CHAPTER 4
MATERIALS AND TESTING PROGRAM

4.1 Flexible Pavement Materials

Pavement is an assembly of materials. These materials with their associated properties and their interactions determine the properties of the resultant pavement. Thus, a good understanding of these materials, how they are characterized, and how they perform is necessary to understand the concept of pavement. The materials which are used in the construction of highway are of intense interest to the highway engineer. This requires not only a thorough understanding of the soil and aggregate properties which affect pavement stability and durability, but also the binding materials which may be added to improve these pavement features.

The selection of material for flexible pavement design is very important to ensure longer design life. Following are the main three types of materials used in flexible pavements:

- Sub-grade Soil
- Aggregate
- Bitumen

4.1.1 Sub-grade Soil

4.1.1.1 Introduction

Soil is an accumulation or deposit of earth material, derived naturally from the disintegration of rocks or decay of vegetation that can be excavated readily with power equipment in the field or disintegrated by gentle mechanical means in the laboratory. The supporting soil beneath pavement and its special under courses is called Sub-grade. Undisturbed soil beneath the pavement is called natural Sub-grade. Compacted Sub-grade is the soil compacted by controlled movement of heavy compactors.

4.1.1.2 Desirable Properties of Sub-grade Soil

The desirable properties of Sub-grade soil as a runway pavement material are:

- Stability
- Incompressibility
- Permanency of strength
- Minimum changes in volume and stability under adverse conditions of weather and groundwater.
- Good drainage
- Ease of compaction

4.1.1.3 Classification of Soil

This method describes a procedure for classifying soils into seven groups based on laboratory determination of particle-size distribution, liquid limit, and plasticity index. The group classification should be useful in determining the relative quality of the soil material for use in embankments, Sub-grades, and backfills. For detailed design of important structures, additional data concerning strength or performance characteristics of the soil under field conditions will usually be required.

4.1.1.4 Description of Soil Classification Groups

According to the AASHTO system, soils are divided into two major groups. These are the granular materials with 35 percent or less passing the 75-µm (No. 200) sieve (5.1, Note 2) and the silt-clay materials with more than 35 percent passing the 75-µm (No. 200) sieve. Moreover, five soil fractions are recognized and often used in word descriptions of a material. These five fractions are defined as follows:

Boulders and Cobbles – Material retained on the 75 mm (3 in.) sieve. They should be excluded from the portion of a sample to which the classification is applied, but the percentage of such material should be recorded.

Gravel – Materials passing sieve with 75 mm (3 in.) square openings and retained on the 2.0 mm (No. 10) sieve.

Coarse Sand – Materials passing the 2.0 mm (No. 10) sieve and retained on the 425-µm (No. 40) sieve.

Fine Sand – Materials passing the 425-µm (No. 40) sieve and retained on the 75-µm (No. 200) sieve.

Combined Silt and Clay – Material passing the 75-µm (No. 200) sieve. The word “silty” is applied to a fine material having a Plasticity Index of 10 or less, and the term “clayey” is applied to fine material having a PI of more than 10.

According to materials, soil is classified into two types:

- Granular Materials
- Silt-Clay Materials

4.1.1.4 (a) Granular Materials

Group A-1

Well-graded mixtures of stone fragments or gravel ranging from coarse to fine with a non-plastic or slightly plastic soil binder. However, this group also includes coarse materials without soil binder.

Subgroup A-1-a: Materials consisting predominantly of stone fragments or gravel, either with or without a well graded soil binder.

Subgroup A-1-b: Materials consisting predominantly of coarse sand either with or without a well-graded soil binder.

Group A-2

This group includes a wide variety of "granular" materials that are border line between the materials falling in Groups A-1 and A-3 and silt-clay materials of Groups A-4, A-5, A-6 and A-7. It includes all materials containing 35 percent or less passing the 75-µm (No.200) sieve that cannot be classified as A-1 or A-3.

Subgroups A-2-4 and A-2-5: These subgroups include various granular materials containing 35 percent or less passing the 75-µm (No. 200) sieve, and with that portion passing 425-µm (No. 40) sieve having the characteristics of the A-4 and A-5 groups. These groups include such materials as gravel and coarse sand with silt contents or Plasticity Indexes in excess of Soil the limitations of Group A-1, and fine sand with non- plastic silt content in excess of the limitations of Group A-3.

Subgroups A-2-6 and A-2-7: Include materials similar to those describe under Subgroups A-2-4 and A-2-5, except that the fine portion contains plastic clay having the characteristics of the A-6 or A-7 group.

A-2 soils are given a poorer rating than A-1 soils because of inferior binder, poor grading, or a combination of the two. Depending on the character and amount of binder, A-2 soils may become soft during wet weather and loose and dusty in dry weather when used as a road surface. If, however, they are protected from these extreme changes in moisture content, they may be quite stable. The A-2-4 and A-2-5 soils are satisfactory as base materials when properly compacted and drained. A-2-6 and A-2-7 soils with low percentages of minus 75-µm (no. 200) sieve material are classified as good bases, whereas these same soils with high percentages of minus 75-µm (No. 200) sieve and PI's of 10 or higher are questionable as a base material. Frequently, the A-2 soils are employed as a cover material for very plastic Sub-grades.

Group A-3

Material consists of sands deficient in coarse material and soil binder. Typical is fine beach sand or fine desert blow sand, without silt or clay fines or with a very small amount of non-plastic silt. This group also includes stream deposited mixtures of poorly graded fine sand and limited amounts of coarse sand and gravel. These soils make suitable Sub-grades for all types of pavements when confined and damp. They are subject to erosion and have been known to pump and blow under rigid pavements. (Information: They can be compacted by vibratory, pneumatic-tired, and steel-wheeled rollers but not with a sheep's foot roller.)

4.1.1.4 (b) Silt-Clay Materials

Group A-4

The typical material of this group is a non-plastic or moderately plastic silty soil usually having 75 percent or more passing the 75 µm (No. 200) sieve. The group includes also mixtures of fine silty soil and up to 64 percent of sand and gravel retained on the 75-µm (No. 200) sieve. These predominantly silty soils are quite common in occurrence. Their texture varies from sandy loams to silty and clayey loams. With the proper amount of moisture present, they may perform well as a pavement component. However, they frequently have an affinity for water and will swell and lose much of their stability unless properly compacted and drained. Moreover, they are subject to frost heave. These soils do not drain readily and may absorb water by capillary action with resulting loss in strength. The silty loams are often difficult to

compact properly. Careful field control of moisture content and pneumatic tired rollers are normally required for proper compaction.

Group A-5

`The typical material of this group is similar to that described under Group A-4, except that it is usually of diatomaceous or micaceous character and may be highly elastic as indicated by the high liquid limit (5.2.2). These soils do not occur as widely as the A-4 soils. They are normally elastic or resilient in both the damp and semi-dry conditions. They are subject to frost heave, erosion, and loss of stability if not properly drained. Since these soils do not drain readily and may absorb water by capillary action with resulting loss in strength. Careful control of moisture content is normally required for proper compaction.

Group A-6

The typical material of this group is plastic clay soil usually having 75 percent or more passing the 75-µm (No. 200) sieve. The group includes also mixtures of fine clayey soil and up to 64 percent of sand and gravel retained on the 75-µm (No. 200) sieve. Materials of this group usually have high volume change between wet and dry states (5.2.3). These soils are quite common in occurrence and are widely used in fills. When moisture content is properly controlled, they compact quite readily with either a sheepsfoot or pneumatic tired roller. They have high dry strength but lose much of this strength upon absorbing water. The A-6 soils will compress when wet and shrink and swell with changes in moisture content. When placed in the shoulders adjacent to the pavement, they tend to shrink away from the pavement edge upon drying and thereby provide an access route to the underside of the pavement for surface water. The A-6 soils do not drain readily and may absorb water by capillary action with resulting loss in strength.

Group A-7

The typical materials and problems of this group are similar to those described under Group A-6, except that they have the high liquid limits characteristic of the A-5 group and may be elastic as well as subject to high volume change.

Subgroup A-7-5: It includes those materials with moderate Plasticity Indexes in relation to Liquid Limit and which may be highly elastic as well as subject to considerable volume change.

Subgroup A-7-6: It includes those materials with high Plasticity Indexes in relation to Liquid Limit and which are subject to extremely high volume change. Highly organic soils such as peat or muck are not included in this classification. Because of their many undesirable properties, their use should be avoided, if possible, in all types of construction.

4.1.2 Aggregates:

It is the prime material used in pavement construction, so it forms the major portion of pavement structure. These aggregate are used in pavement construction in cement concrete, bituminous concrete and also as granular base and sub-base course underlying the superior pavement. Therefore the properties of the aggregates are of considerable significance to the highway engineers. Most of the road aggregates are prepared from natural rock. Gravel aggregates are small rounded stones of different sizes which are generally obtained as such from some river beds. Sand is fine aggregate from weathering of rocks. The properties rock, from which the aggregates are formed, depends on the properties of constituent material and the nature of bonds between them. The aggregates are classified based on their grain size,

shape, texture, and its gradation. Based on the strength property, the course aggregates may be divided as “Hard aggregates” and “Soft aggregates”.

Hard Aggregates: Hard aggregates are generally preferred to resist the crushing effects due to heavy traffic loads and to resist adverse weather conditions.

Soft Aggregates: Soft aggregates are used for low cost road, or for lower layers of pavements.

4.1.2.1 Desirable properties of road aggregates:

Following are the some properties of aggregates which would be investigated while using as road material.

Strength:

The aggregates to be used in road construction should be sufficiently strong to resist the stresses due to gradual applied traffic wheel loads. The aggregates used in top layers of pavements should have high strength.

Hardness:

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. They should be hard enough to resist the wear due to abrasive action of traffic. Abrasion action may be increased due to the presence of abrasive material like sand between the tyres of moving vehicles and the aggregates exposed at the top surface. Heavy wheel loads can also cause deformation on some types of pavements resulting in relative movement of aggregates and rubbing of aggregates with each other within pavement layer.

Toughness:

Aggregates in pavements are subjected to impact due to moving wheel loads. The magnitude of impact would increase with the roughness of the load surface, the speed of the vehicle and vehicular characteristics. The resistance to impact or toughness is hence another desirable property of aggregates.

Durability:

The stones used in pavement construction should be durable and should resist the action of weather. The property of the aggregates to withstand the adverse action of weather may be called soundness.

Shape of Aggregates:

Too flaky and too much elongated aggregates should be avoided as far as possible. Flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of same stone.

4.1.3 Bitumen

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark colored solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

4.1.3.1 Production of Bitumen

Bitumen is the residue or by-product when the crude petroleum is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed.

4.1.3.2 Vacuum Steam Distillation of Petroleum Oils

The crude oil is heated in vacuum-steam distillation process and is introduced into a large cylindrical still. Steam is introduced into the still to aid in the vaporization of the more volatile constituents of the petroleum and to minimize decomposition of the distillates and residues. The volatile constituents are collected, condensed, and the various fractions stored for further refining, if needed. The residues from this distillation are then fed into a vacuum distillation unit, where residue pressure and steam will further separate out heavier gas oils. The bottom fraction from this unit is the vacuum-steam-refined asphalt cement. The consistency of asphalt cement from this process can be controlled by the amount of heavy gas oil removed. Normally, asphalt produced by this process is softer. As the asphalt cools down to room temperature, it becomes a semi solid viscous material.

4.1.3.3 Different forms of Bitumen

Following are the different forms of bitumen which are used worldwide.

Cutback bitumen

Normal practice is to heat bitumen to reduce its viscosity. In some situations preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen. From the environmental point of view also cutback bitumen is preferred. The solvent from the bituminous material will evaporate and the bitumen will bind the aggregate. Cutback bitumen is used for cold weather bituminous road construction and maintenance. The distillates used for preparation of cutback bitumen are naphtha, kerosene, diesel oil, and furnace oil. There are different types of cutback bitumen like rapid curing (RC), medium curing (MC), and slow curing (SC). RC is recommended for surface dressing and patchwork. MC is recommended for premix with less quantity of fine aggregates. SC is used for premix with appreciable quantity of fine aggregates.

Bitumen Emulsion

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilized by suitable material. Normally cationic type emulsions are used in India. The bitumen content in the emulsion is around 60% and the remaining is water. When the emulsion is applied on the road it breaks down resulting in release of water and the mix starts to set. The time of setting depends upon the grade of bitumen. The viscosity of bituminous emulsions can be measured as per IS: 8887-1995. Three types of bituminous emulsions are available, which are Rapid setting (RS), Medium setting (MS), and Slow setting (SC). Bitumen emulsions are ideal binders for hill road construction. Where heating of bitumen or aggregates are difficult. Rapid setting emulsions are used for surface

dressing work. Medium setting emulsions are preferred for premix jobs and patch repairs work. Slow setting emulsions are preferred in rainy season.

Bituminous primers

In bituminous primer the distillate is absorbed by the road surface on which it is spread. The absorption therefore depends on the porosity of the surface. Bitumen primers are useful on the stabilized surfaces and water bound macadam base courses. Bituminous primers are generally prepared on road sites by mixing penetration bitumen with petroleum distillate.

Modified Bitumen

Certain additives or blend of additives called as bitumen modifiers can improve properties of Bitumen and bituminous mixes. Bitumen treated with these modifiers is known as modified bitumen. Polymer modified bitumen (PMB)/ crumb rubber modified bitumen (CRMB) should be used only in wearing course depending upon the requirements of extreme climatic variations. The detailed specifications for modified bitumen have been issued by IRC: SP: 53-1999. It must be noted that the performance of PMB and CRMB is dependent on strict control on temperature during construction. The advantages of using modified bitumen are as follows:

- Lower susceptibility to daily and seasonal temperature variations
- Higher resistance to deformation at high pavement temperature
- Better age resistance properties
- Higher fatigue life for mixes
- Better adhesion between aggregates and binder
- Prevention of cracking and reflective cracking.

4.1.3.4 Requirements of Bitumen

The desirable properties of bitumen depend on the mix type and construction. In general, Bitumen should possess following desirable properties.

The bitumen should not be highly temperature susceptible: during the hottest weather the mix should not become too soft or unstable, and during cold weather the mix should not become too brittle causing cracks.

The viscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing.

There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.

4.2 Flexible Pavement Distresses

Roads are very important for public. It is important to connecting people to go from one place to another. Modern roads are normally smoothed, paved, or otherwise prepared to allow people easy travelling. To ensure its continued efficiency and accessibility, the road network has to be maintained to high standard. Normally roads are damaged due to environment influence, vehicle load and the presents of water on road pavement.

The loss of pavement layers ability to spreading load and water-proofing will usually lead to accelerated deterioration (Asphalt Institute MS-16).

Asphalt pavement distresses can generally be classified as one of the following types:

- Cracking
- Distortion
- Disintegration
- Skid Hazard
- Surface treatment distresses
- Distresses caused can be related to
- Wheel loads
- Environment
- Poor drainage
- Material deficiencies
- Construction related deficiencies
- External causes (Utilities)