Lecture T3 – Design Inputs

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Introduction

The concept of a road being provided to enhance mobility is so entrenched in modern society that it is normally taken for granted by the user.

With regard to vehicular movement, the design of the road is based on many restricting elements relating to the driver and the vehicle, in addition to the consideration of land use and topography. These characteristics will be discussed in some detail in this and subsequent lectures. The point of departure of all design is the selection of characteristics which most clearly define the needs to be served by the road and the selection of values of characteristics that best meet those needs.

Introduction

The relationship between the driver and the vehicle and the range of operating characteristics resulting from this will be dealt with in subsequent lectures. The prime outcome, however, from the designer's point of view is operating speed as discussed later in this lecture.

Fundamental Concepts

The Design Vehicle

Before commencing the detail design of the road, a principal concept that requires consideration is the vehicle for which the road is to be designed.

Streets in residential areas will almost exclusively serve passenger cars, with some buses and utility vehicles making their appearance.

Fundamental Concepts

In shopping areas, although actual numbers will be high, the proportion of passenger cars in the traffic stream will reduce, buses will increase and freight vehicles increase substantially. In industrial areas, there will be relatively few passengers cars and buses and those present will appear within sharply defined peak periods whereas freight vehicles, of which a substantial proportion will be articulated vehicles, will be in evidence for most of the day.

Fundamental Concepts

Although legal limits are placed on vehicle design, differences between the characteristics of the different classes of vehicles are substantial.

Intra-class differences in vehicles are no less dramatic. The low-slung sports car with a ridiculous power/mass ratio, broad tyres and super disc brakes overtaking the elderly, heavy, low performance sedan with inadequate braking and all-round vision are both representatives of the passenger car.

Fundamental Concepts

Commercial vehicles on the other hand are custom built for a wide number of applications, from rapid delivery of small loads in heavily trafficked conditions over short distances to long distance haulage of mass or volume loads.

Consequently, the spread of values of their characteristics is greater than that found in passenger cars.

On certain routes, abnormal vehicles, i.e. those that fall outside the legal limits, also have to be accommodated.

Fundamental Concepts

For design purposes, certain vehicles are selected as being representative of their class and, in this sense they represent a "worst case".

Vehicle characteristics that are of importance to the designer are:

1. its physical dimensions, being length, width, height, wheelbase, front and rear overhang and configuration, the last-mentioned referring to the number of wheels.

Fundamental Concepts

2. performance parameters such as engine size, torque, power, mass, braking capability, rolling resistance, virtual mass, air resistance.

3. operational restraints such as drivers' eye height and minimum turning circle.

Actual values of these characteristics that are selected to describe the design vehicle depend on the intended application of the particular design value and are usually predicated on some or other percentile value of a distribution of values.

Fundamental Concepts

The design of parking bays, if based on the fiftieth percentile, would result in one vehicle in two not being accommodated. The 95th percentile is thus selected.

The lower the driver's eye height, the less sight distance he has over a vertical curve. The fiftieth percentile would suggest that half the vehicles on the road would not have adequate stopping sight distance and the fifteenth percentile is thus selected. The rationale behind not accepting the lowest percentile is that the very low driver eye heights are typically found in high performance vehicles that usually have superior braking abilities.

Fundamental Concepts

Driver eye height introduces another thought worthy of consideration and that is that vehicle characteristics cannot always be divorced from driver characteristics. The designer is thus in the position of being required to consider the composite of man and his means of transport so that the design vehicle tacitly includes the person driving it.

The objectives of road provision include in addition to safety, convenience and minimum side effects, considerations of economy.

Fundamental Concepts

Safety requires pure geometric design; convenience calls for a combination of regional planning, transportation engineering and geometric design; minimum side effects require environmental awareness, artistry and geometric design. Economic considerations require an ability to combine geometric design with economic analysis

Seeing that our interest lies in the overall economy of the road, we normally use the average or the fiftieth percentile values relating to vehicle performance.

Fundamental Concepts

Classes of design vehicle normally considered are the passenger car (P), the rigid chassis truck (SU), the articulated truck (WB-17) with the abbreviation deriving from the overall wheelbase of the combination vehicle and the bus (B).

In South Africa the minibus taxi has become a phenomenon that needs to be considered as a separate design vehicle. It is typically poorly maintained, heavily overloaded and entirely unpredictable. Very broadly, it combines the physical dimensions of the passenger car with the power/mass ratio of a truck and the psychology of the average suicide bomber.

Fundamental Concepts

Strictly speaking, the pedestrian can also be described as a design vehicle that has to be accommodated within the road. Widths of sidewalk are predicated on pedestrian volumes and pedestrian crossings require knowledge of the operating speed of the "vehicle", e.g. walking speed.

Table 2.1 shows current values of the various parameters of the design vehicle. The values given in the table derive from work by Wolhuter and Skutil[1]

Fundamental Concepts

The Design Speed

The design speed used to be defined as the highest speed at which a vehicle can operate safely on a road when circumstances are so ideal that only the design of the road prevails. If you think about it, this definition actually goes around in a circle. These days we simply say that it is the speed selected for design purposes.

Fundamental Concepts

Various values of the different features of the road are combined in groups representing a combination of factors that will contribute to the driver's interpretation of the environment in which he finds himself. "Design speed" is thus a generic name for the various groupings that result rather than a speed, per se.

Alternatively, design speed is a speed measure of the standards for these factors, the most important of which are:

Fundamental Concepts

sight distance;

horizontal and vertical curvature;

surface skid resistance;

lane width;

superelevation;

vertical grade; and

lateral clearance.

Fundamental Concepts

To achieve a desired operating speed, certain characteristics have to be designed into the road, creating in the driver a perception of safety and convenience at that speed. One of the most important initial decisions in relation to the design of the road is the selection of the design speed. The design speed is chosen in relation to:

- the classification of the road
- the topography traversed, be it level, rolling or mountainous for example
- the location of the road, e.g. in an urban or rural environment
- the level of service desired

Fundamental Concepts

The posted speed limit should relate directly to the operating speed, which is often chosen as the 85th percentile value of observed running speed. Minimum speed limits are based on the 15th percentile observed speed.

The important concept of consistency of design implies constant design, operating, safe and average speed. Lower design speeds would be acceptable and expected in mountainous terrain and urban areas. Higher design speeds would however be demanded where trip lengths are long.

Fundamental Concepts

The design speed is really only indicative of the lowest standards found on the road and can, thus, be a snare and a delusion for the young designer. The driver is not party to selection of the design speed and consistent design would spell out to him what the design, i.e. safe, speed is.

Changes in design speed have to be introduced with great care and forethought. Not to mention signage telling the driver what you have done if this is not obvious from changes in topography and the like.

Fundamental Concepts

The Design Hour

Traffic flow is measured by the number of vehicles passing a fixed point in a specified period of time, usually an hour or a day. . An important value in design is Average Daily Traffic (ADT), or where continuous counting occurs over a full year, Annual Average Daily Traffic (AADT).

ADT provides the basis for selection of a design flow but, by itself, it does not reflect fluctuations in flow and hence the operating conditions for which the road must be designed.

Fundamental Concepts

As in the case of the selection of value of vehicle characteristic, it would be wasteful to design for the maximum value of flow that is likely to occur and some lower percentile value is selected.

If the design were to be predicated on flows that currently occur, annual increases in traffic would soon cause the road to be obsolete. It is thus customary to design for a future year, typically twenty years hence on the basis of funding of loan finance and the concept that each generation should pay for its own services.

Fundamental Concepts

Traffic flow varies enormously during the course of the year. The nature of the variation is dependent on the location of the road.

Traditionally, the volume associated with thirtieth highest hour of the year is used for design purposes. In rural areas, the thirtieth highest hour corresponds to about 15 % of the ADT and, in urban areas, to about 10 %.

Traffic composition is a difficult animal to cope with. Heterogeneous traffic streams do not readily lend themselves to analysis.

Fundamental Concepts

Trucks and buses, because of their size and operating characteristics, have as much effect on the surrounding traffic as a number of passenger cars. Reference is thus made to Passenger Car Equivalents (PCE's). PCE's are not constant values. They vary according to the circumstances being considered. For example, in stationery queues, the PCE of a bus could be as low as 2 whereas, when the right-turning movement is considered it could be significantly higher. On gradients, PCE's can range between 2 and 8 and even higher on very steep gradients.

Fundamental Concepts

It is necessary to arrive at an assessment of the traffic composition for which provision must be made. From this assessment, the heterogeneous traffic stream is converted to its equivalent passenger car stream.

A further variable in traffic is the directional split, i.e. the ratio between opposing flows. Even on rural roads, which are not particularly prone to the tidal flows of the urban street network, flows are rarely balanced. The directional split under rural conditions is typically not more than 60:40, whereas, under urban conditions, 80:20 splits are not uncommon.

Fundamental Concepts

The interaction between opposing flows on a two-lane road reduces capacity and trucks also have a disproportionate effect on other traffic because of the need to overtake in the face of oncoming traffic. Design is therefore of both lanes as a unit. In the case of multilane roads, the lanes in the direction of interest must suffice for the design hour volume anticipated.

Road User Costs

Road user cost finds two applications of interest to the designer.

In the first instance, the application is purely concerned with the economics of the proposed road. "Whole life economy", as a frequently used phrase, includes the costs incurred by the road authority in providing and maintaining the road and the operational costs incurred by the user.

Road user costs are principally subdivided into standing costs and running costs.

Road User Costs

Standing costs are time-based and refer to such items as depreciation, licensing, insurance and garaging.

Running costs are distance-based and refer to the cost, exclusive of tax, of fuel, oil and tyres and may also include the cost of time and collisions.

A further use of road user cost concerns route selection. A driver selects the "best" route, and what is best is based on many factors. A major factor is minimum travel time.

Trip Generation, Attraction, Distribution and Assignment

Having made reference to the design hour and the volume of traffic to be served in that hour, it is clear that a need exists for estimation of traffic demand in some future year.

In rural areas, development and changes in land use are slow. Traffic growth is restricted and can be estimated with adequate accuracy by attaching some constant rate of escalation to present day traffic counts.

Trip Generation, Attraction, Distribution and Assignment

Urban areas, particularly in an era of rapid urbanisation, are much more dynamic in terms of growth and changes in land use. Methods more sophisticated than annual growth factors have to be employed if reliable forecasts of traffic demands are to be made.

Traffic forecasting is a major field of interest of the transportation engineer and it is useful for the geometric designer to have some conception of the source of this basic information as derived by the transportation engineer.

Trip Generation, Attraction, Distribution and Assignment

The first step in the exercise is to estimate the number of trips that are going to emanate from any given origin and many studies have been carried out to develop trip generation factors for various land uses.

Trip attraction factors thus come into play and, for any given land use, it is possible to estimate the number of trips which are going to terminate at a specified destination.

Trip Generation, Attraction, Distribution and Assignment

The third step in the process is the distribution of all these goods- and person-trips among the various modes of transport available.

The final step is to assign all these trips to the network. Network trips are specified in terms of mode and numbers of vehicles and this is the information that the geometric designer ultimately requires as input to the process of planning the road network and ultimately designing the individual links in the network.

Conclusion

This lecture has introduced the concepts of :

- the design vehicle;
- the design speed; and
- the design hour

If these are correctly selected and applied, the designer is halfway towards producing a design appropriate to the function of the road. The road, as built, should then be able to accommodate actual traffic volumes at speeds and levels of comfort acceptable to the driver. The designer must however always be aware of the cost implications of his or her actions.