DESIGN STANDARDS
for
URBAN INFRASTRUCTURE
6 PAVEMENT DESIGN

URBAN SERVICES

6 PAVEMENT DESIGN

6.1 General

This Chapter sets out the requirements for the design of pavements for subdivision roads, arterial roads and rural roads in the ACT.

Unless otherwise specifically stated:

- term *road* is used as a generic term and includes subdivision roads, arterial roads and rural roads;
- in this Chapter, terms *road* and *street* have the same meaning and are interchangeable.

Issues covered in this Chapter:

- subsurface investigations;
- pavement materials
- design traffic;
- design of new flexible pavements;
- design of new rigid pavements;
- pavement rehabilitation;
- Whole of Life Cost Analysis;
- cyclepath and footpath pavements; and
- pavement drainage.

6.2 Related codes of practice and guidelines

6.2.1 Industry standards

AS 1348:1 Road And Traffic Engineering - Glossary of Terms, Road Design and Construction, Standards Australia.

6.2.2 Policy and Guidelines

Guide to the Structural Design of Road Pavements, AUSTROADS

RTA Form 76 Supplement to the AUSTROADS Guide to the Structural Design of Road Pavements, RTA NSW

A Guide to the Visual Assessment of Pavement Condition, AUSTROADS

Guide to Stabilisation in Roadworks, AUSTROADS

APRG Report No. 18 - Selection & Design of Asphalt Mixes: Australian Provisional Guide, AUSTROADS

APRG Report No. 21 - A Guide to the Design of Pavements for Light Traffic, AUSTROADS

Sealed Local Roads Manual – Guidelines to Good Practice for the Construction, Maintenance and Rehabilitation of Pavements, ARRB

Unsealed Roads Manual – Guidelines to Good Practice, ARRB

Standard Specification for Urban Infrastructure Works, ACT Department of Urban Services

AS2150-1995 Hot mix asphalt, Standards Australia

Benefit Cost Analysis Manual, AUSTROADS.

6.3 Pavement materials

6.3.1 Subgrade

Subgrade condition and design parameters should be assessed from subsurface investigations. The program of investigations and laboratory testing should be agreed with the Client.

For greenfield sites, it is preferred that materials were sampled and subsurface condition assessed from test pits rather than drill holes although in assessing existing pavements drill holes are preferred. As a minimum, subsurface investigations and laboratory testing of the subgrade should provide the following results:

- 4 day soaked CBR.
- Particle size distribution.
- Plastic limits, liquid limits and plasticity index (PI), if applicable.
- At least one dynamic cone penetrometer (DCP) test per test pit.

Excavation of test pits should extend below the proposed subgrade level (if known) to sample material and undertake DCP test. If practical, excavation of a test pit should continue minimum 1 metre below the proposed subgrade level.

The following factors should be taken into consideration in determining the design CBR of the subgrade:

- Sequence of earthworks construction.
- Reduction in strength of cut material after placement and compaction in fill areas.
- In situ moisture content at the time of subgrade assessment.
- Specified compaction.
- Moisture variation during the pavement life.
- Subgrade variability.
- The presence of lower strength materials particularly within the first 600mm below the exposed subgrade surface (DCP testing provides excellent and cost effective guide).

The design CBR value is determined in accordance with the *Guide to the Structural Design of Road Pavements*.

Design CBR values derived from in situ DCP results should be used with caution since the DCP results are sensitive to seasonal and moisture variations. Use of design CBR values derived from in situ DCP results should be avoided at later project stages.

For the purpose of mechanistic pavement design, it is assumed that the subgrade is a semi-infinite layer with elastic parameters determined in accordance with the *Guide to the Structural Design of Road Pavements.*

The subgrade performance criterion (failure criterion) is given in the *Guide to the Structural Design of Road Pavements*.

6.3.2 Granular materials

Refer to the *Guide to the Structural Design of Road Pavements* for the design properties of granular pavement materials.

Granular pavements are sub-layered in accordance with the *Guide to the Structural Design of Road Pavements*, unless a granular layer is specified as a working platform.

Designers should take note of locally available granular materials, especially when specifying lower pavement layers such as select material. If high moduli or CBR values are specified (CBR > 8% or modulus greater than 80MPa), the designer must specify the exact source of the material. Designers' attention is specially drawn to the *Standard Specification* addressing select material properties, in particular the pre-treatment requirements.

6.3.3 Bound materials

Bound materials are granular materials produced with addition of binding material to improve strength.

The binding agent could be either cementitious material (cement, lime, slag of other hydraulically binding agent or blend of agents) or bituminous material (cut back bitumen, bitumen emulsion, foamed bitumen or similar).

Design parameters and performance criteria for cementitious stabilised materials are given in the *Guide to the Structural Design of Road Pavements*. Cementitious stabilised materials are very sensitive to construction tolerances (example in Figure 6.1 shows a typical trend). This should be recognised and allowed for in the thickness design as well as in the Specification.

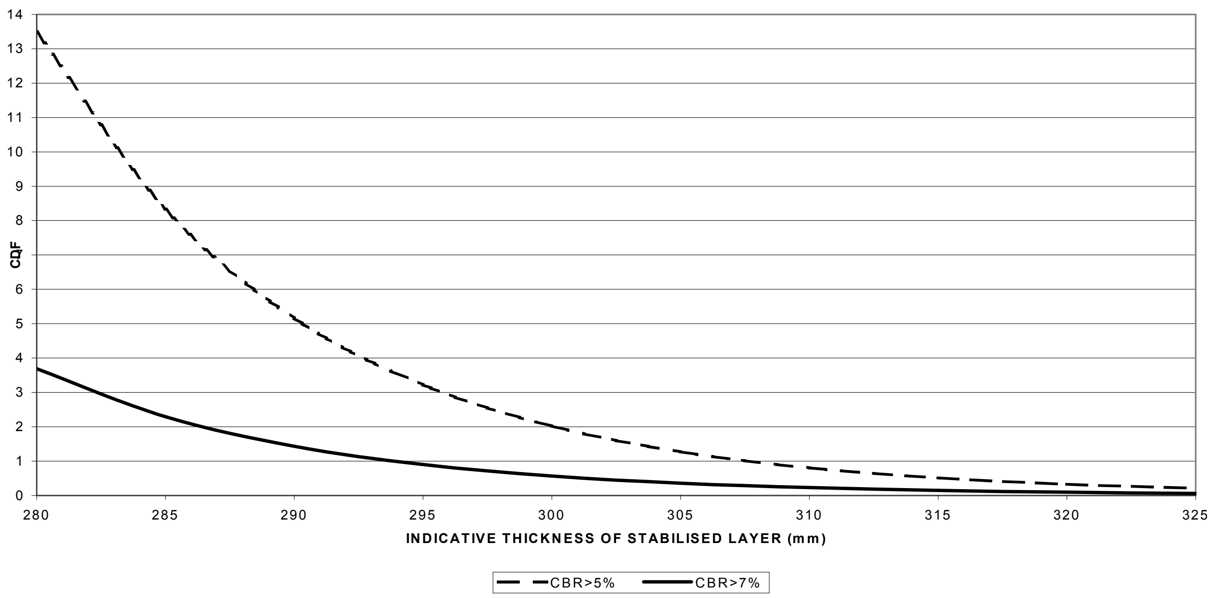

Figure 6.1: Example of a relationship between stabilised layer thickness and cumulative damages factor (CDF)

In the absence of other design criteria, it may be assumed that bituminous stabilised materials behave as asphalt materials therefore their properties and performance criteria are similar to requirements for asphalt given in the *Guide to the Structural Design of Road Pavements*. However, for testing for compliance with the Specification, bituminous stabilised materials are normally regarded as modified granular materials.

6.3.4 Asphalt

6.3.4.1 General

Asphaltic concrete is a combination of bituminous binder and aggregates. The binder is usually a conventional bitumen but for special applications it may be modified by the addition of specific polymers. Design parameters and performance criteria for asphalt materials are given in the *Guide to the Structural Design of Road Pavements*.

In accordance with *AS2150-1995 Hot mix asphalt*, mix types used in Australia are:

- Dense graded hot mix asphalt (DGA);
- Open Graded asphalt (OGA);
- Stone Mastic Asphalt (SMA);
- Fine Gap Graded asphalt (FGGA) and
- Ultra Thin Surfacings (UTA).

The following format should be used to describe asphalt mixes:

AC 14 50 320 R

where:

AC mix type (see above);

14 nominal size, ie the largest aggregate particle size in the mix (5mm to 40mm);

50 gyratory compaction level in cycles (50, 80 and 120 cycles);

320 binder class or type; standard classes are 170, 320 and 600; some other types are Multigrade or Polymer Modified Bitumen (PMB);

R additional suffix to designate special mix requirements (eg *R* stands for bitumen rich mix).

Notwithstanding the provisions of the *Guide to the Structural Design of Road Pavements*, the following three general type asphalt mixes (based on the performance criteria) shall be used in the ACT:

- Residential mix (FGGA);
- Highway mix (DGA); and
- Special surfacing mixes (OGA and SMA).

Mix types are generally not interchangeable without premature defects occurring.

6.3.4.2 Residential mix

Conventional (highway) type mixes have been commonly used for residential streets. Such practice led to “inexplicable” failures of asphalt surfacing on streets that have not received any traffic.

APRG Report No. 18 - Selection & Design of Asphalt Mixes: Australian Provisional Guide discusses performance requirements for residential mixes. It is recognised that, in contrast to the highway mixes, residential mixes should have:

- high density, ie low air voids; and
- high binder content.

Residential mix is usually FGGA 10 50 170 (or 320). The mix should be designed with a minimum of 6.5% of binder (by mass) and should have air void content between 3.5% and 4.5% using 50 cycles gyratory compaction. The following mix composition is proposed as a starting point for the mix design:

Component	% by mass of total aggregate
10mm aggregate	29
Passing 4.75mm aggregate	33
Natural or rounded sand	33
Filler	5
Binder	6.5% by mass of total mix

(source: *APRG Report No. 18 - Selection & Design of Asphalt Mixes: Australian Provisional Guide)*.

For the purpose of the pavement design (see Section 6.4.4 Design of New Flexible Pavements), FGGA shall not be considered as a structural layer.

The above mix is to be also used for asphalt surfaces for paths.

6.3.4.3 Highway mix

The following performance requirements are applicable to the highway mixes:

- high stability, ie deformation resistance; and
- optimum binder content sufficient for cohesion and fatigue resistance.

Properties that are required of a highway mix in order to meet the above performance requirements, and mix design procedure are discussed in *APRG Report No. 18 - Selection & Design of Asphalt Mixes: Australian Provisional Guide*.

6.3.4.4 Special surfacing mixes

OGA should be used in the areas where the following performance requirements are applicable:

- improvement of the surface drainage, ie reduction of potential for aquaplaning and reduction of water spray; and/or
- reduction of the surface generated noise.

For the purpose of the pavement design (see Section 6.4.4 Design of New Flexible Pavements), OGA shall not be considered as a structural layer.

SMA can be used for surfacing of:

- pavements with high curvatures; and/or
- pavements requiring high resistance to deformation.

For the purpose of the pavement design (see Section 6.4.4 Design of New Flexible Pavements), SMA may be considered as a structural layer similar to AC noting of course that the stiffness will be considerably lower than for DGA. If the required SMA surfacing (wearing course) thickness exceeds 50mm-55mm, pavement design should be modified to include a layer of more cost effective DGA and reduce overall thickness of the SMA.

Properties that are required of the OGA and SMA in order to meet the performance requirements and mix design procedures are discussed in *APRG Report No. 18 - Selection & Design of Asphalt Mixes: Australian Provisional Guide*.

6.3.5 Concrete

Two types of concrete are used for the rigid pavements:

- lean mix concrete with 28 days compressive strength of 5MPa (with flyash) or 7MPA (without flyash) is used for sub-base; and
- Portland cement concrete, with 28 days design characteristic flexural strength of 4.25MPa (normally corresponds with the 28 days compressive strength of 32MPa) is used for base.

A bond breaker (bituminous seal, wax or other approved material) is applied between the lean mix sub-base and concrete base. Refer to the *Guide to the Structural Design of Road Pavements* for detailed design procedure.

6.4 Pavement design

6.4.1 General design principles

Pavement design is a process of selection of appropriate pavement and surfacing materials to ensure that the pavement performs adequately and requires minimal maintenance under the anticipated traffic loading for the design period adopted. This selection process involves adoption of material types, thicknesses and configurations of the pavement layers to meet the design objectives.

Performance objectives are to:

- provide safe and comfortable riding conditions to all road users, being motor vehicles, cyclists and pedestrians, optimised for the road's intended function and the level of use;
- provide low cost of ownership (ie minimum whole of life cost) to the ACT Government;
- comply with these Standards and relevant AUSTROADS and other State Road Authorities' Guidelines and/or Standards.

6.4.2 Pavement types

These ACT Standards set out procedures for the design of the following pavement types:

- flexible pavements consisting of granular pavement materials with thin bituminous surfacing ("granular pavements");
- flexible pavements that include one or more lightly bound layers, either in situ or in a plant ("stabilised pavements");
- flexible pavements consisting of predominantly asphaltic concrete layers ("deep lift DGA pavements"); and
- rigid pavements ("concrete pavements").

Flexible pavements consisting of granular pavement materials without dust free surfacing ("gravel pavements") should be considered only for remote rural roads, minor access roads or temporary roads.

This Chapter does not cover the design of special pavements (eg concrete or clay segmental road paving).

6.4.3 Design traffic

The designer should assume that all flexible pavements are to be designed for 20 years design period and rigid pavement for 40 years design period. However the appropriateness of these figures should be verified by the Whole of Life Cost analysis.

Traffic volumes for the pavement design for new residential developments could be assessed by multiplying number of dwellings with an average trip generation per dwelling per day (currently in the ACT: 10 trips per dwelling per day). The design traffic for the light duty road pavements should then be calculated in accordance with *Sealed Local Roads Manual – Guidelines to Good Practice for the Construction, Maintenance and Rehabilitation of Pavements* and *APRG Report No. 21 - A Guide to the Design of Pavements for Light Traffic.*

Typically, the following design traffic could be adopted for the design of all light duty flexible pavements:

Street type	Design traffic based on 20 years design period (ESA)
Access streets	1×10^4
Minor collector roads (no buses)	1×10^5
Major collector roads (with buses)	1×10^6

The design traffic for the medium duty, heavy duty and very heavy duty road pavements will be calculated in accordance with the *Guide to the Structural Design of Road Pavements*.

Typical values of the design traffic for the design of all flexible pavements other than the light duty ones are:

Road type	Design traffic based on 20 years design period (ESA)
Sub-arterial road	5×10^6
Arterial road	1×10^7
Parkway	$>1 \times 10^7$

The design period to be adopted should be assessed on a case-by-case basis utilising Whole of Life Costing Analysis. In general, very high traffic volumes combined with a low growth rate may favour longer design life

Existing traffic volumes should be assessed from traffic counts. For the purpose of calculation of AADT from peak hour traffic volumes, it should be assumed that peak hour traffic volumes represent between 10% and 12% of AADT.

Future traffic volumes and growth rate will be based on results obtained from a traffic model calibrated for Canberra.

Some values of growth factor for most common combinations of growth rate and design period are given in the *Guide to the Structural Design of Road Pavements*. Growth factor for unlisted combinations of growth rates and design periods could be calculated as:

$$GF = \frac{(1+GR)^n - 1}{GR}$$

where:

GF growth factor

GR growth rate

n design period

The ESA/CV conversion factor should be assessed from a weight in motion count or classified traffic counts. If suitable traffic counts were not available, an appropriate ESA/CV must be submitted to Roads ACT for approval prior to carrying out the design.

Design traffic for the design of rigid pavements should be calculated in accordance with the *Guide to the Structural Design of Road Pavements* or *APRG Report No. 21 - A Guide to the Design of Pavements for Light Traffic* as appropriate.

The designer should be aware of the risks attributed to, among other things, the uncertainty associated with predicted traffic volumes and traffic composition. Therefore, the designer should consider adopting design traffic values higher than calculated as discussed in the *Guide to the Structural Design of Road Pavements.* The reliability factors presented in RTA Form 76 may be used pending the release of the new Austroads Guide.

6.4.4 Design of new flexible pavements

Road pavements shall be designed using the following guidelines and standards:

- mechanistic procedure in accordance with the *Guide to the Structural Design of Road Pavements* supplemented by RTA Form 76 for design traffic over $1x10^6$ ESA;
- empirical procedure in accordance with the *APRG Report No. 21 - A Guide to the Design of Pavements for Light Traffic* for design traffic less than $1x10^5$ ESA;
- using both mechanistic and empirical procedures, then adopting greater pavement thickness, for design traffic between $1x10^5$ ESA and $1x10^6$ ESA.

The designer should be taken into account the following:

- AC moduli of thin layers historically produced in the ACT are in the order of 2,800MPa to 5,000MPa. For design purposes, minimum modulus of 3,500MPa shall be adopted for a thin AC layer on granular pavement (preferably, the designer should assess and report on the asphalt fatigue for a range of moduli between 3,500MPa and 5,000MPa). Pavement design shall always be conservative, ie thin asphalt layer on granular pavement should use higher values of moduli and full depth asphalt pavement lower values of moduli.
- When calculating design moduli of deep lift AC pavement layers the designer should take into account traffic speed of the road and/or intersection. These moduli are typically lower than the thin layer moduli.
- The modulus of the asphalt layer overlaying cementitious stabilised base is maximum 1,000MPa.
- The pavement life multiplier should be applied to the design traffic. The modified value of the design traffic should then be used for any part of the design procedure related to the asphalt layers in accordance with the *Guide to the Structural Design of*

Road Pavements. Typical values of the pavement life multipliers in the ACT for a range of day/night time spectra are given in Figure 6.2.

- For the calculation of damage of the pavement layers from the design traffic, the following constants should be used:
  - for structural asphalt layers: 1.1
  - for subgrade: 1.1
  - for bituminous stabilised materials: 1.1
  - for cementitious stabilised materials: 10.0
- Design traffic at an intersection should be calculated by adding the design traffic applicable to one road to the design traffic applicable to the cross road. Selection of the pavement structure should be based on minimum maintenance requirements. Selection of the pavement surfacing (wearing course) should be based on the performance criteria, the two most important being deformation resistance and skid resistance. Wearing course asphalt for intersections (including roundabouts) and their approach and departure legs on roads with a design AADT > 3,000 vehicles per day is to be PMB AC, SMA or PMB SMA, depending on the percentage of heavy vehicles in the traffic flow. A factor of 4 should be applied to the traffic loading at intersections, in accordance with Section 7.9 of the *Guide to the Structural Design of Road Pavements* to alleviate risks associated with the design traffic, variable subgrade condition and variable pavement material properties. Rutting and shoving problems should be catered for by the selection of an appropriate mix design.
- Cementitious stabilised layers should be primed and sealed with a 7mm or a 10mm PMB SAMI prior to applying asphalt.
- The designer should specify the following design parameters on the drawings:
  - design moduli of the various layers (for flexible pavements) or concrete compressive and flexural strengths (for rigid pavements);
  - subgrade CBR;
  - design traffic in ESAs (for flexible pavements) or CVAGs (for rigid pavements);
- Working platforms should not be considered as a structural layer. This approach attracts lower risk. Including a 100mm granular layer with a modulus of some 100-120MPa would add marginally to the structural capacity of the pavement.
- Trafficking of a high bitumen content base layer (deep lift AC pavements) should be avoided without application of an intermediate layer. If early trafficking of the base layer could not be avoided, both base layer and intermediate layer of the asphalt mixes should be standard mixes (ie normal bitumen content) with either PMB or Multigrade (say 170/600) binder.

6.4.5 Rehabilitation of existing pavements

6.4.5.1 Visual assessment

Existing pavement condition will be assessed in accordance with *A Guide to the Visual Assessment of Pavement Condition.*

6.4.5.2 Subsurface investigations

Existing pavements' structure and subgrade condition should be assessed from excavation of test pits. Drill holes should be avoided except for logging the pavement structure, visual soil classification and visual assessment of moisture content.

As a minimum, subsurface investigations and laboratory testing of existing pavement materials subgrade should provide the following results:

- 4 day soaked CBR (subgrade and select material, if latter is present);
- particle size distribution;
- plastic limits and liquid limits (PI), if applicable;
- at least one DCP test per test pit at top of sub-base and/or top of subgrade level;
- in situ densities of base course in a wheel path and between wheel paths; and
- in situ densities of subgrade between wheel paths.

Excavation of test pits in existing pavement should stop at the top of base course level, top of sub-base course level and top of subgrade level to sample material and undertake in situ testing. If practical, excavation of a test pit should continue minimum 600mm below the subgrade level.

The design CBR value should be determined in accordance with the *Guide for the Structural Design of Road Pavements*. Design CBR values derived from in situ DCP results should be used with caution since the DCP results are sensitive to seasonal and moisture variations. Use of design CBR values derived from in situ DCP results should be avoided at later project stages.

The subgrade performance criterion is given in the *Guide for the Structural Design of Road Pavements.*

6.4.5.3 Assessment of pavement structural capacity

The assessment of the structural capacity of an existing pavement should be undertaken in accordance with the *Guide for the Structural Design of Road Pavements*.

The preferred method for the deflection testing is electronic Benkelman Beam. In the absence of Benkelman Beam results, deflection testing results obtained using Deflectograph or PASE could be converted to the equivalent Benkelman Beam values using conversion factors approved by Roads ACT.

For easier comparison, it is possible to associate the deflection testing results to the equivalent asphalt overlay thickness. The deflection testing results obtained using a Falling Weight Deflectograph are normally presented as the equivalent asphalt overlay thickness for comparison with the Benkelman Beam results. The advantage is that deflection and curvature values have a physical meaning. Maximum deflection can be described as being equivalent to, say, "35mm overlay" instead as a comparison with an abstract value, say, "0.241 over the design deflection".

6.4.5.4 Other factors

The following factors should be taken into account when assessing existing pavement and selecting an appropriate rehabilitation strategy:

- Operation of the existing drainage system.
- Environmental effects.
- Presence of the underground services.
- Impact on the existing drainage system, in particular the existing kerbs, gutters and sumps.
- Construction associated risks (eg. inclement weather, unsuitable subgrade, plant breakdown, etc).
- Public inconvenience.
- Temporary traffic management.
- Maintenance requirements.
- Whole of life cost.

6.4.5.5 Whole of life cost

The Whole of Life Cost analysis is carried out in accordance with the *Guide to the Structural Design of Road Pavements*.

At the early stages of the analysis when a range rehabilitation strategies are compared, the construction cost is usually supplemented with the unit rate cost of the pavement and the maintenance and rehabilitation cost with the unit rate cost of the treatment. However, the designer should take notice that different pavement rehabilitation strategies may attract different additional cost associated with, for example, modification of kerbs, drainage, barriers, etc. In these circumstances, the designer should take into account all other costs and include them in the total construction cost or in the unit rate cost.

6.4.5.6 Cycleway and footpath pavements

Cyclepath and footpath pavements shall be designed in accordance with these Standards supplemented with *APRG Report No. 21 - A Guide to the Design of Pavements for Light Traffic*.

6.4.5.7 Pavement drainage

Pavement drainage should be provided:

- On unkerbed roads, by sub-soil drains installed at the edge of the shoulder as shown in Standard Drawings; or
- On kerbed roads, by sub-soil drains installed in front of the kerb or the gutter lip, with depth minimum 1.0m below the finished surface level and longitudinal grade of minimum 1.0% (refer to Standard Drawings).

In special cases, a combination of a table drain and a sub-soil drain could be appropriate.

The sub-soil drain should extend up to the underside of the base course, ie:

- For granular pavements, to the bottom of the fine crushed rock material.
- For stabilised pavements, to the bottom of the lowest stabilised layer.

- For deep lift AC pavements, to the bottom of the lowest asphalt layer.
- For concrete pavements, to the bottom of the base concrete.

If a sub-soil drain is located in the wheel path, a consideration should be given to using 75mm thick no fines concrete capping to the sub-soil drain.

6.5 Glossary

AADT: *Annual Average Daily Traffic is determined by measuring the number of axle pairs crossing at a specific site per year and dividing this number by 365.*

At most sites, the number given is the sum of both directions.

The number does not take into account the volume of vehicles with more than two axles. Hence, the AADT must be factored down to represent the actual number of vehicles passing the site

Carriageway: *That portion of a road or bridge devoted particularly to the use of vehicles, inclusive of the shoulders and auxiliary lanes.*

Design Life: *The period during which the quality of a structure (eg. Riding quality of a pavement) is expected to remain acceptable.*

Design Traffic: *The cumulative traffic, expressed in terms of equivalent standard axles, predicted to use a road over the structural design life of the pavement.*

Design Vehicle: *A hypothetical road vehicle whose mass, dimensions and operating characteristics are used to determine geometric requirements.*

Design Year: *The predicted year in which the design traffic would be reached.*

Drainage: *Natural or artificial means for the interception and removal of surface of subsurface water.*

ESA: *Equivalent standard axle (see* Guide to the Structural Design of Road Pavements *for the full definition).*

Footpath: *A public way reserved for the movement of pedestrians and manually propelled vehicles.*

Grade: *A length of carriageway sloping longitudinally.*

The rate of longitudinal rise (or fall) of a carriageway with respect to the horizontal, expressed as a percentage.

To design the longitudinal profile of a road.

To secure a predetermined level or inclination to a road or other surface.

To shape or smooth an earth, gravel, or other surface by means of a grader of similar implement.

To mix aggregates according to a particle size distribution.

Intersection: *A place at which two or more roads at grade or with grade separation.*

Intersection (at-grade): *An intersection where carriageways cross at a common level.*

Intersection Leg: *Any one of the carriageways radiating from and forming part of an intersection.*

Kerb: *A raised border of rigid material formed at the edge of a carriageway.*

Lane (Traffic): *A portion of the paved carriageway marked out by kerbs, painted line or barriers, which carries a single line of vehicles in one constant direction.*

Pavement: *That portion of a road designed for the support of, and to form the running surface for, vehicular traffic.*

Road(way): *A route trafficable by motor vehicles; in law, the public right-of-way between boundaries of adjoining property.*

Roundabout: *An intersection where all traffic travels in one direction around a central island.*

Table Drain: *The side drain of a road adjacent to the shoulder, having its invert lower than the pavement base and being part of the formation.*

Terrain: *Topography of the land.*

Traffic: *A generic term covering all vehicles, people, and animals using a road.*

Working platform: *A thin granular layer (usually 100mm thick sub-base) placed over poor quality subgrade to improve workability and prevent loss of the pavement material into the subgrade.*

6.6 Standard Drawings

Title	**Drawing Number**
Subsoil Drainage Standard Details Sheet 1	DS6-01
Subsoil Drainage Standard Details Sheet 2	DS6-02