CHAPTER II

LITERATURE REVIEW

2.1. Definition of Road

According to *Undang-Undang Dasar No. 38 tahun 2004*, Road is a land transportation infrastructure covering all parts of the road, including complementary buildings and equipment intended for traffic, both above ground level, below ground level, and above water level except railroads, lorries and cable roads.

2.2. Pavement

Pavement is a mixture of aggregates and bonding materials used to serve the traffic load. Aggregates that is used, such as: crushed stone, river stone, and steel product. The binding materials used include asphalt, cement, and clay**.** Based on the binder, pavement construction can be distinguished as follows:

1. Flexible pavement

Flexible pavement is composed of a bituminous material surface course and underlying base and subbase courses. The bituminous material is more often asphalt whose viscous nature allows significant plastic deformation. Most asphalt surfaces are built on a gravel base, although some full depth asphalt surfaces are built directly on the subgrade. Depending on the temperature at which it is applied, asphalt is categorized as hot mix asphalt (HMA), warm mix asphalt, or cold mix asphalt. Flexible Pavement is so named as the pavement surface reflects the total

deflection of all subsequent layers due to the traffic load acting upon it. The flexible pavement design is based on the load distributing characteristics of a layered system.

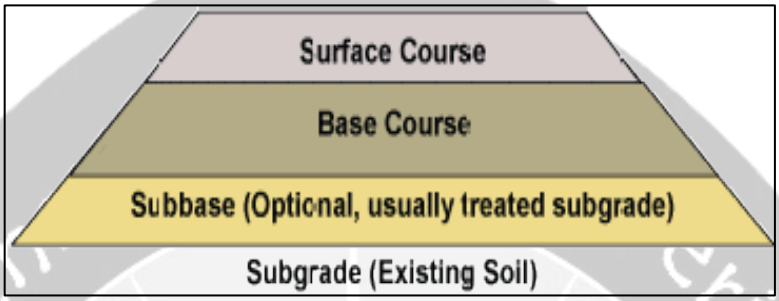

Figure 2.1. Detail of Flexible Pavement
Source: Cain, T.D., 2017, Pavement Manual

2. Rigid pavement

Basically, the main difference between rigid pavement and flexible pavement is located on the pavement layer above it, the type of material used, and the method. **Dewobroto, W (2010)** said that concrete pavement is carried out in several stages, ranging from soil work (soil filling and excavation), making of foundation layer, and the layer above (in the form of concrete). The arrangement of paved layers for concrete roads is shown in Figure 2.2.

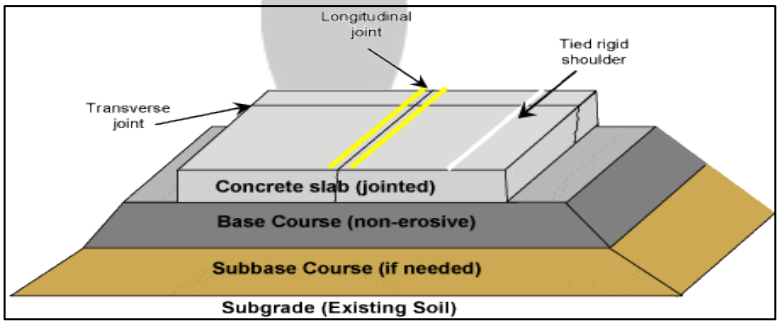

Figure 2.2 Detail of Rigid Pavement
Source: Cain, T.D., 2017, Pavement Manual

The composition of the concrete pavement layer consists of two layers, namely the concrete layer and the underlying layer of foundation. Concrete pavement layers are worked on a segment basis and given a bulkhead to anticipate the risk of damage due to shrinkage factor. The concrete layer is above the foundation layer which can be either a grained material with a minimum thickness of 15 cm or lean – mix concrete with a minimum thickness of 10 cm.

This is certainly different from the asphalt road construction consisting of three layers, namely: asphalt layer (surface course), base course, subgrade. Since the asphalt pavement strength is supported by the underlying reinforcing layer, the foundation for asphalt road construction is relatively thick (at least 12-15 cm).

Dewobroto, W (2010) said that the concrete road from the behavioral side of the structure does look better, the voltage arising from the same load is relatively smaller, so there is no need for a thick base course. However, due to the material of the concrete, the influence of shrinkage due to temperature changes become dominant. This causes the construction of concrete roads to have some methods of working, namely:

a. Continuously Reinforced Concrete Pavement

The concrete road is made lengthwise with the distance between segments up to 15 meters, so to anticipate the effect of shrinkage on the road should be installed steel reinforcement as shrinking reinforcement. Although the amount is relatively small, but the use of steel reinforcement

causes the concrete road to be expensive and the process will be more complex, but it can demonstrate superior long-term performance. Details of the continuous concrete road are shown in Figure 2.3.

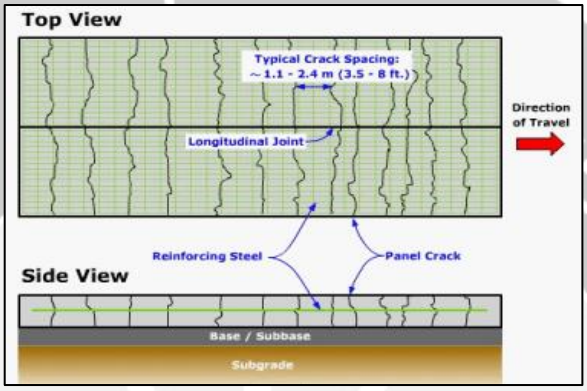

Figure 2.3. Detail of Continuously Reinforced Concrete Road
Source: Cain, T.D., 2017, Pavement Manual

b. Concrete Pavement Contraction Design (CPCD)

Concrete Pavement Contraction Design uses contraction joints to control cracking and does not use any reinforcing steel. An alternative slab design designation used by the industry is jointed concrete pavement (JCP). Transverse joint spacing is selected such that temperature and moisture stresses do not produce intermediate cracking between joints. Nationally, this results in a spacing no longer than 20 ft. The standard spacing in Texas is 15.0 ft. Dowel bars are typically used at transverse joints to assist in load transfer. Tie bars are typically used at longitudinal joints. Figure 2.4. shows a detail of Concrete Pavement Contraction Design.

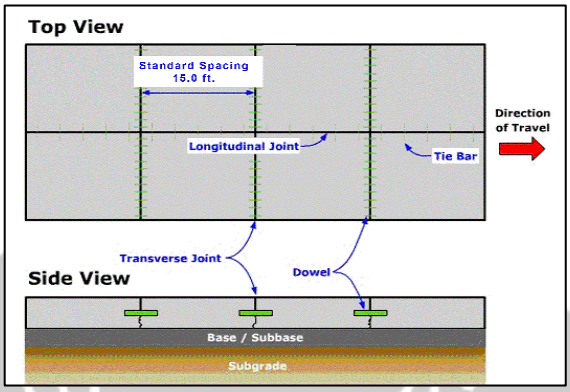

Figure 2.4. Detail of Concrete Pavement Contraction Design
Source: Cain, T.D., 2017, Pavement Manual

c. Jointed Reinforced Concrete Pavement (JRCP)

JRCP uses contraction joints and reinforcing steel to control cracking. This kind of rigid pavement is the combination of Continuously Reinforced Concrete Pavement and Concrete Pavement Contraction Design (CPCD). With this concept, the resulting crack is relatively small and the connection distance between segments becomes longer, so the road becomes more comfortable when passed.

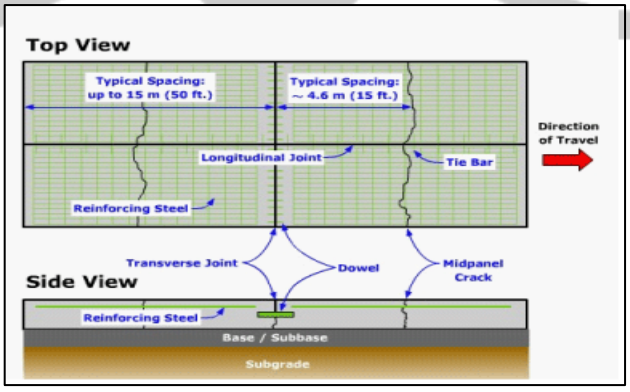

Figure 2.5. Detail of Jointed Reinforced Concrete Pavement
Source: Cain, T.D., 2017, Pavement Manual

3. Composite Pavement

   Composite pavement is the combination of *rigid pavement* and *flexible pavement.*

2.3. Type of Road Damage

The causes of road damage are divided into two categories, which are an internal and external failure. Internal failures of road damage are usually because of the lack pavement mixture, weaknesses of component materials and poor construction. Meanwhile, external failures are due to overloading, diesel spillage, flooding, sink holes and other unforeseen cause such as earthquake, volcanoes and others. There are types of road damage (Shahin, 1994):

1. Alligator Cracking

   This kind of cracking is like alligator skin with width of cracking space is more or equal to 3 mm. The cause of this cracking is:

   a. The material pavement is bad than causing the pavement become brittle and weak.
   b. Asphalt corrosion
   c. Sub base is not stable

Table 2.1. The level of Alligator Cracking

Damage Level	Damage Identification
Low	Smooth, smooth cracks extend parallel to each other, with or without connect with each other cracks do not experience a chop
Medium	The mild crocodile skin grows continuously into the pattern or tissue of the crack followed with lightweight chips.
High	The network and fracture patterns continue so that the fragments can be easily identified, and can occur chipped edge. Some fractions have ricking due to traffic

Source: Shahin, 1994, Pavement for airports, Roads, Parking Lots

2. Corrugation

Corrugation is damage that formed to be wave (shove). Shoving is the formation of ripples across a pavement. This characteristic shape is why this type of distress is sometimes called wash-boarding. Shoving occurs at locations having severe horizontal stresses, such as intersections. Possible cause is:

a. Low surface course stability.

b. Too many using the fine aggregate

c. The base has already wave

Table 2.2. Level of Corrugation

Damage Level	Damage Identification
Low	Corrugation cause low disturbance
Medium	Corrugation cause medium disturbance
High	Corrugation cause high disturbance

Source: Shahin, 1994, Pavement for airports, Roads, Parking Lots

3. Depression

Depressions are localized pavement surface areas with slightly lower elevations than the surrounding pavement. Depressions are very noticeable after a rain when they fill with water. Possible cause is:

a. Overloading
b. depression of sub grade makes the pavement also depression
c. soil compaction is bad

Table 2.3. Level of Depression

Damage Level	Damage Identification
Low	Maximum depression depth ½ - 1 inches.
Medium	Maximum depression depth 1 - 2 inches (12 - 51 mm).
High	Maximum depression depth >2 inches.

Source: Shahin, 1994, Pavement for airports, Roads, Parking Lots

4. Edge Cracking

Edge Cracks travel along the inside edge of a pavement surface within one or two feet. The most common cause for this type of crack is poor drainage conditions and lack of support at the pavement edge. As a result underlying base materials settle and become weakened. Heavy vegetation along the pavement edge and heavy traffic can also be the instigator of edge cracking. Possible cause is:

a. Lack of support from the lateral ground (from the shoulder of the road)
b. Bad Drainage
c. Over loading

Table 2.4. Level of Edge Cracking

Damage Level	Damage Identification
Low	Low to medium crack with no fractions or loose grains
Medium	Medium crack with some loose grain
High	Many fractions or loose grains on along the edge of the pavement

Source: Shahin, 1994, Pavement for airports, Roads, Parking Lots

5. Longitudinal and Transverse Cracks

Longitudinal cracking are cracks that are parallel to the pavements centerline or laydown direction, meanwhile Transverse cracks are single cracks perpendicular to the pavement's centerline or laydown direction. Possible cause is:

a. poor joint construction
b. daily temperature cycles
c. poor construction
d. reflective cracks from an underlying layer

Table 2.5. Level of Longitudinal and transverse Crack

Damage Level	Damage Identification
Low	One of the following conditions: 1. Unfulfilled crack width <10 mm. 2. Fulfilled crack, any width.
Medium	One of the following conditions: 1. Unfilled cracks width <10 mm - 76 mm. 2. Unfilled cracks, any width of 76 mm, surrounded by light random cracks. 3. Fill filled, any width surrounded by light random cracks.
High	One of the following conditions: 1. Any fulfilled or unfulfilled cracks are surrounded by random cracks, medium or high damage. 2. Unfilled cracks more than 76 mm. 3. Crack any width with a few millimeters around the crack.

Source: Shahin, 1994, Pavement for airports, Roads, Parking Lots

6. Patch

Patch can be categorized to surface damage, because on certain level (if amount/area of patch is big) will make uncomfortable. Patch is grouped into two; (a) temporary patch: irregularly shaped follow form of hole damage, (b) permanent patch: rectangular shape according to the reconstruction. Possible cause is:

a. Repairing the road

b. Installation of pipe

Table 2.6. Level of Patch

Damage Level	Damage Identification
Low	Good patch condition, low disturbance
Medium	A few of damage patch condition, medium disturbance
High	Bad patch condition, high disturbance

Source: Shahin, 1994, Pavement for airports, Roads, Parking Lots

7. Potholes

Small, bowl-shaped depressions in the pavement surface that penetrate all the way through the asphalt layer down to the base course. They generally have sharp edges and vertical sides near the top of the hole. Potholes are the result of moisture infiltration and usually the end result of untreated alligator cracking. As alligator cracking becomes severe, the interconnected cracks create small chunks of pavement, which can be dislodged as vehicles drive over them. The remaining hole after the pavement chunk is dislodged is called a pothole. Possible cause is:

a. Asphalt content is poor, so making aggregates is easy to release
b. Asphalt Corrosion
c. Using dirty aggregate
d. Temperature of mixture does not fulfill the requirement

Table 2.7. Level of Potholes

Maximum Depth of holes (mm)	**Diameter of holes (mm)**		
	102-204	**204-458**	**458-762**
13 - 25	Low	Low	Medium
25 - 50	Low	Medium	High
➢ 50	Medium	Medium	High
L : not need to repair; partial repairing or all of depth M : partial repairing or all of the depth H : repairing in all of depth			

Source: Shahin, 1994

8. Rutting

Ruts in asphalt pavements are channelized depressions in the wheel-tracks. Rutting results from consolidation or lateral movement of any of the pavement layers or the subgrade under traffic. Possible cause is:

a. insufficient pavement thickness
b. lack of compaction of the asphalt, stone base or soil
c. weak asphalt mixes
d. moisture infiltration.

Table 2.8. Level of Rutting

Damage Level	Damage Identification Damage
Low	Average depth (6 mm – 13 mm)
Medium	Average depth (13 mm – 25,5 mm)
High	Average depth > 25,5 mm

Source: Shahin, 1994, Pavement for airports, Roads, Parking Lots

2.4. Designing of Rigid Pavement

Basically rigid pavement is planned to support a relatively heavy traffic vehicle load, such as in a toll road entrance stop, red light stops, parking lots and sharp turns. In planning, the implementation of rigid pavement refers to the Semen Concrete Road Planning Guideline issued by *Departemen Permukiman dan Prasarana Wilayah, Pd T-14-2003*.

The author will use the Jointed Reinforced Concrete Pavement (JRCP) for designing the rigid pavement. This method will make the concrete roads stronger and more comfortable when traversed, because the loads arising from the vehicle

load can be distributed evenly to all parts of the concrete road segment with a longer segment spacing. Dowel connection serves as a binder or integer between segments.

2.4.1. Massive plan

a. Life planning

Rigid pavement can be planned with age of 20-40 years.

b. Traffic planning

1. Traffic shall be analyzed based on the calculation of traffic volume and axis configuration based on the latest data (≤ 2 years).
2. For rigid pavement purposes, only commercial vehicles having a minimum total weight of 5 tons.

2.4.2. Factors of designing

a. Traffic

Traffic factors that influence:

1. Traffic volume
2. Configuration of axes and wheel
3. Axle load
4. Size and load of wheel
5. Lanes number and direction of traffic

b. Life planning

The life planning of pavement is determined by consideration of roads function, traffic system and economic value of roads.

c. Road capacity

The maximum capacity of the planned road should be viewed as a limitation.

d. The existing pavement layers

The existing layer really influence to the analysis, because the layer will give the CBR value. And because the rigid pavement will change the old pavement, so there is some layer that will use.

2.4.3. Slab thickness

There are some considerations for designing the slab thickness:

a. Traffic loads and traffic growth
b. Subgrade and subbases
c. Drainage
d. Concrete properties
e. Load transfer
f. Reliability

2.4.4. Reinforcement

The reinforcing steel used should be clean of oil, dirt, rust, and peeling. The reinforcing steel used in rigid pavement has the main function of:

a. Limit the width of the crack, so that the strength of the plate can be maintained.
b. Allows the use of longer plates in order to reduce the number of cross connections so as to increase the comfort.
c. Reduce the effect of shrinkage due to temperature changes.
d. Reduce maintenance costs.