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## DEVELOPMENT OF ROADSIDE SAFETY HARDWARE IN SWEDEN

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### Introduction

No extensive research and development in the field of roadside safety hardware was done in Sweden before 1970. When our Institute moved to its new laboratories in 1975 we gained the capability of performing full scale crash tests at speeds up to 130 kmph. At the same time several projects were started and this presentation will describe some of them.

### Luminaire Supports

In the directives on road lighting issued by the National Swedish Road Administration a distinction is made between rigid and non-rigid luminaire supports. The accepted minimum distance from the roadway to the obstacle is different depending on the category of obstacle.

Our first goal was to define a test procedure and requirements in order to classify different types of roadside objects, especially luminaire supports (1).

After considering several alternatives we decided to build a deformable moving barrier for these tests. This barrier has the general shape of the roofline of a car, a mass of 1000 kg and a front end that will deform at a specified level.

As for the performance requirements it was felt that more or less filtered peak acceleration values from the impacting vehicles were not significant in determining the injury risk to the occupants. The concept of three impact speeds (V1, V2, V3) was therefore introduced where:

- V1 is the impact speed of the vehicle into the obstacle.
- V2 is the impact speed into the interior of the vehicle by an unrestrained occupant sitting 0.6 m from the vehicle interior.
- V3 is the remaining speed of the vehicle after the collision with the primary object.

The definition of V2 as the main performance criterion was later also introduced in the Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances (2) in the USA.

The most common type of non rigid luminaire support around the world is the slipbase type which breaks away easily, allowing the vehicle to continue at a slightly reduced speed. Expressed in the terms of the three impact speeds, a breakaway support can be described at (50, 06, 44). This means that the primary injury risk for the occupants is small, but the remaining speed is high, and secondary collisions may occur.

The development of luminaire supports in Sweden has followed another route. Several types of yield supports have been developed. These supports will give an almost constant deceleration level of 5-10 g and stop the vehicle completely. By changing the dimensions of the supports, the energy dissipation can be optimized for different vehicle masses and speeds. A typical performance can be expressed as (50, 22, 00), which means a higher primary injury risk than the slip-base, but no secondary risk, since the vehicle will come to a complete stop. The present recommendations in Sweden are that V2 shall be less than 50 percent of V1, which can be regarded as equal to lowering the speed limit of the road by 50 percent and keeping the rigid supports. Regarding V3, the recommendation is that it should be considered in the light of the secondary impacts that may occur at the specific installation site. If there is a clear area, V3 might be high, but if there is a risk for secondary collisions, it should be kept low.

A problem for the manufacturers of these yielding supports is that the occupant impact speed V2 is a little higher than recommended in the U.S. test procedures (2). The support will meet the U.S. requirements for a crash cushion but not for a luminaire support. It is our hope that future revisions of the U.S. test procedures will be changed accordingly so that these yielding supports can be allowed.

Approximately 30,000 yielding poles have been installed in Sweden. The experience so far has been very good since no cases of personal injury have been reported, although there have been a large number of collisions.

## Guardrails

By far, the most common type of guardrail in Sweden is the W-beam on yielding posts. Due to problems with snow drifts and snow removal, alternative types of beams have been studied. No difference in the impact performance has been observed when a lower beam with a thicker material has been used.

Another problem that is being studied at present is the spacing of the posts. An increase of the spacing from 2 m to 4 m will reduce the installation cost substantially and also give a softer guardrail. Tests with medium size cars at 90 kmph and a $25^{o}$ impact angle show satisfactory performance. It has also been observed that with the large deflections that occur in these cases it is essential that the connection between the beam and the post break at an early stage. If this is not the case, the cars can be caught by the posts or the posts can pull the beam down and introduce a rollover of the vehicle.

At the ESV conference in 1985 a joint Swedish project about optimum bumper height was presented (3). The main conclusion from this study was that a lower bumper level would be beneficial in side and pedestrian impacts. In side impacts the forces from the sticking car would be transmitted into the doorsill and the floor of the struck car instead deforming the door. In the case of a pedestrian impact a lower bumper would produce less injury especially to the knee. This has raised the following questions about the present guardrail configuration.

- Is the interaction between the bumper and the guardrail significant with the present geometry?

- If the cars have lower bumpers in the future, would it then be beneficial to lower the guardrails?

Our present opinion is that since a guardrail collision mainly loads the side of the car, the influence of the bumper is very small. Considering the risk of a rollover when the guardrail is too low, there might be no reason to change the present dimensions even if the bumpers were lowered in the future.

A major problem with the steel guardrails is that repair after a collision is costly and dangerous to perform. Traffic lanes have to be closed down for a long time, and this has caused a demand for non-deformable median barriers in places where there are many accidents.

A system of precast concrete median barriers has been developed by a Swedish company and crash-tested at our Institute. Complete tests according to the U.S. specifications (2) have not been made yet, but the results so far show a satisfactory performance (4). This system has been installed in several places in Europe, and its performance in actual traffic conditions seems to be good.

## Crash Cushions

A new type of crash cushion developed cooperatively between our Institute and a private company was released last year (5). This system consists of 800 kg cubes of Light Expanded Clay Aggregate (LECA) covered by a rubber shield. In a 104 kmph barrier crash with three of these units protecting the barrier the stopping distance of the vehicle was about 4 m and the deceleration level about 10 g. A small number of these units have now been installed. Further tests will be carried out to investigate their performance as free-standing units to provide protection at road maintenance zones. The safety of the road workers has become one of the main concerns in this field. A number of different concepts have been used to keep vehicles out of the construction zones. Unfortunately, most of these devices seem to be inadequate to stop a vehicle, and if they will stop it, they might be very dangerous to the people in the car. In order to investigate this field further our Institute has started a project sponsored by the Nordic Road Safety Council. This project will cover all aspects of permanent and mobile roadwork operations.

## Conclusions

For the future traffic environment where:

- the cars will change in mass and shape
- personal restraints will be used more often
- new materials for roadside safety devices will be used
- the safety of roadworkers will be in focus

there will be a demand for continuous research and development in this field in order to match requirements and test procedures to new situations.

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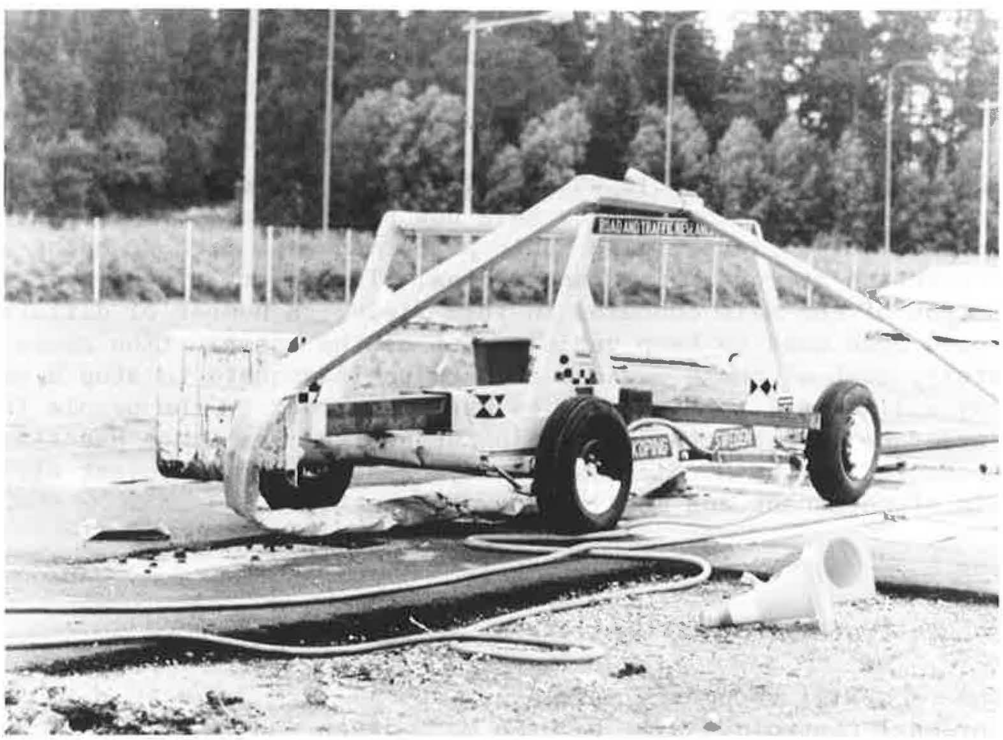

Results of a crash test with the deformable moving barrier impacting an 8 m (26 ft) luminaire support at 50 kmph (30 mph). The stopping distance was 3.5 m (11 ft), the mean (50 ms) deceleration was 6.3 g and the calculated impact speed of an unrestricted occupant 0.6 m (24 in.) into the vehicle interior was 21 kmph (19 fps).