6 PAVEMENT DESIGN

STRUCTURAL CLASSIFICATION

6.1 The structural or pavement design of the road is the process in which the various layers of the pavement are selected so that they are capable of supporting the traffic for as long as required. The principal elements in this process are the choice of materials and their thickness for each pavement layer.

For structural design, roads can be classified as follows:

- Unimproved earth roads and tracks
- Gravel surfaced roads
- Roads incorporating pavement quality concrete or 'rigid' pavements
- Roads incorporating bituminous materials or 'flexible' pavements.

6.2 The aims in designing a pavement are to protect the natural ground, or subgrade, from the high and concentrated load stresses which would be applied to the subgrade by the wheels of vehicles, whilst at the same time ensuring that the pavement layers are strong enough to support the traffic loads. Since the imposed load stresses are higher nearer to the wheel and the road surface, the traditional type of construction consists of various layers of material with the weakest layer at the bottom and the strongest layer at the top.

6.3 There are various ways of describing the pavement layers and this has often led to confusion. Figure 6.1 illustrates the most common method. The most important layers are the surface layers and the road base since these need to be the strongest.

EARTH ROADS

6.4 Earth roads have no added pavement and layers are therefore not structurally designed. Their performance depends very strongly on their cross-sectional shape (see Section 7), material properties, location in the terrain (see Section 5) and the drainage facilities incorporated in the design (see Section 8). With very low traffic roads, the most important consideration is whether or not the road is passable, since very high costs may be associated with the road being closed. Consideration should be given to the provision of simple drainage structures and local gravelling and improvements to provide all-weather access where appropriate. The engineering aspects of earth roads will not be discussed further.

GRAVEL ROADS

6.5 Roads may be surfaced with gravel to provide traction for vehicles in wet weather at relatively low cost. Surfacing with gravel also retards the increase in deformation of the surface, but regular reshaping is needed as part of recurrent maintenance activities. Even when badly deformed, gravel roads can normally carry traffic successfully as drivers try to avoid deformed areas by choosing different wheelpaths, but vehicle operating costs will be increased considerably as gravel roads deteriorate. Gravel roads normally have properly designed and built drainage structures compared with earth roads and provide all-weather instead of seasonal access.

6.6 Gravel roads are rarely designed in the structural sense. Within the normal range of conditions, differences in performance which can be attributed to gravel thickness are not pronounced except on very weak subgrades. Usually a fixed thickness of gravel (150 mm or

Fig.6.1 Pavement layer description
200 mm) is used irrespective of climate, subgrade strength or traffic loading conditions, and it is replenished periodically as it is worn away. Rates of gravel loss are of the order of 20-30 mm thickness a year per 100 vehicles per day, but this will vary depending on local materials and conditions. The gravel itself should be selected on the basis of its material properties and its expected behaviour under the climatic conditions prevailing. Recommended specifications are given in Tables 3 and 4 of Overseas Road Note 2 (TRRL Overseas Unit 1985).

6.7 If traffic volumes are high, total vehicle operating costs will rise rapidly as the road deteriorates and rates of gravel loss will be correspondingly large. Under these circumstances, there may be some justification for increasing the gravel thickness, but it is often cheaper to provide a surface dressed road. Considerable information has been gained in recent years on the performance of gravel roads under a variety of conditions. It is now possible to estimate the total transport costs associated with a gravel road including vehicle operating costs, maintenance costs and regravelling costs under a variety of traffic, climatic and maintenance conditions using road investment models. Their use is described in Section 10. The traffic level at which a bituminous surface is justified will depend on many factors including the expected rate of gravel loss and the cost of hauling gravel, and can range from 50-800 vehicles per day. It is not possible to give general guidelines for this and each case must be studied individually on its merits using an investment model.

6.8 As with earth roads, the performance of gravel roads depends very strongly on their positioning in the terrain (see Section 5), their cross-sectional shape (see Section 7) and the adequacy of drainage facilities (see Section 8). The engineering aspects of gravel roads will not be discussed further.

CHOICE OF PAVED ROAD CONSTRUCTION TYPE

6.9 Where a paved road is necessary, there are two basic types of construction that can be used. In the past, flexible pavements with an asphalt surfacing have normally been used in most tropical countries because they have provided a more economic solution. However, with variations in oil prices affecting the cost of using bitumen, the cost of using rigid pavements constructed with portland cement concrete has become more competitive, particularly in those countries having their own cement manufacturing capability.

6.10 The choice between flexible and rigid pavements should be made on considerations of the likely cost of both construction and maintenance, the pavement life and effect on road user costs.

RIGID PAVEMENTS

6.11 Feasibility studies for paved roads should normally consider the potential for building in concrete. Particularly in those countries which manufacture their own cement, but import bitumen, the initial costs of construction are likely to be comparable. Even where the initial cost of construction is higher than for a comparable bituminous surfaced road, the reduced maintenance requirement over the design life may make this type of construction more economic in the long term. This should be considered particularly in those countries experiencing difficulties maintaining their road network to an economic standard (see para 2.22-26). It is also probable that the riding quality of concrete, although initially rougher than on bituminous roads, will deteriorate much less, so that future vehicle operating costs will not increase so rapidly.

6.12 A further advantage of concrete roads is that they can be built by labour based methods using skills and technology learned in the building trade. The introduction of concrete technology in the road building sector can also do much to develop local skills and offers scope for the fostering of local contracting industries.

6.13 However, the benefits associated with concrete roads will only be obtained if they are well constructed; if not, remedial works are much more costly than for bituminous roads and vehicle operating costs on a very deteriorated concrete road are likely to be high. Attempts should be made to quantify these longer term effects when comparing the lifetime costs of bituminous and concrete roads. These issues are discussed in Sections 10 and 11.

6.14 No design methods have been produced specifically for concrete roads in developing countries in the tropics. Until such time as a specific method is available, designs should be based on either the ASSHTO (1974), CPCA (1984) or the TRRL (Mayhew and Harding 1987) methods.

FLEXIBLE PAVEMENT MATERIALS

Surfacings

6.15 The essential requirement of all bituminous surfacings is that they should be waterproof. They should also provide a skid resistant surface. Surfacings do not necessarily have to perform a load spreading function because this can often be done by the underlying structural layers.

6.16 The surfacing is the most expensive of all the layers and therefore needs to be kept as thin as possible commensurate with the stresses that it can withstand and the tolerances on thickness which can be achieved with
the construction methods and materials chosen. The following list of surfacing materials is not complete, but it includes the principal types that are met in practice.

6.17 Surface treatments. The simplest type of surfacing is a surface dressing consisting of a thin layer of bitumen into which single sized stone chippings are rolled. This type of surfacing is very flexible and provides a reasonably waterproof seal. Depending on traffic and climatic conditions a single, double or even triple surface dressing may be used. A surface dressing is too thin to provide any structural strength. Other similar surfacings whose main function is to waterproof the road surface are sand seals (sand plus bitumen), slurry seals (graded fine aggregate or sand plus bitumen emulsion) and a combination of slurry seal and surface dressing, often called a cape seal.

6.18 Structural surfacings. There are many types of surfacings which provide substantial structural strength to a pavement. These consist of precisely defined mixtures of bitumen, coarse and fine aggregate, sand and fine material called filler. In order to make them properly, it is usually necessary to mix the constituents in specialised plant and hence the materials are generally known as premix or plant mix. However, in some countries, lower quality materials are often made by mixing on the road itself or by the side of the road, usually by a more labour intensive method. Such methods can be useful for producing patching material, but are rarely practicable for surfacing or resurfacing. The principal types of premixed structural surfacings are as follows:

- **Hot rolled asphalt (HRA).** This type of mix has been used extensively in the United Kingdom. It derives its strength from the properties of a mortar of bitumen, sand and filler. Larger stones are added to the mix mainly to act as an extender. HRA is easier to make successfully than some of the other mixes but has not been used extensively in hot countries because of fears that under hot conditions and heavy traffic it will deform more easily than other mixes. However the deformation properties of HRA can be controlled in the mix design process and can be verified by simple laboratory tests at elevated temperatures. Provided that suitable sand is available, the use of HRA should be encouraged since it is resistant to cracking and therefore provides a more resilient water proof surfacing than other mix types.

- **Asphaltic concrete (AC).** Asphaltic concrete is the most common surfacing material in use on heavily trafficked roads in developing countries. Asphaltic concrete was developed in the USA and derives much of its strength from the interlocking of angular particles within the particle/bitumen matrix. All sizes of particle need to be present in precisely the right proportions to ensure a satisfactory mix. It is more difficult to make than HRA because the proportions of each sized particle need to be more accurately controlled. It can be made very stiff or strong to reduce the risk of deformation occurring at high temperatures, but it is intrinsically rather brittle and thus liable to crack under heavy traffic loads, allowing water to penetrate the road base.

- **Bitumen macadams.** These mixes are similar to AC, deriving much of their strength from the interlocking of angular particles. Dense bitumen macadam (DBM) is suitable as a wearing course. Open textured mixes are suitable as the base course of a surfacing or as road bases (see Figure 6.1) and in other situations where their permeability is of no consequence, such as regulating courses under strengthening overlays on roads which have deformed excessively.

6.19 Mix-in-place surfacings. In some countries, mix-in-place and hand mixed surfacings are constructed for use both on trunk roads as well as more minor roads. The results are not easy to control and the methods are often wasteful in their use of bitumen. Their use is not recommended.

**Road bases**

6.20 The road base is generally the main structural element of a road. Base materials are conveniently divided into three categories.

- **Unbound bases.** Unbound materials are the most common in developing countries. The materials should be a mechanically stable mixture of angular particles of different sizes ranging from about 50 mm in diameter down to dust. Usually rock or gravel needs to be crushed for this purpose although some natural gravels are suitable. It is important that the fine particles should not cause too much weakening of the base when wet, hence they should have little or no clay present. The most common type of unbound base is graded crushed stone, or ‘wet mix’, but other types, such as dry bound macadam and water bound macadam which, despite their names, are two types of unbound aggregate base are frequently encountered.

- **Cement or lime stabilised bases.** If unbound material of suitable strength is not available, use can be made of material which is inadequate in some way. To do this, the material is strengthened and improved by the addition of cement or lime. Not all materials are suitable for lime stabilisation as clay numerals are necessary in the soil for the stabilisation reaction to occur. For both cement and lime stabilisation to be effective, the material to be stabilised should not be too uniform in size and should be free from organic matter.
• **Bitumen stabilised bases.** Bitumen stabilisation is rarely used for lower grade aggregates in road bases because other alternatives are usually cheaper and more reliable. If bitumen is used in bases at all, it is usually because a high strength, high quality pavement is justified and, in such a situation, good quality aggregates will be used to make a premix. One exception to this general rule occurs in areas where there are no aggregates available. Here bitumen stabilised sand is an alternative which can be used successfully for moderate traffic.

**Sub-bases and other pavement layers**

6.21 The quality of material used for sub-base does not need to be as high as for bases. Usually the material is required to meet few selection criteria. The most common materials for use as sub-bases are naturally occurring (unmodified) gravels and gravel-sand-clay mixtures. Sometimes cement or lime stabilised soils are used. Selected fill material and 'capping' layers are of still lower quality and are usually selected on the basis of a simple strength test to ensure a platform of minimum guaranteed strength on which to build the pavement proper.

**Use of marginal materials**

6.22 Specifications for pavement materials used in developing countries have normally been copied from those used in the more industrialised countries. These original specifications have usually been evolved to overcome different climatic and loading conditions to those found in developing countries, such as the need to reduce frost damage. Local experience sometimes suggests that standard specifications can be relaxed to make use of materials that are marginal in quality, but are abundant and relatively cheap to use. The need to do this will be dictated by a lack of conventional materials or a need to build a lower cost road.

6.23 Consulting engineers are often reluctant to allow the use of marginal materials and, in many countries, they are discouraged from trying new techniques. There is often little incentive to propose the use of non-standard techniques under normal contractual arrangements since any benefits are accepted with little acknowledgement, but the results of failure are remembered for a long time. The result is that unnecessarily expensive designs are sometimes recommended.

6.24 The use of marginal materials needs a greater degree of control during construction and may lead to an increased rate of deterioration. However, these materials should always be considered when carrying out pavement design in situations where their use is economic.

**FACTORS AFFECTING FLEXIBLE PAVEMENT DESIGN**

6.25 The structural design of road pavements depends primarily on the following factors:

- strength of the subgrade
- traffic loading
- materials
- variability and uncertainty in the above three items and in the quality control of the construction process.

6.26 In addition, the structural performance of the road will depend on the adequacy of drainage measures within the road structure, the design of the shoulders and the level of maintenance.

**Subgrade strength**

6.27 The most important factor which controls the pavement thickness is the strength of the subgrade soil. This, in turn, depends on the type of soil, its moisture content and the level of compaction (density) achieved during construction. The thickness of pavement required to carry a particular traffic level is very sensitive to subgrade strength when the subgrade is weak, but insensitive to subgrade strength when the subgrade is very strong. The strength of the subgrade can change with time as a result of moisture changes in the soil. Such changes are often associated with poor maintenance and are therefore unpredictable. Designers often include substantial safety factors at this stage of the design process. It is important to estimate the strength of the subgrade under the most likely adverse conditions and guidance on how this can be done is given in Road Note 31 (Transport and Road Research Laboratory 1977 -currently under revision).

**Traffic loading**

6.28 The second important factor to influence pavement thickness is traffic loading. The damage that vehicles do to a road depends very strongly on the axle loads of the vehicles. The exact relationship is influenced by the type of road structure and the way the road deteriorates but a 'fourth power' damage law gives a good approximation for most practical applications. All axle loads are converted to an equivalent number of 80 kN (8.157 tonne) axles, referred to as standard axles, using Figure 6.2. Multiple axles are treated as separate axles for this purpose.

6.29 Figure 6.2 illustrates the importance of axle load surveys for structural design. An increase in axle load of 60 per cent increases the number of standard axles by 700 per cent and the passage of one 13 tonne axle causes as much damage as the passage of eight 8.2 tonne axles.
One of the most common causes of premature pavement failure in third world countries is incorrect estimates of traffic loading. In most developing countries, overloading is common and it is also unwise to assume that axle loads on all roads in a country are similar. It is essential to carry out independent axle load surveys when planning paved road projects. Guidance on how to carry out such surveys is given in Road Note 40 (Transport and Road Research Laboratory 1978). It is important to ensure that traffic cannot bypass the weighing site and that axle loads do not decrease as drivers and vehicle operators become aware of the survey and temporarily reduce the vehicle loads.

6.30 Although traffic induced damage is sensitive to axle loads, once the traffic has been expressed in terms of equivalent standard axles it is found that pavement design thicknesses are much less dependent on traffic load than on subgrade strength. For example, an increase in pavement thickness of ten per cent should enable several hundred per cent more traffic to be carried. Conversely, if the thickness is too low, very rapid failure can be expected.

### Materials

6.31 The third factor which influences thickness is the choice of materials for the construction of the pavement layers themselves. This becomes most significant for the design of very heavily trafficked roads and depends on the detailed mechanisms of deterioration for each type of material. The better design methods available take this into account, but the subject is complex and specialist engineering advice should be sought.

### Variability and uncertainty

6.32 The design must take account of inherent variability in the materials, variability in the quality control, uncertainties associated with climate, in particular rainfall and depth of water table and uncertainties in future maintenance, future vehicle axle loadings and traffic flow levels.

6.33 **Subgrade strength.** The subgrade strength normally varies both along the road alignment, from season to season and from year to year. Soil properties can change within a few metres, but it is quite impractical to change the structural design over short distances, hence a representative value must be chosen for the subgrade strength for design purposes which reduces the risk of early localised pavement failures to acceptable levels. The more soil testing that is done beforehand, the easier it is to reduce the risk in the design and to produce a cheaper pavement. It is recommended that the value of subgrade strength chosen for design purposes should be the lower ten percentile value for each nominally uniform section of subgrade.

6.34 The variation of subgrade strength with time is more difficult to assess. Underneath the centre of an impermeable road the strength remains reasonably constant and its value can be estimated from knowledge of the depth of water table and easily measured properties of the soil. Problems arise when road maintenance cannot be guaranteed to ensure that the surface is always impermeable. The ingress of water through damaged or aged surfaces and shoulders, and the retention of this water through poor maintenance of the drainage systems has a drastic effect on material strength and road performance.
It is not possible to compensate adequately for such effects by means of more conservative designs.

6.35 Materials. Additional problems of variability arise with the aggregates chosen for road bases and, to a lesser extent, sub-bases. There are numerous ways in which the aggregates can fall outside specification and unless sufficient testing of potential quarry sources is done at the feasibility study stage of a project to ensure that all materials are within specification, problems are inevitable. There are so many factors which affect the performance of a road that it is extremely difficult to evaluate the effects of deviations from the specifications for many of the material properties specified. Lack of sufficient testing is likely to give rise to disputes during the construction phase, often with serious financial consequences.

6.36 However, selection of pavement materials is probably one aspect of structural design where large financial savings can be made in road construction, especially for low and intermediate levels of traffic, by using marginal materials as discussed in para 6.22-24, particularly on more lightly trafficked roads.

6.37 Construction control. The construction process itself is seldom as well controlled as expected or desired. Sources of variability arise in all aspects of the work such as the mix proportions of premixed bituminous materials and the degree of road base compaction achieved transversely across the road. Variation in the thickness of the pavement layers is often a major cause for concern because of the extreme sensitivity of traffic carrying capacity to structural thickness. This sensitivity means that small increases in thickness should ensure that the road carries the traffic satisfactorily despite large uncertainties in traffic forecasts providing that the natural variations in thickness arising from the construction process are properly accounted for in the design.

**Shoulders**

6.38 Shoulders are an essential element of the structural design of a road, providing lateral support for the pavement layers. They are especially important when unbound materials are used in the pavement and, for this type of construction, shoulders should be at least two metres wide. Narrower shoulders are acceptable for roads with bound bases (see Section 7). In order to exclude water from the road, at least one metre of the shoulder nearest the road should be impermeable and a surface dressing or other seal should be applied. Unsealed shoulders are not recommended as they often require considerable maintenance if satisfactory performance is to be guaranteed.

**Drainage of pavement layers**

6.39 Drainage within the pavement layers themselves is an essential element of structural design as the strength of the subgrade used for design purposes depends on the moisture content during the most likely adverse conditions. It is impossible to guarantee that roads will remain waterproof throughout their lives, hence it is important to ensure that if any layer of the pavement, including the subgrade, consists of material which is seriously weakened by the presence of water, the water must be able to drain away quickly. To facilitate this, correct camber should be maintained on all layers that are impermeable and a suitable path for water to escape must.

![Fig.6.3 Drainage of pavement layers](image-url)
be provided, either by extending a permeable pavement layer right through the shoulder as indicated in Figure 6.3, or by including a permeable layer within the shoulder.

**PREPARATION AND CHECKING OF FLEXIBLE PAVEMENT DESIGNS**

**Collection of information**

6.40 In order to estimate pavement costs for a feasibility study, it is necessary to carry out a preliminary pavement design. This task should be carried out by a road engineer. If a paved road is being considered, the cost of the pavement will represent a significant proportion of the construction cost, so comparable effort should be put into the design study.

6.41 For most projects, a pavement design life equivalent to 15 years should normally be used to match that of the project analysis period. This not only simplifies the calculation of the residual value at the end of the analysis period, but reduces the problem of forecasting uncertain traffic trends for long periods into the future. However, shorter design periods do increase the accuracy of the assessment.

6.42 Information from the traffic and axle load surveys should be used to determine the cumulative equivalent standard axle loading that the road is forecast to carry over the design life. Information from the geotechnical surveys should indicate the likely availability of materials and the unit costs for using them in pavement construction. All of this information should be used together to prepare several alternative designs. The alternatives should contain different types of pavement construction and should reflect the uncertainties in traffic forecasts.

**Choice of design method**

6.43 Most pavement design methods in current use are derived primarily from empirical studies in Europe and North America. These methods have proved reasonably satisfactory, provided the materials, environment and traffic loading conditions do not differ significantly from those which pertained during the original studies on which the design methods were based. However, the extension of these empirical design methods to the different materials, different weights and volumes of traffic and different environmental conditions found in developing countries can pose serious problems. During the last decade, considerable advances have been made in the theoretical understanding of pavement behaviour. It is now claimed by proponents of the theoretical techniques that cheaper and better roads can be designed using these methods. Whilst this is somewhat overstating the case, it is from this area that future improvements in designs will come, and some developing countries are beginning to introduce some of these ideas into their pavement design methods.

6.44 There is an increasing body of evidence that suggests that the mechanism of deterioration of flexible pavements in tropical countries are often quite different to those in temperate climates. In addition, considerably different structural designs are obtained by using different design charts. Total thickness variations exceeding 100 per cent are not uncommon and, for heavily trafficked roads, even larger differences can occur. There are various reasons for this. Each type of structure behaves differently and therefore the same thickness design would not be expected to apply. Furthermore, criteria for determining terminal conditions, which are inherent in each design method, are often quite different. The result of this is that the designs to carry a particular traffic vary quite significantly from method to method. Inbuilt assumptions in the design methods are not normally described in the published manuals and it is often quite difficult to find them described at all. Technical comparisons between structural designs are therefore always difficult and economic comparisons often impossible.

6.45 Road Note 31 (Transport and Road Research Laboratory 1977–currently under revision) is a general design guide for bituminous surfaced roads in developing countries and emphasises good engineering practice which applies universally. It is based on research by the Overseas Unit of TRRL, but it cannot encompass all of the conditions likely to be encountered in all countries. In particular, extreme conditions of climate and axle loading are not dealt with. This design guide can be used to prepare or to check the pavement design being put forward as part of a project analysis to ensure that the design being proposed is of the correct order of magnitude.

**STRENGTHENING FLEXIBLE PAVEMENTS**

6.46 Strengthening overlays are designed using similar empirical or theoretical techniques as for the design of new roads. Usually some method of non-destructive testing, such as dynamic cone pentrometer or benkelman beam deflection testing, is used to assess the ‘strength’ of the existing road and to determine how much additional strengthening is required. No proven method of overlay design exists for tropical conditions, so, until one is developed, the method described in the Appendix of TRRL Laboratory Report 1043 (Smith and Jones 1982) is recommended. This method should be used either to prepare overlay designs or to check those submitted as part of project reports.
6.47 Problems arise if the road is in poor condition. Under these circumstances, the decision to strengthen the existing road or to rebuild the whole or parts of the road can be difficult. No easy guidelines exist. Conditions along the road will vary so much from place to place that the quantity of pavement layer testing required to assess the structural condition, and the degree of risk attached to overlaying under these circumstances, often mitigates against strengthening in favour of reconstruction. In this situation, engineering judgement plays a major role and risk analysis may be used to help quantify the likely consequences of error. When assessments are made of roads requiring rehabilitation, it is important that sufficient testing is done to enable statistically meaningful results to be obtained. The results will need to be assessed by an experienced road engineer to determine the best remedies.

COSTING

6.48 Costing the design of the new pavement or overlay should be based on final achieved costs in other contracts, as described in Section 4, rather than on current contract rates. Costs are normally specified on a square metre basis for surfacings and on a cubic metre basis for all other layers. However, it is important to ensure that differences in haulage distances and other variables are taken into account, and that realistic prices are allocated for the use of new or modified materials. Local advice should always be sought.

7. GEOMETRIC DESIGN

PURPOSE OF GEOMETRIC DESIGN

7.1 Geometric design is the process whereby the layout of the road in the terrain is designed to meet the needs of the road user. The principal elements of this process are the selection of suitable horizontal and vertical alignments and road widths. The geometric design standards provide the link between the cost of building the road and the costs of the road users. Usually, but by no means always, the higher the geometric standard, the higher the construction cost and the lower the road user costs. Geometric standards are not more than a first approximation to design needs, since it is now accepted that design must be site-specific. The optimal design for a given traffic flow will depend on terrain and other characteristics. Appropriate geometric design standards for use in developing countries are given in Overseas Road Note 6 (TRRL Overseas Unit 1988).

7.2 One of the principal objectives of a feasibility study should be to make recommendations about the geometric design standards for a project such that the optimum balance between road construction cost and road user cost is obtained over the project analysis period. It is vital that decisions are not taken before this is carried out which prejudice the choice of geometric design standard. In the past, insufficient attention has been given to the choice of design standards with the result that roads have been built to standards well in excess of those that are justified by the traffic levels over the life of the project.

7.3 There are few developing countries who have carried out basic research on traffic economics and safety in order to develop their own geometric standards which have therefore been adapted from standards used in industrialised countries. However, the needs of road users in the industrialised countries are usually very different from those in developing countries. In developing countries pedestrians, animal-drawn carts, bicycles, autorickshaws etc are often an important component of traffic mix, even on major highways. In Europe and North America, traffic composition is dominated by the motor car, whilst, in developing countries, lorries and buses often represent the largest proportion of the motorised traffic. As a result, it may be necessary to adapt conventional geometric design standards to meet the needs of all road users by, for example, widening the shoulders of the road to allow their use by slow-moving traffic.

ELEMENTS OF GEOMETRIC DESIGN

7.4 Geometric design covers horizontal and vertical alignments, road width and sight lines. 'Sight distance' is the distance ahead that can be seen by the driver. The sight distance needed for safe stopping from travelling