Lecture T2 – Design Philosophy and Standards

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Introduction

It is useful to consider some of the facets of the road safety problem which should be of concern to the designer.

South African drivers as a breed tend to generate a fundamentally hostile environment. This is due, in part, to the aggressive natures of our drivers and, in part, also attributable to the level of sheer ignorance and incompetence brought to bear on the driving task. In fact, skills are in relatively short supply

Introduction

What skills are available do not match the enthusiasm brought to bear on the driving task. The "get-there-first" syndrome is deeply embedded in the psyche of the South African driver and a variety of weird and unpredictable maneuvers are the manifestation of this syndrome.

Speeds are high and headways short. In this regard it is worthwhile remembering that headways are measured as the time interval between the passage of the front (or rear) of a vehicle past the observer to the passage of the front (or rear) of the trailing vehicle. The space between these two points thus also includes the length of a vehicle.

Introduction

The man at the drawing board must thus go far beyond a knowledge and application of laid down geometric standards and the acquisition of a repertoire of techniques to solve various problems if he is to be a useful member of the design fraternity. An attitude of caring, encompassing the road user, the community and the environment in which it lives, is required. This attitude finds expression in, amongst other things, the concept of the forgiving highway.

Introduction

This does not mean that a bleeding heart is a fundamental requirement for good design. In reverting to the introductory comment on the objectives of transportation, the point is stressed that the designer must be a realist. In addition to an attitude of caring, the designer must also bring a host of technical skills to bear on problem definition and solution in his field. The intention with this course is to set the student on the path towards acquiring those skills required to give sensible expression of a sound philosophy of design.

Driver Expectations

We have just reflected on the fact that drivers tend to bring to bear on their task a level of enthusiasm matched only by their fundamental incompetence. Reference has been made to reaction times of 2,5 seconds (and longer for more complex decisions). In fact, the average driver is a very limited single stream and painfully slow data processing device. Clearly, these are animals that should not be treated to any surprises. A person who knows what to expect is not going to be surprised and do something correspondingly stupid.

Driver Expectations

In travelling along an unfamiliar route, the driver uses an "historical" approach in his assessment of the driving environment. History is the sum of the driver's past experience plus what he has just seen of the road he is traversing. He presumes that what lies ahead will be similar to that which has been passed.

Drivers expect that, after a curve to the left, the next curve will be to the right. If successive curves in the same direction are close enough to each other, the impression of a broken backed curve is created.

Driver Expectations

Drivers also expect that the radius of a curve will remain constant, thus permitting the use of a constant speed.

The compound curve, which can either be a spiral or a series of successive curves in the same direction with either diminishing or increasing radii may be a particularly elegant solution to a design problem but not for the driver, as a too high speed inexorably drags his vehicle off the road on the outside of the curve, will not be a hymn of praise to the designer's skill.

Driver Expectations

The superelevation on a curve is expected to be constant and adequate across the full length of the curve. A reduction in superelevation leads to an increase in the side friction required to maintain the trajectory of the vehicle. The driver will notice the increase in side thrust on his body. He will then find himself in two minds, neither in agreement with the other: he knows that he is now going too fast for the curve but he also "knows" that braking on a curve will inevitably cause his back wheels to break away.

Driver Expectations

Although not an expectation as such, there is a wide spread attachment to the myth of "right of way". This belief is even more prevalent than belief in Father Xmas, the Easter Bunny and the Tooth Fairy. Right of way applies only to traffic circles and level crossings. In the case of a level crosing, it's always in favour of the train.

Not all driver expectations create problems for the designer. For example, drivers expect that, in mountainous terrain, they will not be able to maintain the speeds selected in traversing the approach to the more rugged area.

Driver Expectations

Drivers expect traffic conditions to be more congested in urban areas and are consequently more alert. Falling asleep at the wheel is a largely rural manifestation and, incidentally, is a light hypnotic trance rather than sleep.

Simply giving the driver something to do once every so often is a very effective aid to keeping him awake. A graph of single vehicle off-the-road accident rate related to length of straight is roughly parabolic and at its highest where curves follow each other in quick succession and at a similar height where the length of straight is of the order of 30 km.

Consistency of Design

Having dwelt on what drivers expect, it now remains to consider how best to meet these expectations. Various solutions present themselves with perhaps the most significant being standardisation.

If every intersection and interchange was a substantially unique layout the driver could be forgiven for a degree of confusion. Prior to the adoption of countrywide uniformity of geometric standards, every road authority had its own set of standards.

Consistency of Design

It is, however, possible to take standardisation to ridiculous extremes. The angle of deviation at interchange ramps being specified to the nearest second is an outstanding example of unthinking rigidity being considered to equate to standardisation. It is equally possible to match every geometric design standard in the book and still produce a design that, by even the kindest of criteria, can only be considered disastrous. Design standards are grouped by the convenient device of the design speed, but it has already been stated that the design speed of the road reflects only the lowest standard encountered on the road.

Consistency of Design

In general, curve radii on a given road should be of similar magnitude alternately to right and to left. Furthermore, curve lengths should not fluctuate over the range of a kink to 1,5 km but also be broadly similar for successive curves. In essence, the driver should experience approximately equal time spans on the various curves encountered. The long straight followed by the short radius curve is a glaring example of poor design.

Consistency of Design

As a rough rule of thumb it has been found that if the length of straight in metres is ten times the value of the design speed in km/h, speed fluctuation is minimal. On this basis, an 80 km/h design speed suggests that the maximum length of straight should be of the order of 800 m to 1 000m. Most people tend to drive at speeds of the order of 120 km/h so that, purely in terms of speed fluctuation, artificially maintaining a maximum length of straight of the order of 1,2 km to 1,5 km is not going to serve any practical purpose and the infinitely long straight becomes a proposition apart from the need to keep the driver still functioning as such.

Geometric Design Standards

A point worth considering as that a geometric design standard is not a standard in the normal sense, which usually seeks to attach to the word some or other quality of excellence to be aspired to. For this reason, reference is increasingly to geometric guidelines.

These guidelines appear in one of two forms.

Geometric Design Standards

One is a reference to whether or not a certain facility should be provided. This guideline is referred to as a warrant. There are warrants for the provision of signalisation at an intersection, warrants for climbing lanes, warrants for freeways and so on.

The other seeks to ascribe either a maximum or a minimum (some times both) value to a geometric criterion. In this context, minimum radii of horizontal curvature, maximum extent of superelevation and minimum and maximum values of gradient are specified.

Derivation of Standards

There is a tendency to accept that geometric design standards have almost Biblical overtones and failure to observe them in the most microscopic of detail will inevitably be swiftly followed by eternal damnation and hellfire. Such an approach is unaware of the methods whereby standards are determined. It may be insightful to consider the process, and, by way of illustration, that most fundamental of all standards, being stopping sight distance, is worth consideration.

Derivation of Standards

Stopping sight distance has three fundamental components being the drivers' ability to see the road ahead, their reaction time and the braking ability of the vehicles they drive. The ability to see the road ahead presupposes that all drivers have 20/20 vision and are sober. Ability to see is thus dictated exclusively by the height of the driver's eye above the road. Obviously with drivers ranging in height and the vehicles being anything between a low slung sports car and a truck, the variation in driver eye height can be substantial.

Derivation of Standards

Reaction time, which has already been discussed, is also subject to substantial variation and a value of 2,5 seconds is thus normally employed.

The ability of the vehicle to stop is dependant on its suspension, braking ability and load. Further conditions also come into play, such as the condition of the tyres, (taken for the occasion as being fairly smooth), condition of the road, (assumed as smooth textured) and ambient circumstances, (assumed as a wet surface).

Derivation of Standards

Road geometry has a bearing on the matter, too. It is presumed for the calculation that the road is level. An allowance must thus be made for the fact that stopping distance is longer on downgrades. Mention has also been made of the reluctance of drivers to brake sharply on curves.

The selection of a rate of braking acceptable to the driver may make a nonsense of all the vehicle parameters already listed.

Derivation of Standards

Drivers are prepared to brake harder at lower speeds than at higher and coefficients of friction reduce with increasing speed. As such, the initial speed of the vehicle is more than simply a datum point from which a constant deceleration leads to a mathematically calculable stopping distance. It feeds into what that rate of deceleration is going to be. The one thing that is clear is that constant deceleration finds its only application in the classroom.

Derivation of Standards

The final point, not referred to above, is the question of what the driver should be able to see to cause him to wish to stop. The object-in-the-road model is currently in vogue and has been for several years. It suggests that, seeing that the ground clearance of most vehicles is of the order of 150 mm, an object of this height would cause the driver to take some or other action, which may include stopping. This height is also quoted as being a compromise with a view to reducing earthworks volumes generated by the alternative of suggesting that, at the given distance, the driver should actually be able to see the road surface. As such, a hole in the road is not perceived as an obstacle.

Derivation of Standards

The most recent development is contained in the SANRAL Geometric Design Guideline document. It partially adopts the Neumann approach of having different object heights for different circumstances as shown in Table T2.1

Having come up with an object height, the Guideline also abandons the elaborate assumptions of skid resistance on wet roads with smooth tyres and simply states that drivers will find a rate of deceleration of 3,0 m/s^2 acceptable. The new Green Book proposes a rate of 3,5 m/s^2.

Derivation of Standards

Under these circumstances it is surprising that designers can arrive at any sort of meaningful value of stopping sight distance. Insistence on some or other value as a law of the Medes and Persians is, to say the least, ridiculous. The fact of the matter is that the values accepted for stopping sight distance have been found in practice to work in spite of all the assumptions that go into their calculation. The above is all predicated on the stopping vehicle being a passenger car. What then about the poor truck driver?

Derivation of Standards

Driving a truck, particularly an articulated vehicle which could be a tractor-semitrailer, tractor-semitrailer-trailer or also an Interlink which is a tractor-semitrailer-semitrailer combination) is more difficult than driving a car. Stopping one of these beasts verges on an art form.

In calculating stopping distances required by trucks, the skill of the driver is a variable that outweighs many of the considerations of road surface and tyre condition referred to above.

Derivation of Standards

A final word on the derivation of standards is that, while researchers are questioning current models according to which our standards are calculated, many people (principally politicians) are making noises about "appropriate standards". We will have to embark on a process of seriously considering values of our guidelines and "go closer to the edge" forsaking tried and true albeit rule of thumb methods for establishing design criteria.

Aesthetics

Having produced a road that meets all the requirements of the standards and every last expectation that drivers may have, the road can still be an eyesore of note.

Efforts to produce an aesthetic environment have more practical benefit in terms of contribution towards road safety than purely pleasing the eye of the beholder. The geometric designer is thus cast also in the role of the architect of the road.

Aesthetics

The road requires consideration at two levels, referred to as internal harmony and external harmony respectively.

In the first instance, the driver is principally conscious of the road itself and the way in which curves follow straights and down grades lead to the next up grade. Much of the information about the road comes from the road edges and the way in which they rise, fall and bend as a pair and relative to each other.

Aesthetics

The abstract ribbon in space is a useful concept as a starting point in the design process. However, with the exception of viaducts and tunnels, the road is usually in close proximity to the landscape and perceived by the road user and the community at large as forming part of that landscape.

Locating a road with sensitivity and care is not merely some fantasy. Using the landscape in all its facets results in a road that is visually attractive, useful to the community and also has a tendency to keep earthworks volumes low.

Conclusion

The intention has been to point out that there is a substantial difference between design and the process of committing a series of numbers to memory, regurgitating them on demand. For obvious reasons, this course is principally dedicated to the mechanics of design. However, once absorbed, these should become tools and their application almost instinctive.

Design requires the development of a faculty of highly critical observation and experience.