1 INTRODUCTION

Many years ago, the Riekert Commission proposed that the objectives with provision of transportation include safety, mobility, convenience, economy and minimum side effects. It is difficult to rate these in any order of importance, but it is suggested that any designer who trades off on safety to achieve some financial advantage could be accused of mass murder for the most venal of motives. It is thus 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. The situation still prevails whereby driving is a skill that is handed down from generation to generation rather than via the intervention of a driving school. Bad practices thus have a way of being perpetuated and advanced techniques such as skid control are beyond the capabilities of the average "teacher" who, incidentally, is usually not all that familiar even with the significance of all road signs and what they are intended to convey. 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 manoeuvres are the manifestation of this syndrome. Think of the wrong-way shortcut around a traffic circle or a two-lane two-way road becoming four-lane (three north and one south) by forced use of the shoulders as happens over Easter on the N1 between Pretoria and Polokwane.

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. If speeds are not high, the very short headways measured could not be accommodated because the trailing vehicle would be inside the leading vehicle. Consider a headway of 0,5 seconds involving an articulated truck as the lead vehicle. At a speed of less than 120 km/h, the trailing vehicle would be located immediately in advance of the back wheels of the tridem. A speed of 144 km/h is required to ensure at least a car's length between the two vehicles.

All these factors suggest that, on South African roads, there is little or no margin for error. The designer must accept that collision rates will be high unless he makes a special effort to design risk out of the system. Because of the speed - specifically the speed differential - at which these collisions occur, their consequences are usually severe.

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, which will be discussed in more detail in subsequent lectures.

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.

2 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. It is thus worthwhile to ponder on the topic of driver expectations and then to seek to match these in the design process. This is, in fact, a two-way stream of communication. Through design, certain driver expectations are created, and subsequent design must take due cognisance of these 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. It is expected, therefore, that, where a speed of 120 km/h has proven to be safe and comfortable, it will continue to be so. In short, he believes that curve radii will match speeds likely to be observed on the road.

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. The broken-backed curve comprises two successive curves with broadly common radii in the same direction and with a short length of straight connecting them. It is quite likely that the driver simply would not perceive this combination as anything other than a continuous curve. The result is a tendency for vehicles to leave the road on the inside of the curve. One conclusion that could be drawn from use of a broken-backed curve is that the designer couldn't quite make up his mind about how far around he should have gone in the first instance.

Drivers also expect that the radius of a curve will remain constant, thus permitting the use of a constant speed. This expectation is partially described in the preceding paragraph. 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 the driver's words, 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. Compound curves have an application but require great care if driver expectations are to be met.

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.

This latter piece of driver lore results in the fact that speed changes on curves are either not attempted at all or are, at best, very gingerly applied. As such, the designer should attempt to avoid locating intersections on curves as far as possible and, if this is not possible, should definitely not drop the superelevation to accommodate the intersection. In general, a design requiring a vehicle substantially to change its speed while negotiating a curve can be considered poor.

Driver expectations specific to freeways are that slower vehicles are to be found in the outer lanes and that on- and off-ramps will also be on the left.

This latter expectation was not always so. When freeways were first introduced, drivers had a certain difficulty in coming to terms with the idea of having to leave a road to the left when the ultimate desire was to turn to the right. Designers attempted to accommodate this by commencing directional ramps to the right from the inside (right, median or "fast") lane. In UK nomenclature, the inside lane is referred to as the outside or sometimes off-side lane.

Two problems immediately presented themselves - one being the practical problem of extracting the vehicle from the median island that, invariably, was too narrow to accommodate the geometry involved. The other problem arose from the driver expectation that turning from one road to another required a drop in speed. As a consequence, interchange areas were characterised by high speed differentials in the inside lane. The speed differential increases the probability of a collision and the greater the speed differential the greater the damage arising from the collision. Finally, because of driving habits built up on two-lane roads, drivers expected that an avoiding action involving a sharp swerve to the left would be safer than swerving to the right. This functions more as an instinct than a reasoned reaction to a particular circumstance so that drivers found themselves slewing across other lanes full of high-speed traffic rather than seeking the safety of the median. The multi-car pileup is a logical consequence.

Designers bowed to the inevitable and initiated interchange ramps from the outside lane. Drivers now expect to find the ramps there and have also adapted to the reverse path involved in turning right. As an extension of the reverse path concept, drivers have also adapted to the fact that a right turn onto the freeway involves crossing the freeway first and then coming back to it rather than diving down the first ramp they see. The incidence of wrong-way driving has dropped steadily over the years and the elaborate systems dreamed up to reduce the risk of entering the freeway in the wrong direction are no longer as necessary as previously believed.

Although not an expectation as such, there is a widespread 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 latter case, 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. They also expect a greater impedance from heavy vehicles because of the relatively poor climbing ability of these vehicles and the reduced number of opportunities for overtaking them.

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. For this reason, drivers can successfully travel for long distances to suddenly realise that they cannot remember traversing a particular area at all. There are two ways of leaving a trance and that is by either falling into a deep sleep or waking up. It is the former exit route from the trance that invariably also serves as an exit route from the road.

South Africa has been responsible for various things including the invention of road centreline marking. The thought was that it was the stroboscopic effect of the centreline, where the marks and the gaps were of equal length creating a very regular flashing effect as they disappeared from view that contributed towards effectively hypnotising the driver. For this reason, we moved to the 2/3 ratio between mark and gap lengths.

It is however far more likely that the principal causes of driver hypnosis are a combination of the sheer boredom of long-distance driving, the relatively low requirement for attentiveness and the monotonous sound from the engine, tyres and wind noise.

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. The turning point of the function is in the 10 -15 km range of length of straight, implying that the driver requires some sort of activity at roughly five-minute intervals. European practice as described by Lamm et al[1] specifies maximum lengths of tangents, but these are much shorter than the 10 to 15 kms suggested by this curve. America and South Africa do not lay down guidelines for tangent lengths but with the upcoming revision of our guideline documents this omission could probably be rectified.

3 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. In some cities, use is made of secondary traffic signals with others relying on primaries only. The consequence is that the Cape Town driver will, on his first trip to Pretoria, drive through the intersection and stop at the first set of signals that he sees. And then be very surprised by the hooting of frustrated motorists on the crossing street.

Street names sometimes appear on poles and are sometimes set into the kerb face. Wherever they are located, a certain amount of genius manifests itself in the careful concealment of any useful information from the lost driver.

Prior to the adoption of countrywide uniformity of geometric standards, every road authority had its own set of standards. For example, the nose of a Cape Provincial off-ramp looked substantially different from those found in Gauteng, resulting in dramatic manoeuvres as local drivers sought to avoid being party to out-of-towners' last-second desire to enter the off-ramp which they had just recognised as such.

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. A 120 km/h road with a single sub-standard horizontal curve could quite accurately and simultaneously totally misleadingly be described as having the lower design speed with everything else being a plus for the benefit of the driver. This clearly would represent an inconsistent design so that selection of a design speed appropriate to the circumstances (including the topography) requires careful thought.

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. This criterion suggests a relationship between angle of deviation and radius that deserves to be explored.

The long straight followed by the short radius curve has already been mentioned as a glaring example of poor design. The question therefore follows: What is meant by "long" and "short" in this specific instance? To offer some criterion, it is useful to consider what the driver does when confronted by the short radius. On a long straight the driver will either immediately select, or creep up to, a speed at which he is comfortable. On seeing the curve, he will slow down to whatever speed is, in his opinion, appropriate. The curve is successfully negotiated, and this is followed by a slow return to the previous speed presuming that the next curve is not already in sight or, if in sight, at least a substantial distance away. At the next curve the whole cycle repeats itself. This fluctuation in speed is an irritation and the driver will quite rightly feel that he is being unnecessarily delayed.

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.

4 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.

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. For example, if certain traffic flows are exceeded for a specified period of time during the day, traffic signals could be said to be warranted.

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. Both forms of standard will be discussed in more detail later.

5 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.

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. An assumption of some or other percentile value, usually 15th percentile, differentiating between cars and trucks, comes into play.

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.

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.

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.

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. Having selected the object to be seen, the debate then rages about how much of the object must be visible before it can be perceived - the top third, top quarter, its upper boundary?

Neumann[2] has proposed that the "dead cat" model should be replaced by a "most likely operational event" approach. He claims that the likelihood of encountering an object of 150 mm height on the road is vanishingly small. This is confirmed by Kahl and Fambro[3] who point out that only 0,07 % of accidents that involve striking some or other object in road are in respect of objects of this height or less. Neuman's proposal means that, on low volume rural roads, the most likely event is a 4x4 encountering an object of about 300 mm in height, i.e. a reasonable size boulder. In residential streets, the object should be about the height of a small child (engrossed in a game of marbles in the middle of the road, one presumes) and we are now talking about a height of about 600 mm. On freeways, the object height of 150 mm comes into play because of the way that bits can drop off vehicles. However, hitting a brick that is lying flat, ie 75 mm high, with a front wheel at a speed of 120 km/h or more would result in a blow out. Few drivers have the level of skill necessary to control their vehicle under these circumstances suggesting that an object height lower than 150 mm would be more appropriate to high-speed roads.

This philosophy means that, for a given design speed, a range of stopping sight distances will come into play depending on the function of the road being designed. The Neuman approach has not been generally adopted but it is necessary to be aware of the fact that researchers are questioning our current approach to one of the most fundamental standards in Geometric Design.

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.

Table T2.1: Object height design domain

Object Height (m)	Applicability
0,00	Risk of road washouts Pavement markings in critical locations
0,15	Risk of fallen trees or rocks Risk of log or construction debris fallen from truck Risk of fallen person
0,60	Vehicle tail or brake light
1,30	Passing sight distance for top of car Intersection sight distance

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.

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? 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. When a car's wheels lock, they do so simultaneously. In the case of a truck typically with three axle sets, they don't. If the steering wheels lock first, the driver loses his steering and the combination carries on in a straight line. Rear wheels locking cause the trailer to swing out in an effort to overtake the tractor. A skilful driver can, with very quick and appropriate action, straighten the combination vehicle out and keep on going. Unfortunately, the most likely occurrence is that the driving wheels will lock first. This is because the trailer, in effectively riding up onto the fifth wheel, tends to lift the driving wheels off the road thus making it easier for them to lock. The jack-knife results and drivers that can actually sort out a jack-knife have yet to be born. 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.

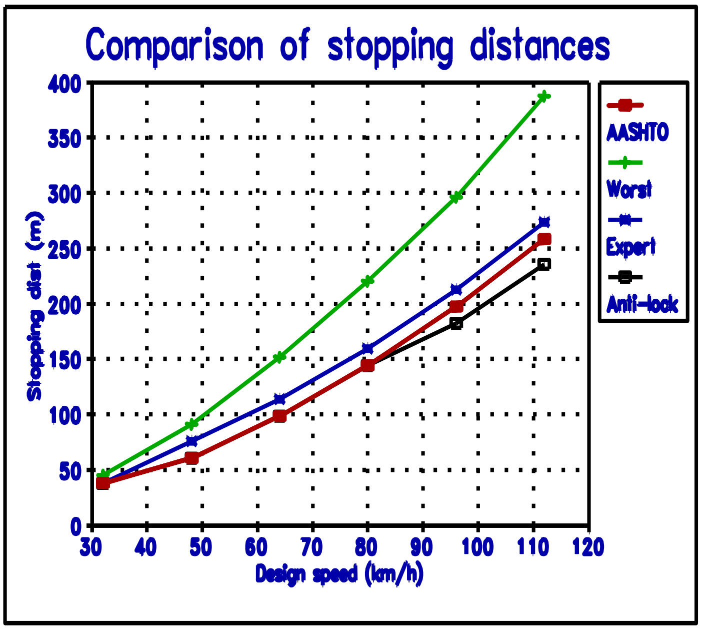

Figure T2.1: Comparison of stopping distances for trucks

It obviously takes longer to stop a truck than a car but we always comforted ourselves with the thought that the higher eye-height of the driver provided the additional stopping sight distance required. In fact, it doesn't always. Recent research on the topic of stopping distance for trucks took account of driver skill. It found that the additional sight distance given by the higher eye height was adequate only in the case of the expert driver and grossly inadequate for the worst performing driver. In the case of sight distance on horizontal curves, the additional eye height offers little or no advantage so that the provision made by our current geometric guidelines constitutes under-design.

Fortunately, antilocking brake systems are rapidly being implemented and these make it possible for a truck to stop in the same or even less distance than the passenger car, regardless of the skill of the driver. Figure T2.1 above illustrates the situation.

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.

Standards for low-volume roads are becoming a critical issue. For example, the Department of Housing Red Book has been revised because standards quoted in its predecessor, supposedly for low volume roads, were very similar to those used for any other. Furthermore, these standards fail to address the wide range of activities and values found in any viable urban community. Rural low-volume roads also require a rethink.

6 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.

It is a fact of life that most people respond to beauty in all its forms, usually pleasurably. Appreciation is typically accompanied by a sense of relaxation. And it deserves to be noted that a relaxed driver is less of a menace than one who is being stressed to the limit. Also, the relaxed driver has a greater spare capacity for observing and reacting to a changing environment than one who has been rendered unsure of himself by a series of surprises. It follows that 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.

Furthermore, in this day and age of environmental awareness, anything which detracts from the beauty of the landscape is not going to be gratefully received by the community at large. The geometric designer is thus cast also in the role of the architect of the road. The end product is required to be functional and, in addition, must be visually pleasing.

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

6.1 Internal harmony

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. The designer must consider the road as an abstract ribbon in space and take care that sharp kinks and discontinuities do not do an injustice to a smoothly flowing alignment.

This consideration is not without its problems. The designer working on a drawing has a bird's eye view of the entire situation. This bird's eye view is however only two-dimensional. A plan view of the horizontal alignment followed by a sectional view of the vertical alignment must somehow be combined in the designer's mind to form the whole picture. The driver on the other hand sees all three dimensions simultaneously but has a worm's eye view from a vantage point of a little over a metre above the road surface.

At no time does he see the whole picture and what he does see is subject to foreshortening. As a final contrast between designer and driver, the former sees a static picture whereas the driver's vantage point is continuously moving along the road. He may see a kink in the road from some distance away and find, when he gets there, that it is actually a smooth curve.

The development of superelevation is famous for its ability to create the appearance of a discontinuity in the road edge. This, very often, is not shown on the vertical alignment although, as an element of the cross-section, it may appear on the same drawing. The matter of the interaction between the horizontal and vertical alignment and the cross-section is dealt with later.

6.2 External harmony

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. The designer is thus actually faced with a problem that contains a hierarchy of issues to be addressed

- ❑ The road should meet or, for preference, slightly exceed the laid down geometric standards. If the standards can be exceeded by too large a margin, it is more than likely that the initial selection of design speed was in error hence calling for serious consideration of redesign.
- ❑ All possible driver expectations should be met.
- ❑ As an abstract ribbon in space, the road should present a low level constantly changing view of the road with a smoothly flowing continuity of alignment in three dimensions
- ❑ As part of the environment, the road should look as though it always was there and, more importantly, without it the landscape would have been the poorer.

No mathematical rules can be laid down to achieve this happy state of affairs. For this reason, the designer is as much artist as he is technologist.

Very often there is a tendency to adopt the approach that the landscape is something to be tamed. Roads run at right angles to the contours, hopping from deep cut to high fill as though the landscape had not been there when the original route location was done. Alternatively, because the designer can stay fairly close to ground level while still meeting up with standards of gradient and vertical curvature, the road roller-coasters across the countryside with a sort of joyous abandon.

The need for materials causes borrow pits to be opened. The landscape could possibly be viewed as nothing more or less than an infinite source of decomposed dolerite but the resulting scars would take some living with.

It is very easy to straighten a river and, for preference, to canalise it in something as durable as concrete to ensure a decent river crossing.

Land use has a significant effect on the general appearance of the landscape. The designer can ignore this too and push across pastures and ploughed lands with a magnificent indifference to all other than that the road should be as directional as possible. Public open space, particularly river valleys in urban areas, lends itself readily to total destruction in the name of Transportation.

Alternatively, the landscape could be promoted to best friend status. A need for height at an interchange could be met by employing a convenient hill. Locating a road above a valley would not only provide a pleasant vista but also have the eminently practical effect of preserving the integrity of farming land and, more importantly from the engineering point of view, reduce problems with storm water drainage at the same time locating the road on more durable material. The reason for the contention regarding the material being more durable is simply that, if it had not been durable, it would have been down in the valley with the rest of the silt being ploughed up for crops.

Locating a road with sensitivity and care is not merely some ethereal 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. It deserves to be pointed out that the most durable aspect of a road is its location. Its surface may change from earth to gravel to bitumen. Its cross-section may change from country lane to six-lane freeway. Its location however is far less likely to change. It therefore demands the very best efforts of the designer.

7 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.

Furthermore:

- ❑ awareness of all aspects of the repertoire of geometric design,

- ❑ knowledge of the frailty and weaknesses of the road user and his vehicle, and
- ❑ sensitivity towards the aspirations of the community in addition to
- ❑ artistry in the application of the plastic possibilities of the medium and
- ❑ respect for the environment that, in the final analysis, is either enhanced or damaged by provision of the road

are essential elements of effective design.

Obviously, the process of becoming a good designer takes years of practical application and requires the development of a sound philosophy of design. It is trusted that the above comments will be of some use in the acquisition of that philosophy.

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