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DESIGN OF PAVEMENT AND ALIGNMENT OF RURAL ROAD

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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 Witczack, 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.

Figure 2.1: Schematic of a Flexible Pavement

The performance of the pavement depends on the satisfactory performance of each component.

2.2.1 Subgrade:
The subgrade is the natural material located along the horizontal alignment of the pavement (It serves as the foundation of the pavement structure). Depending on the type of pavement being constructed, it is necessary to treat the subgrade material to achieve the required the strength properties.

2.3.1.1 Fatigue Cracking:
Fatigue (also called alligator) cracking, which is caused by fatigue damage, is the principal structural distress which occurs in asphalt pavements with granular and weakly stabilized bases. Alligator cracking first appears as parallel longitudinal cracks in the wheel paths, and progresses into a network of interconnecting cracks resembling chicken wire or the skin of an alligator. Alligator cracking may progress further, particularly in areas where the support is weakest, to localized failures and potholes.

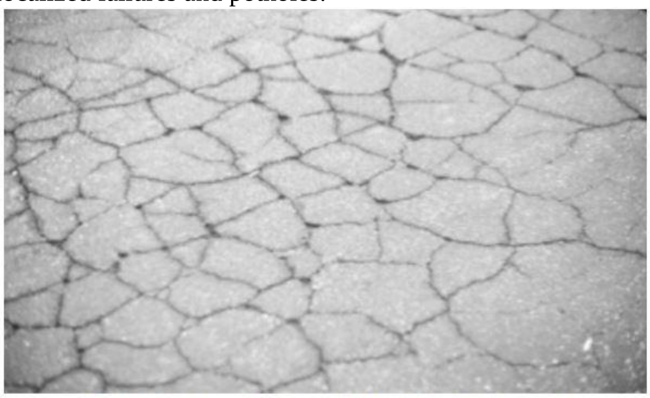


Fig 2.2: Fatigue (alligator) cracking in Flexible Pavement

Factors which influence the development of alligator cracking are:
●The number and magnitude of applied loads;
●The structural design of the pavement (layer materials and thicknesses);
●The quality and uniformity of foundation support;
●The asphalt content.

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.

Figure 2.3: Longitudinal Cracking (Medium Severity)

Block cracking and thermal cracking are both related to the use of asphalt which is or has become too stiff for the climate. Both types of cracking are caused by shrinkage of the asphalt in response to low temperatures, and progress from the surface of the pavement downward. The key to minimizing block and thermal cracking is using an asphalt of sufficiently low stiffness (high penetration).

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.

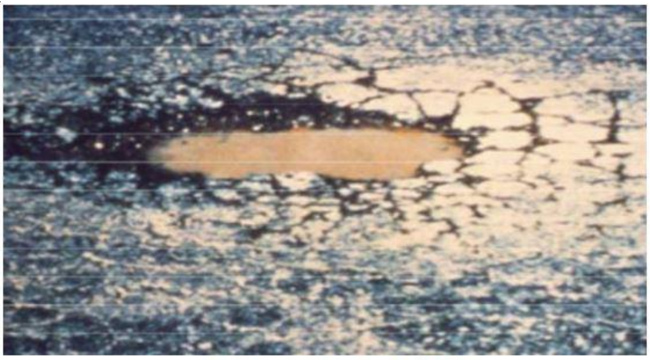


Figure 2.4: High Severity Pothole

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.

Figure 2.5: Rutting

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.

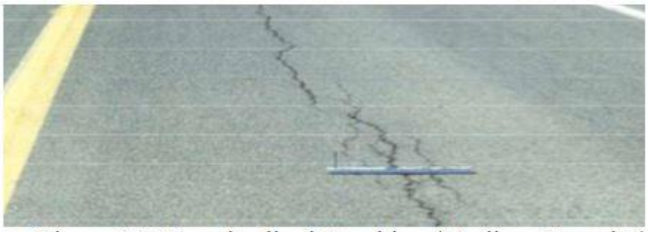


Figure 2.6: Longitudinal Cracking (Medium Severity)

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.

Figure 3.1: Typical section for a flexible pavement

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.

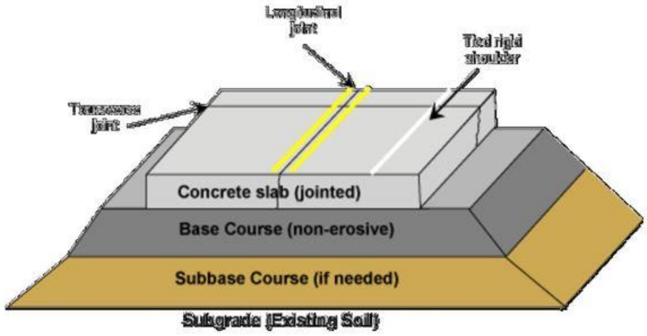


Figure 3.2: Typical section for a rigid pavement

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.

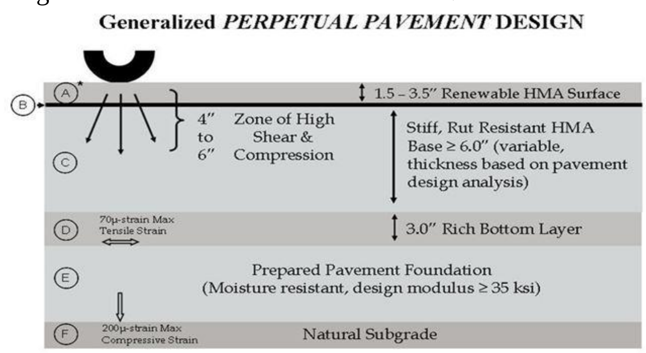


Figure 3.3: Generalized perpetual pavement design

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.

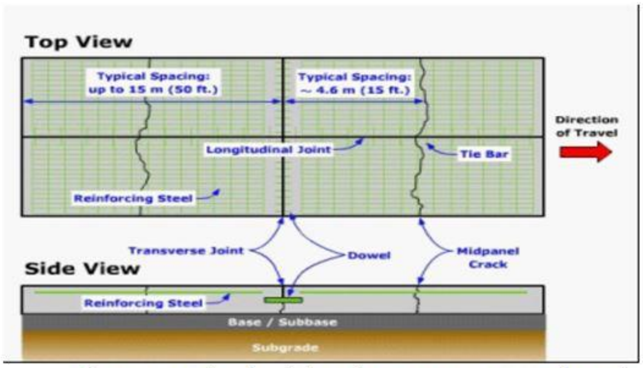


Figure 3.6: Jointed Reinforced Concrete Pavement (JRCP)

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.

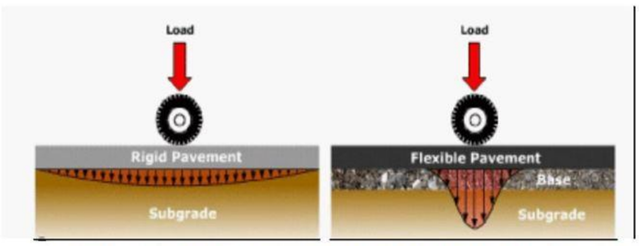
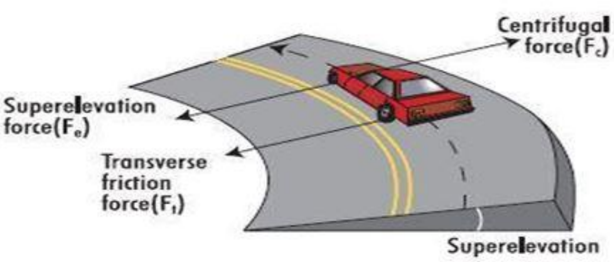


Figure 3.7: Typical stress distribution under a rigid and a flexible pavement.

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



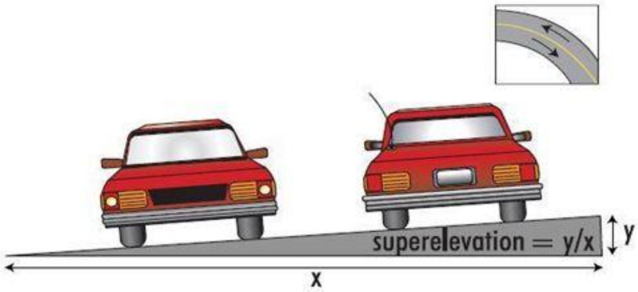


Figure 6.14: Superelevation in Curve

SUPERELEVATION (m/m)	SPEED (km/h)
0.00	62
0.02	67
0.04	71
0.06	76
0.08	80

Radius = 250 m, coefficient of friction = 0.12

Table 6.3: Example showing the Relationship between the Superelevation and Speed

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.

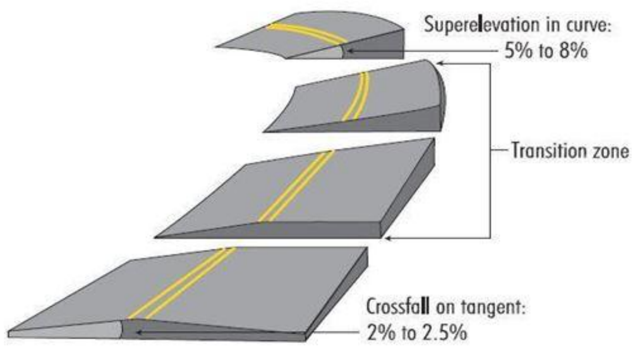


Figure 6.15: Superelevation Development

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%.

6.3.3.1 Stopping Sight Distance:

As previously mentioned, the sight distance, at any point of the road network, must be sufficient to a driver travelling at a reasonable speed (V85) to stop his vehicle safely before hitting a stationary object in his path.

6.3.3.2 Passing Sight Distance:

The passing sight distance is the distance that a driver has to see ahead of him in the incoming lane to be able to complete safe passing maneouvre. This distance is required on two-way, two-lane roads (Of course where the pavement marking allows passing). The maneouvre can be broken down into four stages: Perception and reaction, passing maneouvre, safety margin and distance travelled by the incoming vehicle (Figure 6.37).

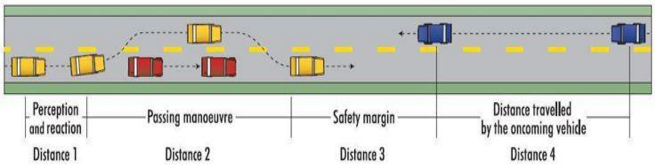


Figure 6.37: Passing Manoeuvre

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.

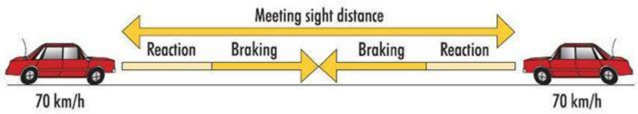


Figure 6.38: Meeting Sight Distance

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.

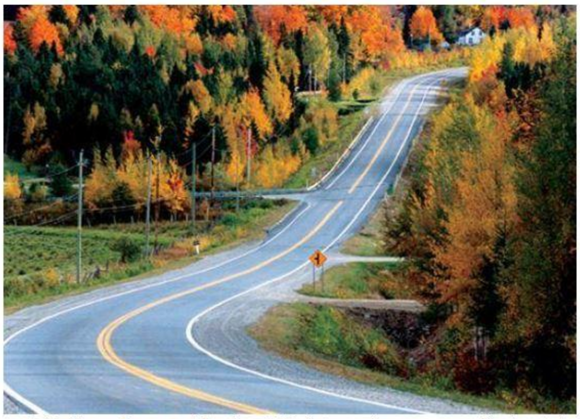


Figure 6.42: Hazardous combination: Hill, intersection, accesses, horizontal curve

Usually, to an intersection and inside it there should not be large variations in grade. For instance, for speeds higher than 70 km/h grade difference between ends of a vertical curve should not exceed 2 %. Besides, for a 50 km/h speed, the difference can reach 4 % if the visibility is sufficient (Comfort is loss but not safety). However, for a 30 km/h speed, the difference can be as high as 6 %.

'Vertical curves should not reach to less than 20 m from the common pavement zone, this distance can be reduced (to 10 m and even to 5 m) if the intersection carries little traffic'

(Road Safety Manual PIARC 2003).

In order to take maximum advantage of this property, material layers are usually arranged in order of descending load bearing capacity with the highest load bearing capacity material (and most expensive) on the top and the lowest load bearing capacity material (and least expensive) on the bottom. The typical flexible pavement structure consists of:

Surface course: This is the top layer and the layer that comes in contact with traffic. It may be composed of one or several different HMA sub-layers.

Base course: This is the layer directly below the HMA layer and generally consists of aggregate (either stabilized or unstabilized).

Sub-base course: This is the layer (or layers) under the base layer. A sub-base is not always needed.

Each of these layers contributes to structural support and drainage. The surface course (typically an HMA layer) is the stiffest and contributes the most to pavement strength. The underlying layers are less stiff but are still important to pavement strength as well as drainage and frost protection. A typical structural design results in a series of layers that gradually decrease in material quality with depth.

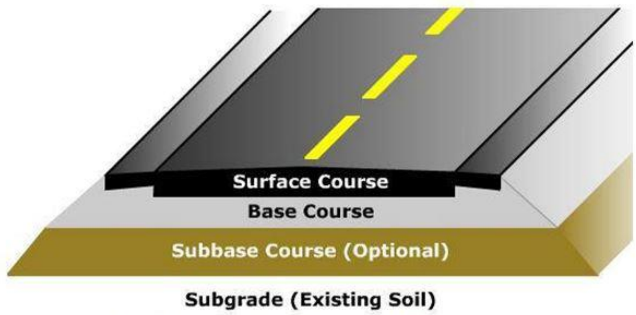


Figure 8.2: Basic Flexible Pavement Structure

The surface course provides characteristics such as friction, smoothness, noise control, rut and shoving resistance and drainage. The base course is immediately beneath the surface course. It provides additional load distribution and contributes to drainage and frost resistance. The sub-base course is between the base course and the subgrade. It functions primarily as structural support but it can also improve drainage, minimize the intrusion of fines from the subgrade into the pavement structure, and provide a working platform for construction.

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.

