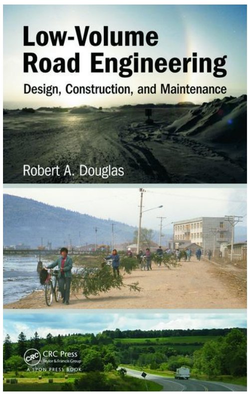

Low-Volume Road Engineering: Design, Construction, and Maintenance

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Pavement concepts

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Chapter 5

Pavement concepts

5.1 INTRODUCTION

While Chapter 7 covers pavement design, the basic concepts of pavements (this chapter), and an understanding of pavement materials (the next chapter) need to be discussed first. This chapter covers the purposes of pavements, the components of road cross sections, common pavement structures, and the load-carrying mechanisms the different pavement types develop.

5.2 PURPOSES OF PAVEMENTS

Pavements must serve multiple purposes. Layers of pavement materials are placed on the native soil—the subgrade—to protect it from the stresses imposed by vehicles that it cannot withstand itself. In fact, each layer of the pavement protects the layer beneath it, thus the strongest layers of the pavement are usually found at the top of the pavement structure. Pavements are designed to provide smooth and safe running surfaces for vehicles. The smoother the surface, the less wear and tear on the vehicles using it, and the faster the possible running speed. Pavements enhance the resistance to the scuffing and abrasion imposed by tires, particularly where vehicles impose severe shear stresses in areas such as intersections, sharp curves in the road, or parking areas. Safety is enhanced by high vehicle skid resistance, particularly in wet weather. While the pavement should be smooth on the macro scale for comfort, the texture of the surface and even the individual particles should be rough enough to generate sufficient wet skid resistance.

Well-designed pavements offer low rolling resistance to the tires of the vehicles using them. This is especially important for industrial haul roads. The stiffer the pavement structure, the lower the rolling resistance and therefore fuel consumption, and as a consequence, the lower the cost of operating the vehicles using the road.

While satisfying all these requirements, well-designed pavements make optimum use of the materials needed to construct them, striking the balance between pavement capital cost, design life, maintenance requirements,

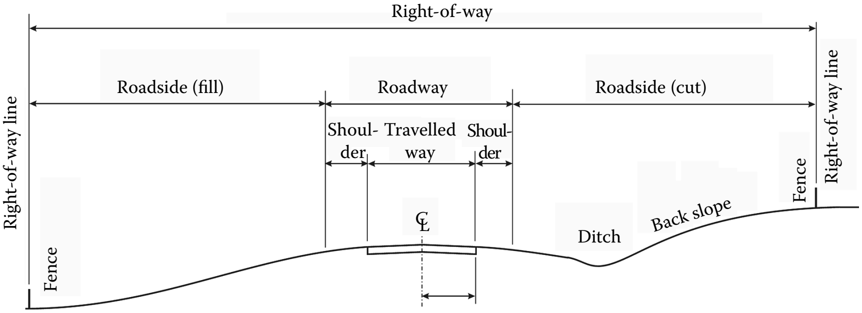

Figure 5.1 Road cross section terminology, North America.

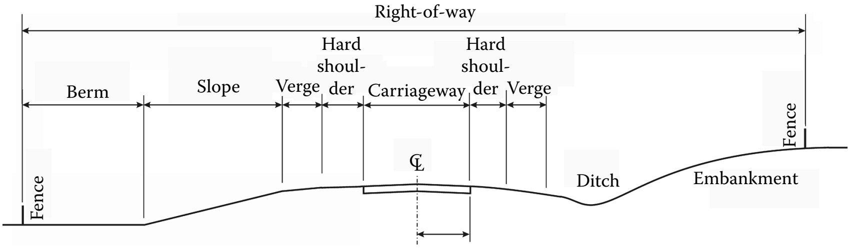

Figure 5.2 Road cross section terminology, Commonwealth countries except Canada.

and vehicle operating costs. Recently, more attention is being paid to the use of aggregates, with designers attempting to minimize the use of what is ultimately a finite resource. Interest in the use of marginal materials and recycled materials is rising.

5.3 ROAD CROSS SECTION COMPONENTS

It is vitally important that designers, constructors, and maintainers speak the same language when discussing the cross-sectional components of their pavements. Specifications and drawings must use consistent and recognized terminology. Unfortunately, the terminology is not consistent around the world. The terminologies prevalent inside and outside North America are indicated in Figures 5.1 and 5.2.

5.4 PAVEMENT STRUCTURES

Pavements are distinguished as *rigid* or *flexible*. Rigid pavements are constructed of Portland cement concrete. Such pavements are often just simply called “concrete,” or, erroneously, “cement.” Flexible pavements are essentially all other pavements: asphalt, bituminous surface treated, crushed rock or crushed gravel, or compacted soil. The layers in typical rigid and flexible pavements and their load-carrying mechanisms are different.

5.4.1 Rigid pavements

The surface layer of a rigid pavement is a concrete slab, which can be constructed in a number of ways, including

- *Plain, jointed, unreinforced*
- *Jointed and reinforced*, with or without dowels across the joints
- *Continuously reinforced*

Beneath the slab the pavement is built with a granular *base* (Figure 5.3a). The base provides drainage for water that penetrates the slab, as well as protection from frost damage. It also serves as a platform for construction of the slab.

Under the base is the *subgrade*, the native soil at the site (or the top of embankment fill if it exists). During construction, the subgrade should be proof-rolled before the pavement structure is built on it, and any soft, loose, wet, organic, or otherwise weak material subexcavated and replaced with clean, well-compacted base material fill.

5.4.2 Flexible pavements

Flexible pavements have a bituminous, aggregate, or soil surface on which the vehicles travel (Figure 5.3b). If the surface is asphalt, there may be more than one layer, with the *surface course* or *wearing course* underlain by one or more asphalt layers called the *binder(s)* or *base course(s)*. The surface course may be a bituminous surface treatment ("tar and chip," "chip seal"),

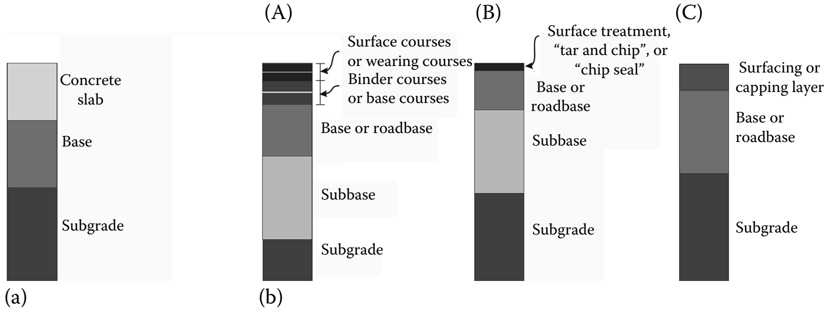

Figure 5.3 Pavement layers in (a) rigid pavements, and (b) flexible pavements ((A) asphalt, (B) surface-treated, (C) aggregate).

or it could be a granular layer consisting of crushed rock, crushed gravel, or gravel. Some designers of industrial haul roads call the surfacing course the *capping layer.*

Beneath the surface layer, flexible pavements usually have a granular *base* or *roadbase*. The base layer is usually designed to be well draining, so that water that penetrates the surface layer can be carried to the sides, out of the pavement structure. Water movement is enhanced by having all layers in the pavement crowned (cambered or constructed with a crossfall). Crossfalls of 2% and 4% are appropriate for asphalt and granular road surfaces, respectively. The granular road surfaces need a higher crossfall to overcome the greater impedance presented by the rough surface to the flow of water, because rutting may counteract drainage, and because grading operations tend to flatten the crossfall. It is a common error to specify too little crossfall for granular road surfaces—2% is inadequate.

Under the base layer the pavement may be designed with a *subbase* layer. The subbase is usually gravelly or sandy well-draining pit-run material. Beside drainage and protection of the subgrade beneath it, in cold regions the subbase is constructed of non-frost-susceptible material. This serves to increase the depth of non-frost-susceptible materials in the pavement structure, so the penetration of the frost front does not reach frost-susceptible soil and cause heaving.

The subbase is in turn underlain by the subgrade, the native soil at the site (or the top of embankment fill if it exists). During construction, the subgrade should be proof-rolled before the pavement structure is built on it, and any soft, loose, wet, organic, or otherwise weak material subexcavated and replaced with clean, well-compacted subbase material fill.

5.4.3 Variations

There are numerous variations beyond those listed here. For example, asphalt variations include full depth and deep strength pavements. The granular layers of any of the types of pavements can be treated with Portland cement, lime, fly ash, bitumen, or other chemicals or additives (as appropriate to the material) to stiffen them. Composite pavements are rigid pavements with the slab surfaced with asphalt. “White-topping” is the inverse of that, with Portland cement placed on an asphalt pavement.

5.5 PAVEMENT LOAD-CARRYING MECHANISMS

The load-carrying mechanisms—the resistances to bending, compressive, tensile, and shear stresses—are markedly different for rigid and flexible pavements. For all pavements, the goal is to reduce the stresses in the subgrade to a tolerable level, to avoid large strains and thus severe rutting or failure, but how the two types of pavement do this is different.

5.5.1 Rigid pavements

The slab of a rigid pavement has significant bending resistance, acting like a bending plate. Vertical deflection of the slab is negligible, and the vertical contact stress on the top of the base is widely spread (Figure 5.4a). In turn,

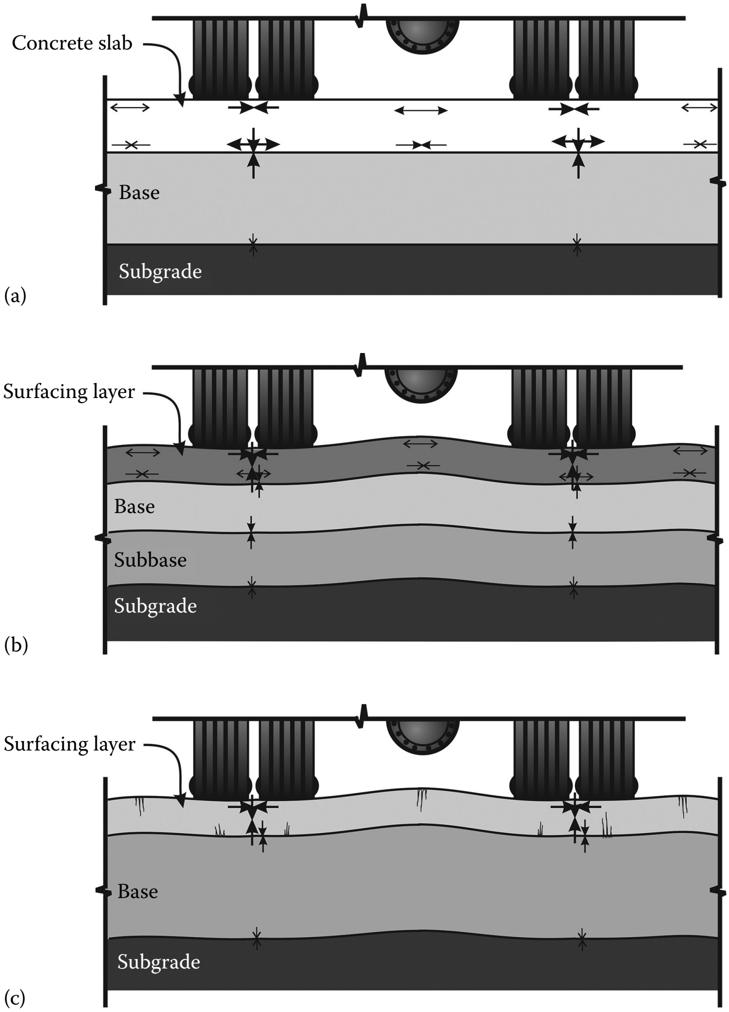

Figure 5.4 Load-carrying mechanisms for (a) rigid pavements, (b) flexible asphalt pavements, and (c) flexible granular pavements. Arrow direction and weight indicate compression or tension, and relative magnitude of the stresses. Note the bending stresses in the slab of the rigid pavement, the weaker bending stresses in the asphalt pavement, and the lack of tension in the granular pavement. Cracking in the granular pavement is shown on the top surface outside the dual wheels and in the bottom of the surfacing layer under the dual wheels. Note that for simplicity, the crossfall has not been shown.

the compressive stress transmitted by the base to the subgrade is dispersed and decreased even more, to the point where vertical displacement of the subgrade is negligible. Faulting at slab joints is avoided by specifying tongue and groove edges and/or dowels.

5.5.2 Flexible pavements

Unlike a rigid pavement, a flexible pavement exhibits detectable vertical elastic deformation under load. Asphalt surface layers have low bending resistance compared to concrete slabs. Bituminous surface treatments and granular surface layers have little or no resistance to tensile stresses and therefore little or no bending resistance. The pavement bends, resisting the imposed load in compression and shear rather than bending, the compressive and shear stresses diminishing with depth (Figure 5.4b and c). If the pavement layers are sufficiently thick and strong, the vertical stresses on the subgrade are tolerable. The subgrade is safe from a bearing capacity failure, and the compressive strain in the subgrade is small enough that no significant rutting is observed at the road surface.