TESTING OF ROADSIDE OBSTACLES WITH A DEFORMABLE IMPACT SLED

THOMAS TURBELL, National Swedish Road and Traffic Research Institute, Linköping Sweden.

ABSTRACT

In order to test the crash performance of roadside obstacles without using real cars a 1 000 kg impact sled with a collapsible front end was developed. An outdoor test facility capable of having the sled impacting different objects at speeds up to 150 km/h has also been built. The test method has been used on lightpoles, roadsigns and catch-fence systems. The performance of the systems is evaluated by using a Risk factor based on the accelerations on the sled. New concepts of extremely yielding poles have been tested with good results. Arresting nets for motor racing tracks have been found to be inadequate.

INTRODUCTION

One important factor in the single-car accidents is the crash performance of the roadside objects. Crash tests of lightpoles, median barriers and impact attenuators have been going on for a long time and different safety systems are in use in many countries. The impact performance of these systems has been evaluated by more or less well defined crashes with old cars. Protection capacities have been estimated by different criteria such as peak acceleration, mean acceleration, change of momentum, speed reduction etc.

The introduction of energy absorbing lightpoles on the Swedish market has put us in a situation where the Road Administration wants compliance tests for these products. The criteria used for slip-base poles in USA could not be used because they require a maximum speed reduction of 10-20 km/h. Preliminary tests with the collapsible lightpoles showed that we could reduce the speed to zero with accelerations slightly higher than in comparable tests with the slip-base concept. The disadvantage of the car continuing more or less out of control after a collision with a slipbase pole could thus be reduced. Other roadside objects, such as roadsigns and impact attenuators for bridge piers, have also become more interesting to increase the safety of our roadsides.

The main objectives of this project have thus been to develop a uniform test procedure and to propose criteria for the protection performance of different types of roadside objects.

IMPACT SLED

At an early stage of this project it was decided that compliance tests with real cars had several drawbacks such as high cost and low reproducibility. It was therefore decided to make an impact sled with the general characteristics of an impacting car. The geometry of the sled is similar to a typical medium size car and the sled weight is 1 000 kg (fig. 2). The front of the sled is deformable at a 10 g-level up to a 1 m deformation distance (fig. 3). These levels were based upon offset collisions with real cars impacting poles installed on our crash barrier. The crash characteristics of the bumper and the soft parts in the front of the car are not simulated because they are of a minor interest since their part in the energy absorption is relatively small. Simulating these parts would also make the sled more complicated to use and that would be in conflict with our intentions to have a reliable method with a minimum of maintenance and preparations between tests.

The sled is guided by rails and towed by a steel cable from our propulsion system on the indoor track. Impact speeds up to 150 km/h can be used. A special concrete foundation with a mass of 40 tons and a system of interchangeable mounting adaptors for different types of poles have also been built. The influence of the soil and foundations is thus eliminated and the tests simulates the worst conditions where the foundation and soil will not absorb any energy which can be the case when we have ground frost of poles mounted on bridges.

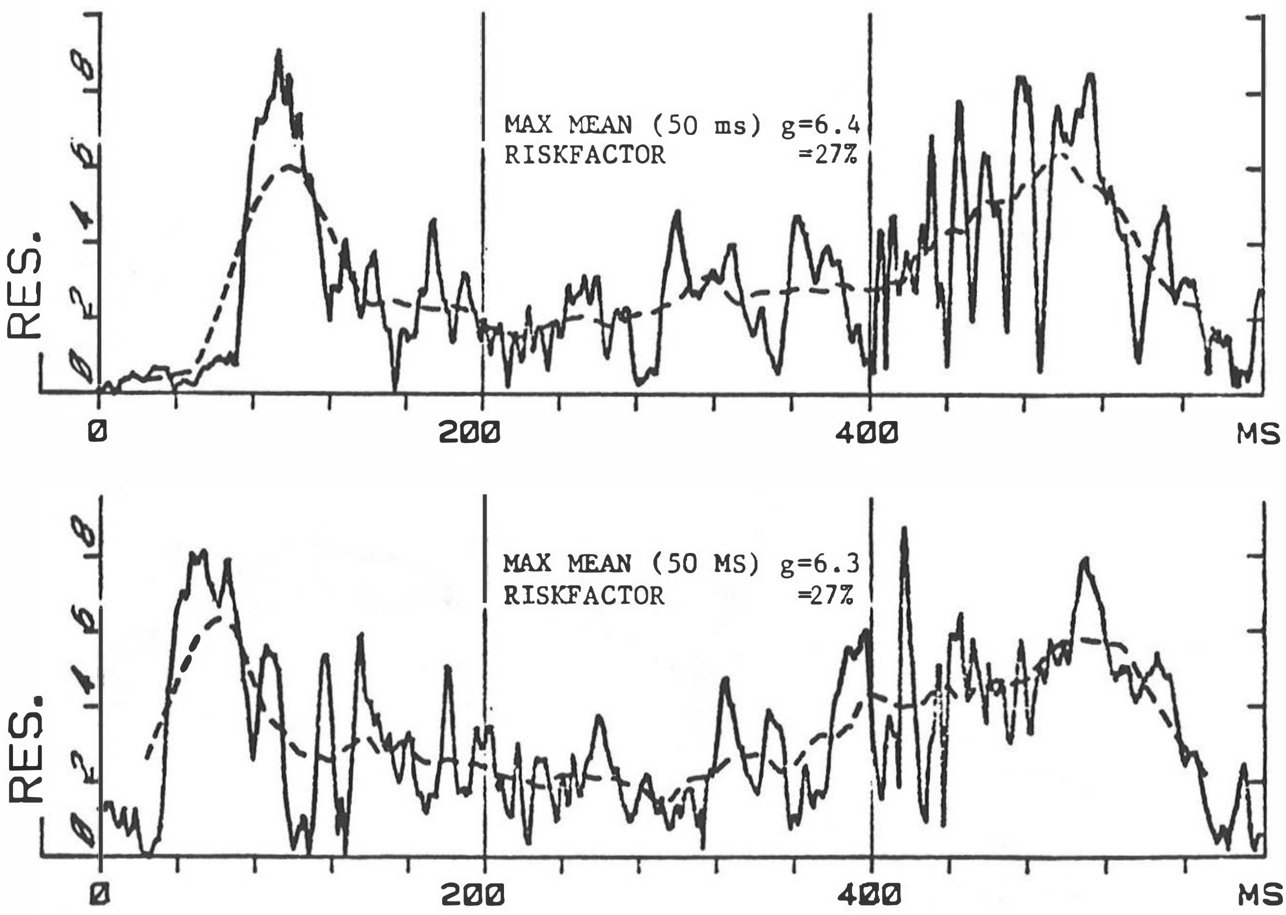


Figure 1 Results from repeated tests with the same pole.

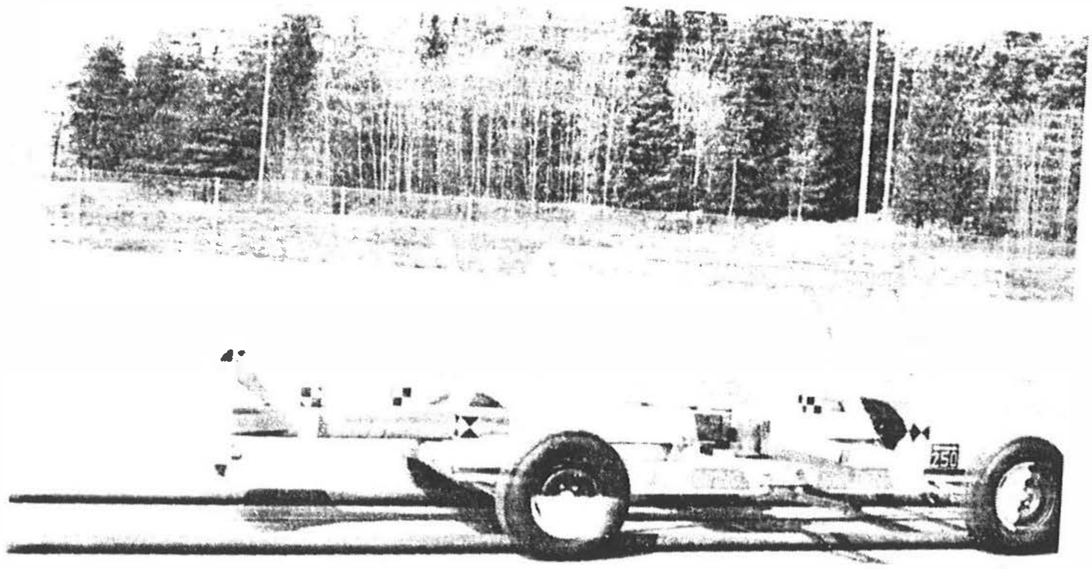


Figure 2 Impact sled

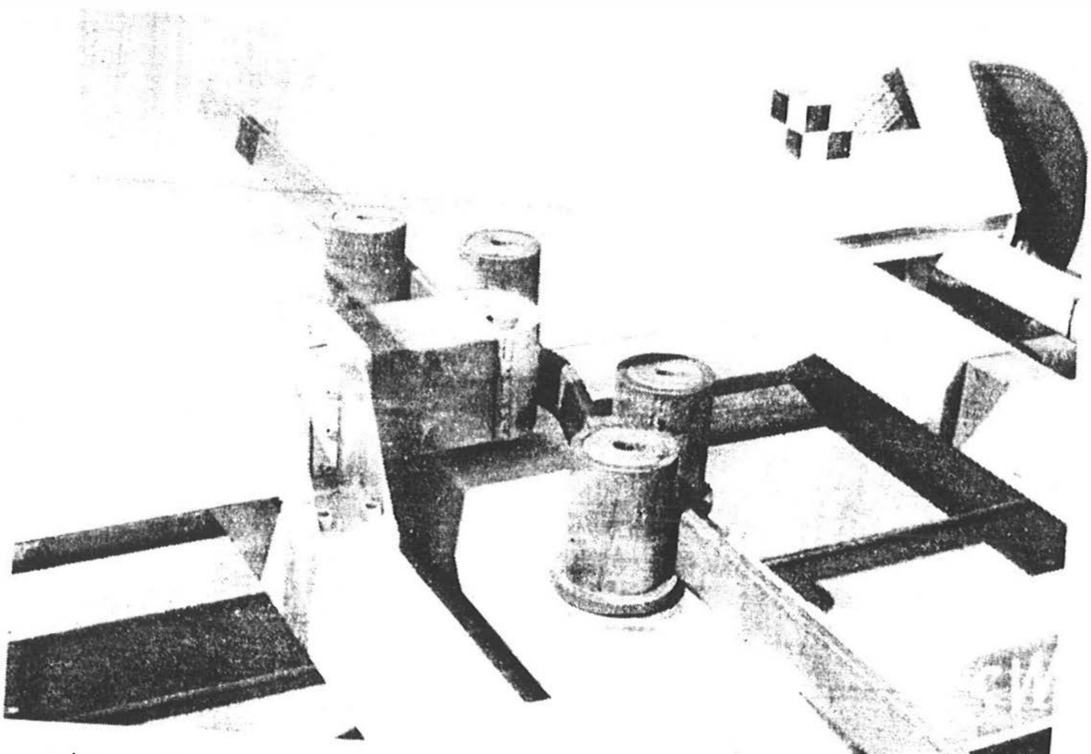


Figure 3 Deformation device on sled

INSTRUMENTATION

Conventional high-speed cinematographic photography has been used for evaluating the deformation sequence at impact. Impact and departure speeds were measured by timing intervals between track contacts and photocell traps at various points along the path of travel. Accelerations were measured at the c.g. of the sled by straingauge transducers connected to amplifiers and FM-tape recorders by cable. Data from the tape recorders were digitized and fed into a computer for calculations and graphical outputs. All measurements were made according to SAE Recommended Practice J 211 b.

RISK FACTOR

Different systems for evaluating the protection performance were considered. The most realistic way might have been to use anthropometric dummies restrained in parts of a car body on the sled. This concept was rejected because it was considered to give too much scatter in the results depending on dummy calibration and positioning, seats and restraint systems.

A model for the probability of injury to unrestrained occupants, in the following called "Risk factor", developed at the Texas Transportation Institute /1/ primarily for guardrail evaluation, was chosen for the following reasons.

- The model takes into account accelerations in all directions. This is important since some systems can give high vertical accelerations on the vehicle.

- The model works with average accelerations over 50 ms which will reduce the effect of short peaks from vibrations on the vehicle and of a minor interest for the protection performance of the system.

- The model works with the risk of injury to unrestrained occupants. Even though we are getting more and more use of restraints there will be a long time before all occupants, including back-seat passengers and children are properly restrained. Even when restraints are used the model gives a possibility to compare different attenuation systems with each other and furthermore the estimated protection effect of e.g. belts can be multipled by the Risk factor. The definition of the Risk factor is

$$\text{Risk factor } (\%) = 30 \sqrt{\left(\frac{Gx}{7g}\right)^2 + \left(\frac{Gy}{5g}\right)^2 + \left(\frac{Gz}{6g}\right)^2}$$

where Gx, Gy and Gz are the maximum mean values calculated over any 50 ms time interval.

APPLICATIONS

1. Lightpoles

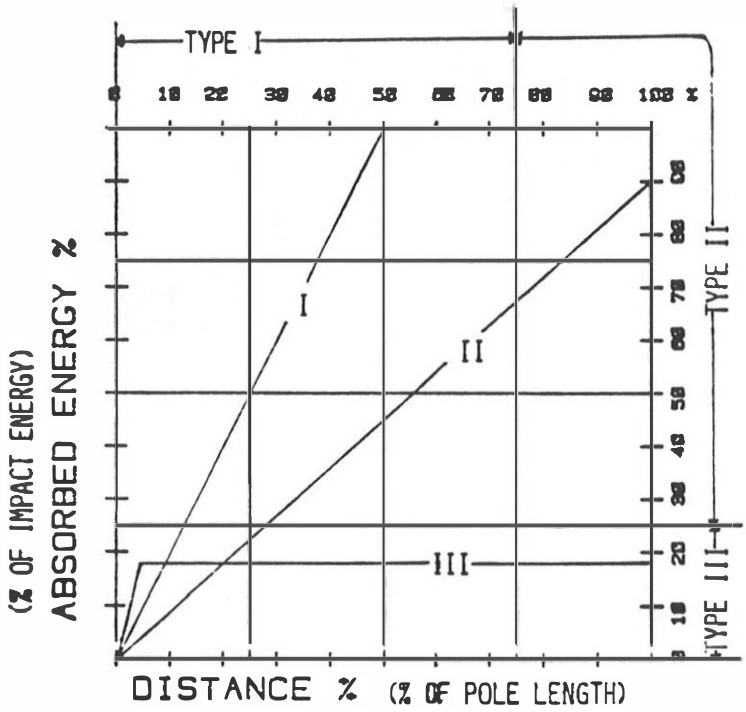
The main objective for building the sled and developing the test procedures was testing of yielding lightpoles. Two types of these poles are on the Swedish market. One type is made of thin sheet metal and the other is a lattice tower. Tests have been conducted with the sled impacting at 50, 70 and 90 km/h on 8-15 m poles (fig. 6). The results are presented in conventional acceleration-time graphs combined with graphs on the 50 ms average accelerations. The risk factor described above is also included in these outputs (fig. 7, 8). Typical results for yielding lightpoles are presented in the following table (fig. 4).

Impact speed km/h	50	50	70	90
Pole length m	8	15	12	15
Peak Longitudinal acceleration (avg. 50 ms) g	5.7	8.8	7.3	10.0
Risk factor %	27	39	34	45

Figure 4 Examples of data from yielding lightpoles.

From the figure above it is obvious that increasing impact speeds and pole lengths will give higher risk factors due to the fact that higher poles have to be more rigid to withstand the requirements on windloads. In the crash performance requirements now in preparation we will therefore propose different risk factors for different combinations of design speeds and pole lengths. This may imply that e.g. 15 m poles will not be allowed in low speed areas where lower - more yielding - poles will give a better protection.

Another way to estimate the efficiency of a yielding pole is in a graph showing the relation between the absorbed energy and the distance (fig.5).



TYPE I Stops a car at the design speed. The 75% distance utilisation will give a safety marigin for cars heavier than 1 000 kg or impacting at higher speeds. To be used at sites where a second impact is not wanted.

TYPE II Can be overrun at the design speed. To be used at sites where a second impact is less severe.

TYPE III Typical slip-base performance. To be used at sites where the second impact is neglectible.

Figure 5 Classification of lightpoles.

The exact limits in figure 5 and the required risk factors for different combinations of design speeds and pole lenghts will be decided late in 1978 and after that all lightpoles to be installed at certain distances from the road on the federal roads in Sweden has to the tested according to the procedures described in this paper.

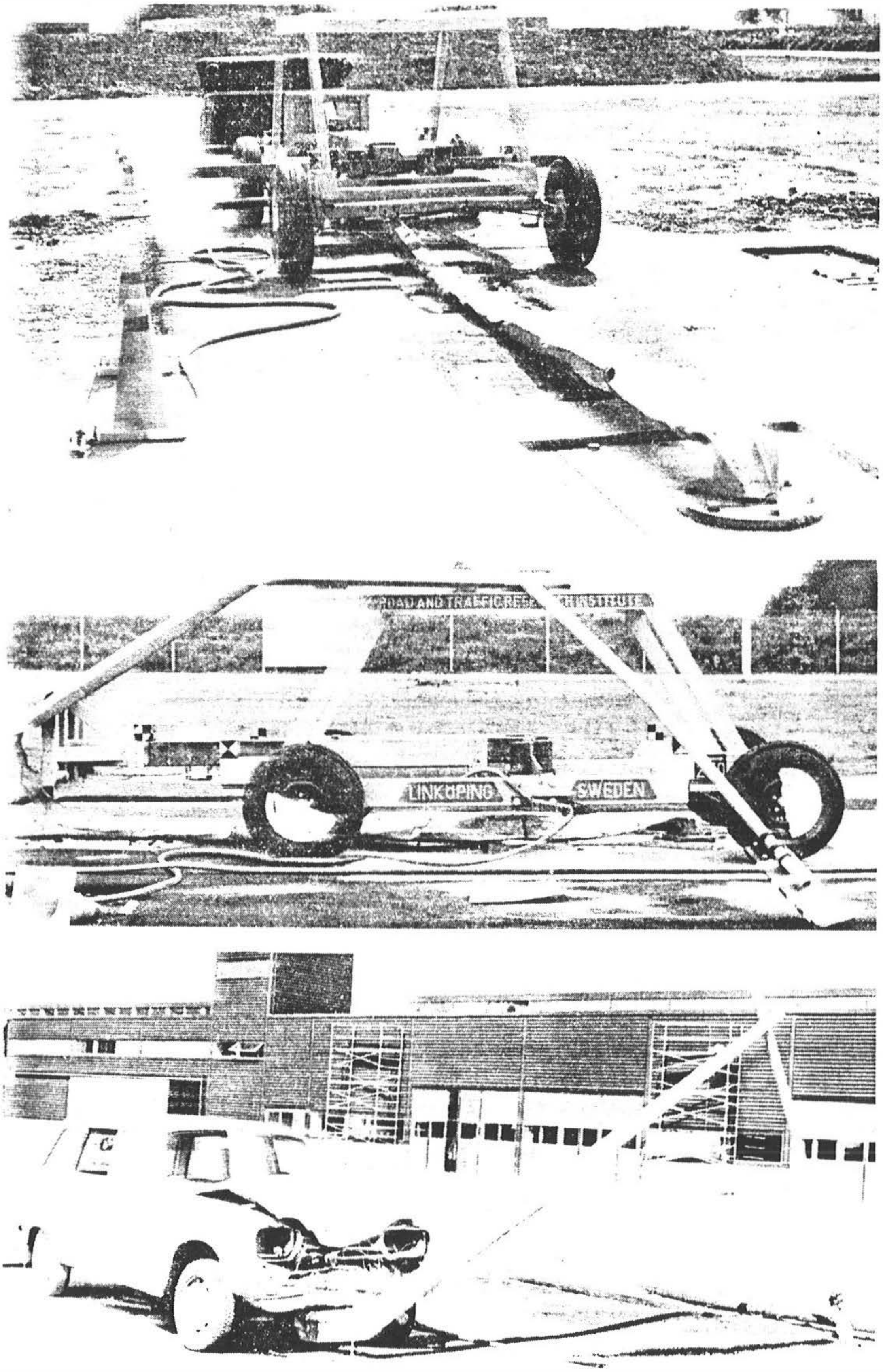


Figure 6   Tests with deformable poles

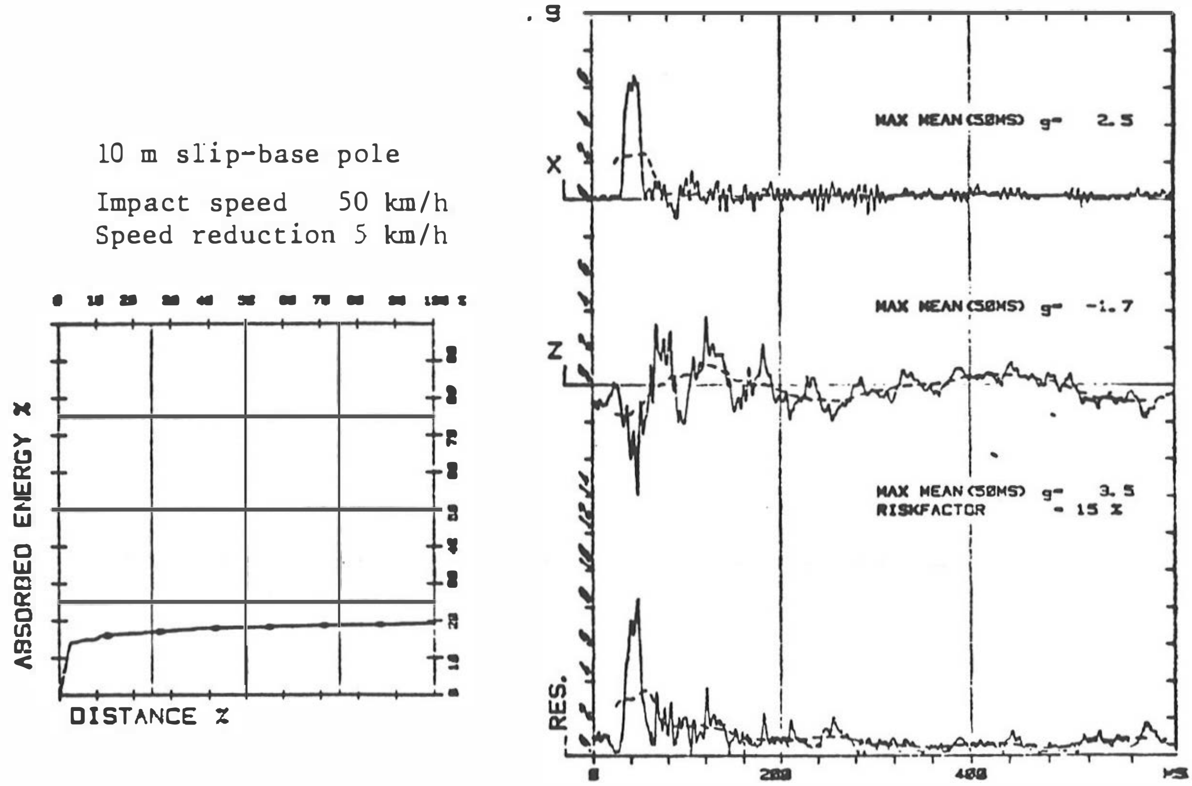


Figure 7 Typical performance for slip-base pole

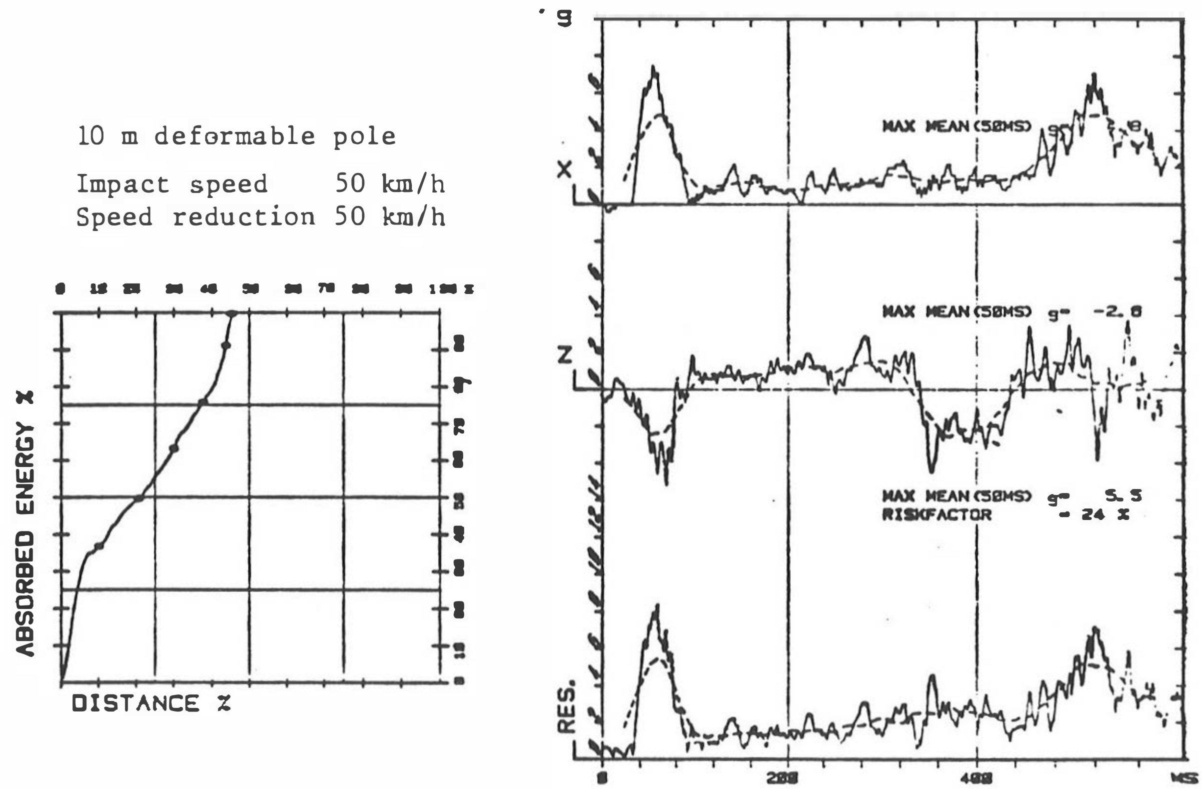


Figure 8 Typical performance for deformable pole

2. Catch-fence systems

At the 1977 IRCOBI-conference in Berlin the effect of catch-fence systems for motor racing was questioned in a paper by Ogilvie-Hardy /2/. At that time we had started a project on testing the energy dissipation capability of these systems since the organisation responsible for these matters in Sweden had their doubts about the performance of these fences.

Five tests were conducted with fences built according to the international recommendations by FIA. Different configurations were impacted by the sled at speeds up to 70 km/h. A model for calculation of the energy dissipation capability was made according to the following figure.

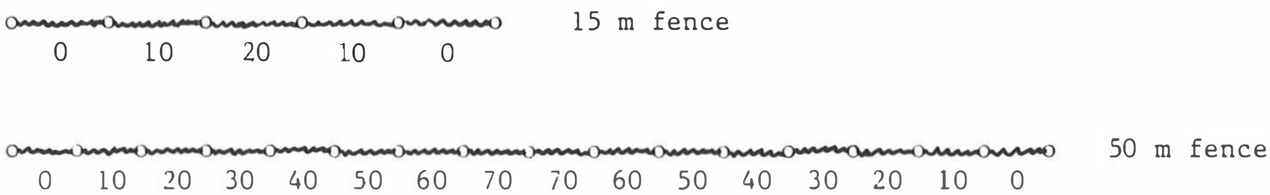


Figure 9 Energy dissipation capability (kJ) depending on impact point and length of fence

Compared to the present situation this model will give the following results:

Impact speed km/h	100	200
Kinetic energy kJ*	200-700	700-1500
FIA RECOMMENDATIONS /3/		
No. of fences	2	4
Energy dissipation per fence kJ*	100-350	350-750
TEST RESULTS /4/		
No. of fences	3-35	10-75
Energy dissipation** per fence kJ	10-35	10-35
* Depending on mass of vehicle ** Depending on length of fence		

Figure 10 Comparison of present recommendations and test results with catch-fences

Apart from other problems like flying poles and the fence's not catching the car it is quite obvious that the present regulations on the necessary number of fences are not adequate. The great amount of fences needed according to our model will introduce practical problems to an extent that other systems must be considered. Later this year we will continue the tests with systems based on sand-filled containers.

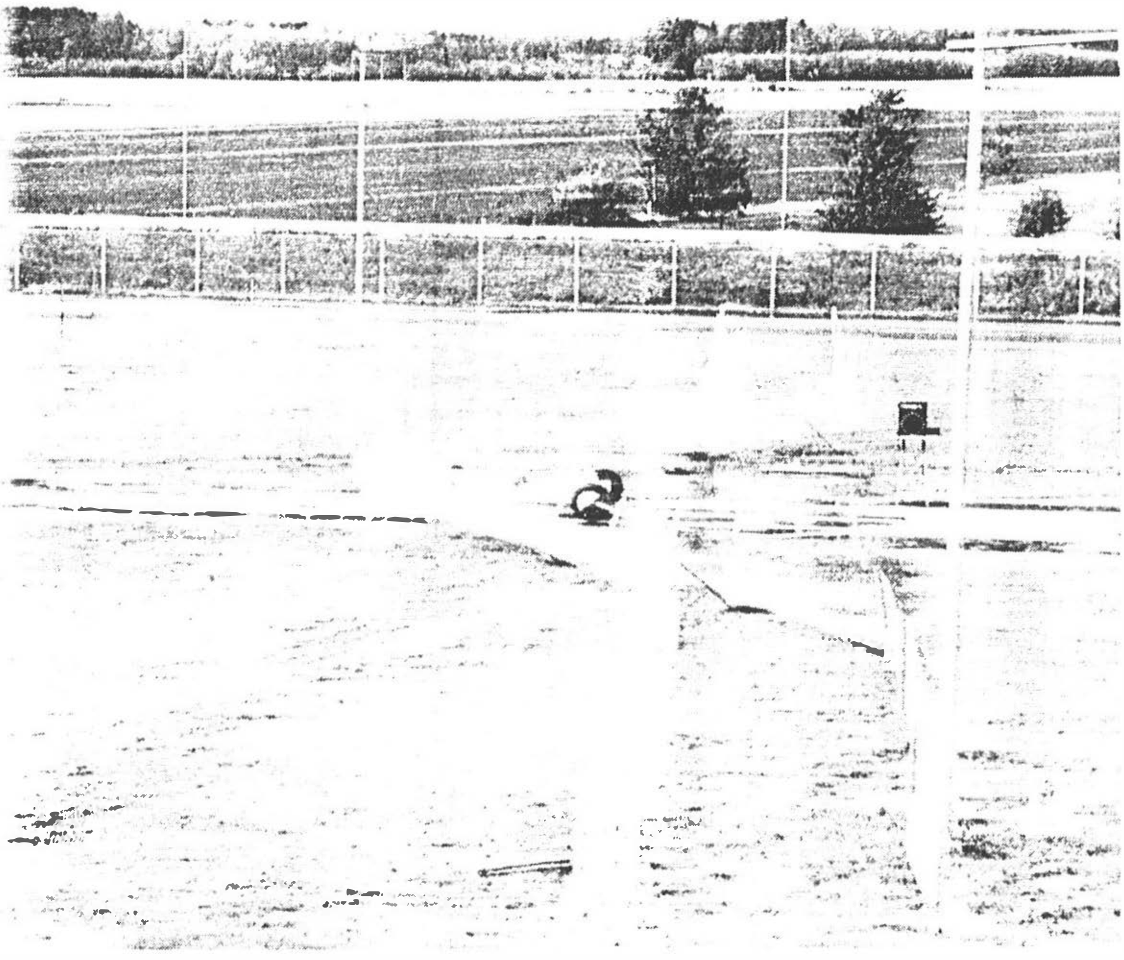


Figure 11   Test with 2 x 50 m catch-fences

3. Road-signs

Another application of the test method has been a series of 15 tests with different designs of road-signs. An example of this can be seen in figures 12 and 13 where the same sign has been tested with and without slip-base anchorage at 50 km/h. The acceleration has been reduced to 1/3 and the risk factor to 1/4 with the introduction of the slip-base. Even very large signs (4 x 5 m) has been tested with remarkably good results (acceleration 2.9 g, risk factor 14% at 70 km/h).

IMPACT SPEED 50 km/h

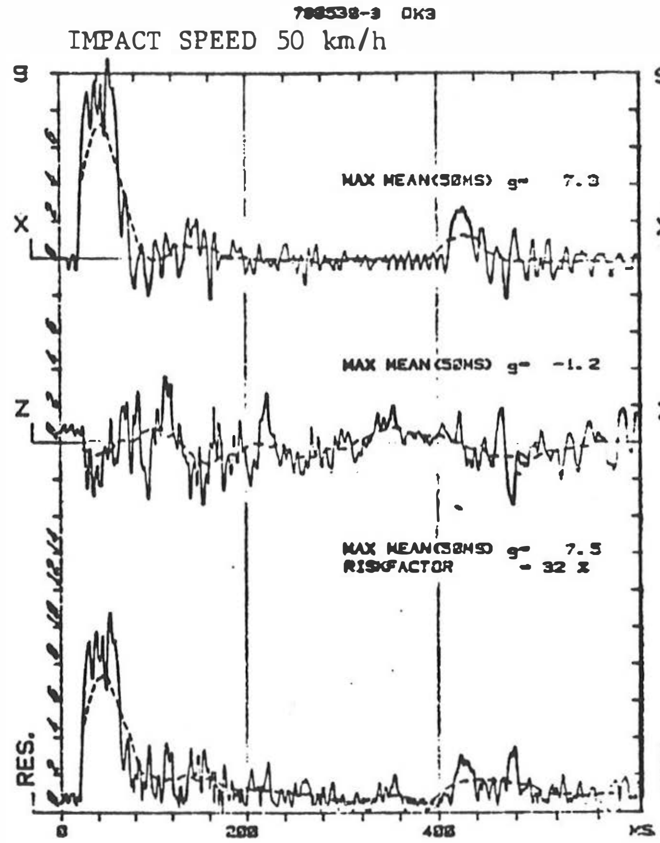


Figure 12 Results with standard design

IMPACT SPEED 50 km/h

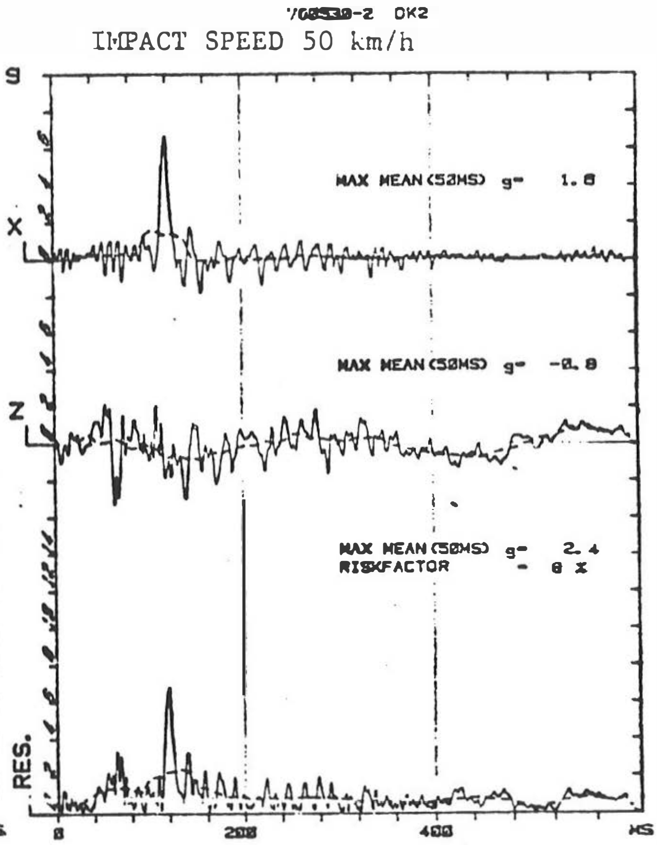


Figure 13 Results with slip-base design

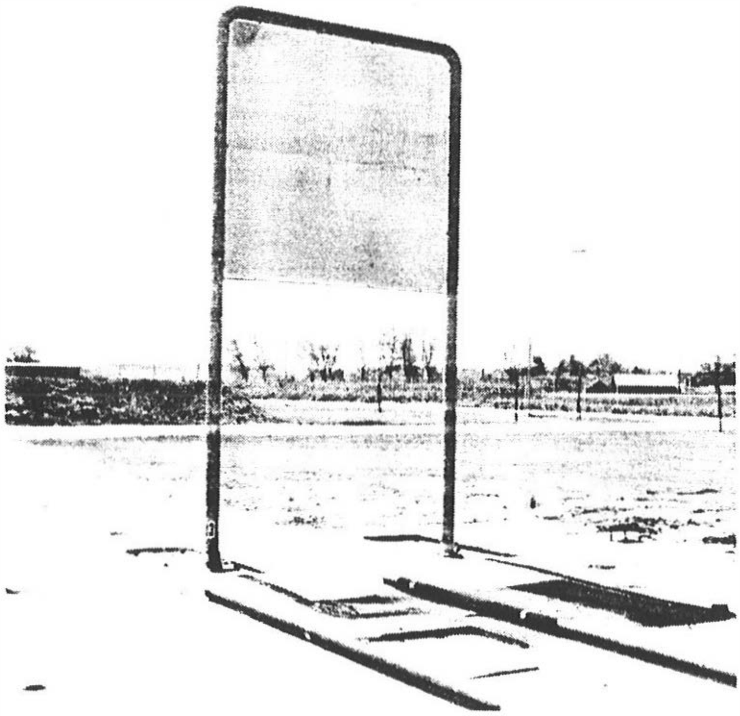


Figure 14 2 x 2 m road-sign

CONCLUSIONS

- The impact sled with the deformable front described in this paper seems to be a useful foot in evaluating the crash performance of roadside obstacles.

- Considering the risk for a second impact when using the slip-base concept for lightpoles, the yielding type of poles might have a better total performance even if the accelerations of the first impact are higher.

- The energy dissipation capability of catch-fence systems for racing tracks built according to the present regulations seems to be highly over-estimated.

- The installation of slip-base joints even on small road-signs have a remarkably good effect.

REFERENCES

/1/ HIRSCH T J et al Vehicle crash test and evaluation of median barriers for Texas highways. Research report 146-4 Study 2-8-68-146 Texas Transportation Institute 1972.

/2/ OGILVIE HARDY Consideration of the peculiar and specific safety requirements of the motor racer driver. 3RD IRCOBI-conference Berlin 1977.

/3/ Year book of automobile sport 1977 Federation Internationale de L'Automobile (F.I.A).

/4/ TURBELL T Skyddsanordningar vid motorbanor. National Swedish Road and Traffic Research Institute. To be published 1978.