LECTURE A6 – CROSS-SECTION DESIGN

CONTENTS

Introduction

Road Function

Cross-Sectional Elements

The Design Process

INTRODUCTION

There is a tendency, particularly amongst road authorities and township developers but sometimes shared by designers, to consider the cross-section as a unit, whole and indivisible, in much the same way that the corridor, the horizontal alignment and the vertical alignment are units. As a result, the designer can find himself in the situation whereby the road reserve width is fixed by someone other than himself prior to design of the cross-section.

In the case of the road authority, the road reserve has a status enshrined as a result of years of court cases and legislation.

INTRODUCTION

The developer has an economic incentive to keep the road reserve as narrow as possible. In fact, two incentives apply. In the first instance, a narrow reserve forces the designer to adopt a cross-section containing the minimum of features, including narrow lanes and sidewalks, no provision for parking or, alternatively, parking beyond a mountable kerb in the area which would normally be reserved for pedestrians.

The extent of surface area dedicated to the township street system also dictates the availability of saleable land. Streets can occupy as much as a quarter of the total land area of the township and there is a correspondingly strong desire to reduce street area as far as possible.

INTRODUCTION

The designer will thus be told by the town planner that a certain part of the street system shall have a road reserve no wider than a specified amount.

In both cases the designer find himself in the situation of starting from the answer and working backwards. A more logical approach is to determine what is required in the cross-section and then, as result of this provision, to determine what the road reserve should be. Cross-section design is thus not so much a case of calculation as a reasoned approach towards selection and locating of elements in the available width to ensure that the function required of the road is met.

ROAD FUNCTION

Road function has already been discussed in terms of a spectrum of needs ranging from dedication to accessibility to exclusively mobility, from the residential street to the freeway. The trip type to be served by the road has also been considered. Finally, thought has been directed to the fact that any trip can be subdivided into various components being initiation at a terminal, collection, the through portion, distribution and termination.

A common feature of these considerations is that they largely revolve around addressing the needs of the occupants of a moving vehicle within the limitations of the vehicle.

ROAD FUNCTION

These needs may find expression in a desire for ready access to or from a property adjacent to the road, freedom to manoeuvre in a terminal or intersection area, high-speed long-distance travel. These desires are to be met in terms of overall objectives of safety, economy and minimum side effects. Ultimately, however, the vehicle has to stop.

The scale of design reduces from vehicle size to human size. The pedestrian (defined as a motorist who has found parking) also has desires to be met in terms of safety, convenience and a pleasant environment for walking in addition to the fact that a now slow speed of travel suggests that distances should be kept short.

ROAD FUNCTION

Road functions also have to include consideration in terms of living space. People enjoy the casual encounter, meeting people on neutral territory as it were and without the formal obligations imposed by having to act as host or hostess in the home. Chatting with the neighbours in the street is a case in point. Children riding their bicycles or skateboards naturally gravitate towards the street. To a child, cricket in the street is more of a practical proposition than on the front lawn where a plate glass window may serve as a sight screen and being hit for a six takes on new meaning.

ROAD FUNCTION

In lower income residential areas, individual properties are small and cannot accommodate the recreational needs of the residents. The street therefore can fulfil a real need by becoming part of their living area.

Road function is thus more than just a device aimed at definition of design hour, design speed and design vehicle, ultimately dictating the route and the horizontal and vertical alignment. In determining the cross-section, the designer is forced to consider not only vehicular needs but also a broad range of human aspirations.

ROAD FUNCTION

A road may be required simultaneously to serve conflicting needs. Residential stands abutting a higher-order mixed usage street are a case in point. The designer thus has to assess which of the functions should take precedence and design accordingly.

In a new or developing area, the designer should attempt to avoid multi-purpose roads where there isn't a guiding predominant function. These tend to result in hybrid cross-sections and, like most compromises, they end up doing nothing particularly well.

ROAD FUNCTION

Functions may change along the length of a road. A lower order mixed usage street may become a higher order street residential street may become a collector and ultimately grow up to be vehicle-only route. Route continuity is not necessarily an objective to be pursued at all costs and it may be advisable to consider the application of deliberate discontinuity.

By way of summary, the movement functions that the road must be able to accommodate include service to:

ROAD FUNCTION

1. vehicular traffic in terms of through or turning movements and provision for stationary vehicles which may be parked or stopped, the latter including queuing and the loading or off-loading of freight or passengers

2. other traffic, which includes pedestrians and could include other forms of wheeled vehicles such as bicycles, prams, wheelchairs and animal drawn wagons

3. public utilities, such as electricity, water, telephone lines, gas and sewerage

4. stormwater drainage of the catchment area

ROAD FUNCTION

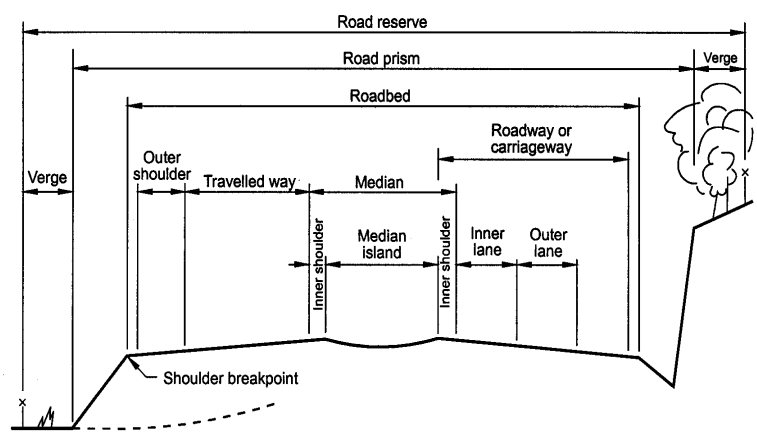
5. stormwater drainage of the reserve itself which can be longitudinal or transverse and above or below ground level including the transition from the one to the other

The last three items were not discussed above but should be self-evident.

Apart from the need for the horizontal and vertical alignment to be designed with safety in mind, certain elements have to be built into the road specifically to enhance safety. For example, Pedestrian safety requires barrier kerbs and Vehicular safety will call for lane markings and refuge for turning traffic.

ROAD FUNCTION

Typical cross-section elements are illustrated below



ROAD FUNCTION

Pedestrian safety does not only concern protection from vehicles but also protection from other pedestrians. Muggings in subways are a case in point and can be minimised by proper design of the subway. Crime operates at its best in the dark and street lighting can thus be a disincentive for the average mugger.

All the elements listed in the preceding two paragraphs form part of the cross-section and it now remains to establish the means of their accommodation.

CROSS-SECTIONAL ELEMENTS

Traffic Lanes

The most obvious element in any cross-section is the traffic lane. A distinction is drawn between basic lanes, which are continuous from end to end of the route, and auxiliary lanes, which are provided to address a specific need and are discontinued once the need has been met.

Auxiliary lanes can be through lanes, i.e. in the direction of travel of the route. These may be required to match the capacity of an intersection with that of the route segment between intersections.

CROSS-SECTIONAL ELEMENTS

They may also be required to remove slow moving vehicles from the traffic stream on a gradient, in which case reference is to climbing lanes.

It is possible that traffic volumes are sufficiently heavy to cause platoon build-up. These platoons can be dissipated by use of passing lanes, typically 500 m long.

Auxiliary lanes can also be provided to accommodate turning movements. These have the effect of removing turning traffic from the through lanes at through lane speeds so that a minimum of impedance is brought to bear on through traffic resulting in improvement of the capacity of the road.

CROSS-SECTIONAL ELEMENTS

These auxiliary lanes typically have three or four separate elements being a deceleration lane, followed by a storage area or possibly a turning roadway, followed in turn by an acceleration lane. The deceleration and acceleration lanes typically commence and terminate respectively with a tapered section, with the degree of taper dictated by the speed at which the vehicles are supposed to transfer from basic lane to auxiliary lane and back.

The designer must select the number of basic lanes required to serve anticipated traffic volumes, and then consider each portion of the road to determine whether or not auxiliary lanes are required and for what purpose.

CROSS-SECTIONAL ELEMENTS

Selection of lane width in the case of basic lanes is based on considerations of anticipated speed, where higher speeds required wider lanes, and traffic volume. High volumes also require wider lanes because vehicles tend to shy away from each other.

South Africa had lane widths ranging from 10 feet to 12 feet and, when we metricated, we opted for widths of 3,1 m, 3,4 m and 3,7 m. The Americans, in metricating their Green Book in 1994, adopted 3,0 m, 3,3 m and 3,6 m. The extra 0,1 m that we stuck on was to allow for road markings.

CROSS-SECTIONAL ELEMENTS

Some urban authorities use lane widths of 5,0 or 5,4 m to allow for parking alongside the moving traffic without having to demarcate parking bays as such. These latter widths cause passenger car drivers to use a single lane as a double lane.

In the case of low volume roads, the need to maintain constant movement of two opposing lanes of traffic reduces. McDonald and Robinson refer to a carriageway width of 5,0 m with 1 m shoulders as being adequate for traffic volumes of 100 to 400 vehicles. They believe that a width of 3,9 m plus 1,5 m shoulders is adequate for volumes of 20 to 100 vehicles per hour and, for less than 20 vehicles per hour a total roadway width (including shoulders) of 2,5 m to 3,0 m is adequate.

CROSS-SECTIONAL ELEMENTS

If auxiliary lanes are intended to serve as through lanes at an intersection, their width should match that of the adjacent through lanes because speeds in these lanes could be similar. Turning lanes can be narrower because speeds are lower and turning flows also not always high. However, at the point at which the turning manoeuvre is actually performed, the lane will have to be widened - especially if it is separated from the adjacent traffic lanes by means of an island, in which case reference is made to a turning roadway. If not separated from the adjacent lanes, and volumes on the crossing street are low, encroachment on these adjacent lanes can be considered.

CROSS-SECTIONAL ELEMENTS

Special purpose lanes are very useful adjuncts to the designer's repertoire. A combination of restricted reserve width and heavily tidal flow could perhaps be accommodated by reversible lanes.

Mass transit may suggest the dedication of lanes to high occupancy vehicles, an example being the bus lane. Heavy right turning flows could suggest common two-way continuous turning lanes for a portion of the route.

CROSS-SECTIONAL ELEMENTS

Shoulders

The shoulder is at the same level as the traffic lane. It can be applied to many purposes, including roadside vending, but the principal intention is that it should cater for emergency stopping. Shoulders may be gravelled or surfaced and, in the latter case, they also serve as informal climbing or passing lanes. In certain instances, traffic is allowed to use the shoulder as a through lane during peak hours.

Shoulder width can be anything from 1,0 m to 3,0 m and the selection of width is largely predicated on traffic volumes in the adjacent lane.

CROSS-SECTIONAL ELEMENTS

If volumes are low, the fact that a stopped car is partially encroaching on the lane is not critical. On the other hand, with high flows, any form of encroachment at all is unacceptable. If flows are as experienced on freeways, the driver would not be able to get out of his vehicle if the shoulder width were less than 3,0 m.

This reference to width is specifically to usable width. If a need for guardrails arises, additional provision must be made for these usually by increasing the distance to the shoulder breakpoint by 800 mm, which allows 300 mm between the guardrail face and the edge of the usable shoulder with 100 mm behind the back of the guardrail post. Traffic signs are usually mounted beyond the shoulder breakpoint.

CROSS-SECTIONAL ELEMENTS

In the case of divided roads, the median comprises a median island and two inner shoulders and the latter are often as little as 1,0 m wide.

The Median

The application of the median was first mooted in the mid-Thirties as "a central island separating the up- and the down-traffic", a function which it admirably fulfils to this day.

The median makes split grading, where the two carriageways have independent gradelines a possibility.

CROSS-SECTIONAL ELEMENTS

The height difference that can be achieved is dependent on the median island treatment, ie as a natural slope or as a retaining wall.

Crossing a multi-lane highway on foot can be a terrifying experience particularly in the South African situation, which suggests that pedestrians achieve invisibility the moment they step off a sidewalk. The median provides a useful central refuge.

Provided it is sufficiently wide, the median also can offer refuge to turning vehicles by accommodating a right-turning lane within its width.

CROSS-SECTIONAL ELEMENTS

A wide median is often a stage in the development of a multilane road that may commence as four-lane divided. The most convenient site for widening is, in fact, within the median island.

Selection of the width of the median is not a trivial exercise. Urban sprawl causes rural roads to become suburban arterials. If the rural road was a dual carriageway, the likelihood is that its median would have been of the order of 9,0 m or wider.

Somewhere, the median must end, and its design must be appropriate to the location.

CROSS-SECTIONAL ELEMENTS

Outer Separator

The outer separator occurs comparatively seldom but serves to separate flows where the road reserve is required to serve two disparate functions such as high speed through flow and local access. It can also be used to accommodate parking bays on the outer side, where a principally pedestrian activity is located at the edge of the reserve.

Central Maputo is a good example of this.

CROSS-SECTIONAL ELEMENTS

Verge

The verge is the home for all the other activities that have to be accommodated by the road reserve. Cycle tracks, pedestrian paths, landscaping and roadside furniture are all located in the verge and it must also accommodate cut and fill slopes, or retaining walls under restricted circumstances.

Passengers boarding or alighting from buses stopped in the through lane can cause substantial queues to develop. A bus bay located in the verge eliminates the problem entirely.

CROSS-SECTIONAL ELEMENTS

Utilities usually are accommodated under the verges. Spatial restraints some times require that they be placed under the carriageway. This is not a desirable state of affairs because manhole covers have to be lifted and reinstated every time the road is resealed. Routine maintenance places workmen at risk and the trenching that seems to be called for at frequent intervals results in a very uneven road surface.

CROSS-SECTIONAL ELEMENTS

With the exception of kerbing and channelling and the associated drop inlets, all storm water drainage is located in or under the verge. The elements that comprise the storm water management system are discussed in a subsequent lecture.

Reference should be made to the Red Book with regard to “hard open spaces” and the functions that they are intended to serve as these will impact on the design of the verge.

THE DESIGN PROCESS

There has been deliberately little or no reference to actual values of the dimensions of cross-sectional elements.

The intention has been to focus on the process whereby the designer commences with the broadest definition of road function and thereafter refines and fills in the list of specific objectives to be met in ever-increasing detail both across and along the length of the road.

The designer must then consider all the cross-sectional elements at his disposal and make a selection of those that best address the situation.

THE DESIGN PROCESS

The selection of elements produces a rough, un-dimensioned sketch of the cross-section.

The sketched cross-section is then dimensioned. These dimensions often derive from other studies, such as capacity studies indicating the number of lanes required for a given flow or the need for auxiliary lanes at intersections.

The cross-section width is then summed and compared to the available road reserve width. Three possible outcomes have to be considered, being that;

THE DESIGN PROCESS

1. at no stage is the available width exceeded, or

2. only at certain isolated points is the available width exceeded, or

3. the available width is exceeded either for considerable stretches of the road or all the time

In the first case, there are clear grounds for satisfaction. The second case indicates that, by and large, the design can be considered acceptable but that some fine tuning may be called for, either by way of accepting the outcome of the design and seeking to obtain the extra territorial requirement or by re-examination of the design at the problem points.

THE DESIGN PROCESS

If the cross-section consistently does not fit the reserve, a major rethink is called for. It may be that the designer has been extravagant in his demand for lebensraum, or that the developer has been overly parsimonious in provision of space.

A decision is then required regarding the functions that are not met. Three possibilities present themselves:

1. These functions are summarily abandoned, or
2. They are provided elsewhere, or
3. The road is rerouted to the extent required to reduce the restraints so that all functions can, in fact, be supplied

THE DESIGN PROCESS

Where public participation is increasingly impinging on the activities of the geometric designer, he would have to discuss such problems not only with his client but with the local residents and business owners as well. It deserves to be noted that, of all the members of the design team, it is the geometric designer who is most likely to be called upon to face inquisitions by irate residents and ratepayers associations.