DEVELOPMENT OF TRAFFIC BARRIERS IN ITALY

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Introduction

First of all I would like to give my special thanks to Mr. Ross for inviting me to participate in this important meeting. I will start by saying that the subject of traffic barriers for large vehicles is a current one in Italy for two main reasons:

1. The recent rise in highway accidents, including catastrophic accidents, has involved barrier rails such as those for heavy vehicles;

2. With new funding for freeways it has been possible to start the construction of two very important and unique projects: a. the freeway for trucks between Bologna and Florence reserved for large vehicles, and b. the suspended bridge over the Strait of Messina which will connect Sicily with the European continent.

It is, therefore, most useful for us in Italy to acquire advanced knowledge for the design of the new freeways. I am sure that the topics being discussed here in the conference offer us a technical and cultural upgrading with application to the the solution of safety problems calling for the use of highway barrier rails.

In Italy the subject of safety barriers has undergone a long evolution during the past 30 years, and at present a radical revision is underway covering all aspects related to factors of safety which include design, construction and maintenance of these important roadway elements.

I would like to stress the importance to us of having access to the full scale crash test results of the Texas Transportation Institute. We have also benefited by the complete and opportune conference held by Mr. Hirsch in Rome in October of last year. I wish to thank Mr. Hirsch for the significant films and words which managed to catch the attention of those administrative heads in Italy who are now in charge of the construction and administration of the highways. The conference stimulated a new way of conceiving and designing safety barriers.

The Problem of Safety in the Italian Freeway Network and the Problem of Safety Barriers

Italy has a road network of approximately 300,000 km, 50,000 of which are state highways or large transportation arteries, and 6,000 of which are freeways having controlled access with 3,000 kms of these being toll roads. The problem of highway safety therefore takes on an important social role, if we consider the incidents occurring on the entire road network and the number of casualties which include about 8,000 fatalities and 200,000 injuries in 1985.

If we concentrate particularly on the freeway network which should in principle be the one which guarantees maximum safety, we observe that here the number of accidents is still relatively high. The high rate continues even though particular attention has been devoted to the prevention and control of the conditions which contribute to these accidents. Of course the rate of accidents per km driven on these freeways is low when compared with the same traffic density on the non-freeway network. In 1985 the number of deaths on the freeways was about 600 in 22,500 accidents (figure 1).

It is important to point out that in Italy one-third of the fatal accidents on freeways are cases where the vehicle, owing to the collision against the safety barrier, runs off the pavement. Furthermore, in the past two years there

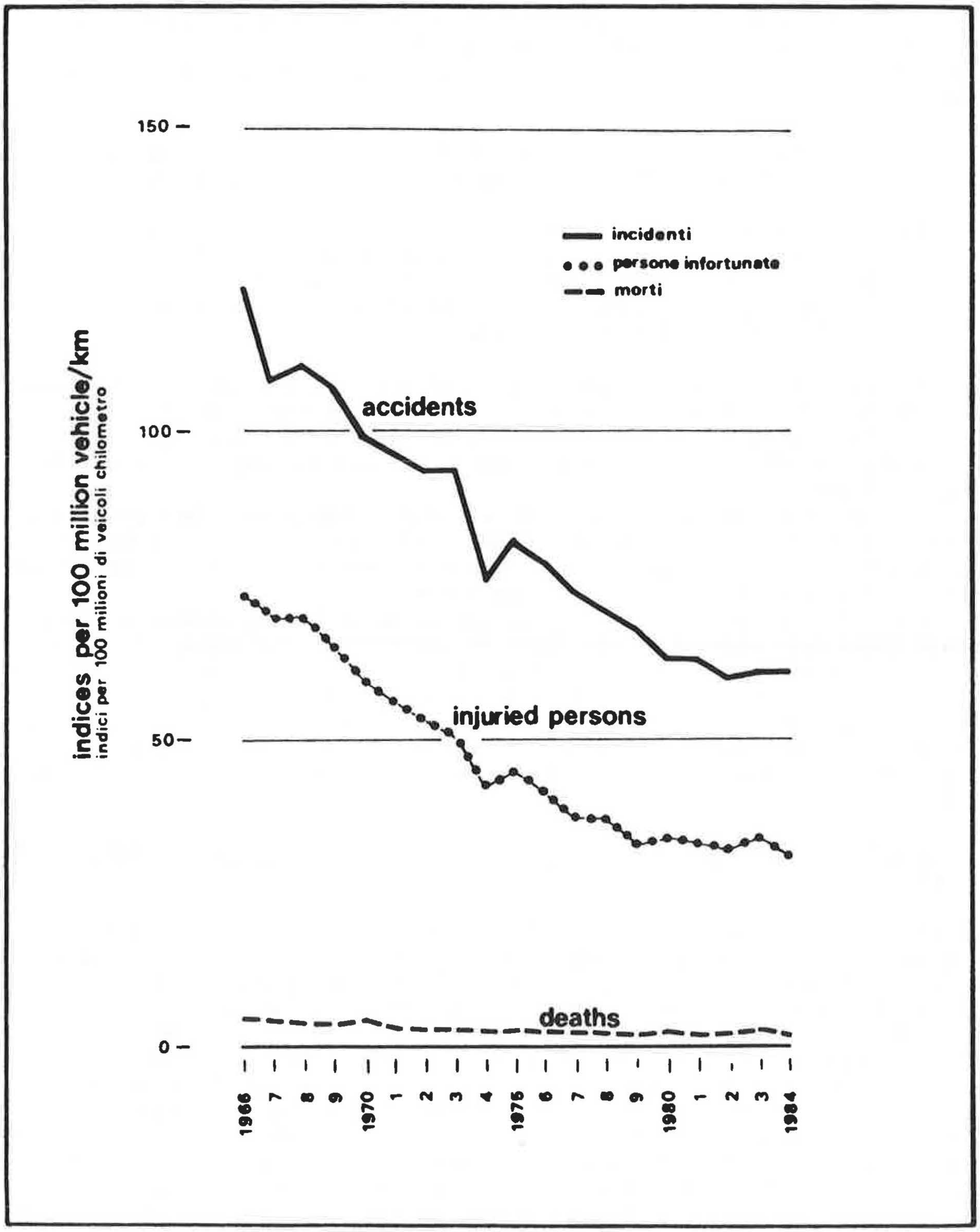


Figure 1. progress of the accidents during the years 1966-1984

have been serious accidents where the safety barriers were inadequate and this involved mostly inter-urban buses transporting commuting workers or tourists.

An increase in heavy truck traffic is forecast (figures 2 and 3) and a large number of viaducts and bridges are planned for new sections of highway construction. Therefore, we need to learn how to keep these heavy vehicles, many of which are buses full of people, on the highway. There is also the problem of trucks transporting flammable liquids or other dangerous substances.

There is the equally dramatic problem of safety barriers for urban busses where the risk of many casualties is possibly higher if the vehicle runs off the highway.

The purpose of the present policy on freeway safety is twofold. First, to determine the causes of accidents, and second, to improve the physical condition of the highway system. In fact, a good part of the research underway is devoted more to the prevention of accidents than to confining the consequences.

However, the methodology used to determine high hazard areas also allows us to solve those cases in which safety barriers are involved directly.

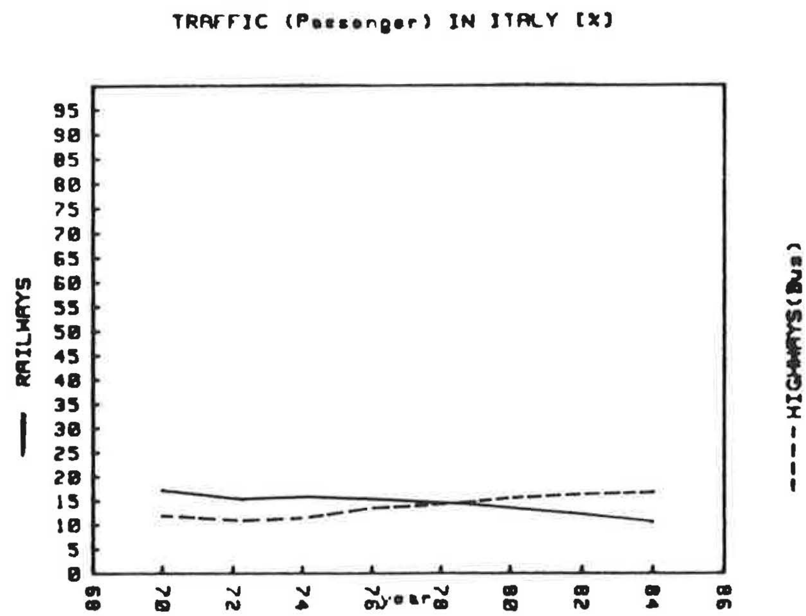


Figure 2.

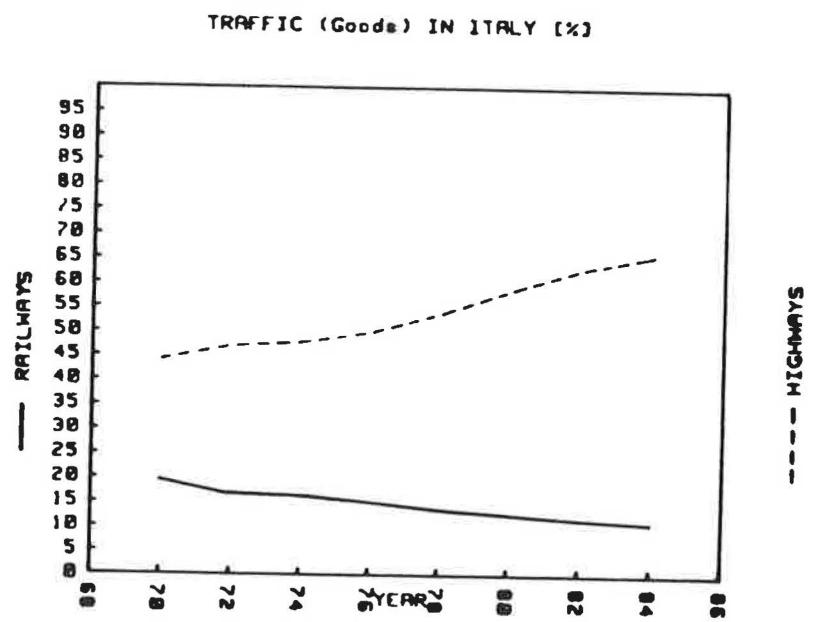


Figure 3.

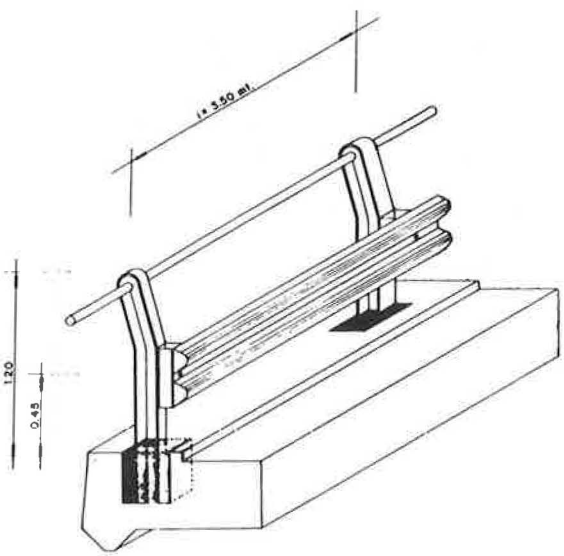
There is no doubt that prior to some barrier collisions there were skidding or visibility problems, both of which are an integral part of the design and maintenance variables.

The Evolution of Safety Barriers in Italy

The use of safety barriers has in Italy, as in many other countries of the world, followed the development of motorization. The profiles of barriers adopted right after the war, followed those used in the USA before the war and were composed of a W-beam metal rail mounted on a C-shaped post (figure 4).

Unfortunately, up to recent times in Italy the concept was to use flexible barriers or, at the most, semi-rigid barriers without taking into account either heavy vehicles or the absolute necessity of keeping these vehicles on bridges or viaducts.

The intense research begun here in the USA in 1955 certainly induced us in Italy to reconsider the problem of containing the vehicles and to consider the possibility of adopting rigid concrete barriers. However, during the first important phase of freeway expansion (1950-60) it wasn't possible to consider the experimental results from the USA, and therefore, the adoption of flexible metal barriers designed for light vehicle collisions took the lead. During the second phase of development of the freeway network (1970-75) there was actually a serious attempt to find new solutions which would be more adequate for traffic and large trucks which in the meantime had been increasing. The combined efforts of the State highway administration and some private industrialists (among which was the automobile manufacturer FIAT) led to research with full scale crash tests carried out by the Politecnico Institute of Milan and in particular Mr. Giavotto and his research team. At this time a semi-rigid barrier was developed which took into account mostly light vehicles and buses. However, the function of a rigid resisting element such as a beam in a longitudinal barrier had started to be understood.



STANDARD TYPE
M 20 - Bridge rail
used in Italy starting from 1950
for all roads network
LOAD CAPACITY ~4.5 Tonn.

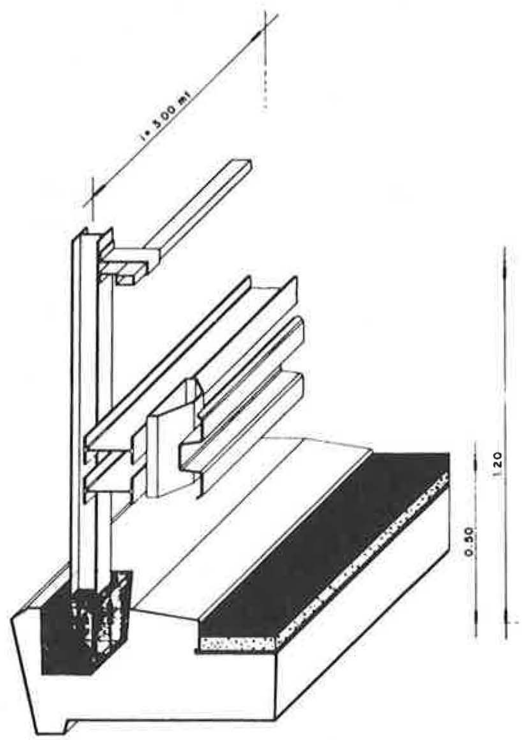
Figure 4.

At this point the SINA (figure 5) type barrier was invented for bridges. It featured two beams with a double T shape covered with a flexible metal rail. Unfortunately, with the halt in freeway construction due to the economic crisis during 1975 and 1976, it was not possible to invest in further research and experimentation in the use of new forms and materials, nor was it possible to revise the standards for bridge rails. Even today bridge rails are designed for a maximum force impact of 4.5 metric tons (about 10 kips) with barriers placed at 35 cm (about 15 in.) from the pavement.

It was only with the start-up of new freeway programs in the early eighties that rigid concrete barriers were first introduced, as had already been done in the other European countries.

Naturally the systematic introduction of this type of barrier has not yet come about. We are just starting to see the occasional use of prefabricated concrete safety barriers both as median barriers and as roadside barriers, but only on new construction. Concrete safety barriers have also been used in special cases together with wind breaker structures constituting a very unique novelty, at least for us. This is the case with a very high viaduct (length of 2200 m) near the port of Genoa called the Gorsezio Viaduct which is subjected to strong crosswind gusts.

However, during the last two years the design of special freeways, and especially the large truck freeway, has forced designers and researchers to reexamine carefully the problem of safety barriers, especially for bridges. This is also necessary because the barriers will be installed on bridges and viaducts which often cross over railways, freeways or thickly populated metropolitan areas. The problem is a very complex and delicate one, but we are now sure that it can be solved by designing structures adequate to contain heavy trucks.



SINA TYPE - Bridge rail
(designed after crash test)
partialy used for freeways network
starting from 1970
ULTIMATE CAPACITY ~ 20 T

Figure 5.

The work carried out by the researchers of the Texas A&M University has produced valuable design guidance. They demonstrate that in the most severe truck impacts safety barriers must resist a maximum impact force of about 100 tons, and barrier heights must be at least 2 m above the pavement surface. Collisions of busses carrying people cause a maximum impact force of 50 tons and barrier heights must be at least 1.40 m (55 in.) from the pavement surface.

It is for these load levels that our designers, researchers and builders are trying to work. We have before us the existing national highway network which is certainly not adequate to control these probable heavy vehicle impact forces.

There is also the problem of how to adapt old bridges, even if only at intersections with other infrastructures. There is also the financial problem and the one of standards.

It is doubtful that these future types of safety barriers will be an integral part of the superstructure of bridges. It will be better, therefore, to examine this particular problem with the same importance given to seismic matters (in fact we are dealing with horizontal forces, loading spectrums, repetition of events patterns, etc).

Even if we go back into the history of roads and bridges, we would certainly find at least partial confirmation of this new way of reasoning. You must excuse me, because being a Roman, I can't avoid calling your attention to some structural elements of the ancient Romans (figure 6).

First we have the Ponte Fabricio built in 62 B.C. It is also called the Four Heads bridge because of the sculptures of Greek origin mounted on it. This bridge is still used. As you can note, the walls railing are completely integrated with the main arches which proves that those rails were supposed to contain the eventual collisions of military convoys and animals crossing the bridges. Even then the railing was not considered an accessory.

The same can be said of the other bridge called Ponte Cestio which connects the East and the West banks of Rome with the Tiberina Island on the Tiber River. There is also the Ponte Emilio bridge built during the second century before Christ. Even later on during the Renaissance period Sant'Angelo's bridge, previously called Ponte Elio was built by the Romans and later restored by architect Bernini during the 17th century. Here the railings have metal elements and their structure also shows impact resistance and valid architecture. The bridges of the past century, such as the Ponte Margherita retrace the Roman and Renaissance forms but also give importance to the safety barriers both from the esthetic and structural point of view.

New Types of Safety Barriers Proposed in Italy for Bridges

(Following the conference held by Mr. Hirsch)

Italian technicians are endeavoring to develop designs for new freeways and especially for the first freeway intended exclusively for large trucks. This task is motivated by the necessity to find new solutions to the problems that will arise due to the exclusivity of this type of vehicle. This is particularly true with regard to keeping trucks from running off the highway.

Since we had not been able to carry out crash tests and we knew that only these would give valid results, we made use of the results of the American experience in order to restrict as much as possible the uncertainty that we have had at the beginning of this investigation.

Presently, after having considered the thoughts presented by Mr. Hirsch in Rome, the conclusion has been reached that at least the new freeways, must have

ITALY ROAD NETWORK DURING AUGUSTUS AGE

Figure 6.

safety barriers for bridges and the median able to contain and redirect light vehicles (through the New Jersey profile) and some heavier vehicles such as intercity buses.

However, for large trucks and tank trucks it has been decided to undertake in-depth experiments both on a theoretical and practical basis, since it is probably a matter of reviewing the entire design of the deck, piers and, therefore, the foundations.

The last series of full-scale dynamic crash tests results and especially those of the Texas Transportation Institute with large trucks involved have also allowed us to consider again the well known Olson formula in order to predict the magnitude of impact forces for design.

The variables involved in that model are functions of vehicle characteristics (table 1) and roadway conditions. Generally it is possible to estimate the average force against a barrier.

Total Length of Road Network:		300,000 Km.
Total Length of State Highways:		50,000 Km.
Total Length of Freeways:		6,000 Km.
Total Viaduct Length on Freeways:	≃	1,000 Km.
Total Viaduct Length on Highways:	≃	3,000 Km.
Total Viaduct Length on Roads:	≃	10,000 Km.
Total Length of Longitudinal Barriers on Freeway Viaduct/Bridges (Steel Barr.):	≃	4,000 Km.
Total Length of Longitudinal Barriers on Highways Viaduct/Bridges (Steel Barr.):	≃	7,000 Km.
Total Length of all Longitudinal Barriers for Entire Network of Roads (on Viaducts, Cuts, Fills)		100,000 Km.

Table 1 - Main Data on Italy - 1984
Population: 55,000,000
Total Vehicles: 20,000,000

Unfortunately, when the forces computed from that model are compared with crash test data, particularly selected by Mr. Hirsch for good redirection and no-roll overs, we observe a large difference between the two numeric values.

A first step that was proposed to correct that model, was the use of Π_2 as a correcting multiplier for the average deceleration and force computed by a sinus spectrum model (figure 7).

Really, if we consider the effective accelerometer trace, we can improve the simple Olson model by considering the more complicated sinus spectrum law for load application, versus time.

In fact, the real crash test accelerometer trace may be explained by two main components: one related to the vehicle and the other related to the barrier.

The multisinus spectra may be obtained formally as the sum of the first squared sinus element plus a second simple sinus element (figure 8). Using this

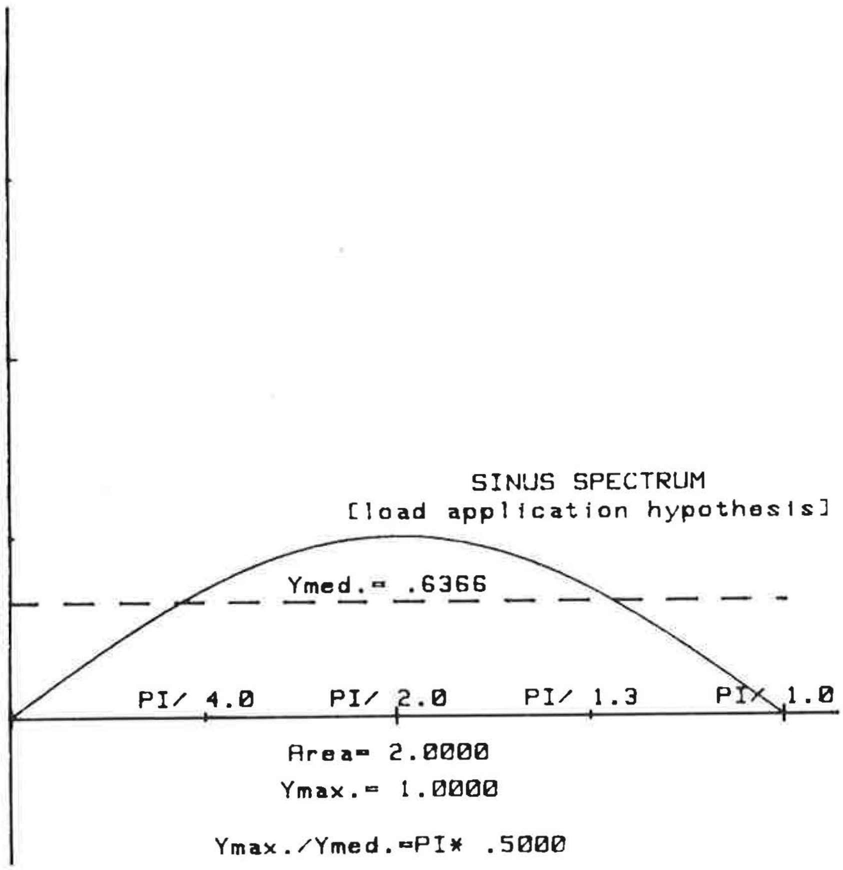


Figure 7.

latter method, the result based on calculated values will be closed by the returned values of the regression analysis function on the selected test results executed and specially homogenized by the lateral kinetic energy.

Our first investigation of the different types of large Italian vehicles was carried out by using this last model (multisinus spectrum model). It was needed to establish a preliminary estimate of strength needed by traffic barriers to match the loadings and geometry of impacting trucks.

The Diagrams (figures 9 and 10), were developed for each class of Italian vehicle. They allowed a preliminary evaluation that also included the non rollover situation. This factor was checked using the minimum barrier height at the maximum impact angle for an assumed vehicle speed and for the deflection value of the barrier.

A new type of safety barrier has been developed which (figure 11), originates from a design installed on recently constructed freeways. However, even though it incorporates the standards presently in force, it does not take into account the collision of heavy vehicles travelling at high speed.

For different reasons such as costs, structural resistance of the deck slab, etc. this has been considered the extent of improvements which we can carry out.

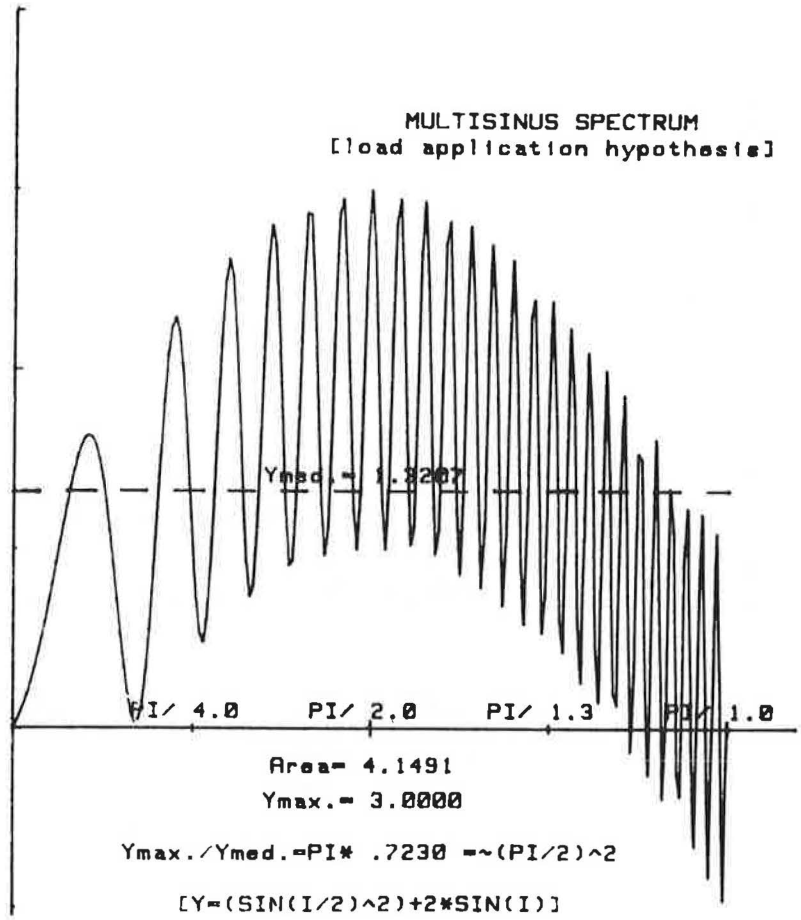


Figure 8.

There is also the materials aspect which would lead us to examine other solutions (figure 12) such as those in steel or in high strength aluminum. This is the case for the suspended bridge over the Strait of Messina. For reasons of limitation of dead loads, it has been decided to use metal barriers. They can resist impact from very heavy trucks which will be required to limit their speed drastically. Therefore, for the time being, the containment strength of those barriers is foreseen as 40 tons (about 90 kips), thereby preserving the inclined profile on the lower side of the barrier for the sake of the lighter vehicles' safety.

However, nothing has yet been proposed for the structural improvement of numerous existing barriers on the network of all highways. And this is the really important aspect that needs specific research to reduce the effects of catastrophic accidents.

Fig. 9a

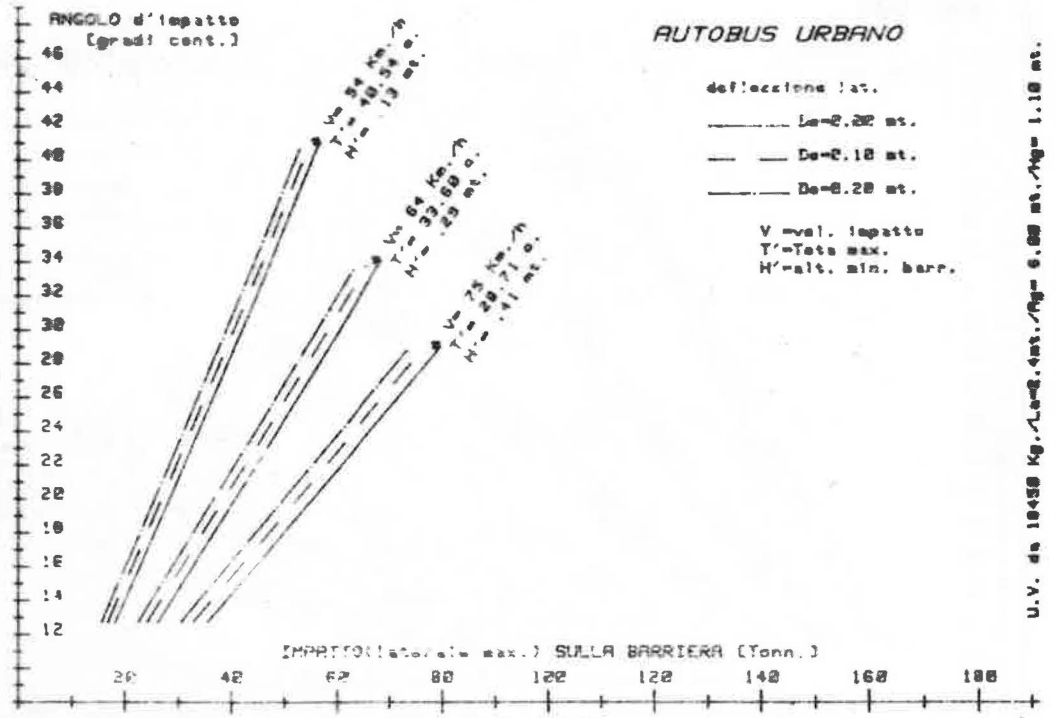


Fig. 9b

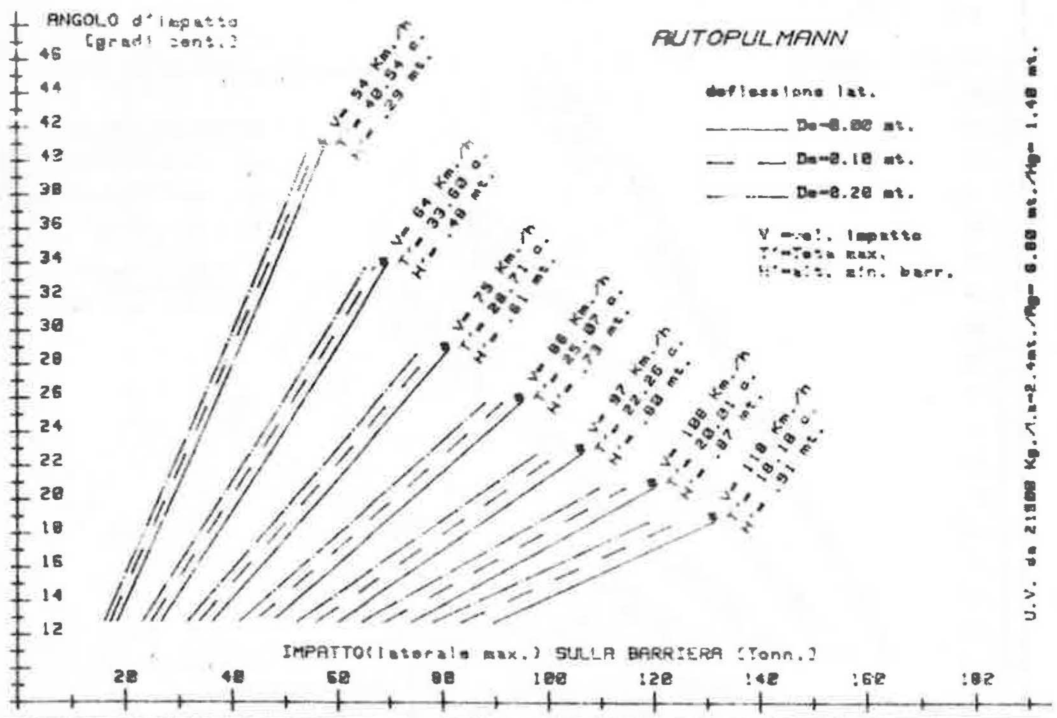


Figure 9.

Fig. 10a

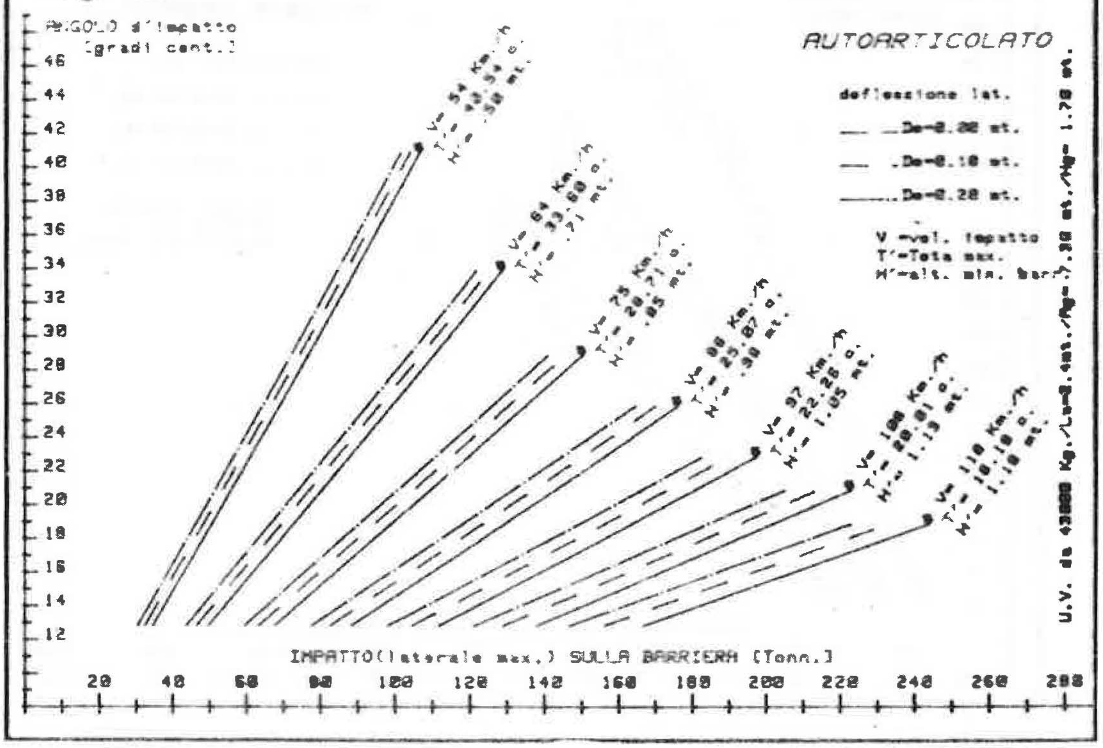


Fig. 10b

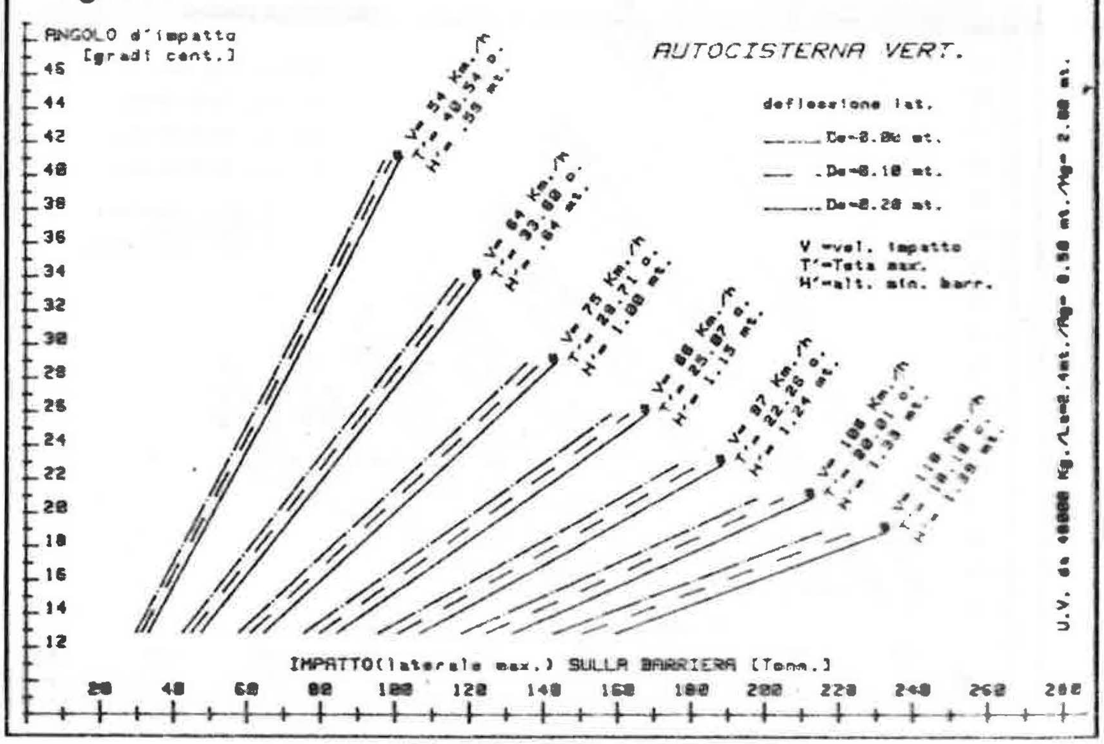
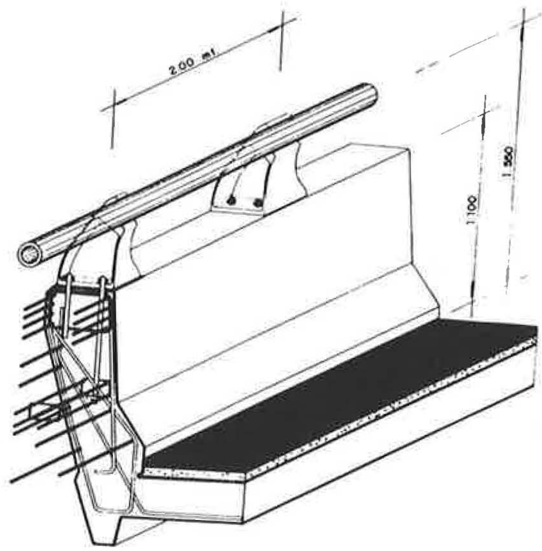
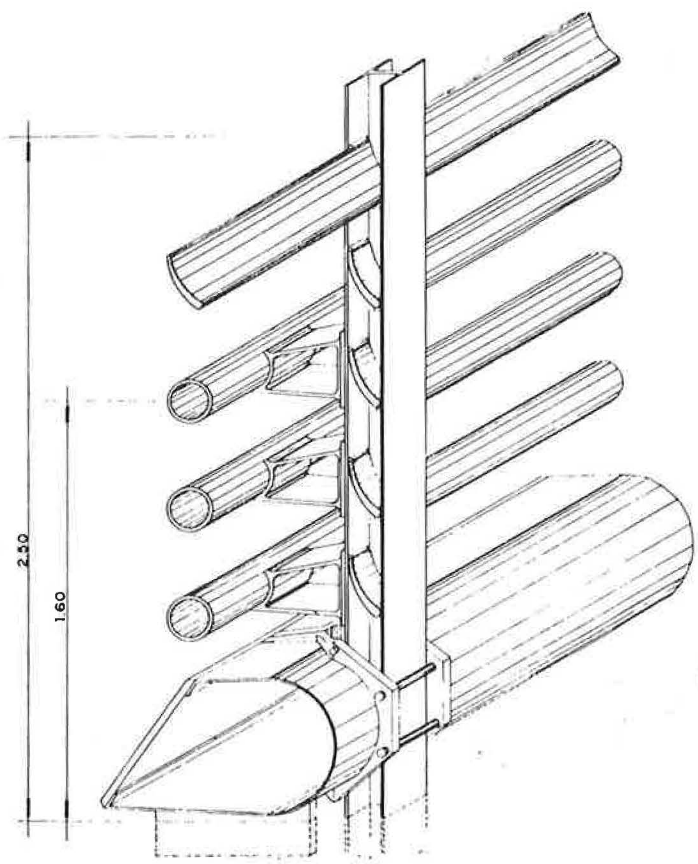


Figure 10.

Figure 11.



NEW TYPE - N.J. + STEEL RAIL
(UNDER STUDY)
WILL BE USED FOR "TRUCKS FREEWAYS"
ULTIMATE CAPACITY: ~40 Tonn.



3 RAILS + N.J. STEEL GUIDE RAIL + WIND REDUCTION ELEMENTS
PROPOSED FOR "STRAIT OF MESSINA BRIDGE"
ULTIMATE CAPACITY ≃ 40 mt Tonn.

Figure 12.