AN INJURY SEVERITY COMPARISON ON SIDE IMPACT CRASH TESTS

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ABSTRACT

The objective of this study is to analyze the type and entity of injuries caused to the occupants of the vehicles involved in accidental impacts against guardrails with the high containment level. At present, the installation of highway guardrails requires the maintaining of some specific control rules imposing some verifications of the characteristics of the chosen vehicle, the dynamic parameters of impacts and the behaviors during the crash.

The results of the crash tests carried out for the different types of guardrails, concerning the trajectory and the acceleration of the vehicle during the impact as well as of the damages suffered by the vehicle itself, do not allow establishing any precise element regarding the possible injuries to the occupants of the vehicle.

The aspect of the relationship between the damages to the vehicle and the injuries which could be caused to the occupants is the main problem to be solved, in order to find out some new solutions for improving road safety. In the field of impacts against the guardrails, this consideration arouses a greater concern, because the components of the speed and the accelerations transversal to the direction of the crash, cause lateral solicitations on the body of the occupant which can have more serious consequences.

Within the framework of studies and research in road traumatology carried out at the University "La Sapienza" in Rome, scientific research has been promoted with the aim of studying the behavior of vehicles and their occupants during accidental impacts against guardrails. Two crash tests on two different types of guardrails were carried out following the European norm EN 1317 parameters. The results were described and discussed.

INTRODUCTION

In order to identify in simple terms the principal aspects to be emphasized in the research as well as the results to be pursued, the following considerations may be made:

- It is necessary to verify the coherence of the standards currently applicable for installation of the barriers at maximum stress values tolerable on the human body in its many parts;
- It is necessary to single out a concept of correlation between the behavior of the vehicle in the impact and the stressful agents transmitted to the occupants in their typology and entity;
- It is hoped that the research may lead to a normalization of the methodolgy to be followed in the use of barriers and in the limits to impose on the various classes of vehicles in order to lower the risks of more serious injuries. For this purpose an exchange organized on the basis of the homogeneity of the data available at all the international organizations in charge of expressway safety should contribute to improve passive safety in a notable manner.

Material and Method

In order to realize a research program that cannot and must not be limited to the mere two tests performed, it has firstly been necessary to set up certain points of reference, both to achieve a coherency with similar activities carried out in other countries and to have a guarantee in the future of the homogeneity of the collected data and their reliability. The first point was to establish which standards were in force concerning the matter and what legislative prospects existed, above all for the international aspects. The reference specifications available today for the purpose of this research and which give to the matter of impacts against barriers an adequate scientific rigour are essentially two:

- the European standard EN 1317
- the United States specification NCHRP Report 350

The requirements provided for in the applicable specifications essentially regard the total mass of the vehicle, its geometric characteristics and, in particular, the height from the ground of the center of gravity, the velocity and the impact angle. The acclereations and the velocities verifiable on the vehicle and those transferred to the occupants represent the parameters to be controlled as well as the trajectories. In the specific case of this research, however having a limited period of time available, it has been decided to effect two tests on two kinds of barriers - two fundamental types currently used and precisely:

- 3n fracasso steel barrier,
- New Jersey barrier in prefabricated concrete.

Both barriers are the traffic divider type and both perform exteremely well with respect to their restraining qualities.

The choice of an automobile has been singled out as the Peugeot 205xA in consideration of its wide diffusion and above all because this model complies with the aforementioned specifications taken as reference for this study, both in terms of mass and height of the center of gravity from the ground.

The two tests were performed (one for each barrier) in conditions of perfect homogeneity, with an impact velocity of 100 km/h and an impact angle of 20°.

The two tests were performed by placing an anthropometric dummy (Ibrid II model) mounted and equipped with instruments inside the automobile, once in the passenger's seat for the impact test at the right and once in the driver's seat for the impact test at the left. In fact, the regulation prescribes that the dummy is to be positioned in the automobile on the side of the impact. For the purpose of exploiting the maximum experience acquired in the sector and establishing presuppositions for future programs with possible exchange of information, the collaboration of the French laboratory, L.I.E.R., in Lyon, was requested - a laboratory where the tests were physically performed and the results obtained were discussed.

The parametric characteristics to pursue and evaluate in an impact test against barriers are indeed many and include both the velocity and the accelerations verifiable on the vehicle and on the dummy as well as the indices of deformation of certain significant parts such as the cockpit, the dashboard and the bumpers of the automobile.

With a view to this study, greater importance was given to the aspect of the accelerations verifiable in the various points of the vehicle and the dummy, integrating the results with a quantitative and qualitative examination with respect to the evaluation of the damages suffered by the vehicle and by the barrier in the collision, and by the shifting of the dummy inside the automobile.

This combined theoretical-experimental examination has made it possible to draw certain considerations which allow stabilizing basic concepts regarding the behavior of the occupant of the vehicle in the crash and the injuries to which he is exposed.

In order to proceed by degrees to a research program founded on new bases which also make it possible to include the damages to which the person is exposed in the specifications of evaluation of the impacts on barriers, it was necessary, as a first step, to examine more closely the comparison of the applicable standards.

The aspect of the accelerations suffered by the vehicle in the collision has been taken as a basic parameter to execute the above-mentioned comparison in the sense that the maximum tolerable values for the acceleration along the three reference axes, or their combination, allow us to evaluate the forces which the hypothetical occupant and the inside of the vehicle reciprocally exchange and the degree of safety to be reached in the various cases.

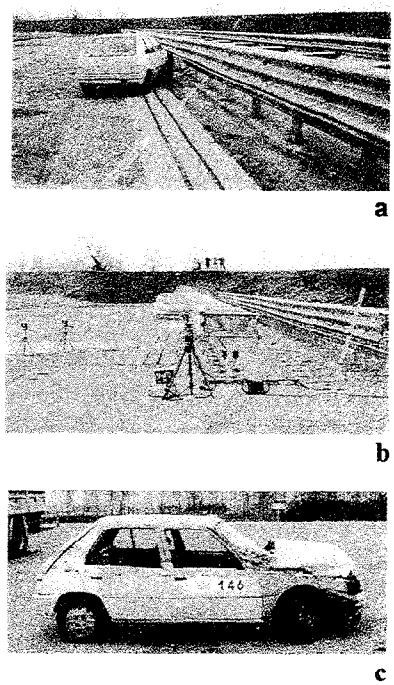
Behavior of the vehicle in the impacts - The tests carried out have revealed that it is possible to study the behavior of the vehicle, both in terms of trajectory as well as accelerations.

The significant data may be summarized and commented as follows:

- the accelerations found along the three axes present sensible differences in the two tests performed, with greater accelerations in the transverse and vertical direction;
- with reference to the periods of time, the acceleration peaks present values that merit closer examination.

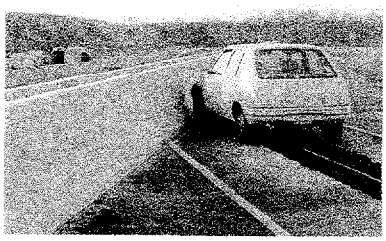
In the 3n fracasso steel barrier impact test the damages suffered by the vehicle in the impact on the right side, i.e. with the dummy in the passenger seat, can be ascribable to the range of normal accidents.

The entire right side and, in particular, the right front part were found damaged, from the lights to the bumper, the front wheel, the windshield, and the side window glasses. Other details may be seen in the attached photographs (Fig. 1a,b,c and Fig. 2a,b,c).



a b c

Fig. 1 - Impact on the 3n Fracasso steel barrier



a

b

c

Fig. 2- Impact on the New Jersey concrete barrier.

It was also useful to localize the damages suffered by the barrier itself. The collision had created a recess in the barrier along the steel beam for a stretch of about 7.5 m and with a maximum 0.15 m deflection; the energy dissipators have undergone the programmed breaking of the diaphragms necessary for the absorption of the crash, with this result :

ASI_t (Acceleration Severity Index) = $\sqrt{\left(\frac{\bar{a}_x}{\hat{a}_x}\right)^2 + \left(\frac{\bar{a}_y}{\hat{a}_y}\right)^2 + \left(\frac{\bar{a}_z}{\hat{a}_z}\right)^2}$ = 0.95 and $\sqrt{a_x^2 + a_y^2 + a_z^2}$ = 19.8g as evidenced by the accelerometric traces (Fig. 3a,b,).

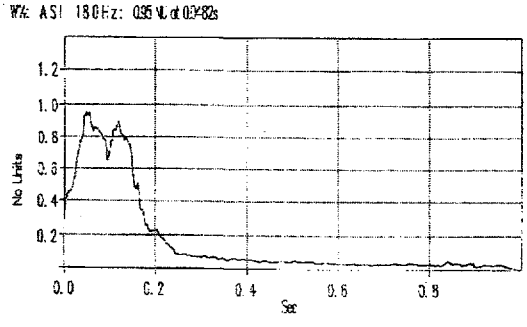


Fig. 3a

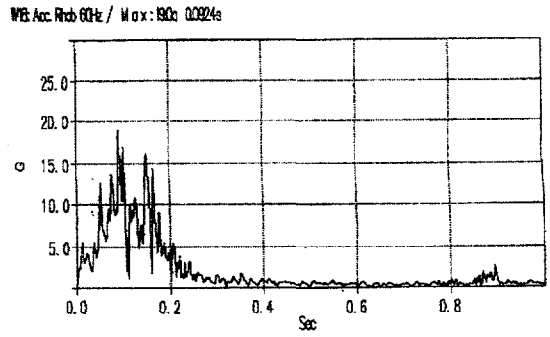


Fig. 3b- Central Reserve 3n Barrier

In the tests performed on a New Jersey concrete barrier with the impact on the left side of the vehicle and the dummy placed in the driver's seat, the damages suffered by the vehicle in the first phase of the impact have not been unlike those seen in the first test.

However, it should be pointed out that in this case a series of rollovers occurred which further damaged both sides of the vehicle.

The damages suffered by the barrier in this case as compared with those relative to the steel barrier may be evidenced by a minor recess (0,025 m compared with the 0,15 m of the other) and a larger area involved in the barriervehicle contact (12.4 m compared with 7.5 m in the preceding test), demonstrating a lesser absorption of energy, with ASI_t = 1.34 and

$\sqrt{a_x^2 + a_y^2 + a_z^2}$ = 25g as seen by the accelerometric traces (Fig. 4a,b).

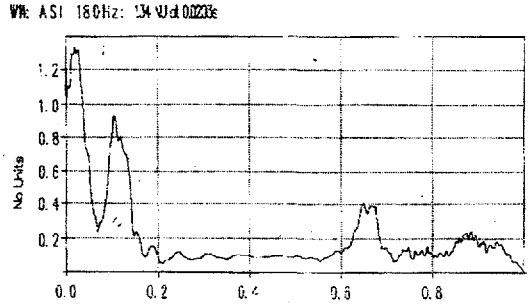


Fig. 4a

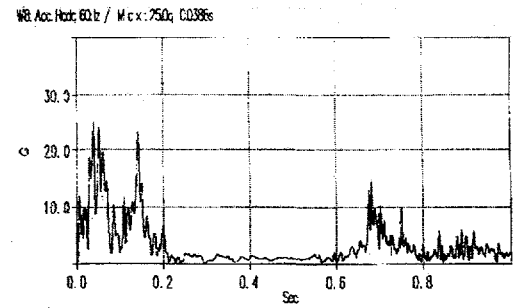


Fig. 4b- Double row prefab-concrete barrier

It is also to be pointed out that the breakage of barrier elements did not occur in either case, nor did either vehicle jump the barrier.

Behavior of the dummy - The purpose of this study in regard to the dummy creates, among other exigencies, the need to identify certain specific anomolies in the movements and rotations it undergoes during the evolutions of the impact. Besides the acceleration values seen in certain significant parts of the body, its behavior was concentrated on movements and, in this respect, the following considerations may be made:

- in the tests performed with the impact on the right side of the vehicle (3n fracasso steel guardrail) the dummy, simulating the passenger, demonstrated a significant lateral inclination of the trunk towards the part opposite the impact and a shifting of the lower limbs towards the car door; the pelvis remained well-positioned as it was protected by the abdominal strip of the safety belt;
- in the impact against the concrete barrier, i.e. with the left side of the vehicle, the dummy, placed in the driver's seat, showed a marked loss of balance of the trunk towards the door and an evident bruise on the head in the left frontoparietal region - which is also a sign of the rolling over of the vehicle consequent on the impact against the barrier.

The two tests, although evidencing the above-mentioned difference, have given a clear indication of the effect of the lateral components of accelerations and this must be taken into consideration in establishing the limits to foresee in impacts, either in terms of velocity or of the lateral mechanisms, which will be specified below.

CONCLUSIONS

The study was seen to be worthwhile and interesting, both concerning the prospects of what must still be done and in the terms of application of the procedures and standards available to date.

The most significant aspects may be summarized as follows:

A) Among the selected parameters in the recording of data characteristic of the impact against barriers, a particularly important role is played by the acceleration severity index (ASI_t) as established by the EN 1317 European specification:

$$\mathbf{ASI_t} = \sqrt{\left(\frac{a_x}{12}\right)^2 + \left(\frac{a_y}{9}\right)^2 + \left(\frac{a_z}{10}\right)^2}$$

Where a_x, a_y, and a_z are the components of the accelerations, expressed in g, in the three directions.

This index foresees ≤ 1 values for the best safety conditions with respect to the occupants but which can be accepted up to 1.4 levels only for uses of limited extension, with conditions of lesser security.

The NCHRP-Report 350 United States Standard provides for the occupant velocity measurement O.I.V. (Occupant Impact Velocity) as well as measurement of the acceleration the occupant is exposed to: O.R.A. (Occupant Ridedown Acceleration).

B) The two standards quoted in this study, in addition to the specific one concerning the combined maximum acceleration indicated earlier, do not refer to the acceleration persistence time on the area of the human body under examination.

A more thorough examination could lead to estimating the acceleration-time effect and its consequences on the human organism. In particular, when considering cerebral concussions, the inertia of the mobile mass in the cranium undoubtedly feels the effects of the application times of the forces.

On the other hand, these considerations are well-known in the study of biomechanics; one only needs to widen the range of parameters to be accounted for in the evaluation of impacts on barriers;

C) An analysis of the values of the three acceleration components, together with the evidence concerning the movements and rotations undergone by the dummy in the impact, require a more thorough study of the damages to persons.

In particular, transversal acceleration component is the most culpable, responsible for the injuries that can be caused, both in the impact against the strucutres and in the stress phenomena due to the forces of energy.

The problem of the whiplash in the typology of lateral accelerations requires greater attention, as evidenced on various occasions.

D) The necessity to study in detail the problem of impacts against highway guardrails appears most opportune from several points of view, as already pointed out in this study. If we wish to utilize this matured experience we must see to it that the results gained are homogeneous - and to do this it is necessary to establish a common basis of specifications and applicable standards.

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