DESIGN OF PAVEMENT AND ALIGNMENT OF RURAL ROAD

Tanveer Hussain
Gurukul Vidyapeeth Institute Of Engineering And Technology,
Maharaja Ranjeet Singh Technical University

I. INTRODUCTION

1.1 Preamble:
Transportation is necessary for a nation’s growth and development. In fact, it has consumed a considerable portion of human race’s time and resources for as long as it has existed. Several factors should be taken into account in a pavement design, for example the traffic flow, the asphalt mixtures materials and also the environmental factors… which will define, all of them, the pavement performance. Pavement performance is defined as the ability of a pavement to satisfactorily serve traffic over time (AASHTO, 2003). The serviceability is defined as the ability of a pavement to serve the traffic for which it was designed.

Integrating both definitions will yield a new understanding of the performance which can be interpreted as the integration of the serviceability over time (Yoder and Witzack, 1975). Usually it is required a traffic evaluation for both design and rehabilitation. Since the pavement of the new road or that under rehabilitation is usually designed for periods ranging from 10 to 20 years or more, it is to estimate or predict the design loads for this period of time accurately.

A satisfactory pavement has to respect some conditions regarding the asphalt surface that has to exhibit sufficient strength and stiffness, also, adequate sub-base layer strength to provide sufficient bearing capacity to the pavement. Moreover, a stable subgrade and adequate drainage system should be installed to eliminate moisture and avoid base layer instability. Finally a regular maintenance plan should be fixed in order to avoid the pavement deterioration.

II. METHODOLOGY

The informations in this thesis were gathered from different sources: in order to study the different types of pavements and the characteristics of each one, several publications and articles were used. Other articles and books helped to understand the pavement maintenance procedure and also the pavement recycling. The AASHTO, TAC and the PIARC books were used to study the technical sheets, and other official reports helped to get informations about the project site and its characteristics. All the statistics and data used in this thesis were gathered from the official web pages.

2.2 Structural components of a flexible pavement:
Flexible pavements consist of a subgrade (prepared roadbed), the sub-base, the base and the wearing surface. This latter, when made of Hot Mix Asphalt becomes stiffer and contribute more to the pavement strength.
2.3.1.2 Block Cracking and Transverse (Thermal):
Block cracking is the cracking of an asphalt pavement into rectangular pieces ranging from approximately 30 cm to 300 cm on a side. Block cracking occurs over large paved areas such as parking lots, as well as roadways, primarily in areas not subjected to traffic loads, but sometimes also in loaded areas. Thermal cracks typically develop transversely across the traffic lanes of a roadway.

2.3.1.3 Potholes:
A pothole is a bowl-shaped hole through one or more layers of the asphalt pavement structure, between about 15 and 90 centimeters in diameter. Potholes begin to form when fragments of asphalt are displaced by traffic wheels, e.g., in alligator-cracked areas. Potholes grow in size and depth as water accumulates in the hole and penetrates into the base and subgrade, weakening support in the vicinity of the pothole.

2.3.1.4 Rutting:
Rutting is the formation of longitudinal depression of the wheel paths, most often due to consolidation or movement of material in either the base or subgrade or in the asphalt layer. Another, unrelated, cause of rutting is abrasion due to studded tires and tire chains. Deformation which occurs in the base and underlying layers is related to the thickness of the asphalt surface, the thickness and stability of the base and sub-base layers, and the quality and uniformity of subgrade support, as well as the number and magnitude of applied loads.

2.3.1.5 Longitudinal Cracking:
Non-wheel path longitudinal cracking in an asphalt pavement may reflect up from the edges of an underlying old pavement or from edges and cracks in a stabilized base, or may be due to poor compaction at the edges of longitudinal paving lanes. Longitudinal cracking may also be produced in the wheel paths by the application of heavy loads or high tire pressures.

3.1 Introduction:
Generally, Pavements are divided into two main categories: Rigid and Flexible. The wearing surface of rigid pavements is usually constructed of Portland cement concrete such that it acts like a beam over any irregularities in the underlying supporting material. The wearing surface of flexible pavements, on the other hand, is usually constructed of bituminous materials such that they remain in contact with the underlying material even when minor irregularities occur. Flexible pavements usually consist of a bituminous surface underlaid with a layer of granular material and a layer of a suitable mixture of coarse and fine materials. Traffic loads are transferred by the wearing surface to the underlying supporting materials through the interlocking of aggregates, the frictional effect of the granular materials and the cohesion of the fine materials. Flexible pavements are further divided into three subgroups: High type, intermediate type and low type. High type pavements have wearing surfaces that adequately support the expected traffic load without visible distress due to fatigue and are not susceptible to weather conditions. Intermediate type pavements have wearing surface that range from surface treated to those with qualities just below that of high type pavements. Low type pavements are used mainly for low cost roads and have wearing surfaces that range from...
untreated to loose natural materials to surface-treated earth. (Traffic and highway engineering, 1999).

3.2 Types of Pavements:
There are several kinds of pavement there can be used for multiple purposes. It often happens that some pavements can be used for more than one type of vehicle/transportation or load, but often only few are suitable for the purpose they are designed for.

3.2.1 Flexible Pavement:
A flexible pavement structure is typically composed of several layers of material with better quality materials on top where the intensity of stress from traffic loads is high and lower quality materials at the bottom where the stress intensity is low. Flexible pavements can be analyzed as a multi-layer system under loading. A typical flexible pavement structure consists of the surface course and underlying base and sub base courses. Each of these layers contributes to structural support and drainage. When hot mix asphalt (HMA) is used as the surface course, it is the stiffest and may contribute the most to pavement strength, which is depending on the thickness. The underlying layers are less stiff, but are still important to pavement strength as well as drainage and frost protection. When a seal coat is used as the surface course, the base generally is the layer that contributes most to the structural stiffness. A typical structural design results in a series of layers that gradually decrease in material quality with depth.

3.2.2 Rigid Pavement:
A rigid pavement structure is composed of a hydraulic cement concrete surface course and underlying base and sub base courses (if used). Another term commonly used is Portland cement concrete (PCC) pavement, although with today’s Pozzolanic additives, cements may no longer be technically classified as “Portland”. The surface course is the stiffest layer and provides the majority of strength. The base or sub base layers are orders of magnitude less stiff than the PCC surface but still make important contributions to pavement drainage and frost protection and provide a working platform for construction equipment.

Rigid pavements are substantially ‘stiffer’ than flexible pavements due to the high modulus of elasticity of the PCC material, resulting in very low deflections under loading. The rigid pavements can be analyzed by the plate theory. Rigid pavements can have reinforcing steel, which is generally used to handle thermal stresses to reduce or eliminate joints and maintain tight crack widths. Figure 3.2 shows a typical section for a rigid pavement.

3.2.3 Composite Pavement:
A composite pavement is composed of both hot mix asphalt (HMA) and hydraulic cement concrete. Typically, composite pavements are asphalt overlays on top of concrete pavements. The HMA overlay may have been placed as the final stage of initial construction, or as part of a rehabilitation or safety treatment. Composite pavement behavior under traffic loading is essentially the same as rigid pavement.

3.2.4 Perpetual Pavement:
Perpetual pavement is a term used to describe a long-life structural design. It uses premium HMA mixtures, appropriate construction techniques and occasional maintenance to renew the surface. Proper construction techniques need to be kept in mind to avoid problems with permeability, trapping moisture, segregation with depth, and variability of density with depth. A perpetual pavement can last 30 yr. or more if properly maintained. Structural deterioration typically occurs due to either classical bottom-up fatigue cracking, rutting of the HMA layers, or rutting of the subgrade. Perpetual pavement is designed to withstand almost infinite number of axle loads without structural deterioration by limiting the level of load-induced strain at the bottom of the HMA layers and top of the subgrade and using deformation resistant HMA mixtures.

Figure 3.2: Typical section for a rigid pavement

3.2.7 Jointed Reinforced Concrete Pavement (JRCP): JRCP uses contraction joints and reinforcing steel to control cracking. Transverse joint spacing is longer than that for concrete pavement contraction design. (CPCD) This rigid pavement design option is no longer endorsed by the department because of past difficulties in selecting effective rehabilitation strategies. However, there are several remaining sections in service. Figure 3.6 shows a typical section of jointed reinforced concrete pavement.
3.2.8 Post-tensioned Concrete Pavement:
Post-tensioned concrete pavements remain in the experimental stage and their design is primarily based on experience and engineering judgment. Post-tensioned concrete has been used more frequently for airport pavements than for highway pavements because the difference in thickness results in greater savings for airport pavements than for highway pavements.

3.3 Rigid and flexible pavement characteristics:
The primary structural difference between a rigid and flexible pavement is the manner in which each type of pavement distributes traffic loads over the subgrade. A rigid pavement has a very high stiffness and distributes loads over a relatively wide area of subgrade – a major portion of the structural capacity is contributed by the slab itself. The load carrying capacity of a true flexible pavement is derived from the load-distributing characteristics of a layered system. Figure 3.7 shows load distribution for a typical flexible pavement and a typical rigid pavement.

6.1.6 Super Elevation:
Superelevation is a road’s transverse incline toward the inside of a horizontal curve (Figure 6.14). It slightly reduces the friction needed to counter the centrifugal force and increases riding comfort. As a result, the maximum speed in a curve increases with superelevation.

Excessive superelevation may cause slow vehicles to slide toward the inside of the curve when the friction level is so low (icy conditions). Superelevation values ranging from 5% to 8% are recommended in design. A transition zone between the tangent and the horizontal zone is needed to gradually introduce the superelevation. In part of this zone, the road profile becomes flat on its outer side, which can lead to water accumulation and contribute to skidding (Figure 6.15). The end of this flat zone must be located before the start of the curve and special attention must be paid to the quality of drainage in that area.

Safety: Dunlap et al. (1978), found the number of accidents on wet pavements to be abnormally high in curves with a superelevation of less than 2%. Zegeer et al. (1992), report that improving the superelevation reduces the number of accidents by 5 to 10%.
see ahead of him in the incoming lane to be able to complete safe passing manoeuvre. This distance is required on two-way, two-lane roads (Of course where the pavement marking allows passing). The manoeuvre can be broken down into four stages: Perception and reaction, passing manoeuvre, safety margin and distance travelled by the incoming vehicle (Figure 6.37).

The required passing sight distance may vary significantly from a country to another depending on the assumptions made at each stage

6.3.3.3 Meeting Sight Distance:
Some countries use the meeting sight distance as a criterion. This is the distance required for two vehicles coming towards each other to stop without colliding. This sight distance should be considered when two-way traffic is allowed but the road is too narrow for cars to meet safely (e.g. narrow bridge). The required meeting sight distance is calculated by adding together the stopping sight distances of both vehicles as shown in the figure 6.38 below.

6.4.7 Road Alignment:
6.4.7.1 Vertical Alignment:
Generally, an ideal approach for an intersection should never have grades more than 6 % and not over 3 % in order to improve the visibility and the comfort of vehicle having to stop at the intersection and also to enable drivers to correctly evaluate needed speed changes. Moreover, intersections should not be located near crest vertical curves.

III. CONCLUSIONS
Basically, all hard surfaced pavement types can be categorized into two groups, flexible and rigid. Flexible pavements are those which are surfaced with bituminous (or asphalt) materials. These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which
can accommodate this "flexing". On the other hand, rigid pavements are composed of a PCC surface course. Such pavements are substantially "stiffer" than flexible pavements due to the high modulus of elasticity of the PCC material. Further, these pavements can have reinforcing steel. Maintenance is an essential practice in providing for the long-term performance and the esthetic appearance of asphalt pavements. The purpose of pavement maintenance is to correct deficiencies caused by distresses and to protect the pavement from further damage. Pavement maintenance can be divided into Preventive maintenance and Structural maintenance. Asphalt pavement recycling is the recycling or reusing an existing asphalt pavement into a new and structurally sound asphalt pavement. The four common methods used in asphalt pavement recycling are the Cold in-place recycling, hot in-place recycling, full Depth Reclamation and the Hot Mix Recycling. The horizontal alignment of a road consists of straight lines, circular curves and spiral curves, whose radius changes regularly to allow for a gradual transfer between adjacent road segments with different curve radii. However, The Vertical Alignment consists of straight segments (Leveled or Inclined) connected by sag or crest curves. The project subject of this thesis is a road of almost 28 Km of length in the province of . After making an alignment design, a safety study of vertical and horizontal alignment is made in order to check the Sight Distance and the Stopping Sight Distance. The main risk is connected to hand turn curves where the field of vision is reduced and therefore, the safe sight distance. Fortunately, our road is made in crops and there are no big obstacles or buildings that prevent the vision. For this reason, we didn’t change any curve radius or design speed throughout the road. Moreover, a pavement design is made for this road using the program PMGSY 3.0 and the results are, generally, acceptable. However, the fatigue life study showed that the road’s characteristics are not sufficient for future traffic volumes and a perpetual pavement can be a solution for such cases.