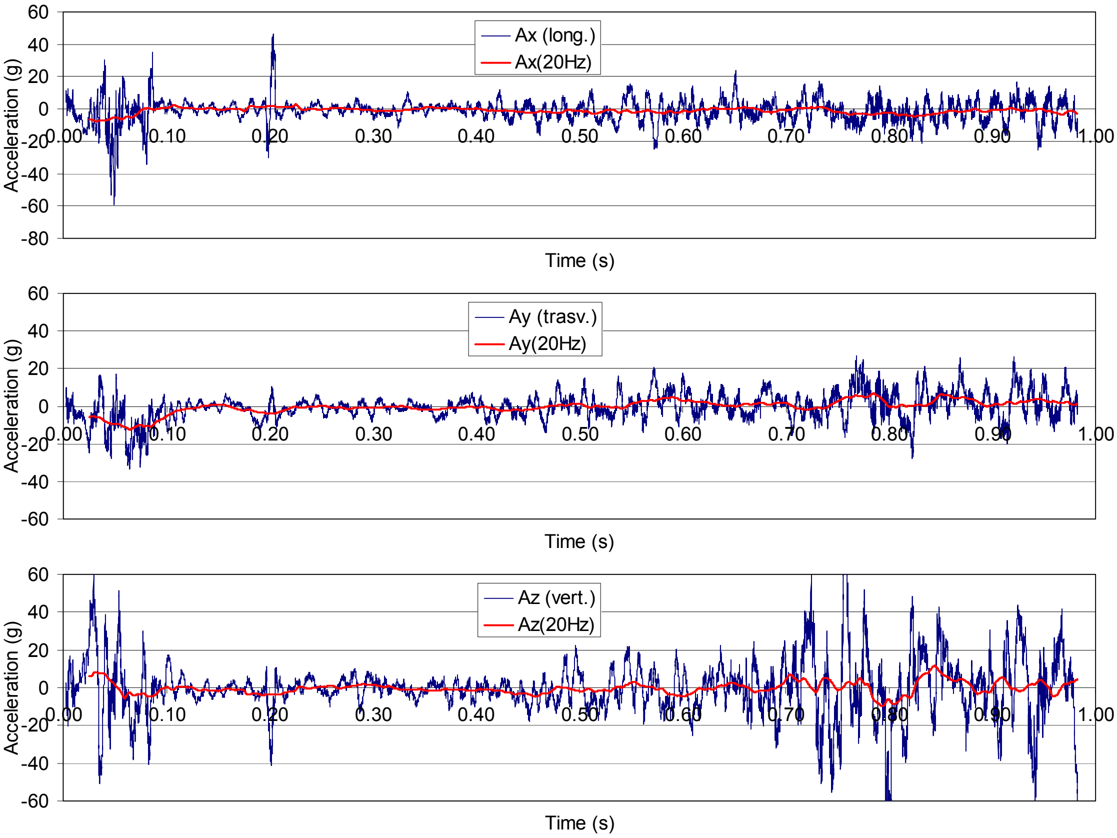

Figure 22 - Acceleration diagram, actual concrete barrier (from Computational Mechanics Simulation)

The Acceleration Severity Index is a conventional index that is used by the current Italian and European standards to evaluate the acceleration on the vehicle occupants. The calculation of this index is based on the accelerations (a_x, a_y, a_z) measured on the three axes x, y, and z (parallel to the vehicle motion direction, lateral and vertical). The accelerations measured on the virtual vehicle (or vehicle model, see Figure 24) are averaged on a mobile 50 ms interval to calculate the index:

$$ASI = \max[ASI(t)]$$

$$ASI(t) = \sqrt{\left(\frac{\bar{a}_x}{\hat{a}_x}\right)^2 + \left(\frac{\bar{a}_y}{\hat{a}_y}\right)^2 + \left(\frac{\bar{a}_z}{\hat{a}_z}\right)^2}$$

$$\bar{a}_j = \frac{1}{\delta}\int_t^{t+\delta} a_j dt\,; \qquad \hat{a}_x = 12g\,,\ \hat{a}_y = 9g\,,\ \hat{a}_z = 10g$$

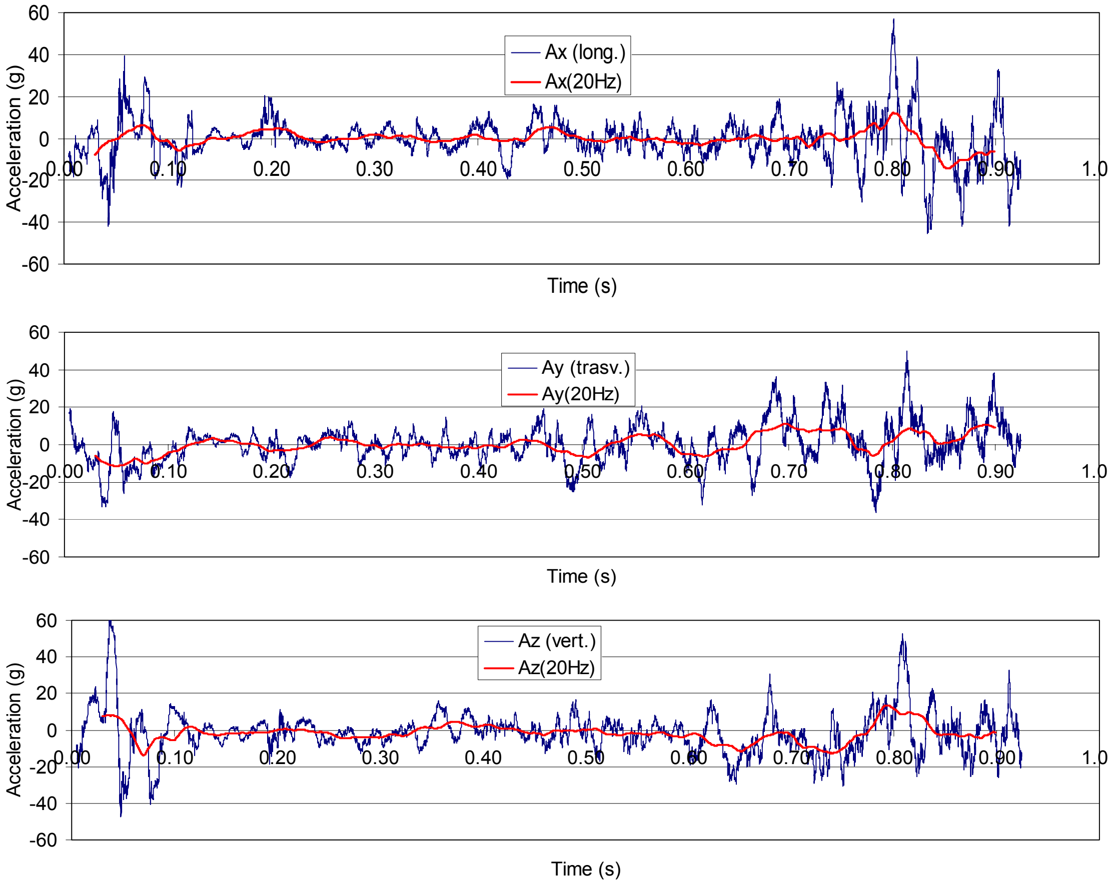

Figure 23 - Acceleration diagram, short element lightweight concrete barrier (from Computational Mechanics Simulation)

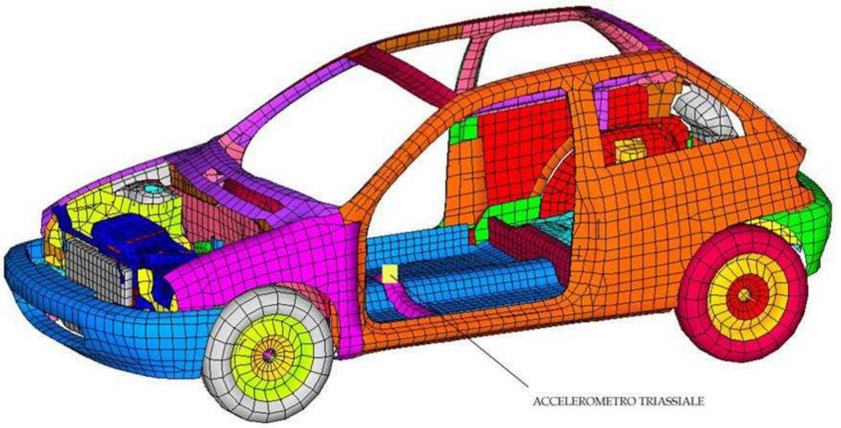

Figure 24 – Position of the virtual accelerometer on the vehicle model

The results of the computational mechanics analysis (Figure 25 and Figure 26) shows that the ASI values, as expected, is higher in the actual design. The ASI passes one time the 1.4 and three times the 1.0 mark, while the new design produces lower values, with the ASI never higher than 1.4.

It is necessary to say that, looking at the ASI diagram, that the peaks on the second part of the test (in particular for the new design) are due to the vehicle landing for actual design and to the rollover experienced with the new design. In fact, the new design stressed something that was already found in some US test with double slope profiles: rollover with light vehicle.
The results of the test are very good, however: the fact that the new design produced a rollover problem is something that need to be addressed using a different cross section but does not affect the improvement reached by using light and short elements.

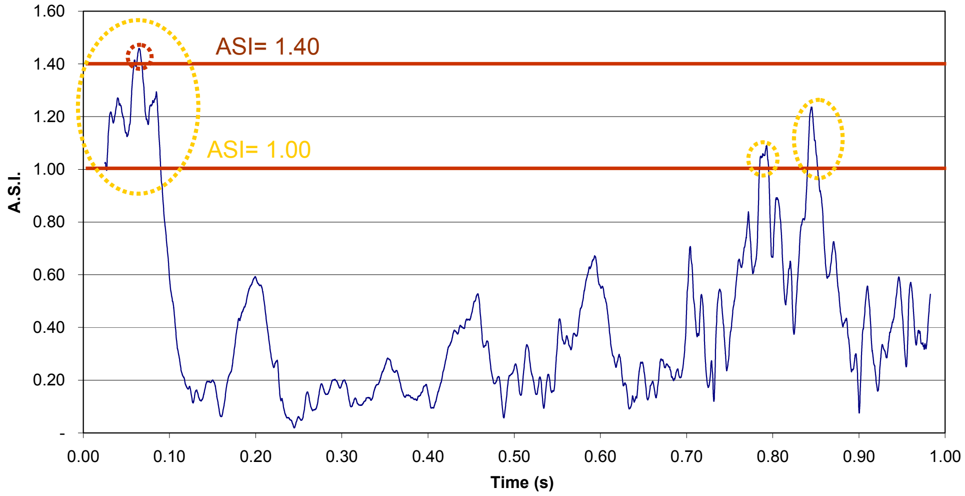

Figure 25 – ASI diagram, TB11 test with the actual PCB design

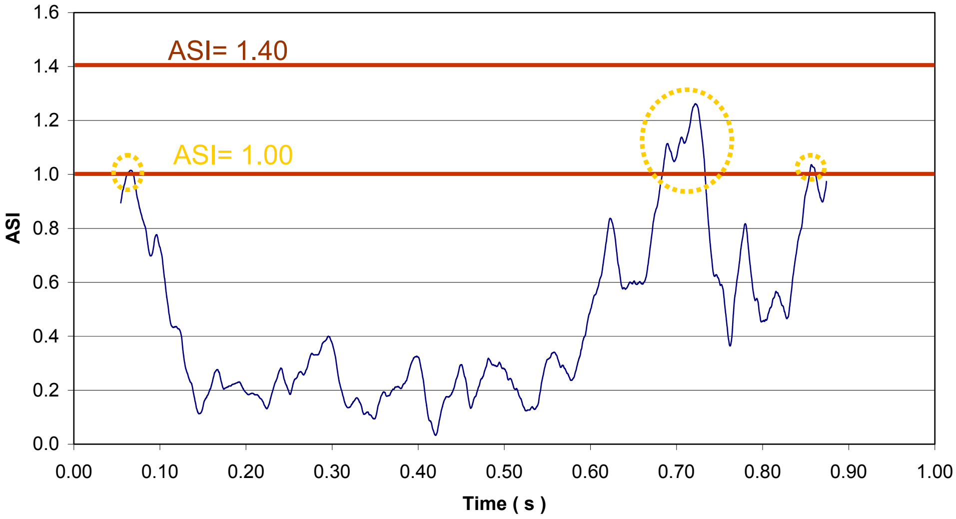

Figure 26 – ASI diagram, TB11 test with the lightweight concrete, short element PCB design

CONCLUSIONS

The development of a new restraint system and its final exercise on new or existing roads must follow an accurate design phase. In the past the study was limited to simplified evaluations, inadequate to the complexity of the problem, while, during the design of the infrastructure, the part regarding roadside safety was resolved after all the other by choosing a device on a catalogue.
Much of this was because of the difficulty to analyze such a complex problem with the classical tools of the solid mechanics applied to structural calculations.
This paper shown that is possible to solve this problem using the computational mechanics with finite element models, that allows to reproduce the real test conditions by simplifying the continuous problem in small discrete steps and running the calculations using a computer.
The results of the virtual tests performed on the new PCB with light concrete and small elements demonstrated that it is possible to improve the performance of these devices: in this paper some simple modifications were introduced to the actual design (mass and length of elements) and there was an

improvement regarding the impact severity, measured with the ASI index that, comparing the new to the traditional design showed an overall reduction. However the new design also shown that, in the particular conditions of the acceptance test and with the particular light vehicle that is commonly used to perform the test, there is a need to modify also the shape of the barrier, since the new design confirm a tendency to cause the vehicle rollover. This behavior was somehow expected by the evidences of the US tests and accident results and the best way to address this issue is studying the cross section shape; also this analysis can be performed using, in the initial phase, the computational mechanics: it is possible to vary the geometry of the cross section and analyze the virtual test results.

The results of these tests are able to give more than the conventional indices diagrams (ASI, THIV, PHD, etc.): it is possible to study in detail the vehicle kinematics and the stress-deformation behavior of each element that take part in the phenomenon. It is also possible to improve the analysis of the severity of the impact to the motorists by using one or more virtual dummy inside the vehicle. However it is necessary to say that, in particularly using the dummy model, the results of the tests are substantially influenced by the vehicle itself: the validity of the analysis is however good (as a comparison between tests where the only variable is the barrier), but the behavior with a different model can be different.

It is also to remark that the development of these models requires a special training because the choice of the details to include in the model is a key element in the good result of the whole analysis.

The design phase for a new device or the improvement of an existing one can have a great help from the computational mechanics: during the initial phase the design will be refined and optimized, defining the final layout of the device to be experimentally tested with a laboratory full scale crash test. The final test with a full scale crash test is something that is necessary, not only because of the acceptance standards requirements, but because, up to now, the models that is possible to create are always a simplification of the reality and sometimes the behaviour of some minor details, not included in the model, make the difference.

This tool, however, it is not useful only in the design phase, but it can be applied valuably also to evaluate all the particular installations that the infrastructure designer has to define and, up to now, had no way to analyze in depth and with good confidence in the results.

It is also important to point out that the acceptance test is performed in conventional conditions, specified in the standard, but it is not representative of all the real installation conditions. Given that in the test conditions the barrier is mounted straight and on a flat and horizontal surface, it is clear that is possible to have critical conditions also for a barrier that fulfilled the homologation test. In these conditions should be good to verify the safety of the installation with a computational mechanics model, that is the only way to consider all the influencing factors and have a comprehensive safety analysis without a real laboratory crash test in the same conditions.

According to the current Italian design standard, that is also a law requirement, these situations must be verified by the infrastructure designer.

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