LECTURE A10 – SAFETY DEVICES AND APPURTENANCES

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INTRODUCTION

Every facet of the design of a road, particularly higher order roads, has the consideration of safety as one of the major criteria. Stringent standards of geometrics and construction lead to safer roads and the reduction of crashes. Good communication with the driver mainly through advisory and direction signage and surface markings will reduce dangerous, sudden, hesitant and erratic maneuvers.

The designer should adopt an attitude of compassion for the driver, for his shortcomings or poor judgment.

INTRODUCTION

There is also the case of the innocent driver who may have been forced off the road by a sideswipe or corrective manoeuvre or who used the roadside to avoid a crash. Any of these may be involved in a run-off the road crash, for which there should be a "forgiving highway". There is no excuse for a road design which compounds the problem. The forgiving road is one that does two things:

- it minimises the possibility of the driver making an error of judgement
- it minimises the consequences of an error of judgement

INTRODUCTION

Designers must always be aware of the fact that good judgement comes with experience and that experience comes from bad judgement. He or she has to allow for the period of bad judgement in every driver's life.

Possibly the most important single rule in road design is consistency. Only by making every element conform to the driver's expectations and by avoiding abrupt changes in standards can a smooth-flowing, crash-free facility be produced.

A "user-friendly" highway is designed to be compatible with a driver's capabilities and limitations.

CRASHES RELATED TO ROAD CLASS AND LOCATION

There is a distinct difference in the number, type and severity of crashes occurring on the various classes of roads.

In South Africa, the reporting and recording of crash details has been of a lower standard in the past but, generally, local patterns follow those of the United States, with the exception that South Africa has between 5 and 10 times more crashes per vehicle or per veh-kms. The following is based on American publications.

CRASHES RELATED TO ROAD CLASS AND LOCATION

Fatality rates on freeways are 1,5 per 100 million vehicle kilometres, whereas 2,93 deaths per 100 million vehicle kilometres occur on arterial routes. The rate increases on secondary rural roads.

Freeway crashes tend to be fatal by virtue of the speeds involved.

The crashes to watch out for on collectors normally occur at intersections. The sheer variety of crashes make these interesting and they are a study in themselves.

CRASHES RELATED TO ROAD CLASS AND LOCATION

On residential streets, crashes between vehicles typically arise from someone emerging unexpectedly from a driveway. Speeds are very low and the damage is normally just restricted to the vehicles themselves. Children are seldom hit by cars in spite of their being found on bicycles, skateboards, roller blades and constituting a fairly sizable unmotorised vehicle population.

Crash rates in urban areas are higher for all classes of roads than in rural areas. However, the higher speeds associated with rural roads result in higher fatality rates. Higher classes of urban roads with partial access control have higher speeds and correspondingly higher fatality rates

CRASHES RELATED TO GEOMETRIC ELEMENTS

Horizontal Alignment

Horizontal alignment features have a strong influence on crash experience. Records indicate that a rural road will have about 2,5 crashes per million vehicle kilometres on a curve of 200 m radius and only a rate of 1,0 for a 1 500 m radius. However the rate increases with the increase in curve frequency, which relates to driver expectancy. Similarly, relatively infrequent reductions in sight distance produce a higher incidence of crashes

CRASHES RELATED TO GEOMETRIC ELEMENTS

Vertical Alignment

There is a marked relationship between gradients and crash rates, largely due to speed differentials on upgrades and increased stopping distances on downgrades. Crash rates increase about threefold on grades of 6 % compared to 2 or 3 % gradients. Similarly, crash rates increase about twofold on crest and sag curves with the latter being slightly worse (probably because of the higher speeds).

CRASHES RELATED TO GEOMETRIC ELEMENTS

Cross-Section

A marked decrease in crash rate for higher order roads with shoulders 2 m wide as opposed to those with minimal or no shoulders is observed. Roadway width and individual lane widths are also critical safety factors.

Surface

Variables such as surface roughness, aggregate, drainage, gradients, cross-slopes and percentage time while road is wet all enter into the friction coefficient and skidding problem.

CRASHES RELATED TO GEOMETRIC ELEMENTS

In Britain it was found that, generally, the crash rate did not increase when roads were wet. However, the nature of crashes changed insofar those due to skidding doubled.

Contrary to popular belief, drivers do not reduce their speed merely because the road is under water and the visibility, because of rain, is reduced.

What all this amounts to is that the geometric designer should also be fairly knowledgeable about materials and be able to talk intelligently to the materials engineer about his needs in respect of skid resistance - particularly at intersections - effective drainage of the road surface and the like.

CRASHES DUE TO ROADSIDE AND ROADSIDE OBSTACLES

In the United States it has been found that 37 % of all fatalities are the result of single car crashes with fixed objects or as a result of leaving the roadway. Hitting fixed objects is one of the two major types of crash experienced. The only higher crash rate is that of rear end crashes.

Roadside Obstacles

Typical roadside obstructions which amount to a series of traps for the errant vehicle are.

good sturdy trees

steep slopes on which the vehicle will overturn

CRASHES DUE TO ROADSIDE AND ROADSIDE OBSTACLES

ditches which the vehicle cannot traverse without severe deceleration (resulting in the front end digging in followed by the somersault)

steep cut slopes in earth or rock resulting in unparalleled g-forces and/or the bounce

exposed bridge parapet ends usually struck end-on resulting in the dead stop in all senses of the word

drainage structures in the median or on the back slopes typically resulting in the vehicle rolling over

CRASHES DUE TO ROADSIDE AND ROADSIDE OBSTACLES

median openings between bridges down which a vehicle can disappear in the best traditions of the Bermuda Triangle

piers and gore areas

light standards and sign posts which formidably replace the original trees as a steel-trunked forest

poorly designed or placed guardrails

This is not intended to be a comprehensive list as drivers are fairly imaginative in their search for different things to hit.

CRASHES DUE TO ROADSIDE AND ROADSIDE OBSTACLES

Roadside Safety

Research developments and some applications are showing progress in this area, but a much broader approach is needed, recognising that:

vehicles WILL leave the roadway

the optimal roadside design should allow the driver to recover control of his vehicle and redirect it to the roadway with little or no damage and with no crash with other vehicles

the optimal design is not always feasible due to economic considerations

CRASHES DUE TO ROADSIDE AND ROADSIDE OBSTACLES

To make the best of the real world with regard to roadside safety, the following priority of actions is recommended:

a) eliminate the hazard

b) relocate the hazard to a point where it is less likely to be struck

c) use break-away devices to reduce the hazard

d) use impact attenuation devices to reduce severity

e) protect the driver through redirection of the errant vehicle

ROADSIDE DEVICES INTENDED FOR SAFETY

Improved Roadside Design

For major roads, the border areas should be kept as free from obstacles as possible and fill slopes for embankments should have a slope of 1:5 or flatter, thus eliminating the need for guardrails.

Steep cut section in rock should be faced in concrete which can be shaped to a "New Jersey" profile.

Recent research has, however, suggested that the New Jersey profile is not without its problems. The small wheels of the compact car do not roll all that well over the vertical 75 mm at the bottom of the profile.

ROADSIDE DEVICES INTENDED FOR SAFETY

The current USA opinion is that the New Jersey profile should be replaced by a constant slope. What that slope should be is still the subject of research.

Where possible, the centre and shoulder piers of underpasses should be eliminated. Unfortunately, the cost implications of the clear span that this suggests renders the probability of being able to follow this course of action very low.

Openings between twin bridges can be eliminated by closing the area with structural decking. This removes the need for bridge rails and parapets in addition to covering the opening.

ROADSIDE DEVICES INTENDED FOR SAFETY

Open median drains with guardrail protection remain a hazard. The solution is to use grate-type inlets which permit the removal of the drainage structure and guardrails.

Sign Support and Light Poles

Highway signs and light poles, so necessary for proper traffic operations, can be very dangerous fixed obstacles. The gore sign can be mounted on a small break-away support. Overhead sign supports however are not well suited to the break-away post concept due to the danger of dropping a large sign bridge on the roadway. Such supports, if placed near the roadway, require guardrails to redirect the off-the-road vehicle away from the unyielding support.

ROADSIDE DEVICES INTENDED FOR SAFETY

Simply by virtue of their frequency, light poles constitute one of the greatest potential fixed-object hazards. Although these can be designed with break-away bases, these have had only limited success and lighting poles are normally located behind protective guardrails. This can be most effectively achieved by using central lighting in the median. In interchange areas, the use of high-mast lighting can virtually eliminate the hazard of light poles adjacent to the travelled way

ROADSIDE DEVICES INTENDED FOR SAFETY

Guardrail Design

The Highway Research Board Special Report No. 81 on highway guardrails states that:

Every highway should be designed through judicious arrangement and balance of geometric features to preclude or minimise the need for guardrails or other protective devices

Guardrails are erected to protect errant vehicles from steep slopes or fixed objects. Many authorities tend to adopt the reverse approach by erecting guardrails to protect fixed objects, such as their signage, from moving traffic thus creating a hazard that need not have been there.

ROADSIDE DEVICES INTENDED FOR SAFETY

A signpost that is well away from the shoulder is not necessarily a hazard, whereas the guardrail, mounted at the shoulder breakpoint to "protect" it, is.

Longitudinal guardrail performs by redirection of errant vehicles away from the roadside hazard, providing constant and not excessively rapid deceleration. The vehicle should not be redirected onto or across the travelled lanes of the roadway.

The three basic types of barrier include

rigid, of which the New Jersey barrier is the prime example

ROADSIDE DEVICES INTENDED FOR SAFETY

Semi-flexible, which basically includes the W-beam (blocked-out, strong post - basically Armco - arrangement)

Flexible, exemplified by the box-beam and the cable type (both of which are weak post arrangements)

Rigid barriers are used in situations where there is no room for deflection of the barrier on impact.

Flexible or semi-flexible guardrails are used where space along the roadside is sufficient to allow deflection of the rail on contact.

ROADSIDE DEVICES INTENDED FOR SAFETY

Vital to the proper use of guardrail is the understanding that guardrail is as much an obstacle as it is a protective device. Guardrails ends are by far the most hazardous portions of the guardrail system. There are three basic end-treatments for guardrail: straight, ramped and flared.

Straight terminals sections are very vulnerable at the ends but have a low probability of being struck. If struck, they operate on the same lines as a chisel so that the phrase "terminal damage" takes on new meaning.

ROADSIDE DEVICES INTENDED FOR SAFETY

Ramped terminals prevent abrupt deceleration and impalement but may launch the vehicle causing rollovers with a more than 50 % probability that the rollover is back towards the road rather than down the slope.

Flared terminals also decrease the possibility of an end hit but they subject the vehicle to a larger angle of impact.

In the case of Armco guardrails, the normal support spacing is of the order of 3,8 m whereas, in the terminal area, the pole spacing is about 1,9 m.

ROADSIDE DEVICES INTENDED FOR SAFETY

The South African approach to end treatment is essentially of the genus belt-and-braces because the flared, buried terminal with double sided rails is the one of choice.

Also important to proper design is the transition from guardrail (flexible barrier) to bridge parapet (rigid barrier).

Warrants for the Location of Guardrail

Traffic barrier warrants are described in terms of geometry and the location of roadside features and also crash experience.

ROADSIDE DEVICES INTENDED FOR SAFETY

Guardrail needs should be considered in conjunction with the basic road conditions of roadway sections on embankments, particularly high fills and/or those with steep slopes; divided roads with narrow medians carrying large volumes of traffic: and roadside hazards in the form of structures and appurtenances

The degree of need for the guardrail depends on the height of embankment, steepness of fill slope, width of shoulder or roadway, horizontal curvature, gradient or profile condition, roadside condition, climatic condition, type or classification of road, traffic characteristics (primarily volume and speed) and crash experience.

ROADSIDE DEVICES INTENDED FOR SAFETY

As stated above, a basic principle is that the road should be designed to preclude or minimise the use of guardrails.

Guardrails may generally be omitted on embankments with 1:4 or flatter side slopes unless other hazards are present

Side slopes of 1:5 and preferably 1:6 should be used where feasible to further enhance roadside safety

On any one road or reasonable length of road, a constant width of shoulder and roadway is recommended, whether guardrail is used or not.

ROADSIDE DEVICES INTENDED FOR SAFETY

Current practice indicates that, when roadside conditions are favourable, guardrails should be installed on major roads when the height of fill exceed 2,5 m, 3 m, 4 m, and 5 m in the conjunction with fill slopes of 1:1½, 1:2, 1:2½ and 1:3 respectively. For less favourable conditions, guardrails should be installed at lesser height of fill

In rural areas, the face of the guardrail should be located not less than 300 mm and preferably 1 000 mm from the outer edge of shoulder; in urban areas the comparable dimensions are 300 mm and 450 mm.

ROADSIDE DEVICES INTENDED FOR SAFETY

Structural elements on the roadside, i.e. parapets, retaining walls, abutments etc, should be offset a uniform distance from the edge of the travelled way and in line with the guardrail.

Guardrail ending at or near parapets, abutments, piers etc should be anchored to these elements.

An isolated section of guardrail on embankments should not be less than 30 m long and preferably a minimum of 50 m in length.

Gaps between twin bridges at overpasses require properly designed guardrail protection.

ROADSIDE DEVICES INTENDED FOR SAFETY

Guardrail used in combination with a concrete kerb section must be located so that an errant vehicle cannot bounce over the rail.

When guardrails are not continuous through or not anchored to bridge abutments that are close to road edges then this happens

ROADSIDE DEVICES INTENDED FOR SAFETY

ROADSIDE DEVICES INTENDED FOR SAFETY

Median Barriers

On high-speed high-volume major roads and freeways, median barriers are normally required when the median is less than 13 m wide.

Median-mounted lighting systems make good use of the median barriers.

Sign supports on the median can be handled similarly where median barriers are used.

The main function of a median barrier is to prevent cross-median head-on crashes between vehicles travelling in opposite directions.

ROADSIDE DEVICES INTENDED FOR SAFETY

Continuous median barriers should be carried, where feasible, uniformly over bridges and through underpass structures. At overpasses with twin bridges, the median guardrail should be aligned to meet the structure parapets and be anchored to them.

Light standards on narrow medians should be positioned within a median barrier with a clear space of not less than 600 mm between the beams.

Where the support for a large sign at a roadway exit must be located in the gore, protective treatment should be provided.

ROADSIDE DEVICES INTENDED FOR SAFETY

The anticipated traffic volumes are a factor in deciding on the need for erecting median barriers. It is recommended that with medians widths of 3 m, 6 m, and 10 m, traffic volumes of 15 000, 30 000 and 45 000 ADT respectively justify the installation of barriers.

Impact Attenuation Devices or "Crash Cushions"

There are certain hazardous situations within the road environment that cannot be protected by continuous barriers and the installation of impact attenuation devices may be called for. These devices control the deceleration of an impacting vehicle and thereby reduce the severity of the crash.

ROADSIDE DEVICES INTENDED FOR SAFETY

Arrestor Beds

Arrestor beds are usually employed on long down hill sections where trucks, particularly when heavily or overloaded, are inclined to suffer overheated brakes, which then fail. The arrestor bed comprises an off ramp, which can be negotiated at speed and the bed itself, which is a long straight section of deep sand or gravel.

Pavement Edge Protection

The edge of the paved roadway is subject to erosion both from stormwater flow and vehicular passage.

ROADSIDE DEVICES INTENDED FOR SAFETY

The use of surfaced shoulders will normally overcome the problem and short lengths of narrow surfaced shoulder beyond the painted edge line.

Ditches and Drainage Structures

Ditches to carry storm water adjacent to the roadway are a necessary part of the road cross-section. Extensive research has been carried out to achieve a hydraulically efficient ditch cross-section that will enable an errant vehicle to traverse the ditch safely and, in particular, to avoid the vehicle's front bumper striking the ground.

ROADSIDE DEVICES INTENDED FOR SAFETY

Some drainage structures are potentially dangerous. To provide safer roads:

Unnecessary drainage structures should be eliminated

Necessary structures should be located so that they create the least possible hazard

Structures, which cannot be eliminated, should be designed to inflict minimum damage

Only when it is not possible to reduce the hazard sufficiently should guardrail protection be installed.

Generally, median inlets can be designed to be flush with the ground, including the use of grid inlets, although this increases the maintenance requirements

On roadsides, inlet and culvert openings should be located well away from the roadway to be beyond the hazard area.